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Dreaded and Unknown: Online Risk Communication and Polyfluoroalkyl Substances (PFAS)

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DREADED AND UNKNOWN: ONLINE RISK COMMUNICATION AND POLYFLUOROALKYL SUBSTANCES (PFAS)

By

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UNIVERSITY OF MAINE GRADUATE SCHOOL LAND ACKNOWLEDGMENT

The University of Maine recognizes that it is located on Marsh Island in the homeland of Penobscot people, where issues of water and territorial rights, and encroachment upon sacred sites, are ongoing. Penobscot homeland is connected to the other Wabanaki Tribal Nations— the Passamaquoddy, Maliseet, and Micmac—through kinship, alliances, and diplomacy. The University also recognizes that the Penobscot Nation and the other Wabanaki Tribal Nations are distinct, sovereign, legal and political entities with their own powers of self-governance and self-determination.

DREADED AND UNKNOWN: ONLINE RISK COMMUNICATION AND POLYFLUOROALKYL SUBSTANCES (PFAS)

By Carrie Loomis

Thesis Advisor: Dr. Laura Rickard

An Abstract of the Thesis
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Polyfluoroalkyl substances (PFAS) are a group of fluorinated chemicals posing both environmental and health threats due to their persistence in the environment and human body. PFAS chemicals are used widely for their broad applications, which has led to them being found in soil and water worldwide. Researchers in the state of Maine and beyond are working to understand PFAS. In this work, online communications about PFAS chemicals are explored using quantitative content analysis, specifically integrative framing analysis, to describe how PFAS risks are being communicated by different organizations at different scales. Using concepts related to efficacy and the psychometric paradigm, I explore both text and images on these websites, drawing connections between the two. Efficacy information (self-efficacy, response efficacy, or societal efficacy) about PFAS, such as information about water testing, is included on just over half of the sampled websites. Regarding the psychometric paradigm, PFAS risk is framed as having personal effects, meaning that the text implies the risk will affect the reader, 65.6% of the time and as inequitable, meaning that the text implies PFAS will affect some populations more than other, 42.2% of the time. Interestingly, efficacy information co-occurs in

the sample with the presentation of PFAS is personal and inequitable; however, framing of PFAS having personal effects does not co-occur with framing of PFAS being inequitable. Websites produced by federal level organizations (as opposed to state or local organizations) are less likely to include efficacy information, less likely to discuss farms or farmers, and less likely to discuss any of the 50 U.S. states. Similarly, websites published by government organizations (as opposed to advocacy or trade organizations) are more likely to discuss the individual U.S. states and less likely to refer to PFAS as "forever chemicals." Text and images present congruent messages in approximately half of cases, though some topics have higher congruency than others. For example, messaging related to farmers or farms is congruent more often than messaging about firefighting foam, water/stain resistant material, packaging, and cookware. From these findings, I suggest that future websites communicating PFAS risk should frame more carefully for their audience, including images where appropriate to highlight messages, and include relevant efficacy information. This research establishes what currently exists with regards to communicating PFAS risks and points to potential for researchers and practitioners to further understanding of best practice for PFAS risk communication.

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There are more people deserving of thanks for their support of my research and quest for a Master's degree than I can fit into this section, though I will still try. First, I would like to thank Dr. Laura Rickard, my advisor, who has devoted countless hours to helping me develop this research, pursue my (varied) academic interests, and grow as an academic, lifelong learner, and person. The support she provided throughout the last two years was integral to my development. I would like to express thanks to the NSF-NRT program for funding this research, but, more specifically, Dr. Emily Uhrig and Dr. Jessica Jansujwicz, for their dedication to supporting my research, academic projects, and internship experience. Next, I would also like to thank my coding team, Medha Bhattacharyya, Lara Naisbitt, and Jacob Russell, who assisted with the development of the codebook and coding throughout the Fall of 2023, for their dedication to the project and never-ending humor throughout the process. I would like to give the greatest thanks to my family and friends for their love and support over the last two years including, but not limited to, learning more than wanted about PFAS, talking through my research problems with me, and sending me just about every news article about PFAS. Lastly, thank you to my partner, Mason Grim, for giving me a shoulder to lean on, in both good and bad times.

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TABLE OF CONTENTS

LIST OF FIGURES

LIST OF TABLES

CHAPTER 1

INTRODUCTION

Background and Scope

"I didn't find out about these forever chemicals until last summer," Brendan Holmes, a Maine farmer, is quoted as saying in *Corn & Soybean Digest* (Torres, 2022). Holmes is one of many farmers in Maine whose products have been found to contain polyfluoroalkyl substances (PFAS), resulting in a loss of sales, and upending his livelihood (Torres, 2022). This is just one example of how these chemicals are affecting lives. PFAS are a class of chemicals that are man-made and have a variety of uses ranging from food packaging to firefighting foams (Lau, 2015). They have been manufactured broadly since the 1950s, and, due to their resilience in the environment, have been detected in soil, water, plant, and animal samples (Lau, 2015; US Environmental Protection Agency [US EPA], 2023). This contamination becomes problematic when you add into the equation that PFAS chemicals can have a variety of negative health effects, such as increased likelihood of certain cancers (Lau, 2015; Overton, 2023; US EPA, 2023).

PFAS chemicals, like many contaminants that came before them, pose risks to both human health and environmental health (US EPA, 2023). As such, they are regulated at both the state and federal level to mitigate their effects. At the state level, the state of Maine has banned the spreading of biosolids, a wastewater treatment byproduct, as well as the sale of PFAS in unnecessary products past 2030 (Overton, 2024). At the federal level, the United States Environmental Protection Agency (EPA) has created legal limits for six common PFAS in drinking water samples (Huang et al., 2024). Alongside the push to learn more about the environmental fate and health effects of these PFAS chemicals (see Lau, 2015; Maine Department of Environmental Protection, 2019; US EPA, 2023), researchers are also working to learn more about the perception of PFAS risk and how this threat is being communicated to public audiences (see Ducatman et al., 2022; Zimmerman et al., 2022; Zindel et al., 2021). This research will aim to build on the latter goal and describe how relevant organizations are communicating PFAS risk to various audiences.

To accomplish this goal, this work examined websites that communicate PFAS risk. As ubiquitous media forms, such as the internet, begin being utilized for risk communication, it is important that researchers pay attention to website content (Neuendorf & Kumar, 2016). So much of people's daily lives play out online, and as such, the internet presents an opportunity for such risk communications to present as static or dynamic, unidirectional or interactive, and any number of characteristics in between (Capriotti, 2007); however, researchers have found the existing online communications about chemical safety in general – and, to a lesser extent, PFAS risk – to be lacking for a variety of reasons (see Ducatman et al., 2022; Zindel et al., 2021). In light of this deficit, knowing how PFAS risks are communicated currently will be essential for improving such tactics to better serve those most in need of PFAS risk information. In this research, we use concepts from risk communication, such as the psychometric paradigm (Slovic et al., 1986) and efficacy (Bigsby & Albarracín, 2022), to describe and assess online communications surrounding PFAS.

This research will concentrate on online PFAS messaging in New England (U.S.), particularly the state of Maine. We will be examining existing websites that communicate PFAS risks, separately analyzing text and images on these websites. We focus on three primary research questions, with the broader goal of describing how organizations are communicating PFAS risks:

1. To what extent are information indicating (un)certainty, information indicating dread, and efficacy information present on websites discussing PFAS risks (RQ1a)? To what extent do they co-occur (RQ1b)?

2. Does the frequency of these concepts differ by the type (government/trade/advocacy) (RQ2a) and the scale (state/national/local) of the website (RQ2b)?

3. To what extent is the message presented in text consistent with the accompanying image?

Positionality Statement

I came to this work with my own past, experiences, and expectations. My education, research experiences, and identity all contribute to how I approached and shaped this work. Objectivity, the idea that a researcher can be separated or removed from their work, is more of a research ideal (if it even is ideal) than a realistic goal (Reid et al., 2021). We, as researchers, but more importantly as people, are connected to our work through our pasts and futures. I make no claims that I came to this work objectively; instead, I bring my passion for chemistry and social science into this work. As such, understanding who I am and what brought me to this point may be relevant for understanding how I approached this research.

My education has been winding, filled with crossroads where I seem to always choose the least expected path. When I first started planning for my future career, I expected to teach high school chemistry after graduating, though this quickly changed as I became more and more interested in environmental issues. This rather quickly morphed again into adding an environmental science major to my existing chemistry major and soon after I began researching abandoned mine drainage in Central Pennsylvania. Through this work, my passion for learning and exploring environmental issues through research began. As I studied the chemical characteristics of one environmental contaminant, I began to consider the consequences of environmental contaminants on the communities of people that they envelop.

As I was faced with family and friends questioning "what's next?," I found myself yearning to know more about the human side of the environmental issues that I had been studying. Chasing this interest, I applied to the University of Maine to study Communication and quickly had to field new questions of "why?" from the same family and friends. Despite these questions, I had set my intention and knew what was next. Coming into a new discipline, my views on science and research were challenged while I learned the ins and outs of an unfamiliar field. While I have much yet to learn, I now feel that I can qualify as both a physical scientist and a social scientist.

Most of the research I do and have done is quantitative, and I do not have much formal experience with qualitative methods. This fact is evident in this research, where I focus firmly on quantifying how organizations are communicating about PFAS in their public-facing websites. My focus on quantitative methods has some benefits, such as the ability to generalize from these findings, but this approach also loses some nuance and context in this generalization (Neuendorf & Kumar, 2016). I encourage other researchers to approach PFAS risk communication with complementary studies that approach the topic with qualitative methods.

Probably most importantly, I came to this work from a position of incredible privilege, as is evident from my experience in education. I am incredibly grateful for the opportunities that I have been given, and it is not lost on me that these opportunities are not afforded to everyone. My goal is to approach my research reflexively, taking time to recognize the structures that have brought me here and how they may change my current and future perspectives on my research and findings. I came to this project as a chemist, and though I now feel I am equally a social scientist, my interest in chemical transport guided my attention to the sources and locations of PFAS as described on these websites. This is not to say that this information should be any less interesting to those with differing backgrounds, but rather to point out that this choice (like others) was definitively influenced by my background.

Moreover, I came to this work with the privilege of extensive resources at my disposal. The time and energy devoted to my work from my professors, graduate student coding team, thesis committee, and advisor were integral to the success of this project. Similarly, this project could not have existed without the support and funding that I received from the Department of Communication and Journalism, the National Science Foundation Research Traineeship for Enhancing Conservation Science, and the Graduate School at the University of Maine.

This Thesis

In this research, I will examine PFAS risk communication in online spaces, with the intent to describe a limited section of the current landscape (i.e., government, trade, and advocacy; local, state, and federal websites). In the literature review, I will start by exploring guiding risk communication concepts, namely the psychometric paradigm and efficacy. Then, I will investigate the ways that sources and types of messages can impact how a risk is understood. I will next put the issue of PFAS into the context of the state of Maine.

In the methods section, I will cover the method used in this research: quantitative content analysis. Then, I will discuss the details, such as the sampling method, coding protocol, and coder training. Lastly, I will clarify the process of data analysis. In the results section, I will report on general descriptive statistics for all codes. We will also walk through the findings for each research question, accompanied by relevant statistics.

Lastly, in the discussion, I will expand on the findings from each research question and explore them in the broader context of risk communication. I will also address the limitations of this work and key takeaways for both theory and practice in this section. Finally, I will discuss future directions for research on PFAS risk communication and offer concluding thoughts.

CHAPTER 2

LITERATURE REVIEW

What Makes a Risk Risky?

Risk communicators have long sought to understand just what makes a hazard risky, and one potential answer to this question can be found in the foundational approach known as the psychometric paradigm (Slovic et al., 2004). While applying a singular definition can be challenging, it often makes sense to understand risk as anything with perceived potential to cause harm (Yang et al., 2014). PFAS risks, like all risks, are not only understood through systematic, rational, or logical analysis, but also by the affective responses they invoke (Slovic et al., 2004; Wilson et al., 2018). Affective responses are learned, either with experience or by association with risk (Slovic et al., 2004). Importantly, affect processing allows for risk decisions to be made quickly, without the extensive thinking required for analytical process (Slovic et al., 2004). These affective responses can then influence information processing, and subsequent risk perceptions (Lui & Yang, 2023). Thus, affective response may be important for understanding how emotional responses such as dread relate to PFAS risk.

On the other hand, experts (i.e., those with technical training in various scientific fields) most commonly define risk by zeroing in on annual fatalities associated with the hazard, whereas publics more often interpret risk by considering other qualities such as catastrophic potential, equity in the distribution of possible benefits or harm, effects on future generations, controllability, and involuntariness, all of which can invoke the aforementioned affective responses (Slovic, 1987; Slovic et al., 1986). Further, risk perception can vary based on an individual's demographic and sociocultural characteristics as well as various characteristics of the risk (Liu & Yang, 2023).

Introducing psychometric paradigm to risk perception research, Slovic et al. (1986) established two key factors that affect risk perception among non-expert audiences: unknown and dread. Using several survey-based studies where laypersons and experts, those who have specific knowledge about a subject (e.g., toxicologists), assessed several hypothetical hazards, Slovic et al. (1986) used factor analysis to show how the unknown and dread factors, when combined, create a taxonomy of such hazards. The higher a hazard scores on these two factors, the more elevated its perceived risk. Concurrently, most individuals tend to want to limit their exposure to risk, motivating demands for stricter regulation (e.g., Slovic, 1987; Slovic et al., 1986). In the current research, these factors of unknown and dread offer a lens through which to examine PFAS risk.

The factor of a risk being perceived as unknown is associated with several attributes. A risk could be unknown because of its occurrence in the physical world, such as being unobservable to exposed individuals (Slovic et al., 1986). Identifying the presence of PFAS contamination requires specific water testing, which is often hard to obtain and costly for most consumers (Rhoda, 2022). As such, those who are exposed may not know of their exposure, and PFAS contamination can function as a relatively "invisible" hazard to most citizens. A risk could also be perceived as unknown because it is viewed as novel and/or understudied by the scientific community (Slovic et al., 1986). For example, researchers applying the psychometric paradigm in the context of the unfamiliar COVID-19 vaccine found that its unknown (in this case, novel) nature may have related to it being perceived differently – usually as riskier – than other established and more well-known vaccines (Wong & Yang, 2023).

As an emergent risk, PFAS similarly poses significant potential to be perceived as unknown, and thus, highly risky. Hedging language regarding the weight of scientific evidence, such as referring to a lack of scientific consensus about human health impacts, can also indicate undue uncertainty to the public, and such language is often employed in online communication about PFAS (Ducatman et al., 2022). Thus, the invisible, emerging, uncertain, and subsequently unknown nature of PFAS may affect the perception of its associated risks.

According to research applying the psychometric paradigm, a risk is often dreaded when associated with a variety of characteristics, including its severity, one's lack of control over its impacts, its lasting effect, widespread susceptibility, and lack of equitability in exposure and/or impacts, and its ability to affect the individual (Slovic et al., 1986); some of these factors may be correlated, such as the perception of a risk having lasting effect and its increased severity (Slovic et al., 1986). To exemplify one of these characteristics, consider that, when reviewed in July 2020, about half of U.S. state government websites discussing PFAS mentioned that the risk may differ for vulnerable populations (i.e., pregnant people or babies) (Zindel et al., 2021). In the context of the psychometric paradigm, distinct levels of risk among various populations could be considered a lack of equitability (Slovic et al., 1986).

Another example of the potential for PFAS to evoke dread relates to a general lack of control over exposure. In the United States, most people have some trace of PFAS in their blood, and an unknown number of people have experienced more extensive exposures, such as those living or working in urban or industrial areas (Ducatman et al., 2022; Lau, 2015). For example, consider the case of Stuart, Florida, which was involved in a settlement with 3M over PFAS contamination from the use of firefighting foams produced by the company in the city, likely contaminating the public's water source and affecting most residents (The Associated Press, 2023). Moreover, a 2020 survey of U.S. state government websites found a lack of information provided on how to avoid or mitigate PFAS exposure (Zindel et al., 2021), also known as efficacy information (described below). Given the widespread nature of PFAS, coupled with insufficient attention on how to limit one's exposure, many may perceive the risk as uncontrollable, and thus highly dreaded.

It is also possible that the widespread nature of PFAS may result in individuals feeling that PFAS will affect them, and thus have personal effects (Ducatman et al., 2022; Lau, 2015; Slovic et al., 1986). In a survey of Maine residents, most respondents thought that they should know about PFAS risk for their own health or the health of their families (Zimmerman et al., 2022). This is an indication that PFAS is being perceived as a personal risk by people in the state of Maine, and possibly elsewhere. As such, there is potential for PFAS to be perceived as dreaded because it will have personal effects.

What Can You Do: Self-Efficacy, Response Efficacy, and Societal Efficacy

Efficacy can play a central role when persuading people to adopt self-protective behavior (Bigsby & Albarracín, 2022). Individuals may understand a great deal about a risk, yet not believe that they can or should change their behavior to mitigate the risk, or that the behavior may be effective in protecting oneself (Bandura, 1990). For this research, we define efficacy as having three subtypes: self-efficacy, response efficacy, and societal efficacy, which all often work together in different ways. When efficacy information is present, it can also be positive, and reinforce feelings of efficacy, or negative, and weaken or instill doubt in efficacy beliefs (Bigsby & Albarracín, 2022). In extant research, self-efficacy and response efficacy are more often examined than societal efficacy, which is also referred to by a variety of names, including collective efficacy (Bandura, 1999; Evensen & Clarke, 2012).

First, self-efficacy represents the underlying belief that an individual can take some action when faced with a risk (Bandura, 1990). As such, a person who believed that they could take many different actions to mitigate their risk of PFAS exposure (i.e. testing their water, switching to PFAS-free cookware) could be said to have high perceived self-efficacy. This is important, as it has been shown in a variety of contexts that those who have low perceived efficacy are, in turn, less likely to commit to taking protective action (Bandura, 1990; Bigsby & Albarracín, 2022; Nazione et al., 2021; Witte, 1992). For example, in a survey-based study of Amazon MTurk participants, regarding the COVID-19 virus, perceived risk and perceived efficacy were the strongest predictors of protective behavior, such as masking or social distancing (Nazione et al., 2021). Self-efficacy is representative of what an individual can do as well as their motivations behind taking action.

Next, response efficacy addresses the perceived certainty of success in mitigating a risk by undertaking a particular behavior (Bigsby & Albarracín, 2022). In Maine, a recent survey conducted in Spring 2022 found that state residents feel they need to know more about PFAS, particularly about limiting their potential for exposure by consuming contaminated water or food (Zimmerman et al., 2022). This desire to know more about protective actions could be considered a desire for efficacy information – that is, information about how to address PFAS risk (Bandura, 1990; Bigsby & Albarracín, 2022); importantly, though not specified in the research, Zimmerman et al.'s (2022) survey wording seems to indicate that such information could be classified as either self or response efficacy, or possibly both. In a recent meta-analysis of mostly health related studies featuring fear appeals, response efficacy was found to be the only significant moderator between fear appeals and positive behavior or behavioral intention (Bigsby & Albarracín, 2022). In other words, across these studies, the relationship between exposure to fear appeals and intended behavioral change tended to be dependent on perceived response efficacy. As such, response efficacy is of interest in relation to the ways in which PFAS risk is discussed in online spaces, since there is evidence that response efficacy is important for understanding behavioral intentions across a variety of contexts (Bigsby & Albarracín, 2022).

Finally, societal efficacy, in this work, serves to represent the collective actions that can be taken by individuals to mitigate PFAS risk. Societal efficacy addresses actions that can be taken to mitigate risk at a broader scale (Evensen & Clarke, 2012). Evensen and Clarke (2012) explore societal efficacy in the context of zoonotic disease, which is both an environmental and health issue. This is similar to the context of PFAS, which also poses both environmental and health impacts (US EPA, 2023). In the work of Evensen and Clarke (2012), societal efficacy is operationalized as actions that an organization can take to mitigate risk. Societal efficacy conceptually contains a related term, collective efficacy, as defined by Bandura (1999). Bandura (1999) describes that those who feel that they can create political change are more motivated to attempt to do so, whereas those who feel that they do not hold political power are less motivated to take action. Following Evensen and Clarke (2012), the present research refers to this form of working together to take collective action as societal efficacy. Given that some websites included in this study were published by advocacy organizations, messaging meant to invoke societal efficacy in the context of PFAS risk might be expected; however, previous research has found that collective action framing is lacking on state government websites discussing PFAS risk

(Zindel et al., 2021). Further, recent survey data from Maine also suggests that residents place much of the responsibility for PFAS action on the individual, rather than on companies, farmers, or the state government, which may imply that self and response efficacy could be more important (at least to citizens) in the context of PFAS (Zimmerman et al., 2022).

Outside of the PFAS context, previous research has linked the presence of efficacy information to risk perceptions and other behavioral outcomes. For instance, in the context of Twitter, messages from public health agencies containing efficacy information about the Zika outbreak were shared more frequently, and consequently may have reached wider audiences (Vos et al., 2018). While this sharing may not apply directly to websites, specific content from these websites, namely infographics, may be shared over social media sites like Twitter (Lazard & Atkinson, 2015). This can be particularly important in the context of emergent risks, such as infectious disease outbreaks (Vos et al., 2018), or, increasingly, PFAS (Zimmerman et al., 2022). Thus, quantifying the presence of efficacy messages present in online communication about PFAS is relevant.

Together, the concepts of risk perception (specifically, as described in the psychometric paradigm) and efficacy offer a useful framework with which to examine how PFAS risks are discussed online. In the literature, there is extensive support for such connections of risk perceptions and efficacy information. For example, the Extended Parallel Process Model (EPPM) links the perception of a threat directly to risk mitigation, with feelings of efficacy playing a central role in the relationship (Witte, 1992). Similarly, the Risk Perception Attitude Framework builds on the EPPM, presenting four groups characterized by varied risk perception and efficacy beliefs (Rimal & Real, 2003). These groups are then predicted to respond to risk differently, potentially finding motivation from risk perception and efficacy (Rimal & Real, 2003). From these examples, the literature shows support for the use of risk perception and efficacy information in tandem in research.

As such, this research examined the prevalence of various factors relating to the psychometric paradigm and efficacy as well as their co-occurrence. The current research also seeks to understand correlations between factors of (un)known, dread, and efficacy. Specifically, we ask:

Research Question 1: To what extent are information indicating (un)certainty, information indicating dread, and efficacy information present on websites discussing PFAS risks (RQ1a)? To what extent do they co-occur (RQ1b)?

Who Writes and For Whom?

Source credibility encompasses perceptions that a source is fair, complete, unbiased, concerned with the community, and truthful, which can influence the perception of risk (Trumbo & McComas, 2003). Sometimes, the source of information (e.g., government agency, news publication) can prove to be just as important as the information itself, though the potential effect of the messenger is still a topic of ongoing research (Cozma, 2006; Odunsi & Farris, 2023; Trumbo & McComas, 2003). Particularly, researchers have examined credibility of government sources in comparison to different or multiple sources (see Cozma, 2006; Miller & Kurpius, 2010; Odunsi & Farris, 2023; Trumbo & McComas, 2003). For example, government sources have been viewed as more credible in comparison to other sources (i.e., social media) (Miller & Kurpius, 2010); however, other experimental research has found support for using multiple, diverse sources in messaging, since source diversity (i.e., how many perspectives are highlighted in a story) has been shown to be positively related to perceived source credibility (Cozma, 2006).

Perceptions of source credibility may also vary based on other factors, such as individuals' familiarity or historical relationships with various industries, publications, or organizations (Trumbo & McComas, 2003). For instance, in Maine, a state with a strong agricultural heritage, residents have been found to trust trade groups, such as farming organizations, more than they trust federal and state government agencies as sources of PFAS information (Zimmerman et al., 2022). Considering this contrast, it may be important to understand the differences in how these sources, particularly government, trade, and advocacy groups, portray PFAS risks.

Another important consideration for these communications is for whom the information is intended, specifically the scale (i.e., local, state, or federal) of the audience. Researchers have found that chemical risk communications from trade organizations, specifically websites from chemical companies, tend to be generalized and lack local perspective (Capriotti, 2007). This may be important given that people process PFAS risk information in a more systematic way when information holds personal relevance (Liu & Yang, 2023). Given the importance of source and scale to risk communication, particularly in the context of novel chemicals, we ask:

Research Question 2: Does the frequency of uncertainty, dread, and/or efficacy differ by type of website source (government/trade/advocacy) (RQ2a) and the scale (state/national/local) of the website (RQ2b)?

Integrative Framing Analysis

Integrative framing analysis is a specific type of content analysis that investigates the interplay between image and text-based content in a given message (Dan, 2018). Most messages are not made up of solely text or solely images, but instead are a combination of text and images working together (Kress, 2010). Using integrative framing analysis, the text and image parts of a given message are separately analyzed through content analysis methods, subsequently using a calculation to assess the degree of congruence (Dan, 2018). While text may be a more typical method of communicating a message, images themselves also serve distinct functions, such as increasing message passing, increasing persuasive effects, and making a message more memorable (Vos et al., 2018; Lazard & Atkinson, 2015; Drew & Grimes, 1987).

It is well established that images within risk communication messaging can alter how risks are perceived (Covi & Kain, 2016; King, 2015; Leiserowitz & Smith, 2017; Trumbo, 1999). As they serve as representatives of existing understandings or data, images can be critical components of risk communication (Covi & Kain, 2016). Images that serve as exemplars, specific cases that serve to represent a whole set, can create emotional responses, which can generate behavior change and foster information seeking (Zillmann, 2006). One empirical study on Twitter investigating the characteristics of messages in the context of the Zika virus provides some evidence that the presence of images may increase message passing (Vos et al., 2018).

In health communication specifically, the presence of images in a message has been shown to promote receptivity, or acceptance, of the primary message (Manno et al., 2018); however, images in risk messaging are often limited in their ability to portray causal relationships, which is often central to communicating about risk topics (Clarke et al., 2012). In some cases, attempting to portray these causal relationships through visuals can result in the spread of misinformation (Heley et al., 2022). Due to these potentially complicated effects, the use of images in risk communication requires careful study to determine possible effects on downstream attitudes and behaviors, as well as how their presence may relate to, or interact with, text (King, 2015).

Messages containing text and visual components are often more effective at persuading readers than is text on its own (Dixon et al., 2015); however, to achieve the intended persuasive effect, visuals and text must present the same, or at least similar, messaging. Two experiments investigated infographics as a combined use of text and images in tandem, emphasizing the potential application of infographics to risk contexts (Lazard & Atkinson, 2015). To accomplish this, this study exposed participants to information regarding recycling or genetically modified organisms (i.e., messaging about "frankenfood"), presented as text only, an infographic, or visuals only (Lazard & Atkinson, 2015). Messages presented with text and visual messages in tandem (i.e., infographics) were more persuasive, though this relationship was also largely dependent on individual characteristics and perceptions (i.e., perceived visual literacy, learning preferences) (Lazard & Atkinson, 2015). The key to persuasion, based on these findings, lies not only in elevating importance of the visual, but also in aligning its content with written text.

Indeed, other experimental research on redundancy of messaging supports the importance of congruency of images and text. In one experiment, college students were shown voice over news clips, manipulated to be either high or low redundancy, which is conceptually similar to congruency (Drew & Grimes, 1987). This experiment showed that messaging with higher congruence between these auditory and visual messages were more memorable and more well understood than messages with less congruence (Drew & Grimes, 1987); however, as other research has found, the presence of the images is not the only important factor, as the type of image matters as well (King, 2015; Lazard & Atkinson, 2015; Lipkus & Hollands, 1999; Lundell et al., 2013, Trumbo, 1999). One study that examined statistical images, such as graphs and maps, that portrayed information about social determinants of health (i.e., access to safe neighborhoods and affordable, healthy food) demonstrated that participants perceived that some of the images oversimplified complex relationships, making participants suspicious of the message (Lundell et al., 2013). This is important in the context of the current study, as it emphasizes the importance of using text alongside images to portray and explain complicated relationships, rather than relying solely on an image. Images on their own portraying counterintuitive relationships may be misunderstood (Lundell et al., 2013), but congruent text can assist with portraying these messages. As such, the congruence between text and images is imperative for clear, understandable risk communication messaging. Thus, we ask:

Research Question 3: To what extent is the message presented in text consistent with the accompanying image?

Polyfluoroalkyl Substances

Polyfluoroalkyl substances, also known as PFAS or PFAS chemicals, have been used widely since the 1950s in a variety of products and industrial processes (Torres, 2022). PFAS are not a singular chemical, but rather make up an entire class of chemicals, most of which possess a noteworthy ability to repel water and stains (Zimmerman et al., 2022). Namely, PFAS chemicals are found in water and stain resistant material, food packaging, and firefighting foams (Lau, 2015). These chemicals also break down remarkably slowly over time, which has granted them the nickname of "forever chemicals" (Lau, 2015; US EPA, 2023; Zimmerman et al., 2022). As a result of this widespread use and extreme durability, PFAS chemicals have been found throughout the United States, and, consequently, many US residents have been exposed to them (US EPA, 2023). Unsurprisingly, PFAS chemicals are regularly found in blood samples throughout the United States population (Lau, 2015). For years, researchers have called for legislative action on PFAS, seeking accountability (Cousins et al., 2019). In April 2024, the US

EPA set new limits for six of the most common PFAS chemicals in drinking water (Huang et al., 2024).

While scientists agree that PFAS poses human health effects in general, less is known about what these specific health impacts may entail. Due to the nuances of PFAS exposure, such as the time and length of exposure, as well as the specific chemical and exposure route, health impacts from PFAS chemicals can differ (Lau, 2015; US EPA, 2023); however, some researchers have proposed that various negative health effects were hidden by industry (Richter et al., 2018). Despite this, there are some known health impacts linked to PFAS exposure, such as reproductive harm, hormonal imbalances, decreased immune response, elevated cholesterol levels, and elevated risk of some cancers (US EPA, 2023). The health effects of PFAS on sensitive populations, such as pregnant people and children, are even less well defined (US EPA, 2023). Overall, further research will be necessary to understand fully the effect of PFAS chemical exposure on human health.

PFAS in the Pine Tree State

In Maine, PFAS chemicals are beginning to receive attention from the media and researchers alike. The state has experienced widespread contamination of food, particularly on dairy farms, from the land application of PFAS contaminated biosolids, which are a wastewater processing byproduct (Torres, 2022). Maine is on the forefront of PFAS legislature, banning the application of sludge, also known as biosolids, and banning PFAS in nonessential products after 2030 (Overton, 2024). In Maine, the use of biosolids as agricultural additive dates to the 1970s and was most common throughout the 1980s and 1990s (Haedicke, 2023; Zimmerman et al., 2022). Not only are there potential health and environmental impacts from this historical practice, but there are also potential economic impacts. For example, one farmer from Albion, Maine, after discovering PFAS contamination, reported steep economic losses, estimated around half a million dollars, due to being unable to sell any of their products, including raw milk, meat, and organic produce (Torres, 2022). Recent reporting from the *Portland Press Herald* states that financial resources will soon be available to any contaminated farm, where these resources were previously limited to certain farms, although given the limited size of the fund, removing eligibility requirements will likely drain the fund sooner than anticipated (Overton, 2023).

PFAS is also receiving attention from researchers in Maine. Maine Department of Environmental Protection (ME DEP) is undertaking a large testing campaign, testing places where biosolids were applied historically and the surrounding areas (ME DEP, 2019; Rhoda, 2022). The main goal of this research is to understand which areas in Maine require the greatest allocation of resources (Rhoda, 2022). Researchers in Maine are also working to better understand how Maine citizens perceive PFAS risk and the extent of PFAS contamination in the state. A recent study of Maine residents found that, despite the news media focusing on the potential for PFAS exposure from Maine farms, most residents do not place most of the blame for the issue on farmers, instead viewing companies as responsible for producing products that contain PFAS (Zimmerman et al., 2022). Moreover, the same survey found that Maine residents remain confident in the local food system, despite uncertainty surrounding PFAS contamination (Zimmerman et al., 2022).

PFAS Online

The internet has, and is still, becoming an increasingly important medium for risk communication, and information about risks related to PFAS is no different (Capriotti, 2007).

For example, a content analysis of government websites conducted in 2020 found that 35 (out of 50) U.S. state governments at the time of the research had a designated website with information about PFAS, which indicates that each of these states viewed communicating PFAS risk to be of value (Zindel et al., 2021). Moreover, the websites provided by state governments were found to focus on uncertainty surrounding PFAS risk and lack collective action framing, instead focusing on the potential mitigative actions individuals could take (Zindel et al., 2021). This study also applauded websites from the state of Maine, along with those produced by the state governments of California and Michigan, for their ability to provide public access to data, such as PFAS testing data, and explanation of data in context relevant to the affected communities, which was one of their major suggestions for websites communicating about PFAS (Zindel et al., 2021). Reflecting on their findings, Zindel et al. (2021) also suggest that websites discussing PFAS should not overemphasize the uncertainty of the issue or personal responsibility for mitigating PFAS risks (Zindel et al., 2021).

While the presence of dedicated, state-level websites is a decent first step, much still needs to be done to provide U.S. – and, more specifically, Maine – residents with the information they need about PFAS. Broadly, past research has found that information about chemical risks is usually generalized and focuses on wide spatial scales, such as state or even national levels (Capriotti, 2007). This has the potential to be problematic, since PFAS contamination is location specific (Capriotti, 2007). Some researchers have even called out government agencies for not recognizing the need for different communications for high and low exposure communities (Ducatman et al., 2022). Moreover, websites discussing PFAS risks have been found to be lacking comprehensive explanation of potential health risks, and, potentially more importantly, how to avoid exposure to PFAS chemicals (Zindel et al., 2021). In Maine, recently surveyed respondents indicated that while they had some general knowledge of PFAS chemicals, they felt that their current knowledge was insufficient (Zimmerman et al., 2022).

In sum, PFAS chemicals pose an imminent threat to human and environmental health for residents of Maine and the greater United States. While researchers are presently engaging in scholarship to better understand the implications of these chemicals, many areas are lacking, such as understanding more specific health effects on certain populations, characterizing the extent of contamination, and determining how PFAS risks are being presented in public communication, particularly in online spaces. The latter category represents an opportunity for communication researchers to apply existing theory to a new context. In this research, we apply concepts of efficacy and the psychometric paradigm to examine differing sources and scales of the intended audience on resulting PFAS website content. Additionally, we examine congruence between the text and images on these websites to better explicate the role of images within these communications.

CHAPTER 3

METHODS

Content Analysis

This work employed quantitative content analysis to investigate existing online materials. Because it utilized existing material as the subject of study, this methodology was nonintrusive and economical (Babbie, 2014; Riffe et al., 2019). The method also allowed for a variety of specifications, such as the unit of analysis (Babbie, 2014). Because this research utilized publicly available websites as the unit of analysis, human subject permissions were not required from the University of Maine Institutional Review Board.

This research also distinguished between text and visual units, using a method called integrative framing analysis to understand the connections between the two types of content (Dan, 2018). As such, the webpage as a whole served as the text unit of analysis and each individual image on these webpages served as the image unit of analysis. Integrative framing analysis involves the separation and coding of text and visual units followed by the calculation of congruence of the results between the types of units (Dan, 2018) (see also below); however, in the present research not every text code could be connected to an image code. In particular, some variables could only be coded as present in the text units. This difference should be expected given that some concepts of interest in this study, such as PFAS information being unavailable, would be difficult to code in a visual context. Although recent studies have examined online PFAS information through the use of content analysis (Zindel et al., 2021), such work has not attempted to explore differences between websites given different spatial scales (e.g., local, state, or federal) and sources (e.g., government, trade, or advocacy groups), as we do in the following research.

This research used deductive coding as the primary coding method to examine theoretically supported concepts as well as other areas of interest, due to an interest in quantification, rather than exploration (Babbie, 2014). Given our interest in concepts of efficacy and the psychometric paradigm, we established a theory-supported codebook to guide the coding process. We included factors of unknown, dread, efficacy, actors, sources/locations of PFAS contamination, spatial scale, and PFAS testing/treatment in these codes (see Table 3.1) (Bigsby & Albarracin, 2022; Slovic et al., 1986).

Table 3.1: Major code concepts and theoretical backing.

Concept	**Sub-concepts**	**Definition**	**Theoretical Backing**
Unknown	Information Unavailability	Information is not available or is inaccessible.	
	Information Uncertainty	Information has low confidence, possibly due to contradictory evidence.	Slovic et al., 1986
	Uncertainty Associated with Risk	Uncertainty with the nature of the risk.	
Dread	Severity	The risk has an extremely negative effect.	
	Inability to Be Mitigated	The risk cannot be avoided.	
	Lasting Effect	The risk will be felt for generations to come.	Slovic et al., 1986

Table 3.1 (continued): Major code concepts and theoretical backing.

Concept	Sub-concepts	Definition	Theoretical Backing
Dread	Personal Effect	The risk will be felt on an individual level.	
	Widespread Susceptibility	The risk will be felt by many individuals.	
	Inequitable Effect	The risk will affect some populations more than others.[1]	
Efficacy	Self-Efficacy	There is a behavior that individuals can do to mitigate risk.	Bigsby & Albarracin, 2022
	Response Efficacy	The behavior that individuals can do to mitigate risk will be effective.	
	Societal Efficacy	There are collective actions that groups of people can undertake to mitigate risk.	
Actors*	Groups of people identified as typical stakeholders in PFAS risk.	Government Official, Farmer, Scientist	Not Applicable
PFAS Sources/Locations*	Locations, environmental attributes, and/or consumer products discussed as potential sources of PFAS contamination.	Water, Soil, Firefighting Foam, Wastewater Sludge (Biosolids), Nonstick Cookware, Packaging, Waterproof/Stainproof Material	Not Applicable
Spatial Scale	Physical scales discussed in reference to PFAS risk.	Specific Location, Local, State, Federal	Not Applicable
PFAS Testing/Treatment	Sampling or testing of relevant PFAS samples.	Water/Soil Testing, Water/Soil Treatment	Not Applicable

*Sub-concept lists generated through informal review of news media and websites not included in the final sample.

[1] Not location-based as spatial scale is coded elsewhere.

After identifying general categories (e.g., PFAS sources/locations, actors), we determined more specific codes for types of actors, specific sources of PFAS, and types of testing after examining recent media coverage of PFAS contamination as well as websites not included in the final sample (i.e., websites from states other than Maine, New Hampshire, Massachusetts, Connecticut, Rhode Island, and Vermont). While sources/locations of PFAS contamination focused on items that typically contain PFAS ranging from water to firefighting foam, spatial scale identified the discussion at the local, state, or federal levels. Although these codes were not exhaustive, they were meant to represent what typically exists on websites discussing PFAS.

While coding was primarily a deductive process, repeated applications of the codebook by a team of researchers identified several additional areas of interest, which further refined the final codebook. This pre-testing utilized state government websites not included in the final sample, (i.e., websites from states other than Maine, New Hampshire, Massachusetts, Connecticut, Rhode Island, and Vermont). (More detail on this process will be discussed below in "Coder Training and Codebook Pre-Testing.")

Sample

Focusing on U.S. PFAS websites, we analyzed both text and visual (hereafter referred to as images) units. From each website, we analyzed only the first or main page discussing PFAS (the "home" or "landing page"), as the home page can be viewed as a gateway to the remainder of the information presented (Baek & Yu, 2009). As such, this work analyzed all images present on these webpages, meaning that often multiple image units could be linked to a singular text unit. Additionally, in line with our research questions, we separated text units into categories by their source (i.e., government, trade, or advocacy-related organization) and spatial scale (i.e., local, state, or federal). We identified source categories by examining the primary goals of the publishing institution. For example, if an organization listed advocacy as a primary goal, that organization would be placed in the advocacy category. We determined spatial scale by assessing the level of the primary audience, such that town water districts would be categorized as "local" and broader U.S.-based advocacy groups would be categorized as "federal." We used these distinctions to explore possible differences in the way each group portrayed PFAS risk information, in line with RQ2.

Researchers analyzed all images present on an included webpage, so long as they existed independent from the page's architecture (e.g., not a banner image included on every linked page of the website) and not part of an advertisement. Additionally, we excluded icons, as they tended to be featured as bullet points comprising an index, rather than portraying information relevant to the study's research questions. After reviewing the types of images present on websites throughout the pre-testing of the codebook, we determined four commonly used image categories: (1) photos; (2) maps; (3) graphs or tables; and (4) infographics. We identified no other types of images in the final sample. We analyzed only the images as part of this process, with captions analyzed as part of the text units. That said, we coded and analyzed any text included within the border of an infographic as part of the infographic image. Due to the difficulty in separating images from text (as required for integrated framing analysis), videos were not coded in this research, although the presence of videos for each unit of analysis was recorded (Dan, 2018).

We collected units iteratively, which involved the generation of an initial list of websites by the primary researcher. Then, we consulted the thesis committee and outside researchers, namely Thomas Danielson, Molly Shea, Charity Zimmerman, and Dr. Caroline Noblet, to identify any additional organizations or webpages to be included. Thomas Danielson serves as an aquatic biologist at the Maine Department of Environmental Protection, which placed him in a unique position to make suggestions for webpages in this research. Similarly, Dr. Caroline Noblet, Charity Zimmerman, and Molly Shea are all associated with an interdisciplinary research group at the University of Maine that investigates PFAS, including how Maine residents receive information about the topic, giving them subject matter expertise. In the end, our sample included 64 webpages, with categories shown in Table 3.2 below. Citations for the final sample can be found in Appendix A.

Table 3.2: Frequency of study text units by category.

	Local	**State**	**Federal**	**Total**
Government	9	15	12	36
Trade	1	4	7	12
Advocacy	0	2	14	16
Total	10	21	33	64

From these webpage units, the primary researcher then collected and categorized images. In total, the sample included 216 total image units, with categories shown below in Table 3.3.

Table 3.3: Frequency of study image units by type.

Image Type	**Count**
Photo	175
Infographic	15
Map	11
Graph/Table	15

All unit collection and categorization occurred during the week of October 22nd, 2023. We created PDFs of each webpage and named all text and image units to link webpage and image units. We stored PDFs in Google Drive, where they could be accessed by the coding team.

Coding Protocol

Coders used a Google Form to record their coding for the units. This process simplified coding, as the form instructed coders through the coding process. Coders were instructed to have this coding form open while examining the study units, and to answer questions one at a time, referring to the unit for each question. Coders also avoided coding text and image units from one webpage in close temporal proximity to each other, to avoid connections being subconsciously drawn between text and images. We made this decision as a result of the team's experience coding practice units that were not in the final sample. We coded images in the order of top to bottom as they appeared on the webpage. If multiple images appeared in line with one another horizontally, we coded them in the order of left to right. (Example instructions provided to coders to illustrate coding order can be found in Appendix B.)

Additionally, the primary researcher created short descriptions of images, which could be found on Google Drive, in connection with the unit identification numbers. For example, a photo of a glass of water may have a description of "water in a cup." This prevented coders from miscoding images. We made these descriptions intentionally brief while ensuring that the image remained identifiable. The Google Forms set-up allowed submissions to be linked to coder, unit identification number, and submission time.

To guide the coding process, we formatted the codebook to include a series of questions, answered by clicking the appropriate response category in Google Form. All codes could be answered dichotomously, meaning that every question on the form could be answered with “yes” or “no.” First, the coder identified the presence of videos, which were not analyzed further. Then, the coder identified references to the U.S. EPA, “forever chemicals,” and outside organizations. After this, the form led coders through questions to identify different aspects of whether PFAS was represented as unknown or dreaded. Then, the form asked coders to identify if several different types of efficacy were present. In the following questions, the form asked coders to indicate the presence of a variety of actors (i.e., government representatives, farmers, scientists, or other individuals). Next, the coder identified the presence of different spatial scales in the text. For example, if the text included a statement about referencing a local water company, the unit would be coded as local level. The form asked coders about whether several potential sources or locations of PFAS were referred to throughout the text (i.e., water, soil, firefighting foam, wastewater sludge, nonstick cookware, packaging, or waterproof clothing). Then, the form asked coders if any statements indicating negative affect, such as worry, concern, fear, sadness, or anger, were present. Finally, the form asked coders to identify whether testing or treatment of water and soil were discussed in the text. (See Appendix C for specific codebook wording.)

When coding the image units, coders encountered questions meant to capture many of the same concepts, and thus similar codes. First, the form asked coders to identify the category of image being coded, which served as a secondary check to ensure that the coders were examining the correct unit. Next, the coder indicated whether a variety of actors were present (i.e., government representatives, farmers, scientists, or other individuals). Then, the form asked coders about the portrayal of several potential sources or locations of PFAS (i.e., water, soil, firefighting foam, wastewater sludge, nonstick cookware, packaging, or waterproof clothing). Next, the form asked coders to identify whether testing or treatment of water or soil was portrayed in the image. Finally, the form asked coders to indicate if negative affect (i.e., worry, concern, fear, sadness, or anger) was depicted in the image. (All image questions and their wording can be found in full in Appendix C.)

Coder Training and Codebook Pretesting

When undertaking quantitative content analysis, it is essential to understand the reliability of measures (Neuendorf & Kumar, 2016). Validity of measures, which establishes that the measure truly captures the concept, holds equal importance (Babbie, 2014). This content analysis utilized human coders, and as such, established reliability and validity through the development of consistent understanding and definitions through the use of multiple coders (Babbie, 2014; Neuendorf & Kumar, 2016). Recruitment of additional coders from a graduate class in risk communication occurred during Fall 2023 at the University of Maine.

A total of four coders were involved in the process of testing and refining the codebook. An initial meeting of the coding team (~ 3 hours) occurred on September 22, 2023, to familiarize them with the codebook and walk them through its use. After this meeting, coders independently analyzed a sample of state government units that were not included in the final sample, which served as a pretest of the codebook. (Citations for these practice units can be found in Appendix D.) The first author tabulated coding results, identifying areas of disagreement and calculating intercoder reliability (see also below). Three such pretests occurred, with hour-long meetings with the coding team on September 28, October 13, and October 20 to discuss coding disagreements. This process was cyclical, and several rounds of coding and discussion helped refine the codebook. After each discussion, we edited the codebook before a new round of coding began. Despite the team's best efforts, there remained a high degree of disagreement among coders for many of the codes, and, as a result, we simplified the codebook by combining response categories, such as combining self-efficacy, response efficacy, and societal efficacy into a catch-all category of “efficacy.”

Prior to coding the final sample, the primary researcher and one member of the coding team completed two additional pretests of the codebook, working with the remainder of the sample of state government units that were not included in the final sample. Subsequent meetings to discuss disagreement occurred on November 2 and November 15, 2023, each lasting one hour. For the final sample, only the primary researcher and this additional coder evaluated the units, as this coder had the highest intercoder reliability with the primary researcher during the pretesting phase. Final coding occurred between November 15 and November 30, 2023.

To calculate intercoder reliability, we used ReCal2, an open-source program that can be used with nominal data and two coders (Freelon, 2010). We included codes with reliability greater than 0.70 in the following analyses. In some cases, percent agreement was significantly higher than Krippendorff’s alpha; however, this research used Krippendorff’s alpha due to it being widely understood as a more conservative measure, though this simplifies the reality of reliability measures (Krippendorff, 2004). Due to the exploratory nature of this work, measures with Krippendorff’s alpha greater than 0.70 were considered to be reliable. This aligned with other work that considered 0.70 to be substantial agreement, though this varies by research context (Hallgren, 2012). (Intercoder reliability for each code can be found in Appendix E.)

Data Analysis

Data cleaning involved reviewing data in Google Sheets to find cases of missing data, in which case, we returned to the Google Form to identify the correct response to replace the missing data. Data analysis was conducted using SPSS version 28. For each of the reliable codes, we calculated the number and percentage of present codes relative to the sample size using SPSS. Additionally, we tested the co-occurrence of dread statements, specifically the way PFAS risk is inequitable and has personal effects, with statements of efficacy using Chi-Square Tests (RQ1b). We used the same process to examine differences between publishing organization and spatial scale (RQ2). When using Chi-Square, it is ideal to have groupings such that the number of units for each group exceeds five (Greenwood & Nikulin, 1996). As shown in Table 3.2, the small sample size did not meet the statistical assumptions required for Chi-square testing to make statements across all the publishing organization and scale groups (i.e., government/trade/advocacy and federal/state/local, respectively). As such, we collapsed these groups from three (i.e., government /trade/advocacy; federal/state/local) into two (i.e., government/non-government; federal/non-federal). With these collapsed groups, the sample size met Chi-square assumptions.

To undertake data analysis for integrative framing analysis, we calculated congruence ratios, which illustrate the level of agreement between text and visual units (Dan, 2018). The first step to integrative framing analysis creates question pairs, such that text and visual codes have matching pairs. For example, for the text units, the form asked coders “Are farmers/farms mentioned as an actor on the website?”, which would be linked to the image coding question “Is there a farmer/farm in the image?” Next, for each unit, the number of cases where the image code aligned with the text code was divided by the total number of images that could have potentially aligned with the text (Dan, 2018). As a result of this calculation, these values range from zero to one, with higher values indicating higher visual and text congruence. These calculations were done in Google Sheets. Then, using SPSS, Analysis of Variance (ANOVA) testing determined if there was any statistically significant difference in the mean congruence ratios. Finally, post hoc analysis using Tukey's range test further illuminated the differences in the average congruence ratios.

CHAPTER 4

RESULTS

Only results with adequate reliability (Krippendorff's alpha > 0.70) were included in the final analysis. Despite the coding team's efforts towards achieving reliability, this reliability threshold caused several codes to need to be dropped from analysis, including codes regarding uncertainty. Because of this, we included the following questions from the text codebook in analyses:

- Is the EPA (Federal (US) Environmental Protection Agency) mentioned?
- Is there an explicit reference to "forever chemicals"?
- Are there links to other webpages/resources?
- Is it stated on the website that the risk is severe, specifically that it is explicitly life threatening?
- Is it stated on the website that PFAS risk will have personal effects as indicated by the use of second person pronouns?
- Is it stated on the website that the risk is inequitable in particular populations?
- Is there any information on efficacy on the website, either as self-efficacy, response efficacy, or societal efficacy?
- Are there government/government organizations mentioned as an actor on the website?
- Are farmers/farms mentioned as an actor on the website?
- Is the state level discussed on the website?
- Is a specified military/industrial/landfill/or other location discussed on the website?
- Is soil mentioned as a source/location of contamination on the website?

- Is firefighting foam mentioned as a source/location of contamination on the website?
- Is wastewater sludge (biosolids) mentioned as a source/location of contamination on the website?
- Is cookware mentioned as a product containing PFAS on the website?
- Is packaging mentioned as a product containing PFAS on the website?
- Is water or stain resistant material mentioned as a product containing PFAS on the website?
- Is there mention of testing/treating water for PFAS on the website?

With regards to the image codebook, we included the following questions from the image codebook in analyses:

- Is there a farmer/farm in the image?
- Is water present in the image?
- Is soil present in the image?
- Is firefighting foam present in the image?
- Is wastewater sludge present in the image?
- Is nonstick cookware present in the image?
- Is packaging present in the image?
- Is water or stain resistant material present in the image?
- Is soil shown being tested/treated in the image?

Descriptive Statistics: Text

Our results indicated that 7.9% (*n* = 5) of websites included videos, which were not included in image analyses. 57.8% (*n* = 37) mentioned the EPA. Additionally, 42.2% (*n* = 27) mentioned the nickname “forever chemicals.” We found farmers or farms discussed on 17.2% (*n* = 11) of these websites. We found the state level discussed on 73.4% (*n* = 47) of the websites. Specific locations were discussed on 20.3% (*n* = 13). Of sources of PFAS, we found references to soil (45.3%; *n* = 29), firefighting foam (62.5%; *n* = 40), wastewater sludge (32.8%; *n* = 21), cookware (48.4%; *n* = 31), packaging (48.4%; *n* = 31), and stain or water-resistance (57.8%; *n* = 37). Lastly, we found water testing or treatment discussed on 62.5% (*n* = 40) of the websites.

Descriptive Statistics: Images

We found farmers or farms depicted in 5.1% (*n* = 11) of images. Of sources of PFAS, we found soil (9.7%; *n* = 21), water (38.9%; *n* = 84), firefighting foam (5.6%; *n* = 12), wastewater sludge (1.9%; *n* = 4), cookware (3.7%; *n* = 8), packaging (7.4%; *n* = 16), and stain or water-resistant material (9.3%; *n* = 20). Lastly, we found soil testing or treatment to be depicted in 2.3% (*n* = 5) of images. A list of all questions and their respective presence within the sample can be found in Appendix F.

Dread and Efficacy

Regarding research question 1a, which asked about the presence of uncertainty, dread, and efficacy variables, we found discussion of PFAS risk as having personal effects and being inequitable present in 65.6% (*n* = 42) and 42.2% (*n* = 27) of website text, respectively. We found efficacy information included in the text of 57.8% (*n* = 37) of the websites in the sample.

Regarding research question 1b, which asked about the co-occurrence of unknown, dread, and efficacy codes, our results suggest that attributes relating to the dread factor (i.e., PFAS being inequitable and having personal-level effects) are associated with the presence of efficacy information. Specifically, of the websites that contained efficacy information, 57% (n = 21) contained information that framed PFAS risk as inequitable, in contrast to 43% (n = 16) that did not ($\chi 2(1) = 7.63$, $p = 0.006$).

With regards to personal effect, when efficacy information was present, 84% (n = 31) of websites contained information that framed PFAS risk as having a personal effect, in contrast to 16% (n = 6) that did not ($\chi 2(1) = 12.82$, $p < 0.001$).

The co-occurrence of the two dread attributes (inequitable and personal effect), was not significant ($\chi 2(1) = 1.478$, $p = 0.224$).

Publishing Organization and Spatial Scale

Regarding research question 2a, which asked about differences in website content depending on publishing organization, our results suggest that the presence of the phrase “forever chemicals” and references to the state level were both associated with publishing organization type (i.e., government vs. non-government). Of the websites published by governmental organizations, 31% (n = 11) referred to “forever chemicals,” in comparison to 69% (n = 25) which did not. Within the same analysis, of the websites published by non-governmental organizations, 57% (n = 16) referenced “forever chemicals” in comparison to 43% (n = 12) which did not, $\chi^2(1) = 4.565$, $p = 0.033$.

Regarding references to the state level, of the websites published by governmental organizations, 83% (n = 30) discussed individual U.S. states, in comparison to 17% (n = 6) which did not. Within the same analysis, of the websites published by non-governmental organizations, 61% (*n* = 17) discussed individual U.S. states, in comparison to 39% (*n* = 11) which did not, $\chi^2(1) = 4.131$, $p = 0.042$.

All other Chi-square tests, including those involving the codes for dread and efficacy, were not statistically significant; see Appendix G for full results.

Regarding research question 2b, which asked about differences in presence of codes between spatial scales (i.e., federal vs. non-federal), our results suggest that the presence of efficacy information, mentions of farmers or farms, discussion of the state level, and mentions of testing or treating water were associated with the spatial scale of the website. Of the websites classified as federal, 45% (*n* =15) included efficacy information, in comparison to 55% (*n* = 18) which did not. Within the same analysis, of the websites classified as state or local, 71% (*n* = 22) included efficacy information, in comparison to 29% (*n* = 9) which did not, $\chi^2(1) = 4.27$, $p = 0.039$.

Of the websites classified as federal, 6% (*n* = 2) mentioned farmers or farms, in comparison to 94% (*n* = 31) which did not. Within the same analysis, of the websites classified as state or local, 29% (*n* = 9) mentioned farmers or farms, in comparison to 71% (*n* = 22) which did not, $\chi2(1) = 5.93$, $p = 0.015$.

Of the websites classified as federal, 55% (*n* = 18) included discussion of individual U.S. states, in comparison to 45% (*n* = 15) which did not. Within the same analysis, of the websites classified as state or local, 94% (*n* = 29) included discussion of individual U.S. states, in comparison to 6% (*n* = 2) which did not, $\chi^2(1)= 12.47$, $p < 0.001$.

Of the websites classified as federal, 45% (*n* = 15) mentioned testing or treating water, in comparison to 55% (*n* = 18) which did not. Within the same analysis, of the websites classified as state or local, 81% (*n* = 25) mentioned testing or treating water, in comparison to 19% (*n* = 6) which did not, $\chi 2(1) = 8.45$, $p = 0.004$.

All other Chi-square comparisons were not significant; full results can be found in Appendix H.

Integrative Framing Analysis: Text and Images

Regarding research question 3, which asked about the consistency of messaging in website text and images, following Dan (2018), we calculated congruence ratios for all text-image code pairs, which can be found below in Table 4.1. The unabbreviated question pairs can be found in Appendix I. Across all question pairs, mean congruence was 0.54 (*SD* = 0.46). ANOVA testing of congruence ratios indicated that there was a statistically significant difference between the question pair means, $F(6, 343) = 5.80$, $p < 0.001$.

Table 4.1: Congruence ratio obtained through Integrative Framing Analysis.

Image/text Category	Average Congruence Ratio	Standard Deviation
Farm/Farmers	0.82	0.37
Biosolids	0.64	0.48
Soil	0.58	0.46
Cookware	0.51	0.50
Packaging	0.48	0.47
Water/Stain Resistant Material	0.43	0.48
Firefighting Foam	0.34	0.45

Subsequent post-hoc Tukey's range tests showed that the congruence ratio for the farm/farmer ($M = 0.82$, $SD = 0.37$) question pair was statistically different from the congruence ratios for question pairs relating to firefighting foam ($M = 0.34$, $SD = 0.45$, $p < 0.001$), water/stain resistant material ($M = 0.43$, $SD = 0.48$, $p < 0.001$), packaging ($M = 0.48$, $SD = 0.473$, $p = 0.004$), and cookware ($M = 0.51$, $SD = 0.48$, $p = 0.014$). Additionally, the congruence ratio for the biosolids ($M = 0.64$, $SD = 0.48$) question pair was statistically different from the congruence ratio for the firefighting foam ($M = 0.34$, $SD = 0.45$, $p = 0.022$) question pair.

CHAPTER 5

DISCUSSION

In this research, we investigated PFAS information published on U.S. websites through quantitative content analysis to explore three primary research questions. First, we quantified the presence of statements indicating that PFAS has personal effects and is inequitable, both of which are components of dread, and efficacy statements on these sites, and examined their co-occurrence. Second, we assessed differences in a variety of codes in connection with the publishing organization and scale. Third, in alignment with integrative framing analysis (Dan, 2018), we connected relevant text and image codes to explore congruence between the two types of information. This section will discuss these results, as well as their implications for theory and practice.

Personal and Inequitable Risk and Efficacy Information

Of the psychometric paradigm and efficacy-related codes, PFAS was framed as personal most often (n = 42 websites, 65.6% of the sample). While we did not measure risk perceptions, given that PFAS is widespread throughout the world, but particularly widespread in the United States (Lau, 2015), it is possible that PFAS would be perceived as personal for more people as a result of its widespread nature. In fact, PFAS are so widespread that most Unites States residents likely have some background PFAS blood contamination (Ducatman et al., 2022); therefore, it might seem logical that a widespread risk would also be framed as posing individual-level effects. While this result may seem obvious, it also points to the potential for an interesting overlap in the psychometric paradigm between risks viewed as widespread and those posing personal effects (Slovic et al., 1986). Unfortunately, in this research, the code indicating PFAS risk was widespread was not reliable, and, as such, we cannot form conclusions about this relationship. Researchers applying the psychometric paradigm have indicated that these conceptual overlaps between variables (i.e., attributes of a risk) can be expected (Slovic et al., 1986), though less is known about what variables tend to co-occur in experimental settings. This may be important as there may be additive effects that alter risk perception, or perhaps are contingent on other audience characteristics (e.g., sociodemographics, familiarity with the risk).

Also drawing from the psychometric paradigm (Slovic et al., 1986), PFAS was framed as being inequitable in just under half of the sampled websites (n = 27, 42.2%). As discussed previously, this code was meant to encompass the ways that PFAS will be inequitable in its distribution of risks and/or benefits for certain individuals or populations, such as pregnant people and children (Lau, 2015; US EPA, 2023). With organizations such as the EPA presenting research as inconclusive on the health effects of PFAS chemicals (2023), it is possible that agencies with fewer resources and personnel to devote exclusively to PFAS communication, such as local water districts, may choose not to list these health effects as inequitable on their webpages. Entities like local water districts may also lack the power and/or latitude afforded to federal-level agencies, such as the EPA, to make certain claims about PFAS risk or they may contrastingly be *more* likely to make definitive claims as a result of having less oversite than federal-level agencies.

Further, it is also possible that state and local organizations look to federal organizations for guidance, leading to a trickle down in messaging from large scale organizations to small scale organizations. For example, a discussion of the health effects of PFAS for children on the EPA website says, “Because children are still developing, they may be more sensitive to the harmful effects of chemicals such as PFAS” (US EPA, 2023) – clearly communicating an unequal (higher) burden of risk but using language that could indicate uncertainty (i.e., "may be"). Similarly, the Commonwealth of Massachusetts states, "Studies indicate that exposure to sufficiently elevated levels of certain PFAS may cause a variety of health effects including developmental effects in fetuses…", which uses the same use of the word "may" to portray uncertainty (Commonwealth of Massachusetts, 2023). This framing of PFAS research as uncertain could explain why PFAS are not often portrayed as inequitable, despite the scientific consensus being aligned with the narrative that PFAS are inequitable (Lau, 2015). However, further research on this possibility would be necessary to test this suggestion empirically.

Previous qualitative research on online communication of PFAS found that efficacy information tends to be lacking on these websites and called for its more widespread inclusion (Ducatman et al., 2022). In this research, efficacy information was included in just over half of the sampled websites (n = 37, 57.8%). While it was not uncommon to see efficacy information in the sampled websites, the lack of efficacy information on just under half of sampled websites indicates that calls for inclusion of efficacy information by researchers have not been entirely accepted by practitioners. Overwhelmingly, the academic literature emphasizes the importance of efficacy information in risk messaging, as it relates to risk perception, behavior change (e.g., following pre- or proscribed behaviors), and information sharing (Bigsby & Albarracín, 2022; Vos et al., 2018; Witte, 1992). According to the extended parallel process model, motivation to undertake behavior change in the face of a risk relates to perceived threat (from the presence of fear appeals, for instance) and perceived efficacy (from presence of efficacy information) (Witte, 1992). Depending on how a person perceives their own efficacy and the threat of a risk, they can either become fear-motivated or protection-motivated (Witte, 1992). Those who perceive a threat as high and perceive their own efficacy as high, which research shows has been related to the presence of efficacy information, are more likely to seek mitigation strategies for the risk, rather than being motivated to cope with their fear, which can lead to nonproductive outcomes (i.e., denial) (Witte, 1992). Ideally, in line with these findings, more PFAS websites should include efficacy information, although it is beyond the scope of this study to determine whether certain types of efficacy information (e.g., self- vs. collective) matter more for inspiring behavioral change.

Additionally, efficacy information occurred more often when a website also had indications that PFAS has personal effects or was inequitable. Research on both fear appeals and the extended parallel process model have shown that risk messages are more effective at creating productive motivation when presented along with efficacy information (Bigsby & Albarracín, 2022; Witte, 1992). Though, less is known about the co-occurrence of dread framing and efficacy information in risk messages. This is yet another avenue for future research on risk communication to explore.

Interestingly, we did not find a significant association between the presence of statements that imply PFAS will have personal effects and its inequitable nature. Psychometric paradigm research has shown that the risk attributes included under the unknown and dreaded factors often closely correlate with one another (Slovic, 1987); however, little published research supports this claim. Though the psychometric paradigm has been foundational to risk communication research, perhaps more critical analysis of how the attributes relate to one another within and between the dread and unknown factors would be beneficial for theory development. It is possible that this could be accomplished through survey work similar to Slovic et al. (1986)'s research, but with further testing for correlations between items. In addition to exploring the interrelationships between attributes, future research should also consider how audiences perceive their presence in text and visual risk communication. Given the difficulties experienced by the coding team in reaching consensus on many of the psychometric paradigm-inspired codes, it is possible that perception of attributes like uncertainty are not universal and may depend on various individual factors. Qualitative research, such as focus groups, could complement more traditional survey-based studies to further shed light on how various individuals identify and think about "dread" and "unknown" attributes in the context of PFAS risk communication.

Publishing Organization Scale: Who Is the Website For?

Efficacy information was included more often on websites that were published at the state or local levels, rather than the federal level. Additionally, water testing for PFAS was discussed most often on state or local websites. Having information regarding water testing can be considered as a form of self or response efficacy, as it is one way to mitigate PFAS risk (Bandura, 1990). One example of this water testing information can be seen on the website from the Commonwealth of Massachusetts, which states, "If you are a private well owner, for more information about whether you should test, how to test and your drinking water treatment options, please see PFAS in Private Well Drinking Water Supplies FAQ" (2023). Knowing that efficacy information can lead to the uptake of preventive behavior (Bigsby & Albarracín, 2022), the presence of efficacy information on state and local websites is promising. The association of efficacy information and local scale also seems to support recent calls from academics to make messages pertaining to PFAS risk more community specific (Ducatman et al., 2022).

Farms or farmers were mentioned most often on local or state websites, in comparison to websites published at the federal level. This may be due to the focus of this research, as the sample focused on New England, and particularly on the state of Maine. Maine has dedicated time and resources to understanding the effect of PFAS on agriculture resulting from historical wastewater byproduct spreading in the state (Rhoda, 2022; Torres, 2022). With this data set, we cannot conclude whether this same state/local-federal difference would be evident in a broader, nationwide sample of websites; however, this finding may also evince the importance of PFAS issues for New England farms.

Finally, discussion of any of the individual 50 states was included most often on state or local websites. This finding is the least surprising, and the most intuitive. It is reasonable that state and local websites will reference their home states more often than federal websites would reference any of the 50 states; however, it is also possible that state and local websites reference states other than their own, as we did not code for this level of granularity. On its own, this finding is not particularly interesting, but rather points to a potential for future research. Future work could address this gap, addressing, for instance, whether states are referencing other states as role models for legislation or action on PFAS.

Publishing Organization Type: Who Makes the Website?

Discussion of the state level was more common on websites published by government organizations, in comparison to non-governmental websites. In our sample, non-governmental websites were mostly also at the national (as opposed to state) level. While there were 24 non-federal governmental websites and 12 federal governmental websites, there were just 7 non-federal, non-government websites and 21 federal non-governmental websites. In other words, governmental websites in the sample were more likely to be focused on the state or local level. Given the exhaustive methods used to identify websites in the study, we believe our sample reflects the true population, though it is possible that the sampling procedure overlooked certain sites. Above, we discussed that it was more common for state or local level websites to refer to the state level. In following, government websites within the sample were more likely to be state or local level, and, therefore, more likely to reference any of the 50 states.

Referencing the PFAS nickname “forever chemicals” was more likely when the publisher was non-governmental, in comparison to government websites. The nickname “forever chemicals” suggests the idea of a risk being problematic for future generations, which represents an aspect of dread from the psychometric paradigm (Slovic et al., 1986). Possibly, governmental organizations are avoiding using this name because it can imply that PFAS will be felt for generations and/or is unable to be managed in an effective way. Along these lines, government websites may be avoiding implying that PFAS effects will be felt for generations, potentially to avoid invoking the associated negative affect. Other researchers investigating government communication about PFAS found that these messages do not align with the current weight of scientific evidence, implying that government communications are giving undue credit to evidence that PFAS risks are not serious (Ducatman et al., 2022). Language has been found to be important in the way that it affects perceptions of credibility, and the use of inflammatory language can negatively impact perceived credibility (König & Jucks, 2019). As credibility can impact risk perception, language choices are important when providing risk information (Trumbo & McComas, 2003). In line with this thought, government organizations may avoid the phrase “forever chemicals” as it is more colloquial than using a scientific name, and, in turn, may challenge the credibility of the institution. To better understand why this relationship unfolds in this way, future research could involve qualitative interviews with the government workers making these websites to understand the nuances in the decision to use (or not use) more colloquial language in these websites.

Images, Text, and What They Have in Common

Congruence can imply either that text and images related to a given topic (e.g., farms) are both present, or that both text and images related to this topic are absent. The congruence ratio for question pairs regarding farms/farmers were significantly higher than those for firefighting foam, water/stain resistant material, packaging, and cookware. Additionally, the congruence ratio for question pairs regarding biosolids were significantly higher than those for firefighting foam. This indicates that when farms/farmers or biosolids are discussed in text, and images are present, the images are more likely to mirror these topics, as compared to other codes in the sample, where alignment between text and image was less pronounced.

With regards to farms, we qualitatively observed that websites that included a photo of a farm/farmer also discussed farms or farmers in the text (see Figure 5.1).

Figure 5.1: Example of congruent text and image for farm/farmers codes.

Interestingly, however, in the dataset, more often, farms/farmers were *not* discussed in text and *not* depicted in the accompanying images, which, by definition, would also be considered congruent. Overall, then, we see an apparent lack of conversation surrounding the effects of PFAS risk on farms/farmers.

Through qualitative observation, we also saw that biosolids were not often discussed on these websites or included in images. By comparison, firefighting foam was discussed more often in text, but still not included in many images, possibly due to firefighting foam being an ambiguous or unfamiliar item for most, and thus not likely to be recognized by casual viewers. (By comparison, referencing farms or farmers arguably elicits a more familiar and universal set of images, such as barns, fields, and tractors, as in Figure 5.1.) Similarly, this could point to a lack of conversation about the relationship between biosolid spreading and PFAS contamination. The practice of biosolid spreading is much more regional and mostly affects places in close proximity to historical spreading. Thus, it is possible that information regarding biosolid spreading is simply not relevant to the broader audiences intended for these websites; in comparison, firefighting foam, however challenging it may be to represent visually, is used worldwide, both at industrial locations, such as airports, and in people's homes.

Broadly, congruence is important as messages with more congruence between text and images encourage better recall and can be more persuasive than messages with less congruence (Drew & Grimes, 1987; Lazard & Atkinson, 2015). Yet, congruence ratios are relative within a given study (Dan, 2018), so it is not within the scope of this research to quantify congruence outside of this context. Similarly, there is no ideal benchmark for congruence between text and images (Dan, 2018). That said, less than half of websites with images present were congruent on several potential PFAS sources, such as firefighting foam, food packaging, and water or stain resistant materials. This congruence ratio should be of critical importance for practitioners. Aligning with persuasion theory, practitioners should pay attention to messages (i.e., water as a source for PFAS) that are most important for the audience to recall and focus on congruence for these specific messages. In other words, individuals crafting online PFAS communication should prioritize what they consider to be the most critical messages and allocate limited space for images to align with these messages.

Limitations

This research did have some distinct limitations. First, videos were not included in these analyses. Coding images and text as separate units would have made coding videos extremely difficult and other researchers have not attempted to analyze videos with this method. While videos were not included on many websites (i.e., just five of the 64 websites), their exclusion does point to an opening for adapting this methodology to be used for video content. Previous research has used real time response methods, such as dial testing, to analyze audience responses to audiovisual content, which could be applied to this context (Eosco, 2015). Second, because of the exploratory nature of this work, codebook development was a long and complicated process involving a coding team. Even after extensive time and energy was spent, achieving acceptable reliability was difficult, and led to our decision to exclude several codes, including those related to uncertainty. Additionally, we decided to limit the number of people on the coding team for the same reason. Particularly, codes for uncertainty were unreliable, likely because defining uncertainty is difficult. Future research could improve this reliability by carefully defining and operationalizing uncertainty. Another limitation of this research was the relatively small size of the sample (i.e., number of websites). Though the sample was developed over time with consultation of other researchers, it is possible that some websites were not identified in this search and were therefore not included, despite our efforts towards compiling an inclusive sample. Lastly, this research analyzed existing and freely available media, presumably consumed by public audiences, making it both ecologically valid and economical. However, by focusing just on the website content and not on the audiences themselves, we cannot make claims about how the information on these sites might be perceived. As discussed below, this is yet another place for future advancement by other researchers, and more experimental research could fill this gap.

Key Takeaways: Theory

This work builds upon the pre-existing social science research being done to address PFAS in Maine and across the country using a variety of methods, such as content analysis, experiment, and survey (Ducatman et al., 2022; Liu & Yang, 2023; Zimmerman et al., 2022; Zindel et al., 2021). In research conducted by Liu and Yang (2023), participants shown PFAS messages with higher personal relevance (i.e., high PFAS concentrations in water of participant's region) processed information more systematically and subsequently more often intended to seek out additional information. This finding emphasizes the importance of making PFAS risk personal. In Maine, survey work has shown that residents have uneven existing knowledge of PFAS, but many are willing to contribute financially to efforts surrounding mitigating PFAS (Zimmerman et al., 2022). Most like the current study, researchers have examined the framing of PFAS on state government websites, finding that only 35 states had official government PFAS websites, and those states that had websites portrayed risk unevenly (Zindel et al., 2021). This work builds upon these findings, focusing on exploring how PFAS is portrayed on websites to better understand the ways that PFAS is being communicated, with importance for both theory and practice.

This research adds to theoretical work around the psychometric paradigm, particularly with regards to the co-occurrence of attributes related to the dread and unknown factors (Slovic et al., 1986). In our discussion, we have posited that the widespread nature of PFAS may contribute to the prevalence of framing PFAS risk as having personal effects. Both widespread and personal effect are attributes of dread in the psychometric paradigm (Slovic et al.,1986); however, we did not find any significant co-occurrence between PFAS being discussed as having a personal effect and PFAS being inequitable, which are also attributes associated with the dread factor in the psychometric paradigm (Slovic et al., 1986). Considering this discrepancy, further research should investigate the degree of co-occurrence of the attributes of the dread and unknown factors from the psychometric paradigm (Slovic et al., 1986). This could be accomplished by repeating this study and expanding the number of reliable variables, particularly codes for risk information being unknown or uncertain, potentially through further development of the codebook and related coder training.

Key Takeaways: Practice

For practitioners, this research offers different insights regarding the construction of PFAS risk messages. First, congruence between text and images in these messages is important, as it can increase the passing of messages as well as make messages more persuasive and memorable (Drew & Grimes, 1987; Lazard & Atkinson, 2015; Vos et al., 2018). In this study, we found text and images to be congruent just over half the time across variables. Practitioners may find use in prioritizing images used on websites to be congruent with the most relevant or important messages for their particular audience. While we are not suggesting that PFAS risk messages should have an image for every theme presented, it may be beneficial to use images to emphasize the most imperative messages. It may be productive for practitioners to test potential messages by showing them to people within their audience, to avoid unintended effects (e.g., lowered risk perception or efficacy beliefs, misattribution of blame) (Salmon et al., 2013). Such formative research, like clinical trials of vaccines in a medical context, can prevent unwanted consequences of risk messaging (Salmon et al., 2013).

Another insight for practitioners can be found in suggestions from other research to make PFAS risk messages community-specific, particularly in communities that are affected severely by PFAS (Ducatman et al., 2022). Further communication research has explored locality, both literally and metaphorically, through construal level theory and the concept of psychological distance (Trope & Liberman, 2010). This theory has been used to posit that risks that are more concrete, or are less psychologically distant, will be perceived as riskier and generate more action to mitigate risk (Spence et al., 2012). In this research, we observed that individual states are discussed on three-quarters of websites, but specific locations are discussed on less than one quarter of websites. In light of this finding and research surrounding locality and psychological distance, it may be important to ensure that PFAS messages make note of any specific communities that are being affected by PFAS in their scope; however, care should be taken to emphasize that PFAS is not an isolated issue, and effects will be seen outside of these specified locations. Additionally, making PFAS too localized of an issue could stigmatize the communities that do see higher contamination. If PFAS are portrayed as isolated, there could be unwanted effects associated with an increase in psychological distance from the issue (Spence et al., 2012; Trope & Liberman, 2010). Again, this type of unintended effect could be avoided by pre-testing potential messaging (Salmon et al., 2013).

Lastly, this research found that efficacy information was present on just over half of PFAS websites. The importance of efficacy information cannot be understated, as it directly impacts the adoption of protective behaviors (Bigsby & Albarracín, 2022). Prior research on PFAS has asserted that there is a deficit of efficacy information on these online messages (Ducatman et al., 2022). This research reaffirms and supports this assertion. As such, practitioners should take care to include efficacy information in their PFAS messages if their goal is to promote protective behaviors such as information seeking, water testing, or discussing PFAS with local officials.

Future Directions

Our results suggest future research applying integrative framing analysis in the context of PFAS. With regards to integrative framing analysis, finding published exemplars of this method in practice proved difficult, as the methodology is relatively novel (Dan, 2018). We would encourage more application of this method to allow for cross-study comparison of congruence ratios, and the development of guidelines for interpreting such ratios. The inability to make broader statements regarding congruence ratios was limiting in this study. Overall, further work should be done using integrative framing analysis as a methodology to develop clearer, and more universal standards for best practice. Similarly, we were unable to analyze videos in this research, due to incompatibility with the methodology. Future research could examine videos using real time audience response methods to better understand perceptions of risk and videos portraying PFAS (see Eosco, 2015).

Additionally, this research was largely centered around websites from New England, particularly Maine. As this research was largely exploratory, limiting the sample to one region was ideal; however, PFAS contamination is problematic across the United States (US EPA, 2023). Future research should seek to expand this work beyond the New England region and should explore PFAS communications from across the United States and in other countries. Additionally, future research could expand to describe messaging in other channels, such as social media platforms, to better understand how messages differ from medium to medium. These expansions will likely be essential to understanding how PFAS risks are being communicated online.

Another future for this research can be found in the work being undertaken by my thesis committee, Drs. Laura Rickard, Amelia Couture Bue, and Janet Yang. Quantitative content analysis is limited in that it is descriptive in nature, and consequently cannot be used to make causal claims. As such, we can conclude about the nature of website content, but not about how such content may affect website viewers. Future experimental work building on this research could be used to better explain how individuals process PFAS information and develop related risk perceptions and behavioral intentions. Ongoing work by the research team seeks to examine PFAS risk communication with an experimental methodology, including utilizing eye-tracking and psychophysiological measures to better understand how specific attributes of PFAS messaging may influence risk perceptions and information processing. The descriptions generated by the current study could be utilized in experimental work to design ecologically valid and relevant stimuli by mimicking the PFAS messaging described here. Future experimental research, both inside and outside of our research team, should seek to fill this gap and build on this research to explore how PFAS information is perceived and processed.

CHAPTER 6

CONCLUSION

Personal Transformation

This work was influenced by my academic interests and history, but I also believe that it has and will continue to shape my future. Prior to coming to the University of Maine, my interests sat firmly in geochemistry and environmental science. I was passionate about emergency response to hazardous waste incidents and the movement of chemical contaminants in the environment. However, at my liberal arts college, my curriculum also included classes that focused on the human dimensions of environmental issues. Perhaps due to fate, I chose to procrastinate and ended up taking most of these classes throughout my third and fourth year. So, as I finished up my undergraduate education, I discovered that I also had a passion for the social science implications of these hazardous waste/chemical incidents. This discovery was transformative for me and led to me “making the jump” and applying to study communication at the University of Maine.

Throughout my time at the University of Maine, I have been challenged to think about environmental issues through a different lens. From reading about communication theories and methods to using eye tracking software and designing surveys, the last two years have been jam-packed with learning experiences. However, I have not just learned the ins and outs of a different discipline. Instead, I have challenged the way I view science and research, and, in the process, discovered new interests and passions, while continuing to develop the research skills that I brought with me to the University of Maine. While coming to the University of Maine and learning a different discipline was a challenge, it also gave me space for growth.

While completing my degree, I have had the opportunity to work across disciplinary boundaries through the National Science Foundation-funded National Research Traineeship in Conservation Science (NSF-NRT). Learning about boundary-less collaboration through academic articles and classroom discussion is one thing, but this program gave me the opportunity to work in the field with practitioners. One such opportunity was a summer internship with Maine Department of Inland Fisheries and Wildlife, where I worked alongside biologists to design and implement outreach regarding nuisance black bears and their associated risk. This internship allowed me to learn about project management, and this skill informed how I managed my team of coders throughout the research process.

Another opportunity to work with practitioners emerged in a long-term project with the Penobscot Nation Water Resources Team. Throughout this project, a group of NSF-NRT students worked in collaboration with the Penobscot Nation Water Resources Team to develop an education-based outreach plan regarding water contaminants and Wabanaki fishing practices. We then drafted a successful proposal for grant funding to support these efforts, and this writing experience heavily influenced how I would later plan my own thesis writing. In particular, this process involved developing and adhering to incremental and early deadlines for our writing, which is a practice that I adopted in my thesis writing. Currently, we have plans to publish our reflections on this work, and the writing process is again ongoing. These experiences were integral to shaping how I have grown to view collaborative work and research in general.

Moving forward, I am excited to carry these experiences and my changing worldview with me to whatever comes next. I hope to continue learning, both through my formal and informal education and research. This program has shaped me as a researcher and learner, but perhaps more importantly as a person. The research and academic challenges that I have faced and overcome throughout the last two years have shown me the importance of flexibility and the need to hold space for adversity. These experiences have taught me how to adapt in the face of a challenge. One of the greatest strengths that I will be leaving this program with is my confidence in my adaptability as a researcher, which will no doubt continue to benefit me inside and outside of the classroom. Though I do not know what comes next as I write this, I am confident that my experiences at the University of Maine have prepared me for whatever may come.

Overall, understanding and managing PFAS risk will require the transdisciplinary knowledge that can tackle such "wicked problems" (Silka, 2016). PFAS is not just an issue for chemists, but it is a problem for environmentalists, industry professionals, psychologists, communicators, water managers, and many others. Moving forward, researchers will need to focus on bringing people together to address PFAS risks in different contexts. I hope that my interdisciplinary education and experiences will help me to bring people together to address PFAS in Maine and beyond.

Closing Thoughts

As we continue developing best practices on communicating PFAS risks, it will be important to examine how theories and methods from other contexts can assist. First, given our finding that efficacy information often occurs with information intended to invoke dread, the fear appeals literature may serve a key role in exploring this relationship and how its use affects risk perception (see Bigsby & Albarracín, 2022; Vos et al., 2018). Additionally, seeking out novel methods, such as integrative framing analysis, which explores the intersection of text and images in messaging (Dan, 2018), may help better understand the nuances of these communications.

Both theory and methods development will be necessary to move forward and address the communication of PFAS risks.

PFAS are not going away, and it would be naïve to think otherwise. The effects of past and current PFAS use and disposal will be felt for generations to come, since these compounds do not break down over time (Lau, 2015; US EPA, 2023). As such, the long future of PFAS will require communicating their risks on an ongoing basis to various publics. Understanding how the risk of PFAS chemicals are being communicated is an integral first step to learning how their risk is best communicated. This study provides potentially useful information to diagnose how PFAS are being discussed in online spaces, but there is still much work to be done.

The United States EPA has begun implementing their April 2024 limits on six of the most commonly found PFAS chemicals (US EPA, 2023; Huang et al., 2024). But science must extend beyond the physical diagnosis and treatment of the PFAS problem. As we address and remediate PFAS contamination in communities, knowing how to communicate PFAS risks most effectively will be imperative. The future of PFAS risk research will depend on understanding the human dimension of these risks. How are PFAS communicated in different contexts? How are the risks understood in different contexts? What can be done to portray PFAS risks more accurately and effectively to inspire the adoption of protective behavior? These questions are the future of PFAS risk communication.

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APPENDICES

APPENDIX A: WEBSITES INCLUDED IN FINAL SAMPLE

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Get the Facts: PFAS "Forever Chemicals." (n.d.). Toxic-Free Future. Retrieved October 29, 2023, from https://toxicfreefuture.org/toxic-chemicals/pfas-forever-chemicals/

Guidance on PFAS Testing and Health Outcomes. (n.d.). Retrieved October 29, 2023, from https://www.nationalacademies.org/our-work/guidance-on-pfas-testing-and-health-outcomes

Home. (n.d.). 3M PFAS. Retrieved October 29, 2023, from https://pfas.3m.com/home

Home—PFAS Exchange. (n.d.). Retrieved October 29, 2023, from https://pfas-exchange.org/

Learn About PFAS. (n.d.). Retrieved October 29, 2023, from https://www.mainewater.com/water-quality/learn-about-pfas/

Learn about PFAS | ATSDR. (n.d.). Retrieved October 29, 2023, from https://www.atsdr.cdc.gov/pfas/index.html

Made without PFCs / PFAS - Patagonia. (n.d.). Retrieved October 29, 2023, from https://www.patagonia.com/our-footprint/pfas.html

Maine DWP - PFAS in Public Water Systems. (n.d.). Retrieved October 29, 2023, from https://www.maine.gov/dhhs/mecdc/environmental-health/dwp/pws/pfas.shtml

MAINE PFAS LABORATORIES. (n.d.). Retrieved October 29, 2023, from https://www.mainelaboratories.com/

MOFGA PFAS Resources | Maine Organic Farmers and Gardeners. (n.d.). Retrieved October 29, 2023, from https://www.mofga.org/pfas/

Per- and polyfluoroalkyl substances (PFAS). (n.d.). Retrieved October 29, 2023, from https://www.iafc.org/topics-and-tools/resources/resource/pfas

Per- and Polyfluoroalkyl Substances (PFAS) | FDA. (n.d.). Retrieved October 29, 2023, from https://www.fda.gov/food/environmental-contaminants-food/and-polyfluoroalkyl-substances-pfas

Per- and Polyfluoroalkyl Substances (PFAS) | Maine Emergency Management Agency. (n.d.). Retrieved October 29, 2023, from https://www.maine.gov/mema/mema/hazards/human-caused-hazards/pfas

Per- and Polyfluoroalkyl Substances (PFAS) in Drinking Water | American Association for the Advancement of Science (AAAS). (n.d.). Retrieved October 29, 2023, from https://www.aaas.org/epi-center/pfas

Per- and Polyfluoroalkyl Substances (PFAS) in drinking water | Mass.gov. (n.d.). Retrieved October 29, 2023, from https://www.mass.gov/info-details/per-and-polyfluoroalkyl-substances-pfas-in-drinking-water

Per- and Polyfluoroalkyl Substances (PFAS)—ASDWA. (n.d.). Retrieved October 29, 2023, from https://www.asdwa.org/pfas/

Per- and Polyfluoroalkyl Substances (PFAS)—Bureau of Agriculture, Food and Rural Resources: Maine DACF. (n.d.). Retrieved October 29, 2023, from https://www.maine.gov/dacf/ag/pfas/index.shtml

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Perfluoroalkyl and Polyfluoroalkyl Substances (PFAS) in Drinking Water | Vermont Department of Health. (n.d.). Retrieved October 29, 2023, from https://www.healthvermont.gov/environment/drinking-water/perfluoroalkyl-and-polyfluoroalkyl-substances-pfas-drinking-water

PFAS. (n.d.-a). Safer States. Retrieved October 29, 2023, from https://www.saferstates.com/toxic-chemicals/pfas/

PFAS. (n.d.-b). Retrieved October 29, 2023, from https://www.llbean.com/llb/shop/518653?page=pfas

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PFAS. (n.d.-d). Retrieved October 29, 2023, from https://portal.ct.gov/DPH/Environmental-Health/PFAS/PFAS

PFAS. (2019, November 25). Portland Water District. https://www.pwd.org/pfas

PFAS | American Water Works Association. (n.d.). Retrieved October 29, 2023, from https://www.awwa.org/Resources-Tools/Resource-Topics/PFAS

PFAS | Gray Water District. (2023, October 30). https://www.graywaterdistrict.org/news-notes/pfas/

PFAS - Maine Farmland Trust. (n.d.). Retrieved October 29, 2023, from https://www.mainefarmlandtrust.org/farmers/pfas

PFAS — Per- and Polyfluoroalkyl Substances. (n.d.). Retrieved October 29, 2023, from https://pfas-1.itrcweb.org/

PFAS - Perfluoroalkyl and polyfluoroalkyl substances—Public Health. (n.d.). Retrieved October 29, 2023, from https://www.publichealth.va.gov/exposures/pfas.asp

PFAS - the "Forever Chemicals." (n.d.). CHEM Trust. Retrieved October 29, 2023, from https://chemtrust.org/pfas/

PFAS Basics—PFAS Central. (n.d.). Retrieved October 29, 2023, from https://pfascentral.org/pfas-basics/

PFAS Chemicals | Environmental Working Group. (n.d.). Retrieved October 29, 2023, from https://www.ewg.org/areas-focus/toxic-chemicals/pfas-chemicals

PFAS Chemicals – Protecting Our Drinking Water And Our Health | Clean Water Action. (n.d.). Retrieved October 29, 2023, from https://cleanwater.org/pfas-chemicals-protecting-our-drinking-water-and-our-health

PFAS Do Not Eat Advisory: Wild Game Consumption Advisory: Laws & Rules: Hunting: Maine Dept of Inland Fisheries and Wildlife. (n.d.). Retrieved October 29, 2023, from https://www.maine.gov/ifw/hunting-trapping/hunting/laws-rules/pfas-related-consumption-advisory.html

PFAS Frequently Asked Questions—Kennebec Water District. (n.d.). Retrieved October 29, 2023, from https://kennebecwater.org/pfas-frequently-asked-questions/

PFAS : Greater Augusta Utility District. (n.d.). Retrieved October 29, 2023, from https://www.greateraugustautilitydistrict.org/pfas

PFAS (Per- and Polyfluoroalkyl Substances) | Department of Energy. (n.d.). Retrieved October 29, 2023, from https://www.energy.gov/pfas/pfas-and-polyfluoroalkyl-substances

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PFAS (Per and Polyfluoroalkyl Substances) / Fluorinated Chemistries. (n.d.). Chemical Safety Facts. Retrieved October 29, 2023, from https://www.chemicalsafetyfacts.org/chemicals/fluorinated-chemicals/

PFAS (Per- and Polyfluoroalkyl Substances): Department of Health. (n.d.). Retrieved October 29, 2023, from https://health.ri.gov/healthrisks/contaminants/about/pfas/

PFAS (Perfluoroalkyl and Polyfluoroalkyl substances) | Sierra Club. (n.d.). Retrieved October 29, 2023, from https://www.sierraclub.org/toxics/pfas

PFAS Resources for States and other ECOS Members. (n.d.). The Environmental Council of the States (ECOS). Retrieved October 29, 2023, from https://www.ecos.org/pfas/

PFAS Task Force. (n.d.). CT.Gov - Connecticut's Official State Website. Retrieved October 29, 2023, from https://portal.ct.gov/DEEP/Remediation--Site-Clean-Up/PFAS-Task-Force/PFAS-Task-Force

PFAS Testing. (n.d.). Retrieved October 29, 2023, from https://maineenvironmentallaboratory.com/?page_id=4833

PFAS Testing Services | PFAS Testing | PFOS Testing | Newport, Brewer, Ellsworth, ME. (n.d.). Aerus. Retrieved October 29, 2023, from https://aerusofbrewer.com/pfas-pfos

PFAS Testing—Bangor Water. (n.d.). Retrieved October 29, 2023, from https://bangorwater.org/water-quality/pfas/

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Poly- and Per-fluoroalkyl Substances (PFAS). (n.d.). New Hampshire Department of Health and Human Services. Retrieved October 29, 2023, from https://www.dhhs.nh.gov/programs-services/environmental-health-and-you/poly-and-fluoroalkyl-substances-pfas

Public Water Emergency Information for Consumers: Department of Health. (n.d.). Retrieved October 29, 2023, from https://health.ri.gov/water/for/consumersduringemergency/

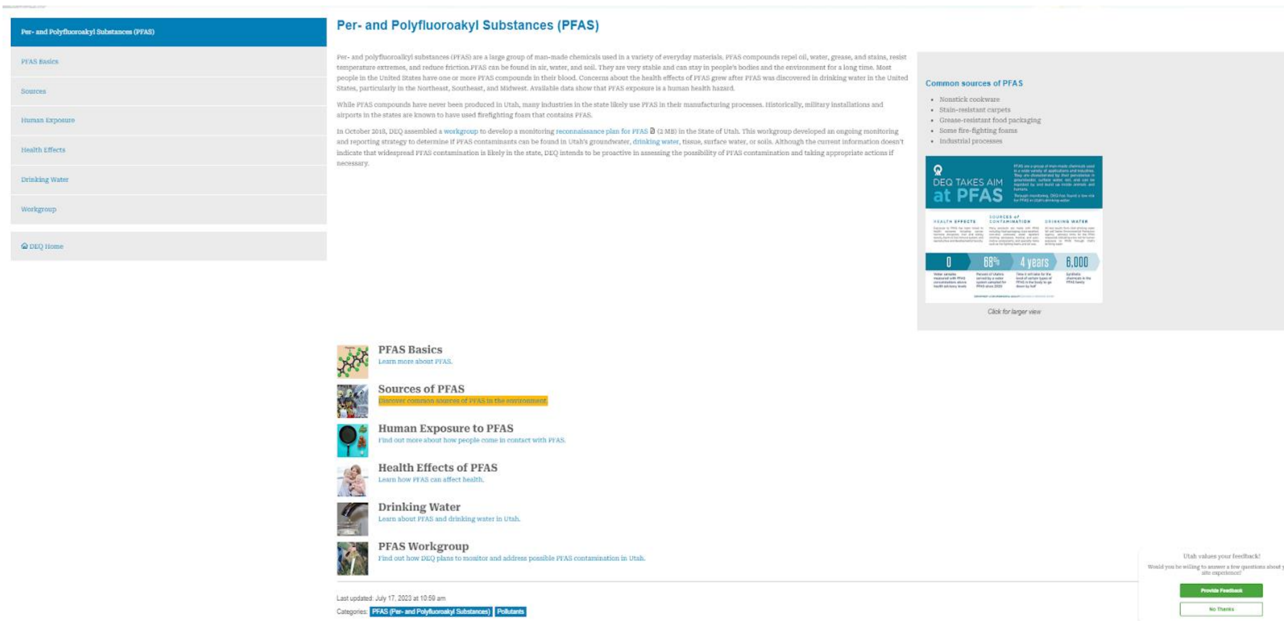
Strengthen the Health Standards for Drinking Water. (n.d.). Defend Our Health. Retrieved October 29, 2023, from https://defendourhealth.org/campaigns/safe-water/strengthen-standards/

The "Forever Chemicals" – PFAS Maine Lawsuit. (n.d.). Retrieved October 29, 2023, from https://pfasmaine.com/our-features/

US EPA, O. (2016, March 30). *Per- and Polyfluoroalkyl Substances (PFAS)* [Collections and Lists]. https://www.epa.gov/pfas

Vermont PFAS | Department of Environmental Conservation. (n.d.). Retrieved October 29, 2023, from https://dec.vermont.gov/pfas

APPENDIX B: EXAMPLE OF CODING ORDER



In this case, coding would start with the text, then the infographic would be coded, and finally the six small images would be completed. For each item (text, infographic, and each of the six images), a form would be completed with reference to that specific unit.

APPENDIX C: CODING QUESTIONS

Text Questions:

Are there any videos present? How many? (please list number 0-100)

Is the EPA (Federal (US) Environmental Protection Agency) mentioned? (0-not present 1-present)

Is there an explicit reference to "forever chemicals"? (0-not present 1-present)

Are there links to other webpages/resources? (0-not present 1-present)

Is it stated on the website that PFAS risk is unknown, either because information is unavailable or uncertain or because there is inherent uncertainty associated with the risk? (0-not present 1-present)

Is it stated on the website that the risk is severe, specifically that it is explicitly life threatening? (0-not present 1-present)

Is it stated on the website that PFAS risk cannot be mitigated? (0-not present 1-present)

Is it stated on the website that PFAS risk will have a lasting effect (length of time, persistence, building up, bioaccumulation)? (0-not present 1-present)

Is it stated on the website that PFAS risk will have personal effects as indicated by the use of second person pronouns? (0-not present 1-present)

Is it stated on the website that many are susceptible to PFAS risk? (0-not present 1-present)

Is it stated on the website that the risk is inequitable in particular populations (not location based)? (0-not present 1-present)

Is there any information on efficacy on the website, either as self-efficacy (What I can do-include information regarding testing or treatment , even if it's a link), response efficacy (How what I can do will help), or societal efficacy (What we can do- community self-organization)? (0-not present 1-present)

Are the government/government organizations mentioned as an actor on the website? (0-not present 1-present)

Are farmers/farms mentioned as an actor on the website? (0-not present 1-present)

Are scientists/scientific organizations not employed by a government agency mentioned as an actor on the website? (0-not present 1-present)

Are there local areas (town/city/county) discussed on the website (exclude places embedded in a proper name of s specific place/entity)? (0-not present 1-present)

Is the state level discussed on the website? (0-not present 1-present)

Is the national level (US Gov. orgs/US/America) discussed on the website? (0-not present 1-present)

Is a specified military/industrial/landfill/or other location discussed on the website (discussed using a proper name)? (0-not present 1-present)

Is water mentioned as a source/location of contamination on the website? (0-not present 1-present)

Is soil mentioned as a source/location of contamination on the website? (0-not present 1-present)

Is firefighting foam mentioned as a source/location of contamination on the website? (0-not present 1-present)

Is wastewater sludge (biosolids) mentioned as a source/location of contamination on the website? (0-not present 1-present)

Is cookware mentioned as a product containing PFAS on the website? (0-not present 1-present)

Is packaging mentioned as a product containing PFAS on the website? (0-not present 1-present)

Is water or stain resistant material mentioned as a product containing PFAS on the website? (0-not present 1-present)

Is there an explicit mention of negative affect (worry, concern, fear, anger, or sadness) on the website? (0-not present 1-present)

Is there a reference to further information seeking by the reader on the website? (0-not present 1-present)

Is there a reference to taking preventative action by the reader on the website? (0-not present 1-present)

Is there mention of testing/treating water for PFAS on the website? (0-not present 1-present)

Is there mention of testing/treating soil for PFAS on the website? (0-not present 1-present)

Image Questions:

Is the image a graph or table? (0-not present 1-present)

Is the image a Map? (0-not present 1-present)

Is the image a Photo? (0-not present 1-present)

Is the image an Infographic? (0-not present 1-present)

Is there a government representative in the image? (0-not present 1-present)

Is there a farmer/farm in the image? (0-not present 1-present)

Is there a scientist in the image? (0-not present 1-present)

Is water (be liberal) present in the image (0-not present 1-present)

Is soil present in the image (0-not present 1-present)

Is firefighting foam present in the image (0-not present 1-present)

Is wastewater sludge present in the image (0-not present 1-present)

Is nonstick cookware (pots/pans/etc) present in the image (0-not present 1-present)

Is packaging present in the image (0-not present 1-present)

Is water or stain resistant material present in the image (0-not present 1-present)

Is water (be liberal) shown being tested/treated in the image (0-not present 1-present)

Is soil shown being tested/treated in the image (0-not present 1-present)

Is there any indication of negative affect (worry, concern, fear, anger, or sadness)? (0-not present 1-present)

APPENDIX D: WEBSITES INCLUDED IN PRACTICE SAMPLE

Alabama Department of Environmental Management. (n.d.). Retrieved September 16, 2023, from https://adem.alabama.gov/programs/water/drinkingwater/pfaspage.cnt

Canada, H. (2021, April 23). *Per- and polyfluoroalkyl substances (PFAS)* [Education and awareness]. Government of Canada. https://www.canada.ca/en/health-canada/services/chemical-substances/other-chemical-substances-interest/per-polyfluoroalkyl-substances.html

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DEP's Efforts to Address PFAS in the Environment. (n.d.). Florida Department of Environmental Protection. Retrieved September 16, 2023, from https://floridadep.gov/waste/waste-cleanup/content/dep%E2%80%99s-efforts-address-pfas-environment

Maryland and PFAS. (n.d.). Department of the Environment. Retrieved September 16, 2023, from https://mde.maryland.gov/PublicHealth/Pages/default.aspx

Michigan PFAS Action Response Team (MPART). (n.d.). Michigan PFAS Action Response Team. Retrieved September 16, 2023, from https://www.michigan.gov/pfasresponse

Municipal Facilities. (n.d.). North Dakota Department of Environmental Quality. Retrieved September 16, 2023, from https://deq.nd.gov/MF/PFAS/

Per- & Polyfluoroalkyl Substances | KDHE, KS. (n.d.). Kansas Division of Environment. Retrieved September 16, 2023, from https://www.kdhe.ks.gov/635/Per--Polyfluoroalkyl-Substances

Per- and Polyfluoroakyl Substances (PFAS). (2019, July 8). Utah Department of Environmental Quality. https://deq.utah.gov/pollutants/per-and-polyfluoroakyl-substances-pfas

Per- and Polyfluoroalkyl Substances. (n.d.). Illinois Environmental Protection Agency. Retrieved September 16, 2023, from https://epa.illinois.gov/topics/water-quality/pfas.html

Per- and Polyfluoroalkyl Substances (PFAS). (n.d.-a). Missouri Department of Natural Resources. Retrieved September 16, 2023, from https://dnr.mo.gov/contaminant-spotlight/perfluoroalkyl-polyfluoroalkyl-substances-pfas

Per- and Polyfluoroalkyl Substances (PFAS). (n.d.-b). Minnesota Department of Health. Retrieved September 16, 2023, from https://www.health.state.mn.us/communities/environment/hazardous/topics/pfcs.html

Per- and Polyfluoroalkyl Substances (PFAS). (n.d.-c). Kentucky Energy and Environment Cabinet. Retrieved September 16, 2023, from https://eec.ky.gov/Environmental-Protection/Water/Protection/Pages/PFAS.aspx

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Per- and Polyfluoroalkyl Substances, (PFAS). (n.d.). New Jersey Department of Environmental Protection. Retrieved September 16, 2023, from https://dep.nj.gov/pfas/

Per– and Polyfluoroalkyl Substances (PFAS). (n.d.). S.C. Department of Health and Environmental Control. Retrieved September 16, 2023, from https://scdhec.gov/environment/polyfluoroalkyl-substances-pfas

Per- and Polyfluoroalkyl Substances (PFAS). (2021, February 22). Indiana Department of Environmental Management. https://www.in.gov/idem/resources/nonrule-policies/per-and-polyfluoroalkyl-substances-pfas/

Per- and Polyfluoroalkyl Substances (PFAS). (2023). Hawaii Hazard Evaluation and Emergency Response. https://health.hawaii.gov/heer/environmental-health/highlighted-projects/pfas/

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PFAS and Idaho Drinking Water. (2021, February 18). Idaho Department of Environmental Quality; State of Idaho. https://www.deq.idaho.gov/water-quality/drinking-water/pfas-and-idaho-drinking-water/

PFAS in Delaware. (n.d.). Department of Natural Resources and Environmental Control. Retrieved September 16, 2023, from https://dnrec.alpha.delaware.gov/waste-hazardous/remediation/pfas/

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PFAS in Pennsylvania. (n.d.). Department of Environmental Protection. Retrieved September 16, 2023, from https://www.dep.pa.gov:443/Citizens/My-Water/drinking_water/PFAS/Pages/default.aspx

PFAS Information. (n.d.-a). Mississippi Department of Environmental Quality. Retrieved September 16, 2023, from https://www.mdeq.ms.gov/water/groundwater-assessment-and-remediation/pfas-information/

PFAS Information. (n.d.-b). South Dakota Department of Agriculture & Natural Resources. Retrieved September 16, 2023, from https://danr.sd.gov/OfficeOfWater/DrinkingWater/PFAS.aspx

PFAS Management. (n.d.). Philadelphia Water Department. Retrieved September 16, 2023, from https://water.phila.gov/sustainability/watershed-protection/pfas/

PFAS (per- and polyfluoroalkyl substances). (n.d.). Iowa Department of Natural Resources. Retrieved September 16, 2023, from https://www.iowadnr.gov/Environmental-Protection/PFAS

PFAS, Per-and Polyfluoroalkyl Substances. (n.d.). Oregon Health Authority. Retrieved September 16, 2023, from https://www.oregon.gov/oha/ph/healthyenvironments/healthyneighborhoods/toxicsubstances/pages/pfas.aspx

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PFOA and PFOS Information. (n.d.). Environmental Protection Division. Retrieved September 16, 2023, from https://epd.georgia.gov/pfoa-and-pfos-information

Tackling California's PFAS Problem. (n.d.). Clean Water Action. Retrieved September 16, 2023, from https://cleanwater.org/tackling-californias-pfas-problem

What to Know About PFAS. (n.d.). Cecil County Health Department. Retrieved September 16, 2023, from https://cecilcountyhealth.org/services/environmental-health-services/what-to-know-about-pfas/

APPENDIX E: RELIABILITIES FOR CODING QUESTIONS

Text Reliabilities	Krippendorff's Alpha	Percent Agreement
Are there any videos present? How many? (please list number 0-100)	Undetermined*	100
Is the EPA (Federal (US) Environmental Protection Agency) mentioned? (0-not present 1-present)	0.762	92.3
Is there an explicit reference to "forever chemicals"? (0-not present 1-present)	1	100
Are there links to other webpages/resources? (0-not present 1-present)	Undetermined*	100
Is it stated on the website that PFAS risk is unknown, either because information is unavailable or uncertain or because there is inherent uncertainty associated with the risk? (0-not present 1-present)	0.375	69.2
Is it stated on the website that the risk is severe, specifically that it is explicitly life threatening? (0-not present 1-present)	Undetermined*	100
Is it stated on the website that PFAS risk cannot be mitigated? (0-not present 1-present)	0	92.3
Is it stated on the website that PFAS risk will have a lasting effect (length of time, persistence, building up, bioaccumulation)? (0-not present 1-present)	0.583	84.6
Is it stated on the website that PFAS risk will have personal effects as indicated by the use of second person pronouns? (0-not present 1-present)	0.638	93.2
Is it stated on the website that many are susceptible to PFAS risk? (0-not present 1-present)	0.167	69.2
Is it stated on the website that the risk is inequitable in particular populations (not location based)? (0-not present 1-present)	0.852	92.3
Is there any information on efficacy on the website, either as self-efficacy (What I can do- include information regarding testing or	0.653	84.6

treatment , even if it’s a link), response efficacy (How what I can do will help), or societal efficacy (What we can do- community self-organization)? (0-not present 1-present)		
Are the government/government organizations mentioned as an actor on the website? (0-not present 1-present)	Undetermined*	100
Are farmers/farms mentioned as an actor on the website? (0-not present 1-present)	1	100
Are scientists/scientific organizations not employed by a government agency mentioned as an actor on the website? (0-not present 1-present)	0.405	69.2
Are there local areas (town/city/county) discussed on the website (exclude places embedded in a proper name of s specific place/entity)? (0-not present 1-present)	0.556	76.9
Is the state level discussed on the website? (0-not present 1-present)	1	100
Is the national level (US Gov. orgs/US/America) discussed on the website? (0-not present 1-present)	0	92.3
Is a specified military/industrial/landfill/or other location discussed on the website (discussed using a proper name)? (0-not present 1-present)	1	100
Is water mentioned as a source/location of contamination on the website? (0-not present 1-present)	1	100
Is soil mentioned as a source/location of contamination on the website? (0-not present 1-present)	0.848	92.3
Is firefighting foam mentioned as a source/location of contamination on the website? (0-not present 1-present)	1	100
Is wastewater sludge (biosolids) mentioned as a source/location of contamination on the website? (0-not present 1-present)	1	100
Is cookware mentioned as a product containing PFAS on the website? (0-not present 1-present)	1	100

Is packaging mentioned as a product containing PFAS on the website? (0-not present 1-present)	1	100
Is water or stain resistant material mentioned as a product containing PFAS on the website? (0-not present 1-present)	0.702	84.6
Is there an explicit mention of negative affect (worry, concern, fear, anger, or sadness) on the website? (0-not present 1-present)	0.653	84,6
Is there a reference to further information seeking by the reader on the website? (0-not present 1-present)	-0.087	76.9
Is there a reference to taking preventative action by the reader on the website? (0-not present 1-present)	0.405	69.2
Is there mention of testing/treating water for PFAS on the website? (0-not present 1-present)	0.653	84.6
Is there mention of testing/treating soil for PFAS on the website? (0-not present 1-present)	0.583	84.6

Image Reliabilities	Krippendorff's Alpha	Percent Agreement
Is the image a graph or table? (0-not present 1-present)	1	100
Is the image a Map? (0-not present 1-present)	1	100
Is the image a Photo? (0-not present 1-present)	1	100
Is the image an Infographic? (0-not present 1-present)	1	100
Is there a government representative in the image? (0-not present 1-present)	0.149	80
Is there a farmer/farm in the image? (0-not present 1-present)	1	100
Is there a scientist in the image? (0-not present 1-present)	0.324	76.7
Is water (be liberal) present in the image? (0-not present 1-present)	0.933	96.7
Is soil present in the image ?(0-not present 1-present)	0.903	96.7

Is firefighting foam present in the image? (0-not present 1-present)	1	100
Is wastewater sludge present in the image? (0-not present 1-present)	0.785	96.7
Is nonstick cookware (pots/pans/etc) present in the image? (0-not present 1-present)	1	100
Is packaging present in the image? (0-not present 1-present)	1	100
Is water or stain resistant material present in the image? (0-not present 1-present)	0.817	93.3
Is water (be liberal) shown being tested/treated in the image (0-not present 1-present)	0.59	86.7
Is soil shown being tested/treated in the image (0-not present 1-present)	1	100
Is there any indication of negative affect (worry, concern, fear, anger, or sadness)? (0-not present 1-present)	0.655	96.7

*Undetermined Krippendorff's Alpha indicates that there were not cases where both coders reported a code present or absent. For example, every website included in the reliability sample included links to other websites or resources, giving this code an undetermined Krippendorff's Alpha. In such cases, Percent agreement may further illuminate agreement between the coders.

APPENDIX F: DESCRIPTIVE STATISTICS FOR TEXT AND IMAGE CODES

Text Codes	Number of Websites Coded Present	Percent of Websites Coded Present
Is the state level discussed on the website? (0-not present 1-present)	47	73.4
Is it stated on the website that PFAS risk will have personal effects as indicated by the use of second person pronouns? (0-not present 1-present)	42	65.6
Is there mention of testing/treating water for PFAS on the website? (0-not present 1-present)	40	62.5
Is firefighting foam mentioned as a source/location of contamination on the website? (0-not present 1-present)	40	62.5
Is the EPA (Federal (US) Environmental Protection Agency) mentioned? (0-not present 1-present)	37	57.8
Is there any information on efficacy on the website, either as self efficacy (What I can do- include information regarding testing or treatment , even if its a link), response efficacy (How what I can do will help), or societal efficacy (What we can do- community self organization)? (0-not present 1-present)	37	57.8
Is water or stain resistant material mentioned as a product containing PFAS on the website? (0-not present 1-present)	37	57.8

Is cookware mentioned as a product containing PFAS on the website? (0-not present 1-present)	31	48.4
Is packaging mentioned as a product containing PFAS on the website? (0-not present 1-present)	31	48.4
Is soil mentioned as a source/location of contamination on the website? (0-not present 1-present)	29	45.3
Is there an explicit reference to "forever chemicals"? (0-not present 1-present)	27	42.2
Is it stated on the website that the risk is inequitable in particular populations (not location based)? (0-not present 1-present)	27	42.2
Is wastewater sludge (biosolids) mentioned as a source/location of contamination on the website? (0-not present 1-present)	21	32.8
Is a specified military/industrial/landfill/or other location discussed on the website (discussed using a proper name)? (0-not present 1-present)	13	20.3
Are farmers/farms mentioned as an actor on the website? (0-not present 1-present)	11	17.2
Are there any videos present? How many? (please list number 0-100)	5 (1 website with 2 videos)	7.9

Image Codes	Number of Websites Coded Present	Percent of Websites Coded Present
Is soil present in the image (0-not present 1-present)	84	38.9
Is water present in the image (0-not present 1-present)	21	9.7
Is water or stain resistant material present in the image (0-not present 1-present)	20	9.3
Is packaging present in the image (0-not present 1-present)	16	7.4
Is firefighting foam present in the image (0-not present 1-present)	12	5.6
Is there a farmer/farm in the image? (0-not present 1-present)	11	5.1
Is nonstick cookware (pots/pans/etc) present in the image (0-not present 1-present)	8	3.7
Is soil shown being tested/treated in the image (0-not present 1-present)	5	2.3
Is wastewater sludge present in the image (0-not present 1-present)	4	1.9

APPENDIX G: NONSIGNIFICANT STATISTICS FOR COMPARING GOVERNMENT/NONGOVERNMENT PUBLISHING ORGANIZATIONS

Variable	$\chi 2$	p-value
Is the EPA (Federal (US) Environmental Protection Agency) mentioned? (0-not present 1-present)	0.009	0.92
Is it stated on the website that PFAS risk will have personal effects as indicated by the use of second person pronouns? (0-not present 1-present)	0.040	0.84
Is it stated on the website that the risk is inequitable in particular populations (not location based)? (0-not present 1-present)	0.367	0.55
Is there any information on efficacy on the website, either as self efficacy (What I can do- include information regarding testing or treatment , even if its a link), response efficacy (How what I can do will help), or societal efficacy (What we can do- community self organization)? (0-not present 1-present)	0.172	0.68
Are farmers/farms mentioned as an actor on the website? (0-not present 1-present)	0.629	0.43
Is a specified military/industrial/landfill/or other location discussed on the website (discussed using a proper name)? (0-not present 1-present)	2.8333	0.09
Is soil mentioned as a source/location of contamination on the website? (0-not present 1-present)	1.370	0.24

Is firefighting foam mentioned as a source/location of contamination on the website? (0-not present 1-present)	1.693	0.19
Is wastewater sludge (biosolids) mentioned as a source/location of contamination on the website? (0-not present 1-present)	0.946	0.33
Is cookware mentioned as a product containing PFAS on the website? (0-not present 1-present)	0.525	0.47
Is packaging mentioned as a product containing PFAS on the website? (0-not present 1-present)	0.525	0.47
Is water or stain resistant material mentioned as a product containing PFAS on the website? (0-not present 1-present)	0.172	0.68
Is there mention of testing/treating water for PFAS on the website? (0-not present 1-present)	0.068	0.80

APPENDIX H: NONSIGNIFICANT STATSTICS FOR COMPARING FEDERAL/NONFEDERAL SPATIAL SCALES

Variable	χ2	p-value
Are there any videos present? How many? (please list number 0-100)	5.095	0.08
Is the EPA (Federal (US) Environmental Protection Agency) mentioned? (0-not present 1-present)	0.218	0.64
Is there an explicit reference to "forever chemicals"? (0-not present 1-present)	1.108	0.29
Is it stated on the website that PFAS risk will have personal effects as indicated by the use of second person pronouns? (0-not present 1-present)	0.761	0.38
Is it stated on the website that the risk is inequitable in particular populations (not location based)? (0-not present 1-present)	2.430	0.12
Is a specified military/industrial/landfill/or other location discussed on the website (discussed using a proper name)? (0-not present 1-present)	2.824	0.09
Is soil mentioned as a source/location of contamination on the website? (0-not present 1-present)	0.277	0.60
Is firefighting foam mentioned as a source/location of contamination on the website? (0-not present 1-present)	1.506	0.22

Is wastewater sludge (biosolids) mentioned as a source/location of contamination on the website? (0-not present 1-present)	2.270	0.13
Is cookware mentioned as a product containing PFAS on the website? (0-not present 1-present)	000	0.99
Is packaging mentioned as a product containing PFAS on the website? (0-not present 1-present)	0.258	0.61
Is water or stain resistant material mentioned as a product containing PFAS on the website? (0-not present 1-present)	0.298	0.59

APPENDIX I: SPECIFIC WORDING OF CONGRUENCE RATIO QUESTION PAIRS

Text Question	Image Question	Abbreviation
Are farmers/farms mentioned as an actor on the website?	Is there a farmer/farm in the image?	Farm/Farmers
Is soil mentioned as a source/location of contamination on the website?	Is soil present in the image?	Soil
Is firefighting foam mentioned as a source/location of contamination on the website?	Is firefighting foam present in the image?	Firefighting Foam
Is wastewater sludge (biosolids) mentioned as a source/location of contamination on the website?	Is wastewater sludge present in the image?	Biosolids
Is cookware mentioned as a product containing PFAS on the website?	Is nonstick cookware (pots/pans/etc) present in the image?	Cookware
Is packaging mentioned as a product containing PFAS on the website?	Is packaging present in the image?	Packaging
Is water or stain resistant material mentioned as a product containing PFAS on the website?	Is water or stain resistant material present in the image?	Water/Stain Resistant Material

BIOGRAPHY OF THE AUTHOR

Carrie Loomis was born on August 15, 2000, in Honesdale, Pennsylvania. She was then raised in Northeast Pennsylvania, graduating in 2018 from Wallenpaupack Area High School. She then went on to attend Bucknell University in Lewisburg, Pennsylvania, receiving a degree in Chemistry and Environmental Science in 2022. During this time, she researched abandoned mine drainage in the Shamokin Creek Watershed and participated in a variety of student activities, such as symphonic band, pep band, discovery residential college, and Alpha Phi Omega National Service Fraternity. She then moved to Maine in 2022 to pursue a Master's degree in Communication. She is a candidate for a Master of Arts in Communication from the University of Maine in August 2024, where she is also a trainee in the National Science Foundation-Natural Resources Traineeship for Enhancing Conservation Science.