Understanding the Impacts of PFAS in Private Drinking Water Wells in MA

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Abstract

Across the US there is a widespread problem of PFAS contamination in well water. In Massachusetts, many private wells are unregulated so it is up to local Boards of Health (BOHs) and well owners to mitigate the impact of PFAS on private well owners. The goal of this project is to help mitigate PFAS impact via recommendations for updating the model bylaw for private wells and to spread awareness via educational materials. For our research we conducted semi-structured interviews, two surveys for the general public and BOH agents, and performed content analysis on our background research and relevant literature. To help address the concern, we recommend the implementation of a database for well testing results, training for BOH agents, and additional educational materials.

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Executive Summary

Introduction

Per- and polyfluoroalkyl substances (PFAS) are a class of synthetic chemicals commonly used in manufacturing processes and consumer products. Unfortunately, these chemicals are persistent in the environment and have been linked to a variety of adverse health outcomes, including cancer, immune system disorders, and environmental imbalance. One significant area of PFAS contamination is through private water wells, which are often used by rural communities and households.

In Massachusetts the Massachusetts Department of Environmental Protection (MassDEP) regulates public water systems to a maximum contaminant level (MCL) of 20 parts per trillion (ppt) for six different PFAS chemicals, that have been deemed to be the most harmful to human and environmental health. Not all Massachusetts residents are on public water systems, some are on private wells. This is where the problem comes in. Currently private wells are not regulated in Massachusetts, and people may unknowingly be ingesting PFAS along with other water contaminants. The state of Massachusetts has been grappling with the impact of PFAS on private water wells for several years, and the issues surrounding PFAS have received increased attention due to recent regulatory changes from the United States Environmental Protection Agency that will regulate all public drinking supplies to an MCL of four ppt. With the changing regulations around PFAS and the crackdown on its presence in public drinking water people are becoming more concerned about private wells that are not being regulated to the same safe drinking water standards as public systems. The goal of this project is to understand the extent of PFAS contamination in private water wells in Massachusetts and the implications for public health, the knowledge gap surrounding PFAS, and how the implementation of bylaws and regulations at the town level can address the PFAS problem in Massachusetts.

Methods

To accomplish our project goal we identified four main objectives:

1) Understand PFAS, effects of PFAS contamination in well-water, and mitigation methods for private wells
2) Identify the knowledge gap among Massachusetts residents, private well owners, and Board of Health (BOH) agents about PFAS and outreach methods
3) Identify and analyze current laws surrounding PFAS in private well water in Massachusetts and other states and process of developing model bylaws
4) Recommend edits to the PFAS Model Bylaw and draft supporting educational materials for private well owners

In objectives one through three, each objective was addressed individually. In objective four, objectives one through three were looked at cumulatively and recommendations were created along with supporting materials. To accomplish our objectives we conducted content analysis on various articles and our background research. We sent out two surveys, one to the general public of Massachusetts and private well owners, and one to BOH agents. We read, reviewed, and compared town bylaws and regulations for private wells in Massachusetts. Finally we made our recommendations and supporting materials.

Findings

The findings include results from surveys, interviews, background research, and bylaw review. They key points are as follows:

- PFAS contamination in well water is a widespread problem that affects the health of humans and the environment.

- There are three key groups to consider when identifying the knowledge gap surrounding PFAS, Massachusetts residents (the general public) regardless of private well ownership, private well owners, and BOH agents.
- In the general public there is a knowledge gap around what PFAS are and the impacts of PFAS on both health and the environment.
- In private well owners, there is a knowledge gap around when wells should be tested, and how often they should be tested.
- In BOH agents, there is a knowledge gap around the current regulations of PFAS at the state and federal levels, as well as a lack of training on current PFAS regulations and bylaw importance.
- Many towns in Massachusetts lack a private well water bylaw dealing with PFAS and very loosely regulate other contaminants.
- There is little to no standardization of the contaminants and parameters that are regulated by local BOH.

Conclusions and Recommendations

The findings identified additional critical concepts surrounding PFAS, as well as several knowledge gaps across three different groups: the general public (regardless of private well ownership status), private well owners, and Board of Health (BOH) agents, and exemplified a range of different private well regulations and bylaws, or lack thereof in several towns in Massachusetts. The following conclusions and recommendations seek to remediate this:

- Include standardized testing requirements to ensure consistent and comparable data collection and monitoring for identifying and addressing PFAS contamination in private wells.

- Consider shortening the model bylaw and where feasible provide more regulations as separate documents or supporting materials to make it easier for municipalities to adopt and implement.
- Encourage use of clear and concise language in the all bylaws to make it easily understandable for all stakeholders.
- Include remediation strategies for private well owners whose wells exceed regulatory standards for PFAS, to ensure consistent remediation efforts and provide homeowners with resources and information to address PFAS contamination.
- Providing clear language and standardized testing requirements, as well as including remediation strategies, will help to ensure that private well owners are aware of the risks associated with PFAS contamination and have access to the resources they need to address it.
- Produce supplemental educational materials, such as infographics and pamphlets, to address knowledge gaps for the general public, private well owners, and BOH agents.
- For the general public, post infographics on town-run websites or social media groups and mail infographics or pamphlets to ensure all residents receive information.
- For private well owners, create educational materials about well testing and water treatment systems and distribute them in the same fashion as the infographics for the general public.
- For BOH agents, provide training and support to help them understand the new model bylaw and its requirements, as well as offer resources to educate private well owners.

In conclusion, the provided recommendations seek to address the issues concerning PFAS in private well water across Massachusetts. These recommendations will help to empower

Massachusetts residents and Board of Health agents alike to take charge of the issues facing them and their communities respectively and work together to promote safe and clean drinking water for all.

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1) Introduction

Per- and polyfluoroalkyl substances (PFAS) are a class of synthetic chemicals commonly used in manufacturing processes and consumer products. Unfortunately, these chemicals are persistent in the environment and have been linked to a variety of adverse health outcomes, including cancer, immune system disorders, and environmental imbalance. One significant area of PFAS contamination is through private water wells, which are often used by rural communities and households.

The state of Massachusetts has been grappling with the impact of PFAS on private water wells for several years, and the issue has received increased attention due to recent regulatory changes. In Massachusetts, public supplies are regulated, but private wells are not. There is a concern about the publics' awareness of the potential for PFAS in their wells, the importance of testing, and how bylaws may help to manage the concerns.

The goal of this project was to increase understanding of the impacts of PFAS in private well water and recommend language for PFAS model bylaws. To accomplish this goal, we began by providing a general overview of PFAS, including their properties, sources, and health effects. Next, we introduced the specific problem of PFAS contamination in private water wells in Massachusetts, including its prevalence, sources, and potential health risks.

We then define the scope of the problem by summarizing previous work on PFAS in private water wells and highlighting key insights from the research literature. This includes a discussion of regulatory standards, sampling protocols, and remediation strategies.

2) Background

PFAS has been recognized as a contaminant that is so persistent that it has been found in a wide variety of products we use, the food we eat, and the water we drink. This project focuses on understanding our awareness of PFAS in drinking water walls. This chapter provides some background to understand the context of PFAS, its impacts in drinking water wells, and the current use of bylaws to protect the public. We begin by discussing the origin of PFAS. Next, we discuss PFAS as a persistent chemical contaminating air, water, and food, and its health and environmental impacts. We then explore current laws attempting to mitigate PFAS and its impacts on private drinking wells and how model bylaws are created and implemented in small towns and communities. Finally, we introduce the sponsors of this project and the project goal.

2.1) PFAS Origin and History

Per- and poly-fluoroalkyl substances (PFAS) are a group of artificial chemicals that have been in use since the 1940s. The first PFAS, polytetrafluoroethylene (PTFE), was developed by DuPont and introduced as Teflon in the 1950s (Abunada, 2020). PTFE was initially used in the aerospace industry as a coating for electrical wires and non-stick cookware. These chemicals are widely used in various products due to their unique properties, such as resistance to heat, water, oil, and stains. Some everyday products containing PFAS include non-stick cookware, food packaging, firefighting foam, clothing, textiles, carpet, cleaning products, and even cosmetics (Goldenman, 2019).

It is important to note that there are numerous forms of PFAS, with varying properties and health effects. The six PFAS constituents that are currently regulated by the Massachusetts Department of Environmental Protection (MassDEP) are perfluorooctane sulfonic acid (PFOS), perfluorooctanoic acid (PFOA), perfluorohexane sulfonic acid (PFHxS), perfluorononanoic acid (PFNA), PFBS, and HFPO-DA (GenX) (Massachusetts Department of Environmental

Protection, 2023). These six PFAS have been identified as significant concerns due to their prevalence in the environment, potential health risks, and persistence in the environment. While there are other forms of PFAS that may also be present in the environment, MassDEP's current regulatory focus is on these six constituents. Understanding the properties and risks associated with these specific PFAS is critical to developing effective strategies for addressing PFAS contamination in private water wells in Massachusetts.

Per- and poly-fluoroalkyl substances (PFAS) are highly persistent in the environment, meaning they do not break down easily (Goldenman, 2019). As a result, once products containing PFAS are disposed of, the PFAS do not biodegrade, but remain in the environment contaminating groundwater. Some of the most common sources of PFAS contamination in groundwater include industrial discharges, landfills, waste sites, agricultural runoff, air deposition, and leakage from underground storage tanks (Abunada, 2020). Once PFAS contaminates water sources, it is typically very hard to remove. Removal of PFAS is challenging, as the chemicals spread through agricultural means and groundwater, contaminating various environmental resources, including soil, water, and air (Goldenman, 2019).

Testing for PFAS in private water wells is essential for understanding the extent of contamination and assessing potential health risks. The most common method for PFAS testing in private wells is through laboratory analysis of water samples. However, it is important to note that there are several factors to consider when collecting and testing samples, including the location of the well, the time of day the sample is collected, and the sampling protocol used (USEPA, 2021). These factors can impact the accuracy and reliability of the test results, and it is essential to follow established sampling protocols to ensure accurate results (USEPA, 2021). MassDEP has established protocols for testing private wells for PFAS, and it is critical to follow

these guidelines to ensure that the results are accurate and reliable. Regular testing is also recommended, as PFAS contamination can occur over time, and continued monitoring can help identify changes in contamination levels and inform remediation efforts (Massachusetts Department of Environmental Protection, 2023). Additionally, it is important to note that testing for PFAS in private water wells often requires multiple samples to be collected and tested to confirm the presence of PFAS (Massachusetts Department of Environmental Protection, 2023). MassDEP recommends that at least two rounds of testing be conducted to confirm the presence of PFAS in a private water well. If PFAS is detected in the first round of testing, a second round of testing is recommended to confirm the results and assess changes in contamination levels. By conducting multiple rounds of testing, it is possible to develop a more accurate understanding of the extent of PFAS contamination in private water wells, which can inform remediation efforts and help protect public health.

Additionally, conventional water treatment methods are not typically effective in removing PFAS, making it necessary to utilize specialized treatment technologies such as point of entry (POE) and point of use (POU) treatment systems (Massachusetts Department of Environmental Protection, 2023). POE treatment systems are used to treat well water at the entry of the water system to the house, providing clean water for all areas of the living space (Massachusetts Department of Environmental Protection, 2023). Some basic POE treatment systems are sediment filters, carbon filters, water softeners, Ultraviolet systems(Massachusetts Department of Environmental Protection, 2023). POU treatment systems are devices installed on independent faucets to eliminate contaminants as they come through the pipes before they exit through the faucets (Massachusetts Department of Environmental Protection, 2023). Examples include chlorination systems, reverse osmosis systems, and distillers (Massachusetts Department

of Environmental Protection, 2023). The complexity of PFAS removal requires a comprehensive approach, including careful monitoring and assessment, advanced treatment technologies, and effective management strategies to minimize further spread and contamination (Goldenman, 2019).

2.2) Problems with PFAS Contamination

While consumers may have loved the functionality of PFAS products such as non-stick cookware, this group of chemicals severely impact the environment and human health. Due to their chemical properties, resistance to degradation, ability to spread, the complexity of treatment methods, and composition of long carbon-fluorine bonds, PFAS is resistant to breakdown and removal by traditional water treatment methods (Goldenman, 2019). We start this section by exploring the effects that PFAS has on the environment and its persistence. Next, we evaluate some of the health impacts of PFAS contamination.

PFAS contaminates water, soil, and air. PFAS are highly persistent in the environment, meaning they do not break down easily and can travel long distances through groundwater and surface water (Goldenman, 2019). This has led to widespread contamination of drinking water and other water sources, making avoiding exposure to these chemicals difficult. PFAS can also harm wildlife and aquatic ecosystems, affecting the food chain and causing long-term ecological impacts, such as affecting the ability of natural systems to store carbon and regulate their climate.

Along with the effects that PFAS has on the environment, there are also numerous invisible effects on climate change and the ozone layer. PFAS (per and poly-fluoroalkyl substances) can affect the climate in several ways. One of the main ways is by releasing perfluorocarbons (PFCs) during production and usage, which have a global warming potential thousands of times greater than carbon dioxide (Mahmoudnia, 2022). PFAS can also contribute

to climate change by impacting the ozone layer. Some PFAS can create byproducts that damage the ozone layer, leading to increased levels of ultraviolet radiation on Earth's surface. It is important to note that research on the environmental impacts of PFAS is ongoing, and more data is needed to understand it fully. Because of the severe effects that PFAS has on the environment, both on a visible and invisible level, PFAS contamination requires remediation. This remediation is expensive and not always possible (Mahmoudnia, 2022). These expenditures can come from the need to treat water contamination to prevent ecosystem harm, ecosystem rehabilitation, clean-up of PFAS and other chemical byproducts, and lost property values caused by the need to work to mitigate contamination of PFAS on both public and private lands (Goldenman, 2019). Just like the many effects PFAS has on the environment and climate change, it has equally as many effects on human health.

Many health risks are associated with PFAS exposure, especially for women, children, and other vulnerable groups. The effects of PFAS exposure are varied and depend on the amount of time a person is exposed to PFAS and the quantity of PFAS they are exposed to. Currently, there is not a lot of research yet about PFAS exposure and its health effects, especially with long-term PFAS exposure (Steenland & Winquist, 2021). However, from the studies completed so far, some of the harmful effects of PFAS exposure have come to light. According to research by Roth et al., PFAS has been linked to increased cholesterol, bile acid, sterol metabolism, liver weight, and hepatic liver injury in mice (Roth et al., 2021). In people, PFOS and PFNA, which are PFAS chemicals, have been linked to an increase of about 5 mg/dL of non-HDL cholesterol per exposure quartile and an increase of 6 mg/dL of total cholesterol per exposure quartile (Rosen et al., 2022). That means that the higher a person's exposure to PFAS, the higher their overall cholesterol. The increase in cholesterol can lead to heart disease and liver disease. It has

also been seen that exposure to both old and new PFAS compounds can lead to thyroid issues (Coperchini et al., 2021). Some groups of people are at higher risk for health effects after PFAS exposure. These groups include small children, pregnant women, babies, elderly people, and immunocompromised people.

In pregnant women, PFAS can affect the development and function of the placenta, affecting the unborn baby and leading to chronic health problems for the child later in life (Blake & Fenton, 2020). Some health problems that male babies can experience later in life are lower total sperm count and sperm concentration. They can experience more immotile and nonprogressive sperm as well (Haervig et al., 2022). Men are also more likely to get kidney, testicular, and prostate cancers from high exposure to PFAS (Steenland & Winquist, 2021). Although PFAS exposure can put both men and women at higher risk for developing cancer, women may also experience more issues with their menstrual cycle and ovaries. With high amounts of PFAS exposure, women can experience "later menarche, irregular menstrual cycles, longer cycle length, earlier age of menopause, and reduced levels of estrogens and androgens" (Ding et al., 2020). People are mainly exposed to PFAS from their environments, including but not limited to the air, water, and food. Mitigation is an important factor in protecting the environment and reducing people’s exposure to PFAS.

2.3) Methods to Mitigate PFAS

There is no doubt that PFAS in drinking water is a problem, but it isn't a problem without solutions. Keeping PFAS from coming in contact with humans is the easiest way to keep people safe. There are two main ways to do this: removing PFAS from the water before it is used and preventing PFAS from getting into the water in the first place. In short, remediation and prevention. In this section, we cover PFAS filtration and treatment options and then explore the

United States Environmental Protection Agency's (USEPA) approach, the Massachusetts approach, and the potential role of local bylaws.

Three of the most prevalent methods for removing PFAS from drinking water are granular activated carbon, reverse osmosis filters, and ion exchange resins (Voulgaropoulos, 2022). Granular activated carbon removes PFAS from water by absorbing it into the carbon (Park et al., 2020). It is an effective method of removing PFAS from water and is mainly used to remove PFAS from groundwater. Reverse osmosis filters are mainly used to remove PFAS from drinking water at a household level and have been proven to be very effective (Mahmoudnia et al., 2022). Ion-exchange resins remove short-chain PFAS where activated carbon cannot (Dixit et al., 2021). Ion-exchange resins are mostly used to remove PFAS from the environment rather than at a household level. For this project, we mainly focus on the potential role of government structures to tackle PFAS and not specific PFAS removal methods. To understand the role that governing structures play in PFAS mitigation we must first explore the various government agencies that are currently working on it.

Governing bodies focused on protecting the health and safety of individuals, towns, or regions have different approaches to mitigating PFAS. At a federal level, the United States Environmental Protection Agency (USEPA) approach is focused on keeping PFAS out of groundwater in the first place. To do this, USEPA holds polluters accountable for the PFAS they introduce into the environment by monitoring discharge and charging them for the cost of the cleanup if applicable. The USEPA also has a focus on helping disadvantaged communities. They put prevention before remediation, but the USEPA still makes efforts for the equitable removal of PFAS from the environment (USEPA, 2021). Aside from monitoring polluters, the USEPA also funds projects that help clean up PFAS. They sponsor two separate State Revolving Funds

(SRFs) focused on several PFAS-related aspects of water management. The USEPA committed $1 billion to the Clean Water SRF and $4 billion to the Drinking Water SRF. The USEPA also funds the Safe Drinking Water Act, which is focused on protecting the quality of public drinking water. Although the USEPA doesn't regulate private drinking water, they regulate and enforce standards for public drinking water. In the context of private well water, the overarching idea of the USEPA approach is to secure funding for PFAS-related problems (National Conference of State Legislatures, 2022).

On a state level, we explored what the state of Massachusetts is doing to address PFAS in drinking water. Although they do not directly regulate private wells, they do have a model bylaw aimed at helping individual Boards of Health (BOHs) address PFAS in their private wells. Presently, the model bylaw recommendation is to keep the combined total of the PFAS six chemicals below 20 parts per trillion (ppt) (Baskin et al., 2023). The Massachusetts method focuses on community support through a multi-faceted approach of both prevention and remediation. The Massachusetts Department of Environmental Protection (MassDEP) offers financial assistance to communities to remove PFAS from drinking water. MassDEP also samples public drinking water statewide for PFAS and other contaminants and in 2021 they developed a maximum contaminant level drinking water standard for PFAS. They help private well owners implement methods to remove PFAS from their wells. Presently, Massachusetts offers a zero-interest loan to towns to help towns decrease their PFAS levels and make the town's public drinking water safe (Massachusetts Department of Environmental Protection, 2021).

Although Massachusetts has done work to mitigate the impacts of PFAS, there are no regulations or enforced monitoring for PFAS in private wells (Massachusetts Department of

Environmental Protection, 2023). According to Andrea Briggs (Deputy Regional Director for the MassDEP), Massachusetts offers testing and remediation solutions to residents; however, residents often opt out of testing, leaving testing and cleanup regulations to local health boards (A. Briggs & T. Schiller, personal communication, January 25, 2023).

In the absence of widespread regulations, local communities can pass bylaws to help mitigate the health impacts of PFAS. Bylaws are a set of rules or regulations that an organization or community establishes. In this context, a bylaw is passed by towns or cities to keep their residents safe (Baptista, 2014). Bylaws can be used to help individual people on a case-to-case basis. Some Massachusetts towns have bylaws dealing with testing that can lead to individuals being required to test their wells. The MassDEP needs testing data from private wells to better gauge the contamination throughout Massachusetts. This data can help the MassDEP identify sources of PFAS contamination and may help offset the cost of PFAS mitigation for private well owners if a private company is found responsible for the PFAS contamination. If a source cannot be connected to a private well, the cost of remediation falls to the owner of the private well (Massachusetts Department of Environmental Protection, 2023a). For the purposes of this project, we focus on the utility of bylaws and education in mitigating the impact of PFAS. When creating the language of Model bylaws, several aspects need to be considered, one of which will be the potential cost associated with mitigation techniques for PFAS.

2.4) Process of Passing Local Bylaws

There are already some regulations on the amount of PFAS allowed to be present in public water supplies in Massachusetts, but there are no such regulations on private wells in Massachusetts. The maximum amount of PFAS allowed in public drinking water is 20 parts per trillion (PPT) in MA, which is the suggested maximum amount of PFAS allowed in private wells (Massachusetts Department of Environmental Protection, 2023). Although the MassDEP can

regulate the amount of contamination in public water supplies, it does not have any ability to regulate the contaminant levels in private wells (Massachusetts Department of Environmental Protection, 2023). Private well owners are financially responsible for testing their wells, performing required maintenance, and should PFAS be found, implementing mitigation methods like POEs and POUs (Massachusetts Department of Environmental Protection, 2023). Since the MassDEP has no regulatory power over private wells, regulating them is left to local boards of health and town legislative bodies for those areas (Massachusetts Department of Environmental Protection, 2023). Because regulations of private wells are handled at local levels, the problem of PFAS contamination in private wells needs to be addressed by local bylaws. When working to create bylaws, a model bylaw, which supplies the needed language to make a new law, is often created. Towns can then adapt the language to fit the needs of the specific community.

In Massachusetts, town residents can vote on proposed bylaws via Town Meetings. These Town Meetings are called by the town's board of selectmen or are held at an annually scheduled time in February, March, April, or May. During these meetings, all town members are allowed to vote directly on proposed issues or, in bigger municipalities, town residents elect Town Meeting members to represent them in Town Meeting (Galvin, n.d.). The way these meetings are held gives people the ability to have a say in the local laws, also known as bylaws, that govern their town. Local bylaws can offer a way to regulate PFAS contamination in private wells.

Massachusetts has utilized many model bylaws to help towns pass important laws. One example occurred in 2008, when outdoor wood fire boilers became popular. These wood fire boilers were found to be at the root of several issues, mainly surrounding the smoke that resulted from burning wood (Massachusetts Department of Environmental Protection, 2023). Some of the issues seen with wood fire boilers are the improper location of units, heavy smoke being released

close to the ground, and health and nuisance conditions caused by the heavy smoke (Town of Barre Board of Health, 2008). To remedy these issues and maintain a healthy living space free of pollution, the town of Barre put into effect a bylaw to better manage the installation, use, and regulations of wood fire boilers (Town of Barre Board of Health, 2008). This bylaw set minimum smokestack heights to prevent smoke from exiting the boilers too close to the ground, set guidelines on where boilers can be placed, and set rules on what can be burned (Town of Barre Board of Health, 2008). This bylaw helps eliminate the nuisance conditions caused by smoke, helps reduce health issues caused by breathing in toxins, and limits the pollutants in the air by ensuring that what is burned is not full of toxic chemicals (Town of Barre Board of Health, 2008). Implementing this bylaw demonstrates how a model bylaw can be adapted to fit the needs of the people it serves. Furthermore, using model bylaws to help implement PFAS regulations on private wells allows for the different areas of Massachusetts to tailor regulations to what best suits their town.

To create a model bylaw, there are many things to consider. The process is divided into three main steps: identify the problem, brainstorm solutions, and identify possible expenditures. To fully identify a problem, towns need to assess demographics, finances, and technical abilities (Baptista, 2014).] These factors include but are not limited to the following, demographic information, financial limitations of the town, and technological abilities of the town's inhabitants. Once the problem is identified, the state must outline all the goals it aims to achieve with the bylaw, while keeping a reasonable scope in mind (Baptista, 2014). During this portion of the model bylaw creation, the town identifies the target audience. The last step is to consider the expenditures resulting from implementing the bylaw (Baptista, 2014). The possible expenditures a town might consider at this stage in model bylaw creation can include time,

money, and physical resources. The extent that these expenditures will affect each town varies greatly, which is why model bylaws are merely models. Each town can make changes to the model bylaws so the town can feasibly maintain, implement, and adopt it.

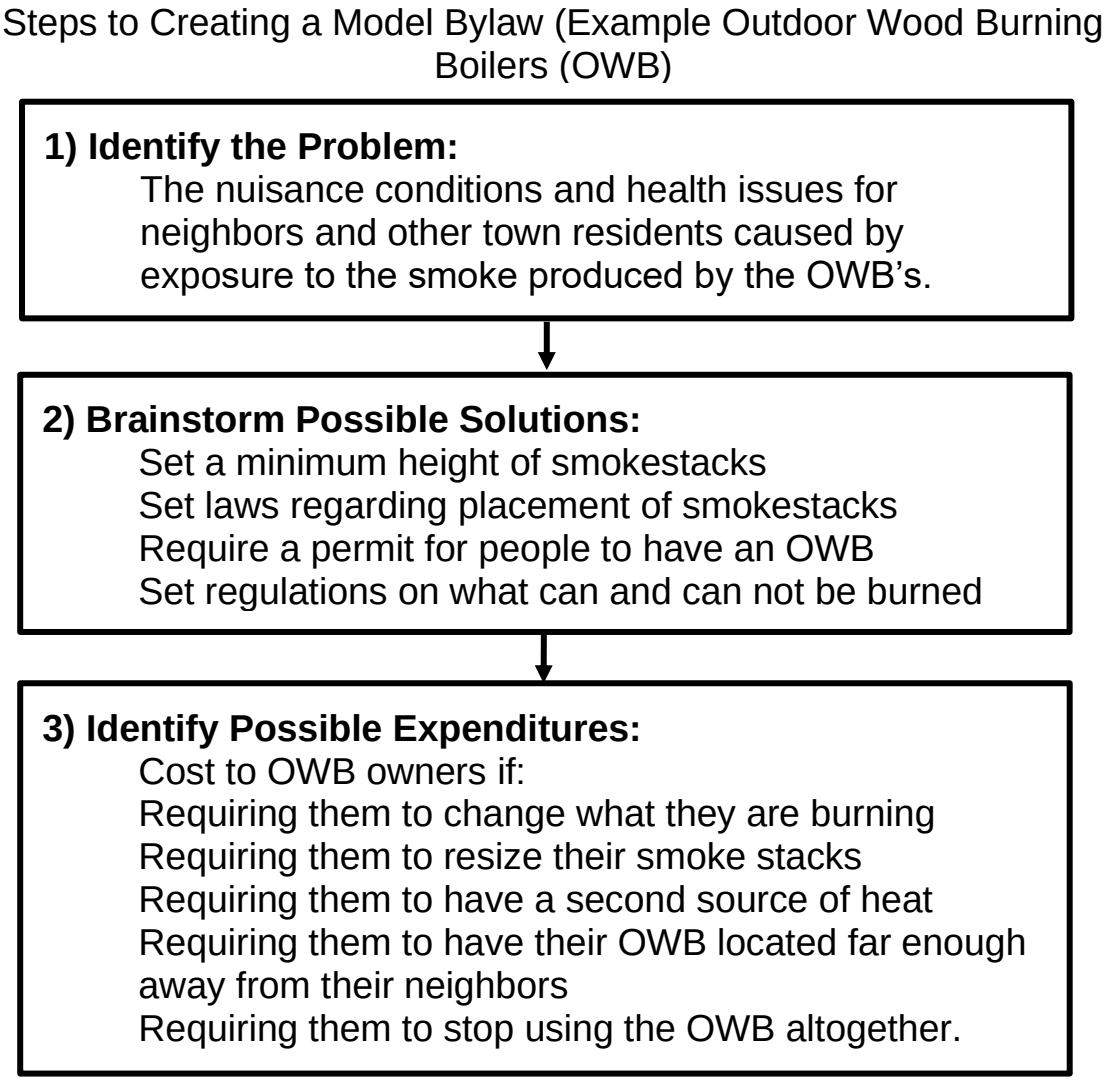

Figure 1: Depiction of a model bylaw creation process using the steps outlined from Baptista (Baptista, 2014) as applied to the Barre, MA outdoor wood-burning boiler bylaw example (Town of Barre Board of Health, 2008).

Adopting a bylaw is not enough to implement even at the local level in towns. To effectively implement an adopted bylaw, town leaders and officials need to ensure that residents understand the purpose of the bylaw and why it has been adopted, as well as consistently enforce

the new bylaw. To ensure that residents understand why a bylaw is being implemented and its expected outcomes, it is imperative for a town to provide some form of education about the new bylaw to its citizens. This can be done through information sessions, online guides, town meetings, and advertisements (Cole et al., 2011). It is also important for towns to monitor how their residents react and adapt to newly implemented bylaws (Cole et al., 2011). Focus groups, surveys, telephone calls, and inspector visits can be helpful for towns trying to gauge the success of new bylaws. This allows the town to make necessary changes in its approach towards its residents in explaining the importance of the bylaw and why it was adopted. According to Cole et al., this education and follow-up approach ensures less pushback against the new bylaw, as residents have a grasp of its importance (2011).

To understand the bylaw creation process we must look at the organizations that play a role in the bylaw creation at different levels of government. For example, the Massachusetts Department of Environmental Protection (MassDEP) regulates contaminant levels in public drinking water systems and recommends regulations on private well water systems (Massachusetts Department of Environmental Protection, 2020). The Massachusetts Health Officers Association (MHOA) oversees local boards of health, which work with the MassDEP and local town governments to pass bylaws and implement suggested regulations on private wells to keep residents safe (Massachusetts Health Officers Association, 2023). Since the MassDEP and the MHOA are big players in drinking water regulations, they are interested in developing a PFAS model bylaw for private well owners. As a result, for our project, we will be working with the MassDEP and the MHOA to develop a model bylaw to tackle the issue of PFAS in Massachusetts private wells. We discuss our methodological approach more in detail in the next chapter.

3) Methodology

The goal of our project was to increase understanding of the impacts of PFAS in private well water and recommend language for PFAS model bylaws. There are several steps we needed to complete before we considered the language for the current model bylaw and supporting educational materials. In this section we summarized the four objectives we developed and how we accomplished them.

- Understood PFAS, effects of PFAS contamination in well-water, and mitigation methods for private wells
- Identified the knowledge gap in private well owners about PFAS and outreach methods
- Identified and analyzed current laws surrounding PFAS in private well water in Massachusetts and other states and process of developing model bylaws
- Recommended edits to the PFAS Model Bylaw and drafted supporting educational materials for private well owners

3.1) Understand PFAS, Effects of PFAS Contamination in Well-Water, and Mitigation Methods for Private Wells

The aim of this objective was to explore the presence of per- and polyfluoroalkyl substances (PFAS) in private well-water, the effects of PFAS contamination on human health, and the mitigation methods available for private wells. In order to achieve this objective we conducted content analysis and semi-structured interviews.

We began by conducting content analysis of relevant literature on PFAS. Using this method we analyzed peer-reviewed articles, scientific reports, and relevant government documents pertaining to PFAS in well-water and methods to mitigate PFAS. Content analysis is a method used to acquire a deeper understanding of a subject by systematically analyzing relevant literature and media (Flick et al., 2004). Our literature review provided an introduction to the current state of knowledge on PFAS.

To gain a deeper understanding of the impact of PFAS on human health and the most effective mitigation methods we conducted semi-structured interviews. We conducted interviews with: public health experts with knowledge and experience on the impact of PFAS on human health; environmental agency representatives with expertise in PFAS mitigation methods, and other experts in the PFAS field specifically those under MHOA towns. While each interview varied slightly based on the interviewee's expertise, we focused on the following topics: the impact of PFAS on human health, the potential for private well contamination, the effectiveness of mitigation methods for private wells, the challenges and barriers to implementing mitigation methods for private wells, the importance of and the steps involved in testing for contaminants in private wells, and the barriers to understanding the impacts of PFAS on private wells (See Appendices B-D for draft interview questions). Through all these interviews we ensured that participants had read the informed consent and were aware of how their information would be used according to the IRB we submitted (See Appendix A for the informed consent form).

3.2) Identify the Knowledge Gap in Private Well Owners and Local Boards of Health Agents about PFAS and Outreach Methods

This objective aimed to identify knowledge gaps regarding PFAS among private well owners in Massachusetts and identify possible outreach materials to close the knowledge gap. To achieve this objective, we conducted semi-structured interviews with area specialists, a survey of private well owners, and a survey of the MHOA boards of health agents. In these surveys and interviews we ensured that participants were aware of how their information would be used according to our IRB (See Appendix A for the informed consent form).

We conducted semi-structured interviews with the Massachusetts Department of Environmental Protection (MassDEP) employees such as Kevin Daoust, Joe Cerutti, and Jim Starbard from RCAP solutions. We also sent out a survey to members of the Massachusetts

Health Officers Association (MHOA) to gain an understanding of the knowledge gap that exists in private well owners about PFAS (see Appendix E for draft MassDEP and MHOA interview questions and Appendix G for draft MHOA survey questions).

We then distributed a survey to private well owners across Massachusetts, and the public. The survey was posted across social media by our sponsors. We used the survey to gauge the general understanding of PFAS and the importance of water quality testing among private well owners and identified our medium for supporting educational materials (see draft survey questions for well owners in appendix F).

3.3) Identify and Analyze Current Laws Surrounding PFAS in Private Well Water in Massachusetts and Other States and Process of Developing Model Bylaw

Before we recommended language for a model bylaw we investigated existing laws dealing with PFAS and other contaminants in private wells. The main methods we used to accomplish this were content analysis and semi-structured interviews.

Using our background research as a starting point, we investigated current legal efforts to remediate PFAS and other contaminants. We analyzed bylaws provided by Board of Health agents associated with the MHOA to gain understanding of the diverse regulations surrounding private wells.

Model bylaws are sample versions of language towns can use and modify to develop town specific bylaws. One place model bylaws can be found is on the MassDEP website, as they often provide towns with model bylaws for environmental issues (Massachusetts Department of Environmental Protection, 2018). A bylaw is a law, adopted by a town through a Town Meeting, that often follows language in a model bylaw. Once a bylaw has been passed it is up to town officials to enforce the new bylaw for all residents.

To develop a deeper understanding of how bylaws are created, we conducted semi-structured interviews with the MassDEP, the MHOA, and several local Board of Health agents with different town bylaws for private wells. Both the MassDEP and the MHOA are key players in the model bylaw creation process because the MassDEP often creates model bylaws for local boards of health, and the MHOA oversees all the local boards of health in Massachusetts (Massachusetts Health Officers Association, 2023).

We interviewed a legislative expert from the Massachusetts Municipal Association (MMA) (a draft list of interview questions can be found in appendix H). The information from this interview helped us understand the process by which a model bylaw becomes an enforceable town law.

By conducting the interviews with the people and organizations listed above we gained an understanding of the process of passing a law on a local level. In these interviews we ensured that participants were aware of how their information would be used according to our IRB (See Appendix A for the informed consent form).

3.4) Revise PFAS Model Bylaw and Draft Educational Materials for Private Well Owners

We analyzed data collected in objectives 1-3 and used findings to adjust the current model bylaw and draft educational materials for private well owners and local board of health agents. These findings helped us identify the important points to include in the model bylaw. After we reviewed and considered edits to the model bylaw and drafted educational materials we met with our sponsors to seek their feedback. We then used this feedback to complete our report and revise both deliverables.

4) Findings and Discussion

This project aimed to explore strategies for mitigating PFAS contamination in private water wells as well as create supporting educational materials for the general public. Throughout the project, we covered basic concepts surrounding PFAS, the gap in knowledge for public health officials and the general public, and the current regulations surrounding PFAS.

4.1) The Concepts Surrounding PFAS

In this section, we will delve into the concepts surrounding PFAS, including the nature of PFAS and the potential health effects associated with exposure to these chemicals. We will also discuss the methods used to test for PFAS in the environment and in products, as well as the mitigation techniques currently available to reduce exposure. Understanding these concepts is essential in addressing the ongoing concerns related to PFAS contamination and protecting human health and the environment.

4.1.1) Nature of PFAS:

PFAS, or per- and polyfluoroalkyl substances, are a group of man-made chemicals that have been widely used in industry and consumer products since the 1950s due to their unique properties, such as resistance to heat, water, and oil. From our interviews with various environmental experts, we found that there are over 5,000 different types of PFAS, but the most studied and concerning are perfluorooctanoic acid (PFOA) and perfluorooctanesulfonic acid (PFOS), which have been linked to a range of adverse health effects, including cancer, liver damage, developmental delays, and immune system dysfunction.

These harmful effects of PFAS have led to their phase-out by major manufacturers in the US and elsewhere. However, PFAS are still found in many consumer products and materials, such as food packaging, non-stick cookware, and stain-resistant fabrics, as well as in firefighting foams used by the military and airports. The persistence of PFAS in the environment, coupled with their widespread use, has resulted in contamination of water and soil in many areas.

To address the issue of PFAS contamination, the United States Environmental Protection Agency (USEPA) recently updated its drinking water standard for PFAS to include six specific forms of the chemical. The new standard, which has a limit of 4 parts per trillion (ppt), is a significant decrease from the previous health advisory level of 70 ppt. This change reflects growing concerns about the health effects of PFAS exposure, especially on vulnerable populations such as pregnant women and children.

Furthermore, talking to legal experts, we learned that the USEPA has also been working to regulate and monitor PFAS in other areas, such as air emissions and waste management. In addition, several states have taken action to regulate PFAS, with some implementing even stricter standards than the federal government. As the health and environmental impacts of PFAS continue to be studied and understood, it is likely that more regulation and mitigation efforts will be needed to address this pervasive and persistent issue.

4.1.2) PFAS Testing:

Testing for PFAS contamination is critical for identifying and mitigating exposure to these chemicals. There are several methods for testing for PFAS in water, soil, and other materials, but the most commonly used methods are based on liquid chromatography-tandem mass spectrometry (LC-MS/MS) as informed by Kevin Daoust. This technique involves separating the individual PFAS compounds and quantifying them based on their mass-to-charge ratios.

From the interview with Kevin Daoust, we also learned that there are also field-testing methods that use portable instruments to measure the total concentration of PFAS in water samples. These methods are generally less accurate and precise than laboratory-based methods but can provide a quick and easy way to screen for PFAS contamination in the field.

One challenge with PFAS testing is that there are no established regulatory limits or standards for these chemicals in many countries, including the US. This can make it difficult to interpret test results and determine what levels of contamination are safe or acceptable. Additionally, the testing methods themselves can be complex and expensive, which may limit their availability and accessibility in certain areas. For example, in Massachusetts, additional testing is required in order to verify the result of the first test.

Despite these challenges, testing for PFAS remains a critical tool for identifying and addressing contamination of these chemicals in the environment. However, it is important to note that PFAS testing can be expensive and could likely discourage private well owners from testing. As research continues to uncover new information about the toxicity and persistence of PFAS, it is likely that regulatory standards and testing methods will continue to evolve to better protect human health and the environment from these persistent pollutants.

4.1.3) Mitigation Methods:

In response to the growing concerns over PFAS contamination, there are several mitigation methods that have been developed to remove these chemicals from water sources. The two most common methods are Granular Activated Carbon (GAC) and Ion Exchange (IX).

During our interview with the town of Ayer, they showed us their PFAS testing system, which uses both GAC and IX. However, they are leaning more towards GAC due to its cost-effectiveness and efficiency. Although the cost of GAC is higher than that of IX (roughly 5 million versus 3.5 million), the town of Ayer found that they were having to replace the IX every 6 months, even though they initially expected it to last for 3 years. This unexpected expense has made them more inclined to use GAC as their primary method for removing PFAS from their water supply.

On the other hand, the Massachusetts Department of Environmental Protection (MassDEP) strongly advises against using Reverse Osmosis (RO) treatment as a method for removing PFAS from water sources. While RO can remove PFAS from water, it is not effective in removing all types of PFAS, particularly those with shorter carbon chains. Additionally, the use of RO can result in concentrated waste streams that contain high levels of PFAS, which can be difficult to dispose of properly and a permit needs to be obtained to install this type of treatment system. As a result, MassDEP recommends using GAC or IX as the primary method for removing PFAS from water sources.

In conclusion, while there are several mitigation methods for removing PFAS from water sources, GAC and IX are the most common and recommended methods. The decision on which method to use will depend on various factors such as cost, efficiency, and the specific type of PFAS that needs to be removed. Ultimately, it is important for communities to address PFAS contamination and take necessary steps to protect the health of their residents and the environment. However, it is important to note that addressing PFAS contamination can be expensive, which may be a concern for homeowners. This can include the cost of testing for PFAS, implementing treatment systems to remove PFAS from drinking water, and potentially even legal fees for those affected by contamination. Homeowners may want to consider reaching out to local authorities or community organizations to discuss options for financial assistance or resources that can help mitigate the cost of addressing PFAS contamination.

4.2) The Knowledge Gap

To understand what needs to be done to support local Boards of Health and private well owners, we identified the knowledge gap that each group has surrounding PFAS. To accomplish this we surveyed the general public of Massachusetts (Massachusetts residents regardless of private well ownership) and Board of Health agents associated with the MHOA.

4.2.1) Understanding the Knowledge Gap among Massachusetts Residents about PFAS

We started by surveying 116 Massachusetts residents about PFAS knowledge, Town meeting attendance and bylaw knowledge, as well as outreach methods people are likely to utilize to gain knowledge about water contaminants. We learned that the majority of the general public are not familiar with PFAS, and the biological or environmental impacts PFAS can have. We also found that although the majority of the people surveyed knew what a bylaw was, they had not been to a Town Meeting recently. When exploring what the best outreach methods are, we found that the majority of people surveyed reported that they turn to the internet to receive education on current water contaminants. To ensure we are reaching as many people as possible with outreach materials it was also clear that towns would also need to leverage mailing of infographics for those that are less technically inclined.

Knowledge Gap around what PFAS are in the General Public

Of those surveyed from the general public in Massachusetts, the majority said they were not familiar with or were unsure of what PFAS are. We found that 20.63% of respondents were unsure what PFAS are and 34.92% of respondents did not know what PFAS are. Only 44.44% of survey respondents knew what PFAS are. This information, illustrated in figure 2, shows that although the United States Environmental Protection Agency (USEPA) has recently released new guidelines on the amount of PFAS allowed in public drinking water in the United States, and the MassDEP has been regulating PFAS in public drinking water in Massachusetts since 2019 (Horewitch Coppinger & Grachuk, 2020), that majority of people in Massachusetts are unfamiliar with what PFAS are. This points to there being a knowledge gap around what PFAS are and what contains PFAS. Furthermore this data depicts that there is a lack of education around PFAS, and its effects on both the environment and human health

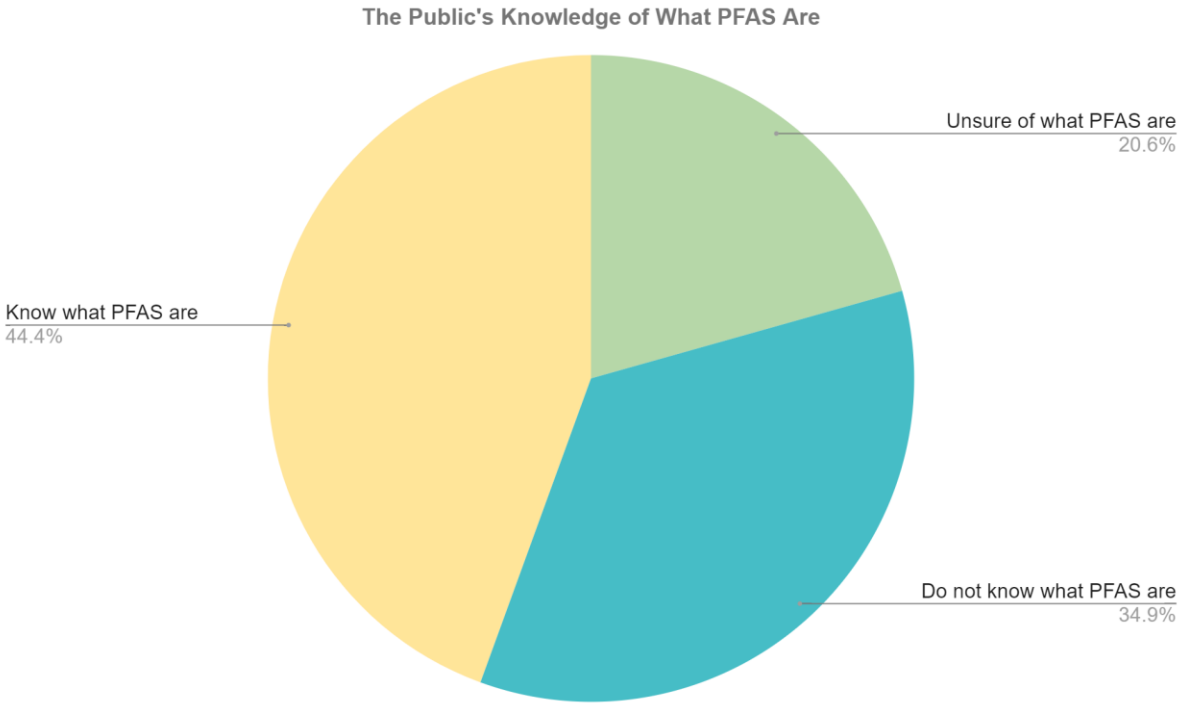

Figure 2: A pie chart show the distribution of survey respondents who know what PFAS are

Knowledge Gap around the Impacts of PFAS in the General Public

In a follow up question in the survey where respondents were asked to identify what was and was not an impact of PFAS, the majority of people misidentified high blood pressure and high cholesterol as not being associated impacts of PFAS exposure, and misidentified healthier plants as being associated with PFAS contamination in the environment, illustrated in figure 3. Despite the few miscategorized effects of PFAS 65.45% of survey respondents correctly categorized the effects of PFAS and 34.55% incorrectly categorized the impacts of PFAS, illustrated in figure 4. This demonstrated that not all effects and impacts of PFAS were understood by the general public and that further educational materials are needed to help the public understand the biological and environmental effects of PFAS.

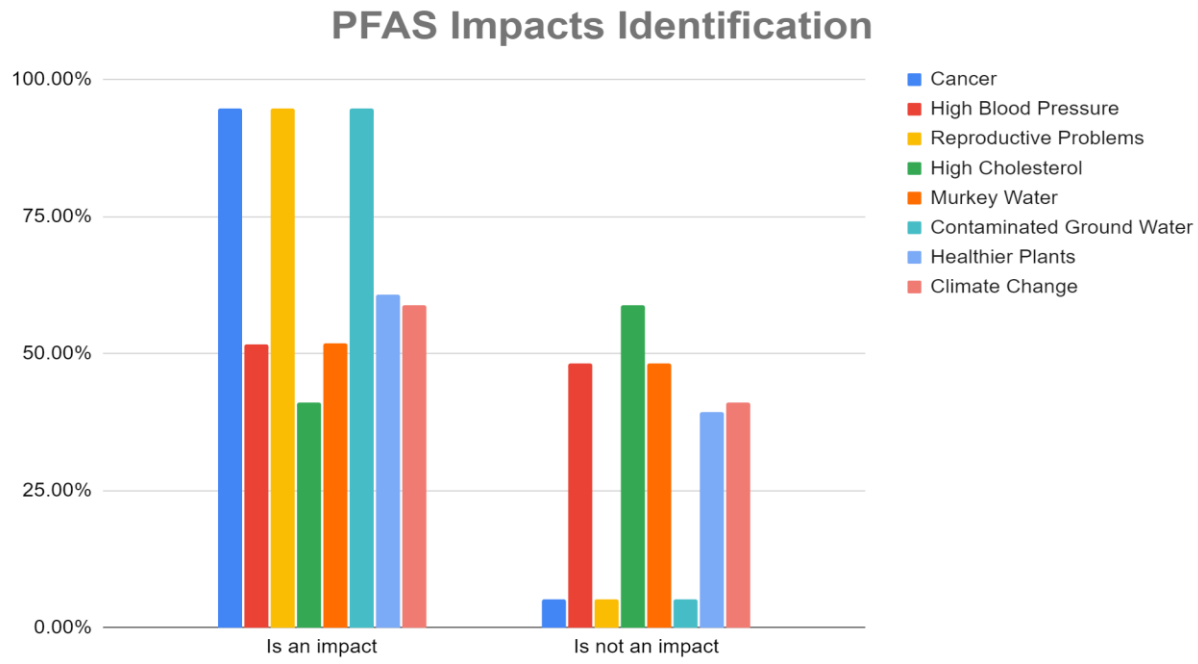

Figure 3: A full breakdown of responses to the question “which of these are impacts of PFAS”

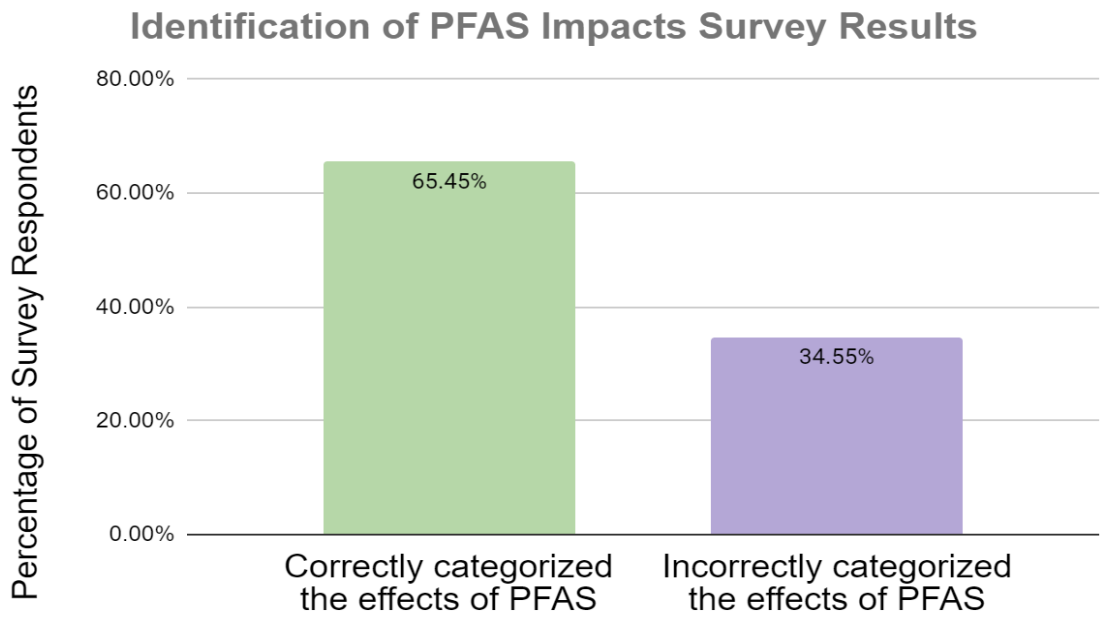

Figure 4: This is a bar graph showing the correctness that survey respondents categorized impacts of PFAS with

Understanding the Role Town Meetings Play in Bylaw Understanding and Information Distribution in the General Public

To evaluate the knowledge of the general public surrounding Town Meetings, and bylaws, all people surveyed were asked if they have been to a Town Meeting and if they know what a bylaw is. It is important that we know the general public's understanding of bylaws because bylaws are used by Boards of Health to regulate private wells. Bylaws are voted upon at Town Meetings, and Town Meetings can serve as a way to get information out to town residents about bylaws and other areas of concern like PFAS. As can be seen in figure 5, 25.81% of survey respondents had been to a Town Meeting within the last year, and 74.19% of those surveyed had been to a Town Meeting more than a year ago or had never attended a Town Meeting. Since most people had not been to a Town Meeting recently or at all it tells us that solely focusing on Town Meetings and making supporting educational materials about PFAS to be distributed at Town Meetings will cause us to miss a large amount of the desired population. This means that we also need to make educational materials that can be sent out in the mail to homeowners, or posted online by local Boards of Health. When asked if they knew what a bylaw was, the majority of people said that they knew what a bylaw was. 87.10% of survey respondents said they knew what a bylaw was, and 12.9% of respondents did not know what a bylaw was or were unsure. This means that although most people did not regularly attend Town Meeting, the majority of Massachusetts residents were familiar with the bylaws that regulated their towns. Since a majority of respondents were familiar with bylaws, most of the supporting educational material produced to close the knowledge gap will not need to focus on explaining how town governments function and what bylaws are. This allows for more attention to be put on water contaminates like PFAS.

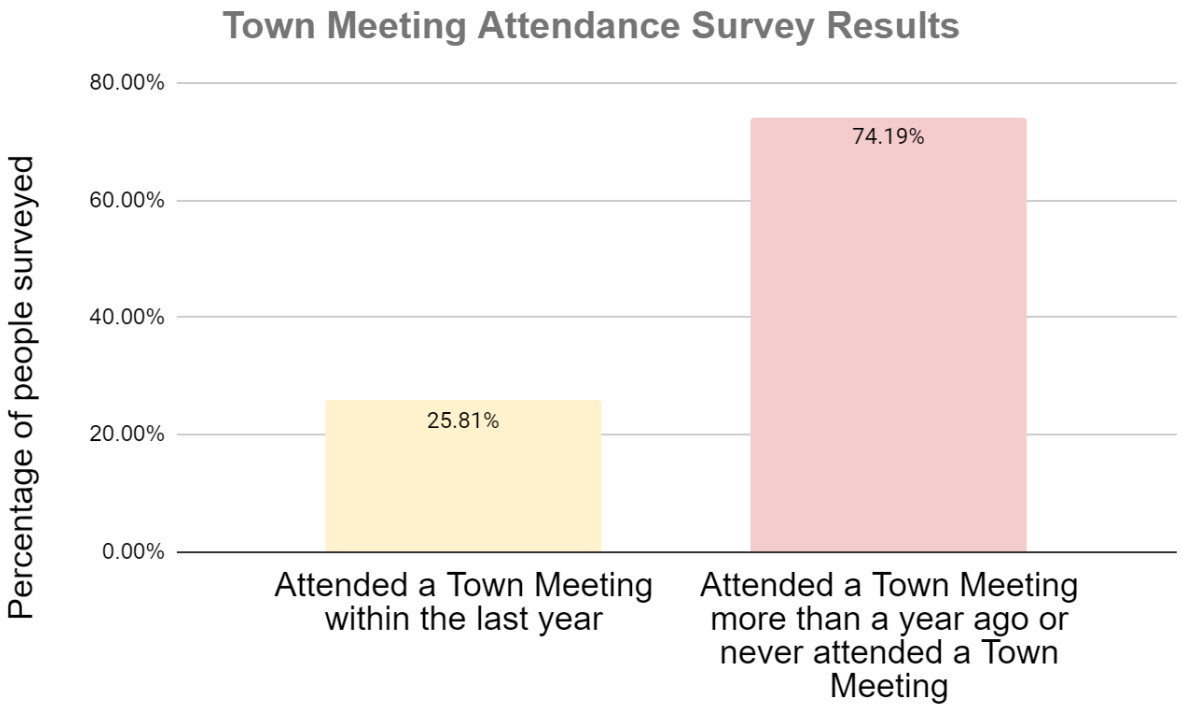

Figure 5: This is a bar graph showing Town Meeting attendance of the general public of Massachusetts that was surveyed.

Understanding How to Best Reach People with Educational Materials

To better understand how to best reach people with education materials, residents of Massachusetts were asked where they primarily looked for information about water contamination. 40.41% of respondents stated that they look for their information on water contaminants online, which is the majority of people. For our project this means we need to take a more digital approach when we make educational materials, so the materials can be posted online on town websites and other places as well as mailed to town residents.

4.2.2) The Knowledge Gap among Private Well Owners in Massachusetts

Of the survey respondents from the survey of the general public of Massachusetts 28.57% have private wells, and 71.43% were either on public water or had a water supply that was not a private well. In this section we focused on the 28.57% of respondents that got their drinking water from private wells. By looking at survey responses from the Massachusetts general public survey and focusing on private well owner respondents only, we found that the majority of

private well owners had knowledge of how often their wells should be tested but lacked knowledge about well treatment systems and why they should consider installing one.

Understanding the Knowledge Gap in Private Well Owners about Well Testing

To better understand the knowledge gap that existed among private well owners about well testing, all private well owners were asked how often they should test their wells, and when was the last time they tested their wells. 30.65% of respondents said that wells should be tested every one to three years, with a majority, 51.61%, of people saying that they did not know how often to test. A full breakdown of the responses can be seen in figure 6. Most private well owners, 47.37%, said that they have tested their wells within the last five years, with 21.05% of owners having tested their wells less than a year ago. This data supports the idea that although not all towns require wells to be tested every couple years, most well owners test their wells in accordance with MassDEP guidelines for well testing. This means that although some educational materials may be useful for private well owners about how often they should be testing their wells the majority of private well owners will likely not need supporting educational material on well testing.

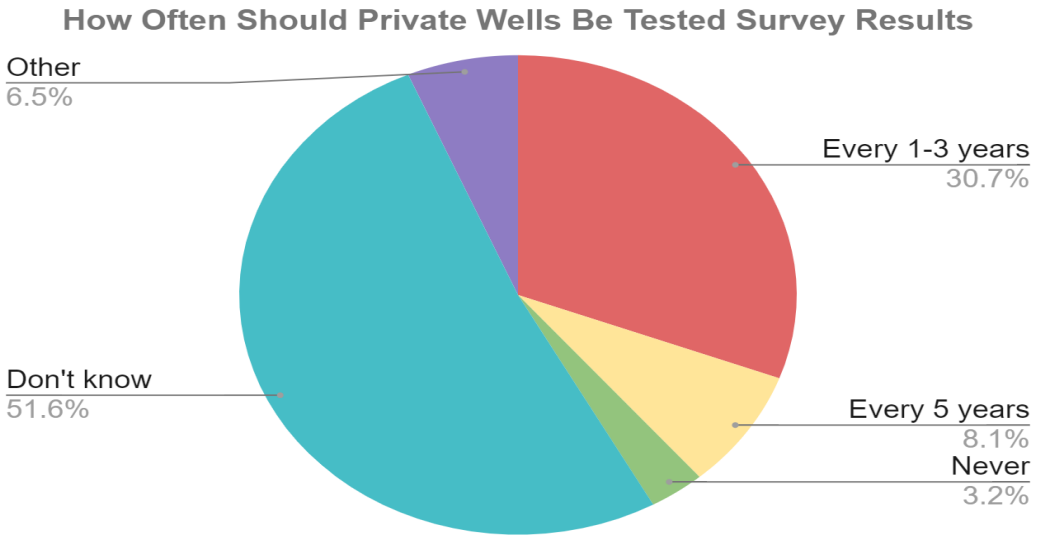

Figure 6: This is a pie chart that shows how often people think their private wells need testing.

The Knowledge Gap in Private Well Owners about Private Well Treatment Systems

Of the private well owners sampled, the majority of them did not have any type of treatment on their wells. 63.63% did not have any water treatment on their private wells. Of those that had water treatment on their well 0.00% had treatment systems in place for PFAS. This data shows that most well owners either do not know about water treatment systems for their wells, or do not need or want well water treatment.

4.2.3) The Knowledge Gap among Board of Health Agents about PFAS

In Massachusetts Boards of Health are responsible for helping towns regulate wells. To better understand the knowledge gap among Board of Health agents, we surveyed a group of 47 Board of Health agents from towns registered with the MHOA. The results provided information on the Board of Health agents' familiarity and experience with PFAS.

The Knowledge Gap in Board of Health Agents about PFAS Regulations

In the survey the health agents were asked several questions to gauge their familiarity with PFAS and private wells. First, the surveys indicated that almost half of the Board of Health agents surveyed were not familiar with current PFAS regulations. When asked if they were familiar with current Massachusetts PFAS regulations for drinking water there was almost a 50/50 split of Board of Health agents that were familiar with the current regulations and those that were only somewhat or not at all familiar with the regulations. 41.18% of Board of Health agents surveyed were only somewhat or not familiar with current PFAS regulation for drinking water contamination, as can be seen in figure 7.

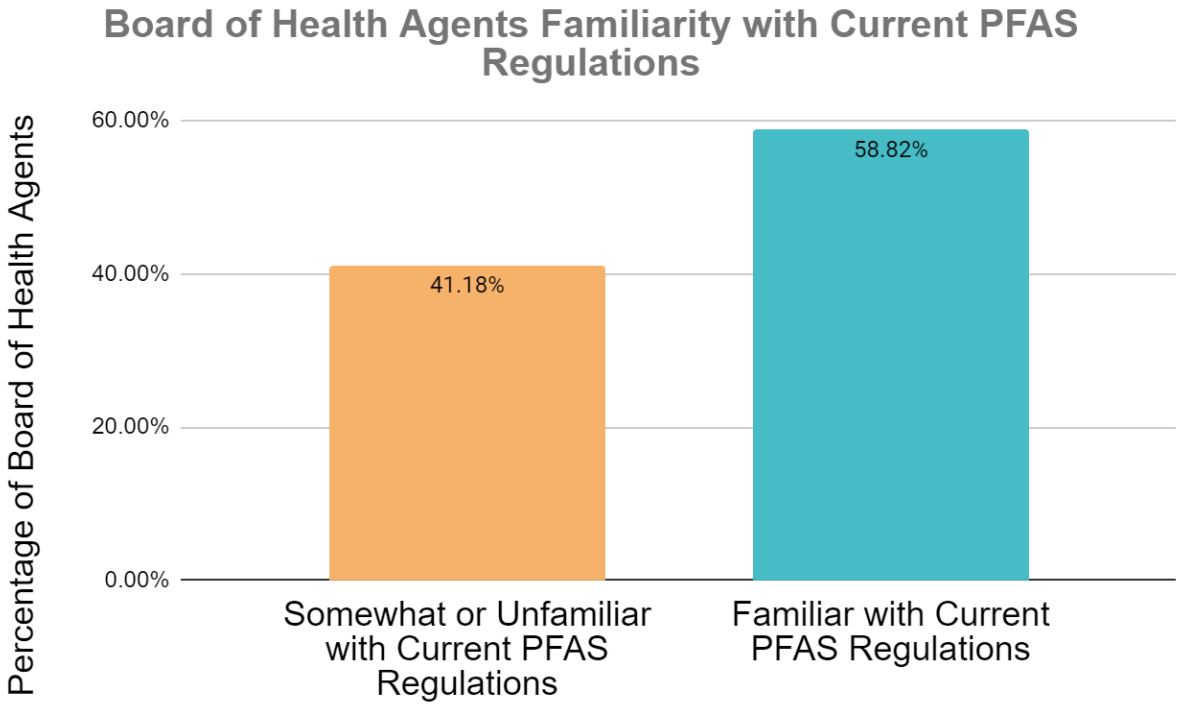

Figure 7: This is a bar graph that shows the familiarity of Board of Health agents with current PFAS regulations.

Understanding the Education Gap about PFAS Regulations among Board of Health Agents

Next, when asked if they have received training on the regulations pertaining to PFAS contamination in private wells in Massachusetts, the majority 61.76% of the Board of Health agents reported that they either received no training or only some training. Only 38.24% of health agents said they received training on the regulations for PFAS in private wells. This data, shown in figure 8, demonstrates that most Board of Health agents do not know enough about PFAS. Since almost half of those surveyed are only partially familiar or unfamiliar with the current regulations surrounding PFAS and drinking water contamination, and the majority of health agents have not received training on the regulations of PFAS in private wells further training or supplemental training on current PFAS regulations is needed.

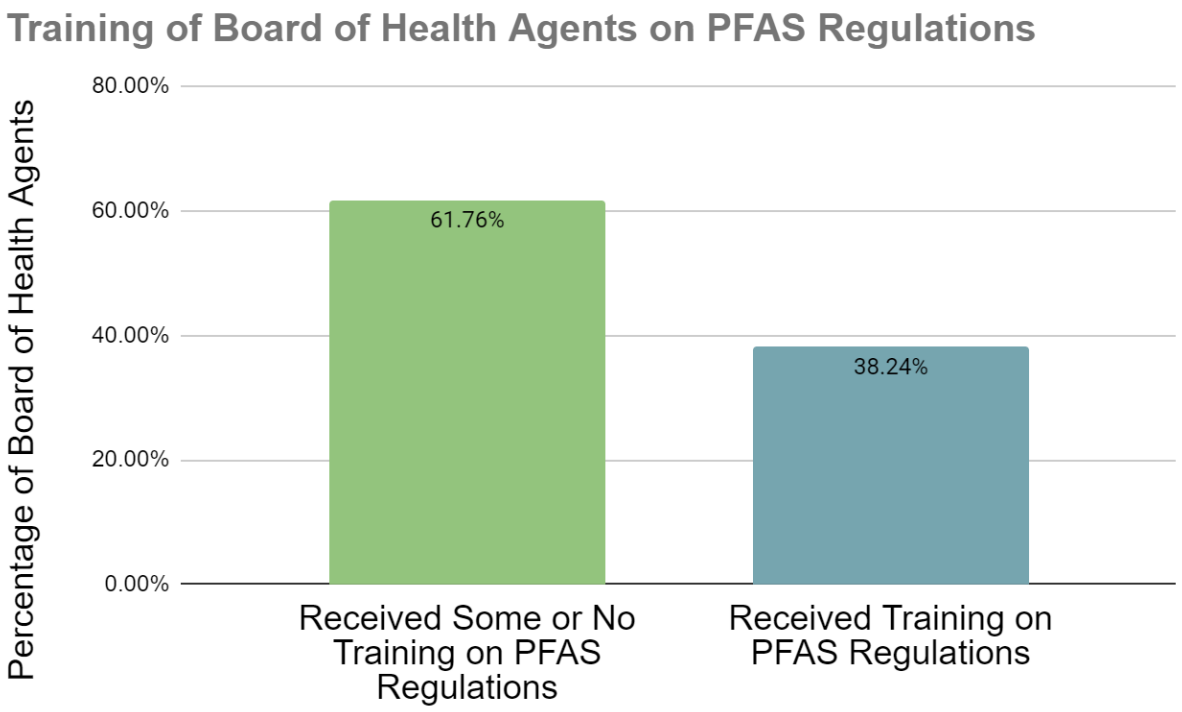

Figure 8: This is a bar graph showing the responses from Board of Health agents when asked if they received training on PFAS regulations.

4.2.4) Summary of the Knowledge Gap

In conclusion, three main groups were identified as key players in the knowledge gap around PFAS. These groups are the general public (Massachusetts residents regardless of private well ownership), private well owners in Massachusetts, and Board of Health agents. Throughout our surveying process two surveys were sent out: one to the general public of Massachusetts, which included private well owners, and one to the Board of health agents. These surveys helped us pinpoint the knowledge gap across the three groups listed above. For the general public, a knowledge gap exists around what PFAS are, and the health and environmental impacts of PFAS. When surveying this group it was also found that the majority of Massachusetts residents do not regularly attend Town Meeting, which suggested that new outreach methods like utilizing the internet or town mailings would be best for reaching the desired audience to educate about PFAS. When breaking down the responses from the general public survey we focused on the

private well owner respondents and identified that among private well owners a knowledge gap about the frequency at which private well testing should be conducted, the contaminates that should be tested for, and the treatment systems that can be utilized to treat contaminated well water. Finally, when looking at Board of Health agents, who're responsible for helping educate the general public about important health issues like PFAS, we identified a knowledge gap around the current regulations surrounding PFAS in public and private drinking supplies. We also learned from surveying this group that a large number of Board of Health agents have not received training on PFAS even though the training was available, note that this is likely due to BOH agents being understaffed and not having enough time or incentives to attend training, which further serves to support the lack of knowledge about PFAS regulations among Board of Health agents.

4.3) Review of Town Bylaws for Private Wells

For this section we gathered 32 bylaws from across Massachusetts by sending an email blast to several MHOA towns with well water bylaws. We then compiled a spreadsheet to make comparing those bylaws easier. After we completed the spreadsheet and finished our interviews for this section, we found a number of interesting trends. We found several similarities in the structure of the bylaws as well as some striking differences in the content. Generally, our interviews supported what we found while looking at the bylaws with only some minor clarifications and explanations pertaining to the bylaws.

4.3.1) Similarities Across Bylaws

Upon review of the bylaws we noted that they had some distinctive similarities. These similarities included permitting, testing frequency, and penalties. Overall, most bylaws were in some way similar to the model bylaw from MassDEP. A summary of key points from each of the bylaws can be found in table 1. For this project we had a special focus on PFAS and from this

table it's clear that most of the towns we looked at did not include any mention of PFAS in their bylaw.

Table 1: A summary of 32 well water regulations/bylaws from across Massachusetts

	Yes	No	Unclear
Towns with enforceable bylaw	31	1	-
Towns considering PFAS	5	25	2
Towns with periodic testing	6	26	-
Towns with testing for occupancy permit	27	5	-
Towns with testing after construction	15	17	-

Nearly all of the bylaws we looked at had a section dealing with permitting. This section had to do with construction permits, water supply permits, and occupancy permits. A construction permit is almost always required before drilling a well and comes with some requirements for obtaining one. This was mostly to ensure that the drilling of the well was safe for all. In the case of drilling a well, a water supply permit usually required some form of testing and safety procedure; a water supply permit could also be issued by simply connecting to public water. Lastly, an occupancy permit is required before people can occupy the space the well serves. In most cases a water supply permit must first be acquired before an occupancy permit can be issued. A number of other factors also come into play when issuing an occupancy permit.

The vast majority of bylaws included a section on testing recommendations and Maximum Contaminant Levels (MCLs). Of these, many also had a requirement for periodic testing or testing after certain events. This can be broken down into testing at construction, testing before issuing a water supply permit, testing at time of transfer, periodic testing when the property is rented/leased, periodic testing regardless of the situation, additional testing at the discretion of the BOH, and testing at any time at the discretion of the BOH.

Testing at construction and before issuing a water supply mostly falls under the same umbrella and nearly all bylaws included this. This was something that was easily regulable since it typically only happened once in the lifetime of the well so it wouldn't overwhelm the BOH with too much work.

Testing at time of transfer was another common similarity we saw. Many towns would require the well to be tested either before or after the transfer of a property between owners. This was to protect the new owner from any potential contaminants in the well. From our interviews we heard that this was moderately successful as it kept the quantity of information sent to the BOH at a manageable level while also ensuring older wells still got tested.

A somewhat common section we saw was testing periodically when a property is rented/leased. This was a protection for renters to ensure that they had drinking quality water.

A rather uncommon regulation but a very common suggestion was periodic testing regardless of the circumstances. Nearly every town at least recommended that well owners test their wells in accordance with MassDEP guidelines, but very few actually regulated this. We got some interesting feedback about the reason for this from our interviews. Many BOHs felt they were understaffed and ill-equipped to enforce a periodic testing regimen like this so many left it as a suggestion.

Many towns had a section allowing their BOH to require additional sampling for any contaminant at the discretion of the BOH. The reason for this was that some contaminants and parameters are flags for others and indicate that something else may be present. This would then require an additional test to ensure that drinking water is potable.

Another important similarity between bylaws was that nearly all of them had sections on enforcement and penalties as can be seen in table 1. Surprisingly, many of the bylaws we received were enforceable either by denial of an occupancy permit or by monetary fines for non-compliance. As mentioned before, many bylaws would require a water supply permit before an occupancy permit and this was a main method of enforcement. There were also usually large fines associated with non-compliance in many of these aspects. These fines ranged between $10 and $1,000 and each day of non-compliance was typically seen as a separate offense.

4.3.2) PFAS and Bylaws

PFAS was an important component in our project so we made sure to look for this in every bylaw we analyzed. PFAS was a commonly excluded contaminant as can be seen in table 1. PFAS would typically not be mentioned in any capacity and in the few cases where it was explicitly mentioned a few of those would list it as a recommendation rather than a regulation. Very few had a PFAS limit as a regulation with an explanation from a small number of towns being that they were still working on implementing PFAS. From our interviews and email correspondence, we learned that many towns were in the process of amending their private well bylaw or regulations to be more in line with the recent change to the MassDEP model bylaw which includes PFAS.

4.3.3) Notable Differences across Bylaws

Although many of the bylaws were similar in structure, many had differences in the contaminants that were regulated and parameters that were tested for. These regulations ranged

from extremely lenient to extremely strict and differed in length from a few lines to several pages. The contaminant list often had separate sections for regulations and guidelines and additional sections for radiological testing.

Many of the common regulated parameters and contaminants were relatively uniform across the board, but there were some seemingly random exclusions from some towns. For example, many of the towns regulated total coliform bacteria and nitrate, but some also opted to exclude these. A potential reason for this could have been the cost of the tests or historical uses of land.

After closer inspection of the town bylaws, we found another category. This category had a smaller initial list with no further testing. This meant that some towns were comprehensively testing their wells whether it be through initial testing or further testing, and some were hardly testing their wells at all. This lack of standardization was concerning because these contaminants were sometimes still in wells regardless of the type of testing.

4.3.4) Interesting Cases

A select few of the bylaws we found were very different from the rest. Most notably the bylaw for West Newbury and North Andover had some interesting aspects.

West Newbury was the only bylaw we saw that did not have any enforcement. For the most part it was relatively similar to other bylaws. It had a contaminant list, sections on permitting, and many of the other sections as well. It was also brief, but that did not differ from other bylaws. The main difference was that it lacked a section on penalties and enforcement. This meant that the only enforcement was at time of construction due to the permitting section. Even then, there was nothing stopping someone from ignoring the permitting altogether as there were no fines associated with non-compliance.

North Andover had significant restrictions on when, where, and why wells could be constructed. All the typical sections existed in their bylaw with the addition of two particular subsections. The first subsection denied the issuance of any well drilling permit for sites with reasonable access to public water within the watershed protection district. This subsection functionally banned most wells in an area covering roughly a third of the town. The other subsection denied the issuance of permits for non-essential wells which functionally banned any additional water wells other than those required for supplying drinking water.

Summary

Overall, the bylaws we looked at fell in line with the model bylaw in most aspects; however, they differed on some of the important sections such as the list of contaminants and parameters for testing. The lack of standardization in the contaminants was concerning.

5) Recommendations

Utilizing our research and findings we decided upon several recommendations. These recommendations can be summarized as suggestions and edits for the model bylaw, suggestions for supporting materials, and other miscellaneous recommendations. We make these recommendations in order to assist local BOHs deal with PFAS and other contamination in private wells.

5.1) Suggested Edits for the Model Bylaw and Supporting Materials

Based on our findings and discussions, we feel that some clarifications or adjustments to the current MassDEP bylaw could help to clarify testing requirements, lessen the load on local BOHs, and standardize health regulations across Massachusetts. Accordingly, we are recommending the following revisions to the MassDEP model bylaw:

1. Standardized testing requirements: The inclusion of standardized testing requirements in the model bylaw will ensure that all private well owners are using the same protocols and procedures to test for PFAS. This will allow for more accurate and comparable data collection and monitoring, which is essential for identifying and addressing PFAS contamination in private wells. Standardized testing will also provide more consistency in the regulatory process, making it easier for municipal officials and regulators to enforce the bylaw. The bylaw should also require transfer of property water quality testing of all wells on the property in every town. This would require that the private wells on the property are tested before the property can be transferred. This does not always mean that the new owner is made aware of the well or any treatment methods installed on it; however, it has been an effective method of ensuring older wells still get tested periodically.

2. Shorter bylaws with more regulations: The current model bylaw is very comprehensive but as a result it is lengthy and may be difficult for some municipalities to adopt. Converting important parts of the bylaw to model regulations and including those regulations as separate documents or supporting materials will make it easier for municipalities to adopt and implement both regulations and bylaws. This will help to ensure that the bylaw is more widely adopted, increasing the likelihood of identifying and addressing PFAS contamination in private wells. It will also maintain some of the freedom of choice the old model bylaw had.
3. Clarification of language: Since the model bylaw is a model and not a legal document, the model bylaw should use clear and concise language rather than legalese so it is easily understandable for all stakeholders including private well owners, municipal officials, and regulators. It is important to remember that BOH agents are volunteers and are not necessarily trained professionals. Using clear language will ensure that all stakeholders understand the requirements of the bylaw, reducing confusion and increasing compliance. This will also help to ensure that private well owners are aware of the risks associated with PFAS contamination and understand the importance of testing and monitoring their wells.
4. Inclusion of remediation strategies: The model bylaw should include recommendations for remediation strategies for private well owners whose wells exceed regulatory standards for PFAS. Remediation strategies can include treatment technologies such as carbon filtration, ion exchange, and reverse osmosis. Including these strategies in the model bylaw will help to ensure that homeowners have access to resources and information to address PFAS contamination in their private wells. This will also help to

ensure that remediation efforts are consistent across towns and that homeowners are aware of their options for addressing PFAS contamination.

Overall, implementing these recommended revisions to the model bylaw will help to ensure that the bylaw is effective, practical, and accessible for all stakeholders. Providing clear language and standardized testing requirements, as well as including remediation strategies, will help to ensure that private well owners are aware of the risks associated with PFAS contamination and have access to the resources they need to address it. Additionally, shortening the bylaw and providing more regulations as separate documents or supporting materials will make it easier for towns to adopt and implement the bylaw, increasing the likelihood of identifying and addressing PFAS contamination in private wells.

5.2) Supporting Materials

Our results showed that knowledge gaps exist for the three surveyed groups, including the general public (consisting of Massachusetts residents regardless of whether or not they own a private well), private well owners, and BOH agents, such that supporting educational materials would be beneficial. These educational materials can be found in appendices I-K. Since the knowledge requirements and gap differs for each group, the following material recommendations will differ for each audience.

5.2.1) Recommendations on Supporting Materials for the General Public

We recommend that infographics about PFAS and the associated impacts on human and environmental be distributed to the general public of Massachusetts by local BOHs either online or by town wide mailings. This ensures that informational materials reach as many people as possible. From those surveyed in the general public we determined the presence of a knowledge gap in the understanding of PFAS and its health and environmental impacts. We also found that the majority of people surveyed knew what bylaws were which suggest familiarity with the

bylaws that govern their town. Since most people do not regularly attend Town Meetings and report getting their information from online sources we recommend that supplemental educational materials in the form of infographics (as seen in Appendix I) to be posted online or mailed in town wide mailings or dog license renewal reminders. We recommend that the online infographics be posted to town run websites or social media groups that get decent internet traffic. For towns where the BOH does not have their own social media or website we recommend working with other groups serving the town like the fire department, or the town hall to get the information to as many people as possible. It is also a good idea to give any social media style post a hashtag with the word PFAS mentioned to make searching for information on PFAS easier. Although our survey data showed that most individuals receive their information through online means there is still a decent population that either does not have access to or knowledge of how to use a computer. This is where mailed infographics would be beneficial to ensure no portion of the population is neglected.

5.2.2) Recommendations on Supporting Materials for Private Well Owners

We recommend that educational materials about private well testing regulations and well water treatment systems, in the form of a pamphlet, be distributed to private well owners. For private well owners, we identified a knowledge gap around well testing regulations and time frames and a knowledge gap around well treatment systems. To remediate these knowledge gaps we recommend that educational materials, in the form of pamphlets (materials can be found in Appendix J), about well testing, the importance of testing private wells, and different water treatment systems that are effective against PFAS should PFAS be found during testing, be distributed to private well owners. The educational materials may help private well owners learn more about why they should test their wells and possible ways to treat their water, which may encourage them to test their wells and install water treatment systems if needed. We recommend

that the pamphlets be distributed either through mailing them to private well owners or by posting them on BOH websites. It is also a good idea to keep some pamphlets in easily accessible places like town hall for people to pick up and have a physical copy.

5.2.3) Recommendations on Supporting Materials for Board of Health Agents

For BOH agents we recommend that pamphlets about bylaws be distributed in conjunction with MassDEP training on private well bylaws and PFAS regulations. Based on our findings, the knowledge gap in BOH agents mainly surrounds their knowledge of current PFAS regulations in drinking water and the lack of training on such regulations. To close this gap, we recommend that supporting materials like pamphlets (Appendix K) be distributed. The pamphlets should contain more in depth information about current guidelines and serve as supplemental material for training on PFAS and bylaw creation. These materials should be distributed to individual BOHs by the MHOA and MassDEP when training is conducted. We also recommend that a training program be created for BOH agents about bylaw creation to encourage BOH agents to create or adopt model bylaws for private wells and PFAS regulations. We also recommend that more BOH agents attend existing training on PFAS regulations, and that existing training offer an online version as well to ensure that more BOH agents can attend to help educate BOH agents on the importance of PFAS regulations, allowing them to better assist the communities they serve. The training given to BOH agents on bylaws and PFAS should be created by the MassDEP or MHOA and we recommend that it is offered as a virtual training as well as an in person training to ensure that people who are not able to attend in person can either watch a recording or attend virtually. We also recommend that the MHOA makes training required for BOHs that are associated and work with the MHOA as this will help ensure that BOH agents receive the necessary training to be successful in serving the community.

5.3) General Recommendations for the Massachusetts Area

In addition to our recommendations for the model bylaw and our supporting materials, we also have recommendations that do not fit into either category. In this section we will go over our recommendations for a database, public forums, school curriculum, and regulatory changes.

5.3.1) Database Creation

We recommend the creation of a database for private water well testing results. In several interviews with BOHs we heard that many BOHs have a small staff and already have a considerable amount of work placed on them. Add onto this that BOH agents are volunteers and it is easy to see that the increased workload from more rigorous testing regimens would quickly overwhelm them. A potential solution to this came from one of our interviews. In the interview, one of the BOH agents we were speaking to brought up this concern and suggested that a database be created that water testing labs would input test results into. As it presently stands, a private well owner sends a sample to the lab, the lab tests it and sends the results back, the well owner receives the results and sends them to the BOH, and then the BOH receives the results and has to notify the well owner of the next course of action. This process could be simplified by creating a database. The new process would then differ when the lab receives the sample. Instead of just sending the results to the well owner, they would also input the results in the database. This way the BOH can access the already organized and filed results for all private well tests which would drastically decrease the work required from the BOH. The decrease in workload on the BOHs would make more regular testing for all contaminants much more viable to the BOHs.

5.3.2) Public Forum

Another recommendation is for more public forums. From our research we have found that public forums like the one held in the town of Harvard recently are very effective for reaching out to concerned individuals about PFAS. In a public forum it is possible to reach

people who may not have access to other outreach methods and it allows for two way discourse which may not always be possible on social media platforms.

5.3.3) School Curriculum

Our final recommendation is to introduce a curriculum in schools to educate children about PFAS and well water safety. From one of our interviews with BOH agents, we received a suggestion for targeting children with PFAS related education. The reason for this is to not only educate the next generation of potential well owners, but also to educate their parents by proxy. This has worked in the past in the case of recycling, so it can be employed for PFAS as well.

5.3.4) Overall

By advocating for a general understanding of well water safety pertaining to not only PFAS, we can also promote the general welfare of private well owners. Coupled with information about the specific challenges of PFAS, this would suitably target the underlying issue of the knowledge gap in the general public.

6) Conclusion

The goal of this project was to understand the impacts of PFAS on private wells in Massachusetts. To accomplish this goal, we conducted a comprehensive study to collect data on the frequency of PFAS contamination in private wells, assess the potential health risks associated with PFAS exposure, and evaluate the efficacy of current mitigation strategies implemented to address this issue.

Our research has shown that while PFAS contamination is a concern in private wells in Massachusetts, many residents are unaware of the issue and the available solutions to mitigate it. Additionally, our work on the bylaws that regulate PFAS contamination sheds light on the importance of considering legal frameworks when addressing this pertinent issue. From our interview with water quality experts from the MassDEP, we were able to confirm that exposure to PFAS can lead to a range of health risks, including liver damage, thyroid disease, and cancer. We also confirmed that EPA guidelines note six specific types of PFAS being tested for - perfluorooctane sulfonic acid (PFOS), perfluorooctanoic acid (PFOA), perfluorohexane sulfonic acid (PFHxS), perfluorononanoic acid (PFNA), PFBS, and HFPO-DA (GenX). Finally, we have been informed of several mitigation strategies that can be effective in reducing PFAS exposure in private wells, including granular activated carbon (GAC) filters and point-of-entry exchange resins.

In light of these findings, we recommend the following actions:

1. Private well owners should have their wells tested for PFAS once every 1-3 years to ensure their water is safe to drink.
2. The Massachusetts Department of Environmental Protection (MassDEP) should standardize and encourage comprehensive guidelines to limit the use and release of PFAS in the state.

3. Municipalities should work to provide public education and outreach to residents about the risks of PFAS and the importance of regular well testing.
4. Private well owners whose wells tested positive for PFAS should consider installing GAC filters or point-of-entry ion exchange resins to remove PFAS from their water supply.
5. The state should consider funding research into alternative mitigation strategies that can be effective in reducing PFAS exposure in private wells.

The widespread prevalence of PFAS contamination in private wells in Massachusetts is a serious public health concern. Our research has identified key steps that individuals, organizations, and policymakers can take to address this issue and protect public health. By regularly testing private wells, developing and implementing comprehensive guidelines, providing public education and outreach, and investing in alternative mitigation strategies, we can work together to ensure that all residents of Massachusetts have access to safe and clean drinking water.

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Appendix A

Informed Consent for surveys:

(We will place the following preamble at the beginning of the survey we will distribute to private well owners).

We are students from Worcester Polytechnic Institute (WPI) in Worcester Massachusetts, working with the Massachusetts Department of Environmental Protection (MassDEP) and the Massachusetts Health Officers Association (MHOA). We are conducting research on per- and polyfluoroalkyl substances (PFAS) in private well-water and how model bylaws can be used to address this issue. We believe this research will benefit the health of Massachusetts residents. Thank you for taking the time to assist in our research. This survey should take about 5 minutes to complete. Please keep in mind that your participation in this research is completely voluntary and may be withdrawn at any time. Your contribution will remain confidential. No identifying information, including but not limited to names, ages, and private well ownership status, will be used in questionnaires or appear in any publications or project reports without prior consent.

If you have any questions you may reach out to our faculty advisor at mathisen@wpi.edu or contact us at gr-wroc_pfas@wpi.edu. Please email us if you would like a copy of our report upon completion of the project,

Thank you for your participation!

Informed Consent for Interviews:

We are students from Worcester Polytechnic Institute (WPI) in Worcester Massachusetts, working with the Massachusetts Department of Environmental Protection (MassDEP) and the Massachusetts Health Officers Association (MHOA). We are conducting research on per- and polyfluoroalkyl substances (PFAS) in private well-water and how model bylaws can be used to address this issue. We believe this research will benefit the health of Massachusetts residents.

Thank you for taking the time to assist in our research. This interview should take about an hour to complete. Please keep in mind that your participation in this research is completely voluntary and may be withdrawn at any time. If you prefer, we are happy to keep your identity confidential. Please let us know if you are comfortable with us using your name and position in our final project report. We will share the report prior to publishing it on the WPI library website.

If you have any questions you may reach out to our faculty advisor at mathisen@wpi.edu or contact us at gr-wroc_pfas@wpi.edu. Please email us if you would like a copy of our report upon completion of the project.

Thank you for your participation!

Appendix B
Public Health Expert Interview Questions

1. What is your favorite part of your job?
2. How long have you been in this field?
3. What does a typical day look like?
4. Can you tell us about your experience with PFAS and what you think is the most appropriate approach to deal with these chemicals?
5. From our research we have found that some groups of people are more susceptible to PFAS related health issues. Some of these issues include issues with cancer, placenta development, and other long term health issues. Are there any health effects that we might not have found in our research that you could tell us about?
6. Do you have any thoughts on the public's level of awareness of PFAS and its impacts? Have you ever had to create educational materials for the public to educate on health issues? If so, what did you find to be the most effective mode of communicating with the public?
7. Are there any case studies or examples of bylaws you would recommend we look into?
8. With a model bylaw created to address PFAS in private wells, what would you like to see included?
9. Is there anyone else you recommend we interview?

Appendix C
Environmental Consultant Interview Questions:

1. What is your favorite part of your job?
2. How long have you been in this field?
3. What does a typical day look like?
4. Have you worked with other environmental contaminants before? If so, can you tell us a bit about your experiences with working to remove them from the environment?
5. Have you ever had to create materials to educate residents about the contaminants found in the environment? If so, what did you find to be the best way to convey this information?
6. What do you think the issues are surrounding the lack of testing of private wells for contaminates like PFAS?
7. So far from our research we have learned that PFAS can cause climate issues as it degrades and that PFAS can travel long distances in the ground causing widespread groundwater contamination. From your experience are there any other environmental issues we may not know about that are caused by PFAS?
8. In your expert opinion what PFAS mitigation methods would be most beneficial if they were implemented in private wells.
9. With a model bylaw created to address PFAS in private wells, what would you like to see included?
10. Is there anyone else you recommend we interview?

Appendix D
Water treatment Company Interview Questions:

1. What is your favorite part of your job?

2. How long have you been in this field?

3. What does a typical day look like?

4. From what we understand the MassDEP requires water companies to remain under 20 ppt of PFAS in their water supplies. To ensure your company remains compliant with this requirement, how often does your company test your water?

5. What PFAS mitigation methods does your company use?

6. How effective have these mitigation techniques been in reducing PFAS water contamination?

7. Have you worked with the MassDEP to pinpoint where the PFAS is getting into your water supplies?

8. Has there been any particular legislation that has helped your company reduce PFAS contamination?

9. If you had to scale down your water treatment processes, specifically the ones used to remove PFAS, to work for small wells what mitigation methods would work the best?

10. With a model bylaw created to address PFAS in private wells, what would you like to see included?

11. Is there anyone else you recommend we interview?

Appendix E
Interview questions for MassDEP and MHOA:

1. What is your favorite part of your job?

2. How long have you been in this field?

3. What is the current state of the PFAS problem in Massachusetts and how is private well water impacted in particular?

4. Are there any methods used for public water supplies that could be modified to work with private wells?

5. In your experience with private well owners, what proportion would you say have a good understanding of PFAS?

6. When private well owners opt out of testing their wells for PFAS is there a specific reason they give? Do you have any thoughts to avoid this?

7. Have you ever had to create materials to educate residents about the contaminants found in the environment? If so, what did you find to be the best way to convey this information?

8. What would you like to see us address in our model bylaw?

9. Are there any bylaws that have been passed or are in the works for private wells that we should look at?

10. Is there anyone else you would recommend we interview?

Appendix F
Survey Questions:

1. What town do you live in?

2. Do you own your home?

    a) Yes

    b) No

    c) Other

3. Does your home use well water?

    a) Yes

    b) No

    c) Unsure

    d) Other: please specify

4. Do you know what per- and polyfluoroalkyl substances (PFAS) are?

    a) Yes

    b) No

    c) Unsure

5. Which of the following are impacts of PFAS? Check all that apply.

Cancer	High Blood Pressure	Reproductive problems	High cholesterol	Murky Water	Contaminated Groundwater	Healthier Plants	Climate Change

6. When was the last time you tested your well?

    a) Less than 1 year ago

b) 1 to 5 years ago

c) 5 to 10 years ago

d) More than 10 years ago

e) I have never tested my well

f) I am unsure

g) Other: Please specify

7. How often should you test your well?

a) Every 1-2 years

b) Every 5 years

c) Every 10 years

d) Never

e) Other: please specify

8. When your well was tested last, did it test positive for PFAS contamination?

a) Yes

b) No

c) Unsure/ can’t remember

d) My well has never been tested

e) We didn’t test for PFAS

f) Other: Please specify

9. If you answered yes to the previous question, have you implemented any PFAS mitigation methods?

a) Yes

b) No

c) Other: Please specify

10. Do you know about any PFAS mitigation methods?

	Reverse Osmosis	Carbon filtration	Ion exchange	I don't Know
Effective against PFAS				
Somewhat Effective against PFAS				
Not Very Effective Against PFAS				

11. Where do you look to get information about water contaminants?

	MassDEP website	USEPA website	Town Water Department Website	Board of Health	Online articles	Newspaper
Frequently						
Sometimes						
Never						

Appendix G
Draft survey questions for the MHOA:

1. Are you familiar with the current bylaws related to PFAS contamination in private wells in Massachusetts?
2. Have you received any training on the bylaws related to PFAS contamination in private wells in Massachusetts?
3. Have you ever encountered a situation where a private well owner was in violation of the bylaws related to PFAS contamination?
4. Have you ever issued a warning or citation to a private well owner for violating the bylaws related to PFAS contamination?
5. In your opinion, are the current bylaws related to PFAS contamination in private wells adequate for protecting public health?
6. Are there any changes or improvements you would suggest to the current bylaws related to PFAS contamination in private wells?
7. Have you ever had to work with local government officials or other agencies to enforce the bylaws related to PFAS contamination in private wells?
8. Are there any challenges you have faced in enforcing the bylaws related to PFAS contamination in private wells?
9. Have you noticed any trends or patterns in the types of violations that occur related to the bylaws on PFAS contamination in private wells?
10. Have you received any feedback from private well owners or other community members about the bylaws related to PFAS contamination in private wells?
11. Are the bylaws surrounding private wells informational or enforceable?
12. Has there been any push back against enforceable bylaws?

13. Do more towns have enforceable or informational bylaws for private wells?

Appendix H
Interview questions for lawyers from MMA:

1. What is your favorite part of your job?
2. How long have you been in this field?
3. Can you provide an overview of the current legislative landscape regarding PFAS regulation in Massachusetts?
4. What efforts are currently being made at the state level to address PFAS contamination in private wells?
5. How do you see the state government's role in addressing the issue of PFAS contamination in private wells?
6. Have you ever worked with any towns to create private well regulations? What was the process like and what challenges did you face?
7. What do you think needs to be done at the federal level to better address the issue of PFAS contamination in private wells?
8. What challenges have you faced in enacting PFAS regulations in Massachusetts?
9. Can you discuss any upcoming legislation or policies related to PFAS regulation in Massachusetts?
10. How do Massachusetts' efforts to regulate PFAS compare to other states?
11. How can local communities, like the CPHS towns, work with the state government to address PFAS contamination in private wells?
12. What resources are available to local communities and homeowners concerned about PFAS contamination in private wells?
13. How do you see the issue of PFAS regulation evolving in the future?

14. What advice do you have for individuals and communities who are concerned about the impacts of PFAS on private water wells?
15. Is there anyone else you recommend we interview?

Interview questions for Board of Health agents:

1. What is your favorite part of your job?
2. How long have you been in this field?
3. What is your role as a regional health agent in ensuring the safety of private well water in your area?
4. Can you tell us a little bit about the process of working on the well water regulations in your area? Why those contaminants?
5. Why do you not require testing every 1-3 years?
6. How were you able to standardize this bylaw across several towns?
7. How common is PFAS contamination in private wells in your area?
8. Can you discuss any previous cases of water contamination in private wells in your area and the steps taken to address the issue? Is there testing for PFAS?
9. What measures are being taken to prevent or mitigate PFAS contamination in private wells in your area if applicable?
10. What challenges have you faced in addressing water contamination in private wells?
11. Can you discuss any resources available to homeowners who may be concerned about PFAS in their private well water?
12. What role do you see regional health agents playing in addressing PFAS contamination in private wells in the future?
13. What do you think needs to be done at the state or federal level to better address the issue of PFAS contamination in private wells?

14. Is there anyone else you recommend we interview?

Appendix I

Figure 9: This is a sample infographic to be distributed to Massachusetts residents either by mail or posted on social media by the local Board of Health.

Figure 10: This is a sample infographic to be distributed to Massachusetts residents on social media, as part of a set of social media posts by the local Board of Health. This infographic primarily focuses on products that may contain PFAS.

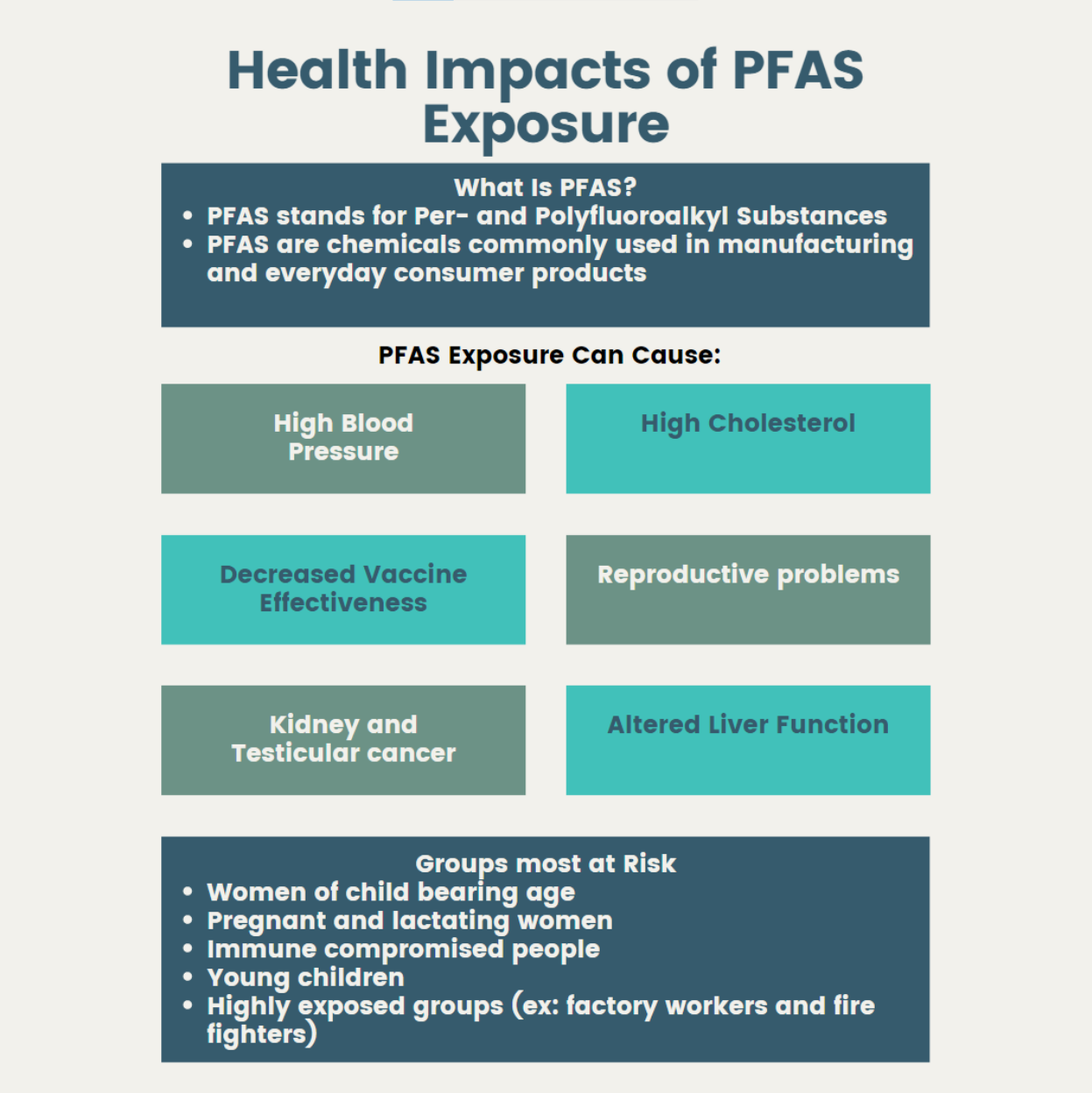

Figure 11: This is a sample infographic to be distributed to Massachusetts residents on social media, as part of a set of social media posts by the local Board of Health. This infographic primarily focuses on the health impacts of PFAS.

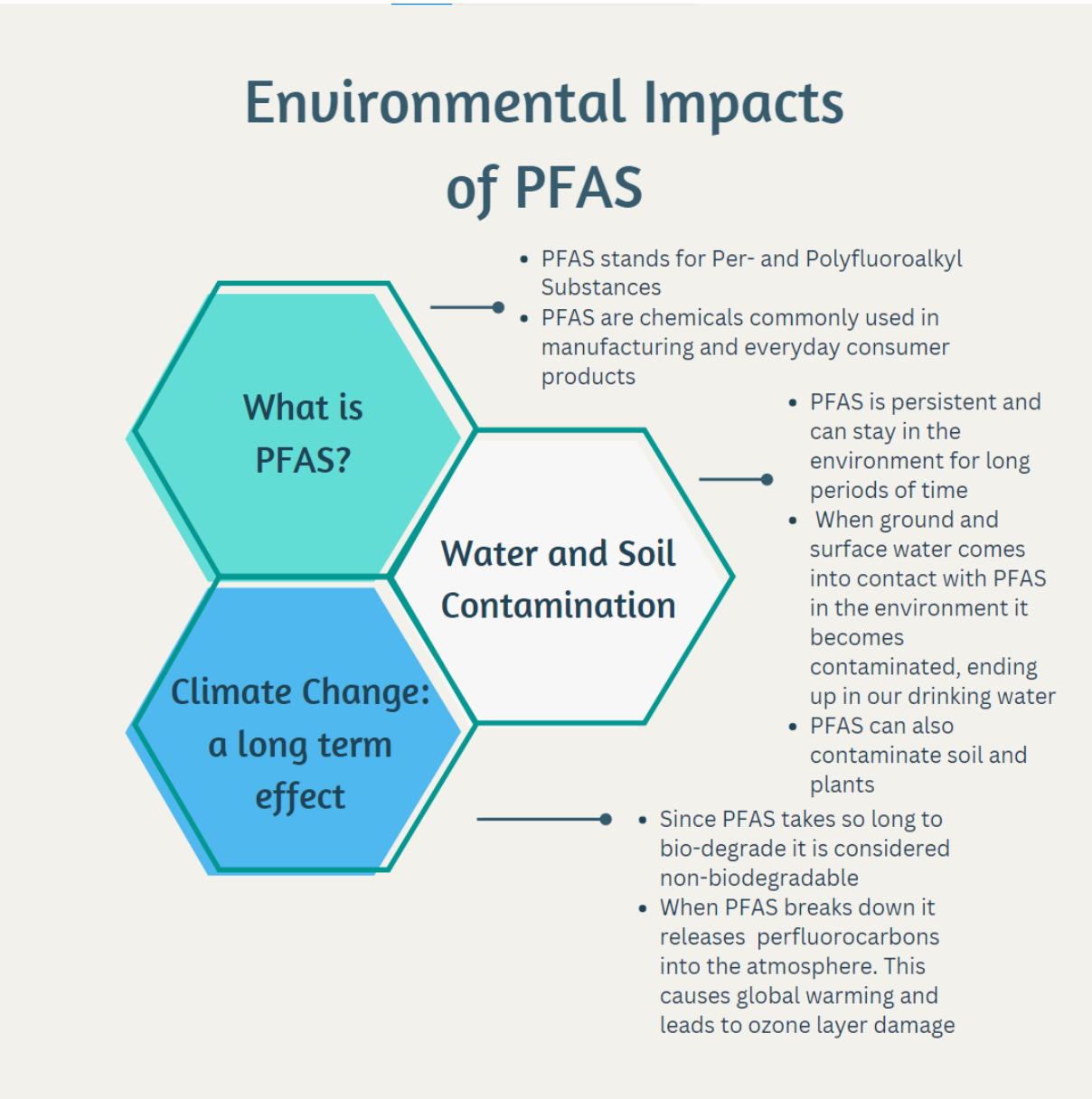

Figure 12: This is a sample infographic to be distributed to Massachusetts residents on social media, as part of a set of social media posts by the local Board of Health. This infographic primarily focuses on the environmental impacts of PFAS.

Appendix J

Figure 13: This is the front page of a pamphlet about well testing and PFAS contamination, to be distributed to private well owners.

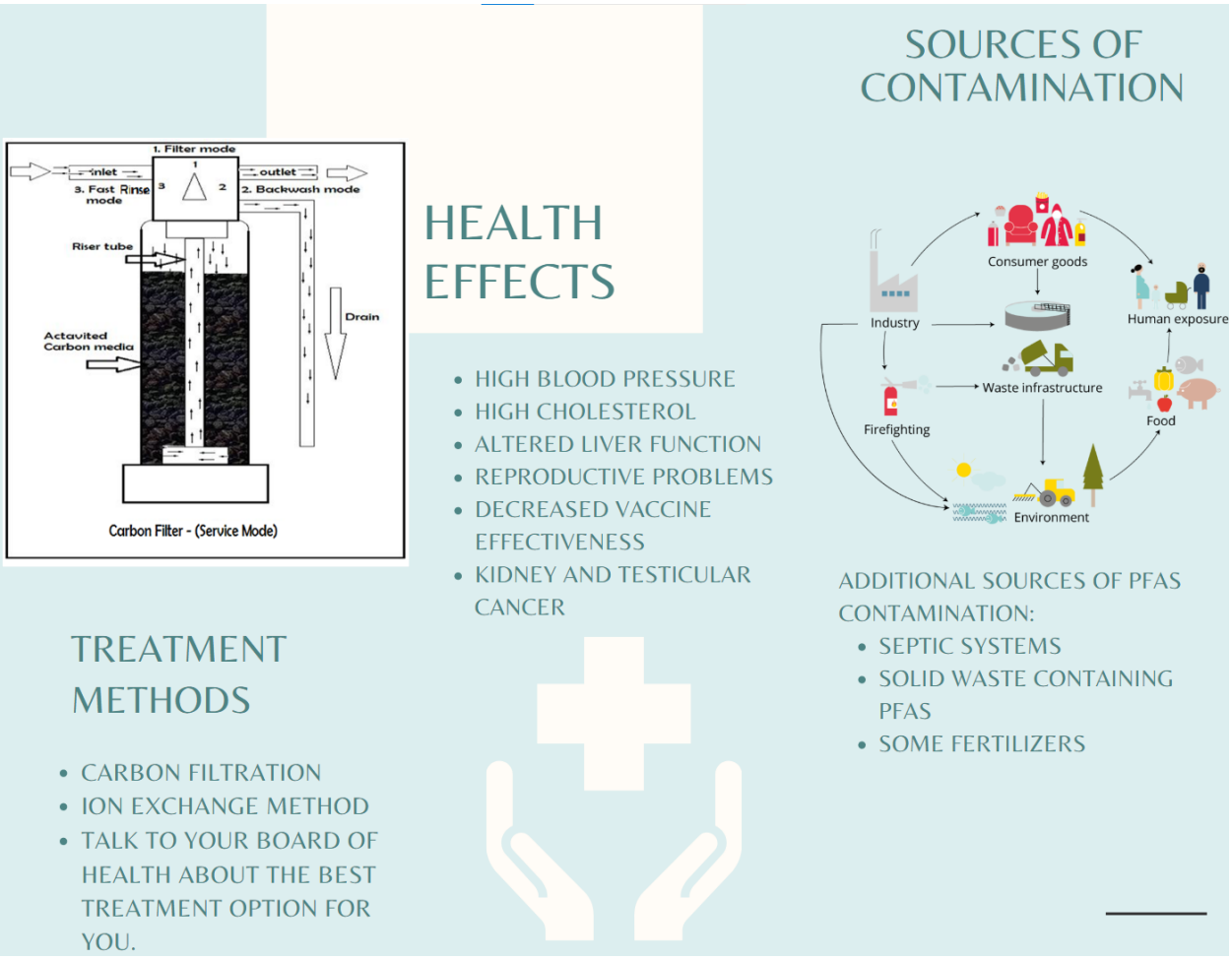

Figure 14: This is the back page of a pamphlet about well testing and PFAS contamination, to be distributed to private well owners.

Appendix K

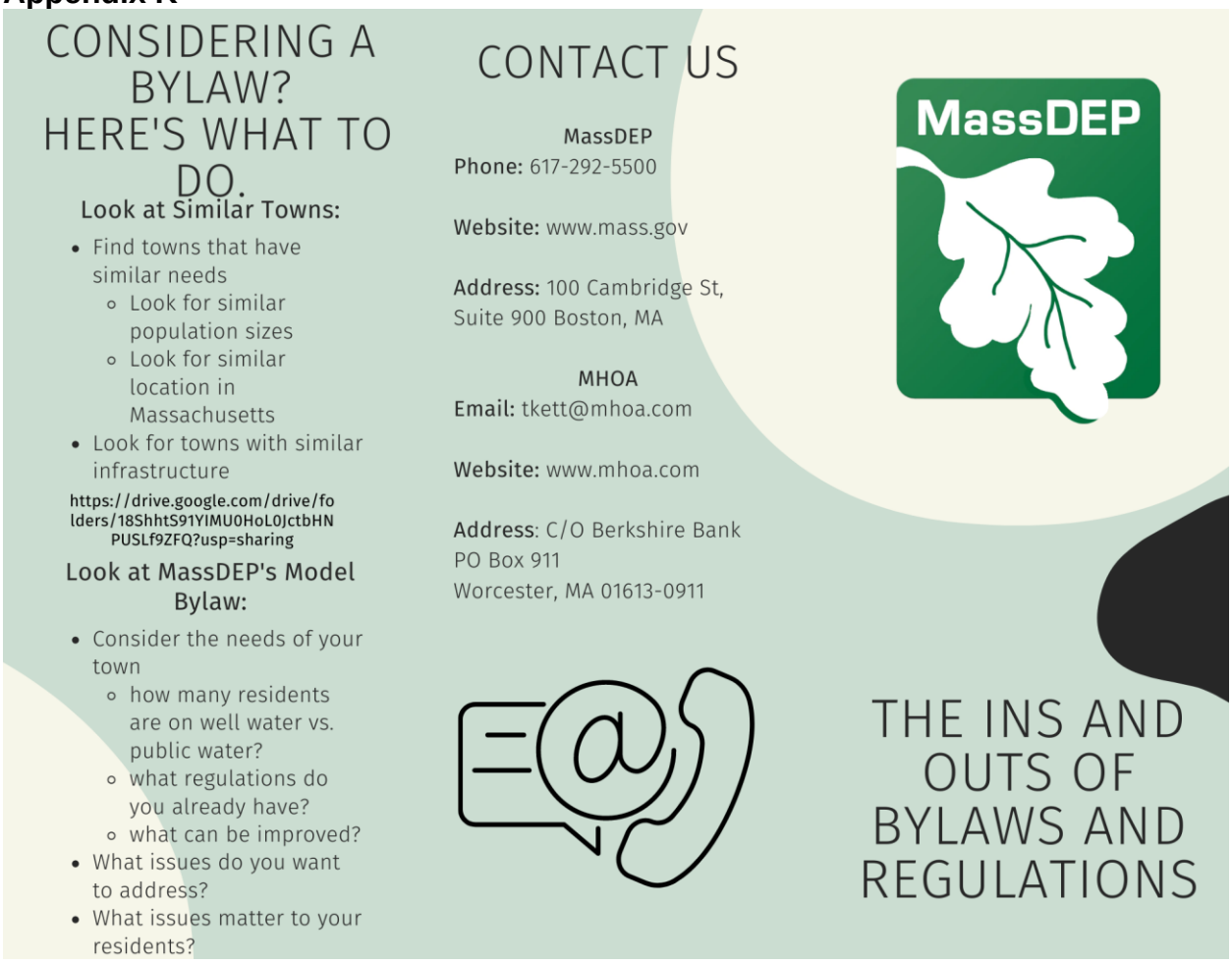

Figure 15: This is the front page of a pamphlet about bylaws and regulations, to be distributed to Board of Health agents, and as a supplemental material to a Board of Health agent training program.

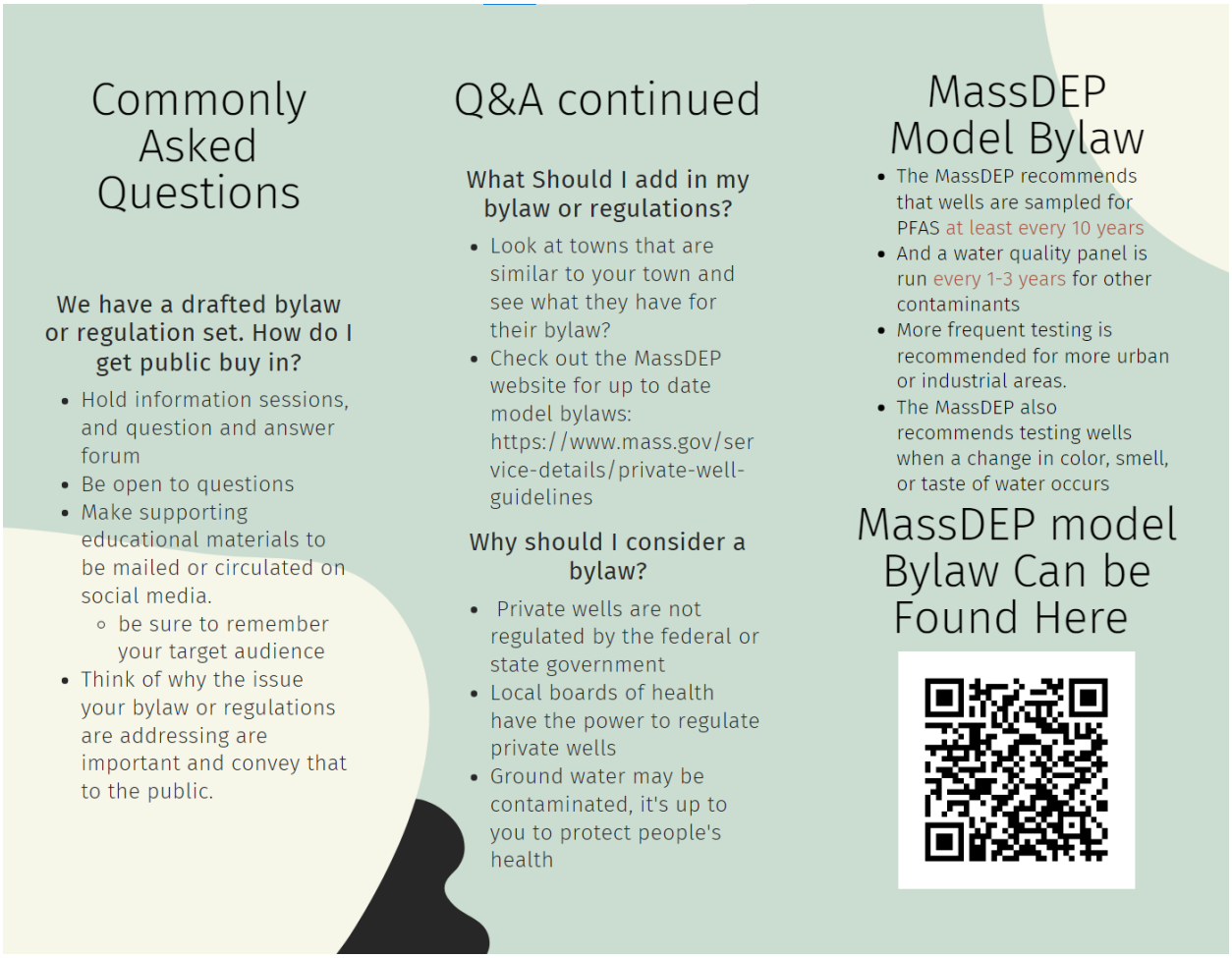

Figure 16: This is the back page of a pamphlet about bylaws and regulations, to be distributed to Board of Health agents, and as a supplemental material to a Board of Health agent training program.