Environmental Risks, the Leverage of Risk Information and Data, and Mediated Risk Knowledge Communication

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Abstract

This dissertation addresses the complex challenge of communicating knowledge about environmental risks from toxic chemicals. Modern environmental risks are often invisible and technically complex, making the management of these risks highly dependent on data and information. Reliance on risk knowledge necessitates effective dissemination and communication by government agencies, yet the public's engagement with this information remains unclear due to limited real-world studies. This dissertation is comprised of three standalone papers bridging this gap. Each focuses on different aspects of risk knowledge communication using news dialogues as data sources.

The first paper investigates the communication of location-specific risk information through a case study of the Radford Army Ammunition Plant (RAAP). Using content analysis and logistic regression, the study examines how scientific information about local environmental issues is presented in news articles and what factors influence its inclusion. Findings highlight the varying capacities among different stakeholder groups to access and utilize scientific information, underscoring the need for governmental and research support for less-resourced groups.

The second paper explores chemical-specific risk knowledge, focusing on the environmental risks associated with per- and polyfluoroalkyl substances (PFAS). Employing a structural topic model (STM) and multinomial logistic regression, the study assesses the impact of the United States Environmental Protection Agency (US EPA)'s

Draft Toxicity Assessment for GenX, one of the PFAS chemicals, on news topics. Results indicate that the influence of new risk knowledge on news topics varies depending on community context, with significant impacts observed when communities are ready for governmental action or legislation using the new assessment.

The third paper examines the use of the US EPA's Toxics Release Inventory (TRI) database in news media. Through exploratory analysis, it reveals how different stakeholders use TRI data to make claims about environmental risks, highlighting that environmental organizations are primary users who often reconstruct TRI data to make it more relevant to the public. This suggests their potential role as intermediaries in risk knowledge communication.

This dissertation provides empirical evidence of the limited news coverage of environmental risk knowledge, the dominance of government sources, and the significant role of intermediary groups. The findings suggest policy implications for government agencies and other organizations, highlighting the need to improve the conveyance and communication of risk knowledge. Recommendations include providing more contextual information and training for communities and intermediary groups on interpreting and utilizing risk data and information. These aim to bolster public comprehension and responsiveness to environmental risks, thereby protecting public safety and health.

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General Audience Abstract

Toxic chemicals in our environment pose serious risks, but these dangers are often invisible and complex, making them hard to understand and manage without data and information about them. This dissertation explores how information about these risks is shared with the public through printed and online news coverage, aiming to enhance communication and our understanding of these environmental threats.

This dissertation presents findings from three studies, each focusing on different types of risk information. The first looks at scientific information about local environmental risks at the Radford Army Ammunition Plant communicated in the news. It shows that not all groups have the same ability to access and use scientific data, and people tend to or feel compelled to bring up scientific information when they claim that risks exist, while the same level of scientific proof is not deemed necessary when denying the risks.

The second study identifies topics in the news coverage of a specific chemical risk, per- and polyfluoroalkyl substances (PFAS) contamination across the United States. This study also reveals how the publication of a new risk assessment for GenX – one type of PFAS chemical that was found to be more harmful than previously thought – changes the topics covered in the news. It finds that the impact of the new risk assessment depends on the readiness of communities to engage with the information and take action.

The third study examines how a broad database of toxic chemical releases – the United

States Environmental Protection Agency's Toxics Release Inventory – is used by various groups speaking in the news. It finds that environmental organizations play a crucial role in making complex data understandable and relevant to the public.

Overall, this dissertation highlights the challenges and importance of effectively sharing information about toxic chemicals. It suggests ways for government agencies and other organizations to improve how they communicate these risk data and information, such as providing more context and training for those who advocate or report on these issues. By doing so, we can help the public better understand and respond to environmental risks, ultimately protecting our health and the planet.

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Table of Contents

List of Figures

List of Tables

1 Introduction

1.1 Motivations

Environmental risks from toxic chemicals pose unique management challenges due to their high dependence on risk knowledge. Modern environmental risks posed by toxic chemicals and radiation are often not easily noticeable, unlike physical injuries that people can directly observe. We may breathe chemicals in the air, but we typically do not immediately recognize the impacts. Additionally, many of these risks originate from new technologies, giving them a highly technical nature. This invisibility and technical complexity make us heavily dependent on risk knowledge to protect human and environmental health from the potential impacts associated with these risks. This reliance on risk knowledge necessitates that governments agencies produce and disseminate a vast amount of risk data and information to the public.

However, the ways in which the public accesses, utilizes, and engages with this risk knowledge remain unclear due to limited studies exploring the relationship between risk knowledge and public understanding in real-world contexts (Ilic et al., 2012; Ramm et al., 2018). Most studies addressing this topic rely on quasi-experimental or hypothetical settings for risk knowledge communication because it is difficult to capture real-life communication of risk data and information within the broader public. While these quasi-experimental studies help us understand public responses to risk knowledge presented to participants, the hypothetical settings limit their ability to provide comprehensive implications for strategies to communicate risk data and information with the public.

This gap in understanding can lead to significant problems, including ineffective dissemination of risk knowledge regarding public health and safety, limited policy impact, and the misallocation of resources in producing and sharing data and information about environmental risks. These issues highlight the need for more studies investigating the interaction between publicly available risk knowledge and the public, or segments of the public, who use that knowledge through various channels to participate in risk communication.

1.2 Dissertation Structure

This three-paper dissertation project explores how different types of risk knowledge communication occur in real-world contexts, using news dialogues as a data source for the communication of risk data and information to overcome limitations in data collection. Three studies (Chapters 2 - 4) in the format of standalone papers share the same purpose of filling the research gap in exploring risk knowledge communication with the public and ultimately provide policy implications for both government agencies and stakeholders participating in risk communication regarding the dissemination and communication of risk data and information. Figure 1-1 displays an overview of this three-essay dissertation. While the three papers share common purposes and themes and use news texts as primary data, each paper investigates different types of risk knowledge communication.

	Type of Risk Knowledge	Research Topic	Method
Paper 1	**Location-specific Risk Information:** Scientific information about local environmental risk (Radford Army Ammunition Plant)	**Impact of stakeholders and risk assertion type** on the inclusion of scientific information in news articles about local environmental risks	Content analysis, Logistic regression
Paper 2	**Chemical-specific Risk Knowledge:** Risk assessment for toxic chemicals (US EPA's Toxicity Assessment for GenX Chemicals)	**Topics in news** regarding environmental risks of a family of toxic chemicals and the **impact of newly published risk assessment on topic prevalences**	Structural topic modeling, Multinomial logistic regression
Paper 3	**Wide-Ranging Risk Data:** National database of toxic chemical releases (US EPA's Toxics Release Inventory)	**Different ways stakeholders utilize national environmental risk database** to make claims in news articles	Content analysis, Exploratory analysis

Figure 1-1 Structure of Three-Essay Dissertation

1.2.1 Paper 1: Location-Specific Risk Knowledge (Chapter 2)

The first study investigates the communication of location-specific risk information using the Radford Army Ammunition Plant (RAAP) as a case study. This study focuses on the inclusion of scientific information in local news articles about environmental issues related to the RAAP using content analysis and a logistic regression model. It explores how scientific information about local environmental issues is communicated in news articles and examines what factors influence the inclusion of scientific risk information, which is often crowded out by non-scientific and sensational stories such as blame, conflict, costs, or dread images (Sandman, 2017). Findings suggest different capacities to access and invoke scientific information in news claims among different stakeholder groups, indicating the need for government agencies and research communities to assist groups with limited resources and capacities.

1.2.2 Paper 2: Chemical-Specific Risk Knowledge (Chapter 3)

The second study examines chemical-specific risk knowledge, focusing on the environmental risks communicated in news texts in the United States about per- and polyfluoroalkyl substances (PFAS). The risk knowledge investigated in this study is the US EPA's Draft Toxicity Assessment for the chemical GenX, which was published following the detection of GenX, a type of PFAS chemical, in the Cape Fear River, which serves as a drinking water source for Eastern North Carolina communities. A structural topic model (STM) is employed to uncover underlying thematic topics in textual data about PFAS environmental risks, followed by a multinomial logistic regression to isolate the impact of the publication of the GenX assessment on the identified topics' prevalence. The study identifies some topics linked to specific contamination cases in Vermont, Michigan, New Hampshire, and North Carolina, as well as other topics common across the nation, including the EPA's regulatory actions on PFAS, contaminations without geographic links, and water management in various cities with PFAS contamination. The multinomial logistic regression indicates that the publication of the new GenX risk assessment affects the prevalence of topics tied to specific contamination cases only when communities are ready to move on to governmental actions or legislation on PFAS environmental risks, indicating that the influence of risk knowledge on news topics varies depending on community contexts.

1.2.3 Paper 3: Wide-Ranging Database (Chapter 4)

The last study explores a wide-ranging database of chemical environmental risks, not location- or chemical-specific. The risk database examined in this study is the US EPA's Toxics Release Inventory (TRI) database, which tracks discharges of designated toxic chemicals from facilities in the United States. This study uses exploratory analysis to understand the pattern in which TRI data is used by different stakeholders to make claims about environmental risks in the news media. The results show that stakeholders utilize TRI data in various ways, from presenting quantities of release, rankings, trends over time, or errors and limitations based on their agenda in claims. Findings also indicate that environmental organizations are the primary users of TRI data in news claims-making, and they frequently reconstruct TRI data to combine it with other information and make it more relevant to the public or communities they are concerned about. These findings indicate the potential for environmental organizations to play important intermediary roles in assisting with the communication of complex risk data in the news and restructuring and delivering risk knowledge to broader audiences.

These three papers contribute to a better understanding of risk knowledge communication for different types of risk knowledge and contexts. The findings shed light on how the utilization of risk knowledge in claims-making varies by different stakeholder types or community contexts. Finally, this dissertation identifies implications for promoting risk knowledge communication through news media channels by examining factors and contexts affecting the way risk knowledge is communicated in the news.

1.3 Summary of Key Theories and Concepts

1.3.1 Characteristics of Modern Environmental Risks

Environmental risks pose unique challenges for management due to their complex nature. Sociologists such as Ulrich Beck and Anthony Giddens suggested the concept of Risk Society to explore characteristics of post-industrial environmental risks and how modern society organizes itself in response to them (Beck, 1992; Giddens, 1991). Modern environmental risks such as synthetic toxicants, nuclear fallout, and air pollution are often not easily noticeable, unlike physical injuries that we can directly observe. Many of these risks result from new technologies and scientific developments, giving them a highly technical and complex nature. Invisibility and technical complexity make the management of environmental risks heavily dependent on risk knowledge to discern environmental risks and their potential impact, as we cannot recognize them with our naked eyes (Fischhoff, 1990; Kasperson & Kasperson, 2013).

In addition, environmental risks as outcomes of intentional decisions imply management responsibility and require policy responses. Luhmann (2017) distinguishes between risk and danger by defining risk as outcomes resulting from decisions made by individuals or organizations, while danger, such as natural hazards, occurs independently of human decisions. This association with human decisions implies that those who make decisions bear the responsibility for the consequences (Rosa et al., 2014) and requires policies managing environmental risks to focus on mitigating those risks through regulation, education, communication, or technological innovation (Luhmann, 2017). Reflection on the characteristics of modern environmental risks provides significant implications for the production and communication of risk knowledge as responsibilities for risk management.

1.3.2 Governmental Responsibilities in Production and Communication of Risk Knowledge

In the context of environmental risks from toxic chemicals within the contemporary regulatory system in the United States, government agencies particularly bear the responsibility and accountability for risk management. This responsibility is grounded in the principle of 'duty of care', which obligates the government to prevent harm to its citizens and the environment (Katzman, 1988). This duty is operationalized through various environmental statutes and regulations aimed at controlling the use and release of toxic chemicals, as well as the production and dissemination of risk knowledge, involving creating databases, conducting risk assessments, and ensuring that information about the risks associated with toxic chemicals is accessible to all stakeholders (Chiapella et al., 2019; Kulin & Johansson Sevä, 2019; National Academies of Sciences, 2021; Zindel et al., 2021).

Government agencies have obligations to provide knowledge about environmental risks to safeguard public health, often mandated by laws and regulations. For instance, the Toxic Substances Control Act (TSCA) mandates the United States Environmental Protection Agency (EPA) to maintain a current inventory of chemicals in commerce and provide evaluations of toxic chemicals to prevent exposure-related health risks (Kapp, 2014; Landrigan & Goldman, 2011; National Academies of Sciences, 2021). The same law also requires the EPA to conduct risk assessments that determine the potential impacts of chemical exposures on human health and the environment, which are foundational in setting regulatory standards and limits for chemical use. The Emergency Planning and Community Right-to-Know Act (EPCRA) also requires the EPA to routinely compile and publish toxic chemical release reports on the storage and release of hazardous chemicals to enable communities to promote public awareness of environmental risks (Purifoy, 2013).

The government's responsibility extends beyond the generation of data to the effective dissemination of this information to ensure that all segments of the population can make informed decisions. Government agencies use a variety of channels to communicate risk information to the public, including traditional media, public databases, dedicated websites, and social media platforms. The US EPA maintains extensive online resources that provide access to data on chemical risks and safety guidelines. The effectiveness of these channels in reaching diverse populations is crucial for ensuring public safety and compliance with safety standards (National Academies of Sciences, 2021). For example, the role of state websites in the U.S. in communicating risks associated with per- and polyfluoroalkyl substances (PFAS) illustrates both the importance and challenges of providing clear and accessible risk information to the public (Zindel et al., 2021). These efforts highlight the need for consistent and understandable risk communication strategies that do not solely rely on individuals' responsibilities but also emphasize governmental accountability.

1.3.3 Importance of Risk Knowledge Communication

The effectiveness of risk communication has direct implications for public health and environmental policy. Various advantages of increased accessibility to risk data and information highlight the critical role of risk knowledge in promoting public health and safety as well as informed community engagement (Beierle, 2004; Honoré et al., 2019; Kuchinskaya, 2018; McKelvey et al., 2017; Rother, 2014).

Making environmental data publicly accessible increases public awareness of environmental risks, which assists the public in making informed choices and motivates them to engage. Accessibility to open government data enables communities to understand local environmental hazards, engage in environmental decision-making, and advocate for improved environmental policies and practices (Janssen et al., 2017; Martin & Begany, 2017).

The publication of risk data can also motivate the public to adopt protective behaviors and preventive actions, reducing exposure to environmental hazards and improving overall public health (Liu et al., 2020; Rother, 2014). Communities can respond more effectively to environmental health threats when they have access to relevant data (Honoré et al., 2019; Winterbottom, 2021). Publicly available environmental data can support grassroots movements and local policy initiatives aimed at addressing environmental risks. When citizens have access to risk data and information, they are better equipped to participate in local governance and influence policy changes that mitigate environmental risks (Beierle, 2004). Data availability of health risk enhances community resilience and fosters a collaborative environment for community-led initiatives aiming to improve local health outcomes (McKelvey et al., 2017).

Open data and information linked to specific companies or facilities, such as potential environmental risks posed by their hazardous waste or violations of environmental laws, can hold significant regulatory impacts (Cohen & Viscusi, 2012; Cortez, 2018; Fung & O'rourke, 2000; Robinson et al., 2009). When companies are aware that their environmental data is publicly accessible, they are more likely to adopt cleaner practices and reduce harmful emissions to maintain a positive public image and comply with regulatory standards (Fung et al., 2007). This transparency drives corporate accountability and incentivizes companies to invest in sustainable technologies and practices, leading to overall better environmental outcomes.

Publishing environmental risk data increases the transparency and accountability of government actions. Access to open data builds public trust and encourages government agencies to maintain high standards in their environmental practices (Ahn & Noh, 2020; Calo et al., 2014; Taylor-Clark et al., 2007). Better access to environmental information significantly enhances public understanding and supports more effective governance (Chin et al., 2019; Gouldson, 2004; Shin et al., 2019). Moreover, accessible environmental risk information is essential for compliance and effective governance (Dresser, 2000; Goshorn, 1996).

Without proper access to scientific data, communities are often unable to accurately assess and manage environmental risks (Koller et al., 2000). This often leads to compromised risk perception and management, particularly in vulnerable communities (Bencko & M. Quinn, 2013; Burger et al., 2010). When risk data and information do not reach the broader public, people may fail to take necessary precautions, leading to increased exposure to harmful chemicals. Conversely, effective communication can enhance public engagement and compliance with safety measures, resulting in better health outcomes and reduced environmental impact. Governments must invest in research to understand the best practices for risk communication and continually adapt their strategies to meet the needs of their populations.

1.3.4 Limited Understandings on Risk Knowledge Communication with the Public

Although governments, especially federal agencies, release a vast amount of risk data and information to the public, there is limited understanding of how this helps the public grasp environmental risks. Even with abundant risk knowledge available, how it is accessed, utilized, understood, and communicated remains unclear.

Most studies examining the relationship between risk knowledge and public understanding use quasi-experimental methods like experimental surveys or hypothetical scenarios, rather than focusing on the actual risk knowledge used in real-world contexts (Freudenstein et al., 2020; Otieku et al., 2023; Raza et al., 2021; Spinks et al., 2021; Zhou et al., 2020). While these studies enhance understanding of public responses to and perceptions of given risk knowledge, their implications for comprehensive strategies to communicate risk data and information to the public are limited.

The prevalence of quasi-experimental studies is likely due to the difficulties associated with collecting data on the communication of risk data and information within the broader public in real-life contexts. Similarly, government agencies that produce and provide risk knowledge track its utilization primarily through anecdotal examples, rather than through systematic data collection and analysis of how and by whom risk data and information are accessed, utilized, and communicated (U.S. Environmental Protection Agency, 2013).

1.3.5 Models for Public Communication of Risk Knowledge

While governments undertake significant efforts to make knowledge about chemical risks available, there are challenges in ensuring that the produced knowledge leads to effective public understanding. The complex and technical nature of risk knowledge demands better strategies for public communication of science and technology. Burns et al. (2003) define science communication as the use of appropriate skills, media, activities, and dialogue to produce one or more of the following personal responses to science: awareness, enjoyment, interest, opinion-forming, and understanding.

The traditional model of science communication is based on the diffusionist model, which posits a straightforward transmission of knowledge from experts to a non-expert public (Bucchi, 2008). This model tends to emphasize the process of spreading scientific ideas more broadly, underpinned by the assumption that increasing both the quantity and quality of information can address the public's knowledge deficit (Hansen, 1994; Jucan & Jucan, 2014; McNeil, 2013). From the diffusionist perspective, government agencies simply need to expose the public to scientifically credible risk knowledge more frequently to enhance their understanding and utilization of provided knowledge. Studies have shown that this model persists in science communication due to the entrenched institutional structures and the traditional training of scientists, which emphasize the clarity and accuracy of information over engagement (Besley & Tanner, 2011; Simis et al., 2016).

However, this model has been increasingly criticized for its simplistic view of the public as merely lacking knowledge and its failure to account for the nuanced ways individuals interpret scientific information. Studies indicate that public engagement with science is influenced by diverse factors, including cultural values and personal beliefs, which affect their reception and understanding of risk information (Wynne, 1995). The interaction between risk scientists and the public is more reciprocal than previously acknowledged. Researchers or institutions that produce risk knowledge are not only sources of information but also active participants in dialogues with values and beliefs as well (Bucchi & Mazzolini, 2003; Dunwoody & Scott, 1982).

In contrast with the diffusionist model, the dialogue model advocates for two-way interactions between scientists and the public and recognizes the need for mutual learning and adjustment of risk messages based on public feedback (Hetland, 2016; Trench, 2008). This model fosters a more relational approach, where communication is seen as an interactive process involving listening, understanding, and responding to public concerns (Bucchi, 2008; Trench, 2008). The dialogue model is reflected in science communication practices that involve discussions, workshops, and other participatory activities where the public can voice their perspectives and influence the framing of scientific information (Sousa et al., 2014; Trench, 2008). This model has been found to enhance public trust in science and increase the relevance of scientific discussions to broader societal issues (Bucchi, 2008; Hetland, 2016).

1.3.6 Dialogical Communication of Risk Knowledge in News Media

Although the dialogue model offers a more interactive and participatory approach to science communication, its practical application is often constrained by the limited availability of platforms and opportunities for direct public engagement. In many cases, organizing discussions, workshops, and other participatory activities is not always feasible due to logistical, financial, and time constraints (Stofer et al., 2019). This limited availability of pure dialogues is why media remain the most influential channels for science communication to this date, evolving from books and exhibitions to news and social media (Bucchi, 2008). One alternative approach to promote the dialogue model while advancing the dissemination of risk knowledge to the broader public is the strategic utilization of news media as a conduit for dialogic communication. Traditional news has served as one of the critical outlets for the diffusion of risk knowledge, yet it has room for a shift from a purely diffusionist perspective to one that embraces elements of dialogic communication.

While news media is not traditionally considered dialogic (Jayyusi, 1991), scholars have found that it has "dialogicity," as individuals discussing a theme in the media (*claims-makers* in other words) are essentially addressing others who are not present or not participating in real-time conversation (Clayman & Heritage, 2002; Greatbatch, 1998; Hutchby, 1995; Leudar & Nekvapil, 2004). These addressees can be targeted towards individuals or organizations or unspecified but targeted towards a segment of people. Although it is not an authentic dialogue in the fullest sense, the concept of dialogic communication in news media incorporates relational and interactive approaches that can enhance the effectiveness of science communication through the media.

In science communication, dialogic communication goes beyond simply broadcasting information from research institutions or government agencies; it aims to engage the audience by incorporating their perspectives, values, and concerns into the claims made in the news media, thereby fostering more meaningful interaction (Kent & Taylor, 2002; Kitzinger, 1999; Leudar & Nekvapil, 2004). This approach aligns with the relational model of communication, which views the public as active participants rather than passive recipients of information, and gives a platform to various stakeholders who may have differing perspectives and interests surrounding risk knowledge (Dudo, 2015; Pruchnicka, 2012). When news media incorporate diverse claims-makers, they create a dialogic space where different arguments can be articulated, contested, and negotiated (Zimmerman et al., 2001). This not only enriches the public discourse but also showcases how claims-makers engage with risk knowledge.

1.3.7 News Dialogue Reflecting Risk Knowledge Communication

Addressing the dialogical communication of risk knowledge in news media also sheds light on methods to overcome the limited understanding of risk knowledge communication. As mentioned, a barrier to studying risk knowledge communication with the broader public is the difficulty in collecting data in real-life contexts. Written news texts provide reflection of how risk knowledge conveyed to the public is utilized by stakeholders as segments of the public to make claims in the news.

Various approaches within the social sciences use news media as a primary data source to reflect and analyze real-world events, providing insights into public discourse, societal concerns, and media influences. In particular, the use of news data for protest event analysis (PEA) has been a common practice in social movement studies (Hutter, 2014). News media have been utilized to analyze political events, protests, and social movements by capturing the frequency and descriptive information in media coverage, which reflects societal interests and concerns (Hutter, 2014; Koopmans & Statham, 1999; Soule, 2013). These studies view news data as an imperfect but the best available reflection of phenomena aimed to explore, owing to the widespread availability and historical continuity of news archives.

While the use of news data for protest event analysis provides valuable insights, it comes with significant challenges related to validity and reliability. Researchers have found that selection bias is influenced by the type of event, the news agency, the issue involved, and other factors relevant to news production, highlighting the need for critical evaluation of media biases and the development of innovative methodologies to improve data accuracy (Dollbaum, 2021; Earl et al., 2004; Herkenrath & Knoll, 2011; Mueller, 1997; Wakefield & Elliott, 2003).

Similar reflections have been made on the use of news data in risk communication. Researchers have identified that the use of news data in risk communication studies presents both opportunities and challenges. While news can be a valuable data source for how risk information and knowledge is communicated among non-experts, there are also several issues regarding the validity and reliability of data in the context of risk communication. A common concern is the potential for selection and description biases. Kitzinger (1999) emphasizes that while the media are crucial in constructing and communicating about risk, their tendency towards sensationalism can lead to exaggerated and distorted portrayals of risk. Similarly, Altheide (2010) notes that risk communication in news media often emphasizes fear and dramatizes risks, which can skew public perceptions. Boholm (2009) adds that news reports frequently provide simplified causal explanations of risks, which may not fully capture the complexity of the issues involved. Mueller (1997) identifies two approaches to addressing these biases: the "media theory" approach, which accepts media data with its biases, and the "representational" approach, which critically evaluates and adjusts for these biases.

1.4 Connecting Theories and Concepts to Dissertation Work

This dissertation employs the concept of dialogic communication in news media to explore and understand the communication of data and information about environmental risks from toxic chemicals. By treating news texts as dialogues reflecting risk knowledge communication among various stakeholders within the broader public, this study promotes the dialogue model of science communication in news media, where diverse stakeholders engage with risk data and information to make claims about environmental risks. This approach expands the venue for two-way communication, previously limited to in-person meetings, discussions, workshops, or other participatory activities, to wide-ranging, asynchronous communication via news articles. It also overcomes the data collection barriers that have hindered previous studies from providing comprehensive implications for real-world dissemination and communication of risk knowledge. To address potential challenges in utilizing news data, this study acknowledges the inherent biases in news media and employs critical evaluation to adjust for these biases in the research findings.

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2 Local Environmental Risks and Communication of Scientific Information in News

2.1 Introduction

Communities learn about the presence and nature of environmental risks from various sources, including news media. Despite downward trends in readership and viewership, traditional news media remain the primary source through which the public obtains environmental information (Zhang et al. 2022; Newman et al. 2021). Media coverage of social issues is proportionally correlated with public attention to those issues and can even alter public attitudes toward them depending on the context (Culpepper, Jung, and Lee 2023; Kneafsey and Regan 2022; Barnes and Hicks 2018; Segev and Baram-Tsabari 2012). Journalists can play an influential role in shaping public understanding of and attitudes toward issues through the processes of representing issues and relevant facts, recognizing and elevating the expertise of some and not others, and prioritizing some issues over others (Schäfer and O'Neill 2017; Allan, Adam, and Carter 2013). This influence can be even more significant when reporting environmental risks associated with complex scientific information. Various scholars have found that failing to provide the public with the scientific context of environmental issues in news media can distort public understanding of those issues and benefit other political interests (Reed, Hiles, and Tipton 2019; Romps and Retzinger 2019; Boykoff 2005). For instance, there are cases in which news media have contributed to the spread of environmental skepticism by not providing sufficient information about the solid scientific consensus over climate change (Merkley and Stecula 2021; Stecula and Merkley 2019; Xie 2015). Without appropriate scientific information, substantial environmental risks threatening society can be portrayed only as conflicts of interest among parties, leading to significant public misunderstanding of those issues. An important caveat is that scientific information, particularly when not properly translated into language that makes it broadly accessible, can alienate readers and paradoxically decrease their interest and attentiveness to issues (Shulman et al. 2020).

This study explores how local newspapers frame and deliver information regarding environmental risks. The case study examined is the Radford Army Ammunition Plant (RAAP), which is the largest point source of toxic chemical releases in the Commonwealth of Virginia (Virginia Department of Environmental Quality 2021). A news content analysis was employed to explore how the press in the surrounding region of Southwest Virginia covers scientific information about the environmental risks associated with the RAAP. This paper presents the findings, examines various factors associated with including scientific information in news articles, and considers why those relationships might exist.

2.2 Literature Review

2.2.1 Influence of Environmental News Coverage on Public Perceptions

Environmental risks are the actual or potential harms to human health and the natural environment that can result from anthropogenic activities (Henry, Dietz, and Sweeney 2020). Raw data and academic scholarship on environmental risks are often inaccessible to the public because of the use of technical terms and complex scientific methods and the enclosure of articles and other datasets behind paywalls and in hard-to-find repositories (Hansen 2013; Kranich 2007). As a result, members of the wider public tend to rely on intermediaries to evaluate environmental information instead of sorting through complex environmental data directly. Previous studies have found that news media is the primary source of environmental information for the public (Zhang et al. 2022; Newman et al. 2021).

Scholars have long studied how news media can frame public perceptions and attitudes toward social and political issues. Many studies have found that public perceptions of issue importance are positively influenced by increased reporting on issues (Murphy and Devine 2020; Barnes and Hicks 2018; Oehl, Schaffer, and Bernauer 2017; Dolan et al. 2012). However, one recent study found the negative estimated effect of media coverage on the public's attitude toward the environment, which means the more the media cover environmental issues, the more uninterested the audience becomes in the issue (Bakaki, Böhmelt, and Ward 2020). This discrepancy indicates that although it is clear that media coverage affects public opinions, directions may vary depending on contexts, contents, and extent of exposure. To gain a deeper understanding of the varying media effects, scholars have focused on two core elements of news media: frames (i.e., how an issue is represented) and claims-makers (i.e., those who succeed in making claims) (Nivas, Arul, and Aram 2016; Harrington, Elliott, and Clarke 2012; Trumbo 1996).

2.2.2 Claims-Makers in Environmental Reporting

Claims-makers compete for space in the media and try to frame any given issue by "select[ing] some aspects of a perceived reality and mak[ing] them more salient […]

to promote a particular problem definition, causal interpretation, moral evaluation, and/or treatment recommendation for the item described" (Trumbo 1996, 52). By providing claims-makers with avenues to promote their frames, the news media signals to the public whose opinions matter (i.e., who counts as experts) and which issues are worth paying attention to (Allan, Adam, and Carter 2013).

Four types of major claims-makers regularly appear in environmental news: governmental officials, community activists, corporate spokespeople, and news media themselves (Duan and Miller 2021; Comfort, Tandoc, and Gruszczynski 2020; Nivas, Arul, and Aram 2016; Takahashi and Meisner 2013; Harrington, Elliott, and Clarke 2012; Trumbo 1996). Studies analyzing news media content have found that government officials are frequently the primary sources of environmental information (Duan and Miller 2021; Comfort, Tandoc, and Gruszczynski 2020; Hedding and Riffe 2016; Benson and Wood 2015; Takahashi and Meisner 2013). Government officials may have a dominant voice because they are perceived to be the most legitimate and are often relatively easy to secure interviews with when reporting on environmental issues (M. Miller and Riechert 2013; Yang 2004). Yang's (2004) interviews with environmental journalists found that they tend to repeatedly rely on government officials who can verify claims with what they perceive to be credibility and responsibility. Most journalists are self-aware of their lack of scientific knowledge and training and thus seek out "authorized knowers" as news sources instead of collecting and attempting to make sense of information themselves (Yang 2004, 97). Governments also push their agendas using their authority and resources to stage events such as press conferences (Comfort, Tandoc, and Gruszczynski 2020).

Community activists are also frequent sources of claims in the news media. In the context of environmental issues, information and opinions are often sought from environmental civil society organizations or nonprofits (Hutchins and Lester 2015; Waisbord 2011). However, environmentalist claims tend to be from ‘mainstream’ environmental groups that are seen as more moderate (Poornananda 2022; Meissner 2012; Spencer 1992). The voices of would-be claims-makers that lack power and prestige are often crowded out of news representation due to difficulties in establishing their credibility as news sources (Meissner 2012). Even if they are equipped with professional press and publicity methods, community activists have a minor role as claims-makers in the daily news-gathering process compared to governments due to newsroom organization and routines (Waisbord 2011; Fenton 2009).

Corporate spokespeople are another source of environmental information preferred by journalists (Lee and Baek 2018; Waisbord 2011; Yang 2004). This is in part because information from corporate spokespeople is often organized and pre-packaged for direct inclusion in articles, in contrast with information from other sources such as ad-hoc community groups, which can require more transposition (M. Miller and Riechert 2013). Corporate public relations professionals strategically provide “information subsidies,” such as directly usable quotes and clearly articulated ‘facts’ to accommodate journalistic demands so that their claims get into news articles (Zerfass, Verčič, and Wiesenberg 2016; D. Miller and Dinan 2008; Davis 2007). However, some studies have found that media outlets still want to maintain journalistic autonomy to some degree and thus are reluctant to fully rely on such information subsidies (D. Miller and Dinan 2008; Turk 1985).

2.2.3 Environmental Risk Framing

News framing is concerned with how issues are presented to the public (Schäfer and O'Neill 2017). It is a major topic in communication studies because of the potent impacts frames can have on how readers perceive and respond to issues (Schäfer and O'Neill 2017; Nivas, Arul, and Aram 2016; Hedding and Riffe 2016; Benson and Wood 2015; M. Miller and Riechert 2013; Hansen 2013; Harrington, Elliott, and Clarke 2012). Frames within news coverage affect public perceptions by "defin[ing] problems," "diagnos[ing] causes," "mak[ing] moral judgments," and "suggest[ing] remedies" (Entman 1993, 52). Framing determines which information is delivered and which information is left out, emphasizing certain aspects of issues. For instance, the dominant framing of the Chernobyl nuclear incident in 1986 as an 'accident' in news reporting, describing it as a "freak accident" or "one in a million technical blunder" (Allan, Adam, and Carter 2013, 7), came at the cost of providing comprehensive information about potential systemic causes and consequences. On a similar note, Rubin (1980, as cited in Griffin and Dunwoody 1997) found that media coverage of the Three Mile Island leak so heavily used an accident frame that scientific information and knowledgeable sources were often pushed out.

Risk assertion framing, which explicitly claims or denies the existence of risks, can precipitate the provision of information in environmental reporting because the frame inherently requires scientific information to support claims-makers' assertions (Chu and Yang 2020; Pjesivac, Hayslett, and Binford 2020). Griffin and Dunwoody (1997) found a positive association between adopting a risk frame and including scientific information in news articles about environmental issues. This suggests that journalists are more likely to seek and convey scientific information that backs up risk assertion claims. However, risk framing is not common in environmental news. Sandman (2017) found in their analysis of environmental risk news stories that nearly 70% of articles did not discuss any risk information but focused more on conflict, blame, cost, and other immediate issues associated with the specific events being covered. Major and Atwood’s (2004) content analysis found a similar result; 63% of the news stories they examined did not mention risk within the context of the environmental issues. Kristiansen’s (2017) literature review of studies about media coverage of nuclear energy across countries suggests that the tendency to focus on immediate events rather than scientific information continues. Most media reports focus on the dreaded image of nuclear accidents rather than the probable benefits and detriments of the technology based on scientific information (Kristiansen 2017). A possible reason for the dearth of risk framing is that claims-making about environmental risks involves scientific uncertainty around the connections between present risks and future harms. It is challenging to acquire expertise on risks and translate the language of risk probability and likelihood into news content (Hansen 2013).

2.3 Research Design

2.3.1 Research Question

This paper builds on previous research to better understand the coverage of environmental risks by local news media and the factors that influence the incorporation of scientific information into such. In particular, it examines the relationships between claims makers, the inclusion of explicit risk claims, and the inclusion of scientific information in environmental news stories.

Based on the literature, this study hypothesizes that there is a positive relationship between the inclusion of specific risk claims and the provision of scientific information and that government officials are more likely to use scientific information in their claims than other claims-makers.

2.3.2 Case: Radford Army Ammunition Plant

The Radford Army Ammunition Plant (RAAP), located in Radford, Virginia, is the case study used for this analysis. The RAAP is an interesting and important case because it is the largest point source of toxic releases in the Commonwealth of Virginia and has been since at least 2001 (U.S. Environmental Protection Agency 2021b).

The RAAP, established in the 1940s, serves as a propellant manufacturing facility for the U.S. Department of Defense, originally constructed to fulfill military ammunition demands during World War II. Today, the plant is the only active military propellant manufacturing facility in the country. The RAAP is a major employer in the New River Valley region, with approximately 1,800 employees (Moxley 2021).

According to the U.S. Census Bureau's American Community Survey (2014-2018), as reported through the EPA's EJSCREEN, which is a screening tool that provides demographic profiles of the areas surrounding EPA-regulated facilities, about 29,214 people live within a 5-mile radius of the plant (U.S. Environmental Protection Agency 2021a). 89% of the population is white, and 96% are English-only speakers (U.S. Environmental Protection Agency 2021a), reflecting very low racial and ethnic diversity. Per capita income within that 5-mile radius was $25,950 in 2018, which is lower than the national average of $32,621 (U.S. Environmental Protection Agency 2021a; U.S. Census Bureau 2020). Employment in the three adjacent municipalities (the City of Radford, Pulaski County, and Montgomery County) is dominated by the Government (28%) and Manufacturing (17%) sectors (Virginia Employment Commission 2019).

According to the plant's own community relations plan released in 2004, more than 40% of community members interviewed (13 out of 30) said that their primary source of environmental information regarding the plant is conversations with RAAP staff and contractors, followed by news media (12 out of 30) (WPI 2004). While it is hard to generalize from those interviews due to the small sample size and time that has passed since they were conducted, these findings suggest that the neighboring communities considerably rely on informal and interpersonal communication channels when it comes to making sense of environmental issues associated with the RAAP facility.

The RAAP has been the top polluter in Virginia since 2001 (U.S. Environmental Protection Agency 2021b). According to the Virginia Toxics Release Inventory (TRI), the plant released 9.23 million pounds of chemicals in 2019, accounting for 33.7% of Virginia's total release to the air (fugitive and stack), water, and land (Virginia Department of Environmental Quality 2021). The majority of chemicals released on-site are nitrate compounds (9.1 million pounds). The plant's EPA Risk Screening Environmental Indicators (RSEI) score, which integrates surrogate dose data with toxicity weighting and the demographic characteristics of the surrounding area, was 1,972,476 in 2019. This score is exceptionally high compared to the national security industry median (33), Montgomery County median (313), Virginia median (9), and U.S. median (14) (U.S. Environmental Protection Agency 2019). The extreme difference between the risk score of the RAAP and the state and national medians is in part because a very small proportion of the TRI reporting facilities account for most of the environmental risks. In the last 13 years of TRI-reported data (2007-2019), approximately one-third of TRI facilities have risk scores of zero, despite chemical releases, while only 2.3 percent of facilities, including the RAAP, have risk scores of over 1 million (U.S. Environmental Protection Agency 2020). Nonetheless, it is clear that the RAAP is a major source of pollution.

In addition to underreporting their emissions prior to 2008 (Hammack 2008), the RAAP has a history of repeated violations of environmental permits. An article published in ProPublica in 2017 investigated the enforcement history of the plant through a Freedom of Information Act request and found that hazardous waste permit limits were violated at least 50 times between 1980 and 2017 (Lustgarten 2017). While planning is underway for a new incinerator, the plant successfully renewed its permit in 2021 for the open burning of waste, which is conducted roughly 2 miles away from a local elementary school (Hammack 2021; Lustgarten 2017).

Despite the seemingly high potential risks associated with the plant, more than 50% of the 451 respondents from the area that participated in a survey conducted as part of a Virginia Tech Appalachian Community Research class said they do not have any concerns about the RAAP and trust its risk management (Adams 2019). These favorable attitudes toward the plant may be linked to its history and stature as one of the primary employers in the region, employing over 23,000 workers at its peak during World War II (BAE Systems n.d.; Lustgarten 2017; WPI 2004). Positive perspectives on the RAAP may also be influenced by the tone and tenor of news reports covering the plant's environmental issues, given that news articles were identified as a primary information source for residents. This case study of the RAAP provides an opportunity to empirically explore the relationships between news media, community, and a facility that is a major source of local environmental risks.

2.3.3 Data Collection

This study uses individual full news articles as the unit of analysis. I conducted an extensive search to collect news articles reporting on environmental issues associated with the RAAP. I used a search string that included different combinations of words, including the plant's old name, to exhaustively capture all news articles about the plant while excluding irrelevant ones to the degree possible: "Radford Army Ammunition Plant" OR "Radford Army Plant" OR "Radford Ammunition Plant" OR "Radford Arsenal." News articles from 2000 to 2019 were gathered from a comprehensive newspaper database providing web-based access information (Access World News from NewsBank).

This initial scan yielded 2,315 results. Approximately two-thirds of the articles mentioning the plant were removed because they were either syndicated news or duplicated online versions. I then manually removed articles irrelevant to the plant's environmental issues, such as articles referring to the plant as the former employee's previous career, or a landmark to locate other places such as the City of Radford (e.g., 'Radford is home to the Radford Army Ammunition Plant'), habitats of fauna and flora, deer hunting, other community events, car accidents, articles related to the military bases without plant-specific information, and articles about the plant's union.

One hundred sixteen relevant articles were ultimately identified for further inclusion in the analysis. I developed a codebook based on three essential elements of news articles identified through the literature review and two basic elements: the inclusion of scientific information claims-makers, types of risk frame, the number of words, and publishing year. The codebook was further revised based on a pilot review of 12 randomly chosen articles. The codebook is attached as an appendix. After the codebook was confirmed, one of the researchers conducted manual coding on all 116 articles.

Coding reliability is deemed acceptable even with a single coder because the coding variables have only two possible states sharply differentiated (McHugh 2012). Furthermore, all articles were coded on three separate occasions to ensure intrarater reliability with a six-month gap between the first and second, and one-year gap between the second and third round. During the second coding round, the category of claims-makers was modified due to one of the claims-maker's type lacking across the articles. During the third round of coding, a few more articles were added as I decided to extend the timeframe from originally ending mid-December in 2019 to the full December 2019. Between rounds 2 and 3, 98% of the articles (112 out of 114, 2 articles added in round 3) were coded in the same way. The remaining 2% discrepancy is attributable to the expanded definition of one code. This falls within the minimum accepted reliability level for intercoder reliability (Lombard, Snyder-Duch, and Bracken 2002).

A news article was coded as ‘including scientific information’ if it refers to scientific information and data to support claims. I define scientific information as any scientific context that assists the public understanding of environmental issues portrayed in news articles. It will be difficult for the public to fully grasp environmental issues if journalists only report confrontations between the plant and community members over certain chemical discharges without explaining the potential health impacts of those chemicals. Therefore, the inclusion of scientific information here broadly ranges from simplistic descriptions of causal relationships, such as ‘It is generally known that exposure to lead compounds produced can cause serious health problems,’ to detailed scientific explanations referencing academic research. For example, when an article attributes the claim that there is no risk of chemical materials migrating off the RAAP site to specific research studies. Another example is an article reporting that the plant is the largest polluter in the Commonwealth, citing the DEQ’s TRI data. Articles were also coded as including scientific information when they mention the types of chemicals. An article coded as not including scientific information might report a claim that there is no risk of an accidental chemical leak without providing any source to support that assertion, such as details about the type or quantity of leakage.

Articles were also coded according to the claims-makers quoted. Any article could have multiple claims and claims-makers. I used Robinson’s (2002) typology of four groups of claims-makers appearing at the community level around local environmental issues: community activists, the news media, local corporate interests, and governmental officials. Although all four categories were used initially, only community activists, local corporate interests (the Radford Army Ammunition Plant in this case), and government officials (Virginia DEQ) have appeared as claims-makers with representative numbers of claims. The news media rarely made independent claims (i.e., editorialized on issues of environmental impacts). Thus, while I believe that the news media still had significant influence in this case by selecting whose claims are reported and what topics are discussed, I ultimately are not considering them as separate claims-makers for our purposes.

Articles were also coded according to the types of risk assertion frames applied. In the scientific community, risk is often understood to be the probability of dangerous events that could potentially harm people (Slovic, Fischhoff, and Lichtenstein 1980). However, news articles typically do not frame risk this way; news reporting of environmental risks tends to translate those probabilities into more simplistic causal relationships that are clearer to the public. For instance, articles replace probability with simple adjectives such as high, moderate, or low instead of specific figures, or discard the notion of probability altogether and only convey causal relationships like 'air pollution causes asthma in children.' Considering the unique nature of the risks reported in news articles, this paper uses Major and Atwood's (2004) definition: risk means both actual and potential harm. Articles are coded as risk-claiming when those actual or potential harms are explicitly claimed to exist. Such claims are distinct from general scientific claims, which are coded as the inclusion of scientific information. Articles are coded as risk-claiming only when claims-makers clearly argue that such actual and potential harms exist in the case area. For instance, an article is coded as 'risk-claiming' when it includes claims made by community activists pointing out the potential health impacts associated with the plant's discharge of toxic compounds. Another example is an article that reported findings from a drone test revealing levels of metal compounds higher than established health standards in the smoke from the plant's open burning. Similarly, articles are coded as risk-denying when actual or potential harms are explicitly claimed not to be present in the region. For instance, the article about the accidental chemical leaks noted above is coded as 'risk-denying' because the plant spokesperson claims there is no danger to anyone outside the plant. Another example of 'risk-denying' is a claim made by the RAAP that all of the plant's discharges are permitted under laws that create discharge limits protective of human health and the environment. It is also coded as 'risk-denying' when a scientist claims that the level of metals and volatile organic compounds in the air and soil downwind of the plant's open burning site are lower than existing health-based standards.

2.3.4 Data Analysis

Coded articles were examined using exploratory analysis and logistic regression models. The exploratory analysis provides a descriptive summary of how local news outlets report environmental risks, including how many articles reporting on environmental issues include scientific information, whose claims are reported, and what types of risk assertion frames are used.

In addition to the exploratory analysis, I employed a logistic regression model to estimate the relationships between predictors and the inclusion of scientific information in local news articles. Logistic regression models are used when dependent variables have dichotomous outcomes instead of continuous values. This model estimates two important factors influencing the inclusion of scientific information in environmental risk reporting: claims-makers and risk frames. In our analysis, the dependent variable is the inclusion of scientific information, which is represented as 1 (including scientific information) and 0 (not including scientific information). Claims-makers and types of risk assertion frames are included as independent variables because claims-making and framing are core components of the social construction of environmental risks. I separate types of risk framing into claiming and denying to see if they have discrete relationships with the inclusion of scientific information.

The number of words is included as a control variable because articles tend to report more information when they are longer. I also considered whether an article was published before or after 2008, as environmental concerns about the RAAP have been raised more frequently and specifically since 2008 when the plant was initially identified as the top polluter in Virginia after rectifying prior underreporting (Hammack 2008).

2.4 Results

2.4.1 Summary Statistics

Only 35.3% (41 out of 116) of news articles reviewed include scientific information and data in their reporting on environmental issues associated with the RAAP (see Figure 2-1). Some articles include more than one piece of scientific information, resulting in 51 instances across the articles reviewed.

Figure 2-1 Inclusion of Scientific Information

63% of the news articles reviewed include a claim or claims explicitly made by at least one claims-maker. As illustrated in Figure 2-2, 44.8% of the articles include claims from the Radford Army Ammunition Plant and Army spokespeople. 32.8% include claims made by officials with the Virginia Department of Environmental Quality (DEQ).

Only 25.0% include claims from community activists. 17.2% of the articles include claims from others, including unaffiliated local residents interviewed, various local officials and organizations (e.g., a member of the Montgomery County Board of Supervisors, an official at the Montgomery County Public Service Authority, the president of the Virginia Manufacturers Association, and a Blacksburg Mayor-elect), individual scientists including university scholars, and federal officials. 37% of the articles do not explicitly cite any claims-makers; most of those articles are short, briefly reporting on events or announcements without including direct claims from claims-makers.

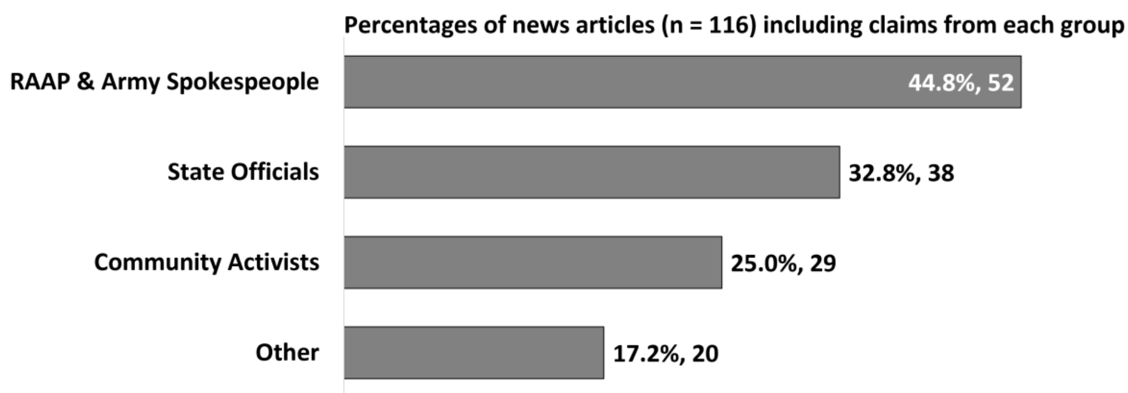

Figure 2-2 Claims-makers (Stakeholders Quoted in News Articles)

40.5% of the articles examined include claims explicitly asserting the existence or non-existence of risks, while 59.5% report on environmental issues without any risk assertions (see Figure 2-3). Of those that do address risks, an equal number (11.2% each) include explicit claims that the RAAP's environmental issues pose an actual or potential risk or voices both asserting and denying risks. 18.1% of articles include claims that the issues pose no or very minimal risk to the general public.

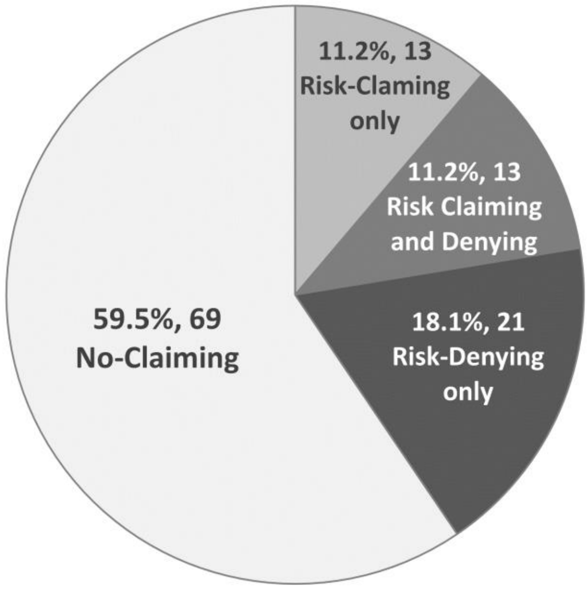

Figure 2-3 Risk Assertion Frame

(n = 116, Total number of news articles)

2.4.2 Binary Logistic Regression

Table 2-1 indicates that the logistic model used for this research is more effective than an intercept-only model because all three indicators of model evaluation (likelihood ratio, score, and Wald test) are significant (p<0.05).

Table 2-1 Overall Model Evaluation

Test	Chi-Square	DF	Pr > ChiSq
Likelihood Ratio	65.5002	7	<.0001
Score	54.9702	7	<.0001
Wald	30.7045	7	<.0001

A Hosmer-Lemeshow (H-L) Goodness-of-Fit test yielded a $\chi^2(8)$ of 4.1731 and was insignificant ($p > 0.5$), suggesting that the data fits the model well. In other words, the observed event rates match the expected rates (Table 2-2). Cox and Snell R^2 is 0.4360 and Nagelkerke R^2 is 0.5995.

Table 2-2 Goodness-of-Fit

Hosmer and Lemeshow Goodness-of-Fit Test			**Cox and Snell R^2**	**Nagelkerke R^2**
Chi-Square	DF	Pr > ChiSq	0.4360	0.5995
4.1731	8	0.8412		

Table 2-3 Validation of Predicted Probabilities

Association of Predicted Probabilities and Observed Responses			
Percent Concordant	91.0	**Somers' D**	0.819
Percent Discordant	9.0	**Gamma**	0.819
Percent Tied	0.0	**Tau-a**	0.378
Pairs	3,075	**c**	0.910

Gamma statistic, Somers's D, and c statistic show validations of predicted probabilities (Table 2-3). The Gamma statistic for the model stands at 0.819. This translates to a reduction of approximately 81.90% in errors when predicting which of two articles would contain scientific information, compared to random chance, by utilizing the estimated probabilities (DeMaris, 1992). Somers's D, a preferred extension of Gamma has the same value.

The c statistic, representing the ratio of articles paired with varying observed outcomes for which the model accurately predicts a higher probability for event outcomes than for non-event outcomes, is 0.910 in the present model. This signifies that in 91.0% of all potential pairs of articles, with one containing scientific information and the other not, the model correctly assigns a higher probability to those with scientific information. The c statistic, ranging from 0.5 to 1, indicates the performance of a model. A value of 0.5 suggests that the model is no more effective than random assignment of observations into outcome categories. Conversely, a value of 1 indicates that the model consistently assigns higher probabilities to observations with the event outcome compared to those without.

Table 2-4 shows the statistical significance of individual regression coefficients. RAAP was used as the reference group for the claims-makers, and claims denying the existence of risk were used as the reference group for the risk assertions. Both reference groups do not significantly associate with the inclusion of scientific information when compared to a baseline without any claims-makers or risk assertions.

State officials as claims-makers are a significant variable ($p<0.05$), and the risk-claiming assertion is highly significant ($p<0.001$), both positively associated with the inclusion of scientific information. Community activists as claims-makers are a significant variable ($p<0.05$) negatively associated with the inclusion of scientific information. When an article includes claims made by state officials, it is approximately 2.6 times more likely to include scientific information compared to when claims were made by RAAP. When an article includes claims made by community activists, it is about 91% less likely to include scientific information compared to claims made by

RAAP. When an article includes claims asserting the existence of environmental risks, it is approximately 3.5 times more likely to include scientific information compared to claims denying the existence of risk.

Table 2-4 Logistic regression analysis on inclusion of scientific information (n = 116)

Independent Variables	Estimate	Standard Error	Odds Ratio
Claims made by RAAP	0	-	1
Claims made by Community Activists	**-2.3855**	**0.7482**	**0.092****
Claims made by the State government	**0.9542**	**0.6100**	**2.597****
Claims asserting the existence of risk	**1.2667**	**0.9833**	**3.548*****
Claims denying the existence of risk	0	-	1
Published after 2008	0.7718	0.7715	2.164
Number of words	0.0031	0.0010	1.003***
Intercept	-3.9510	0.7084	

Note: **significant at $p < 0.05$; ***significant at $p < 0.01$.

2.5 Discussion and Conclusion

The way news media reports on local environmental risks plays an important role in shaping public perceptions of those risks. This study analyzed environmental news reporting on the largest point source of pollution in the Commonwealth of Virginia, the Radford Army Ammunition Plant (RAAP).

Only about a third of the news articles on environmental issues associated with the RAAP (35%) examined in this study include scientific information. This relative dearth of scientific information is somewhat surprising, given that environmental issues, including those associated with the RAAP, are typically scientific in nature. The lack of scientific and technical information on environmental risks in the news media could jeopardize public understanding (Reed, Hiles, and Tipton 2019; Romps and Retzinger 2019; Boykoff 2005). It may suggest that the consumers of such stories are not being provided comprehensive and scientifically grounded coverage of the issues purportedly being reported upon. Environmental reporting may be improved through the provision of more accessible scientific and technical information and through increased scientific literacy and expectations among the public that such information will be present.

Previous studies have found that governments and corporations are preferred sources of environmental claims due, at least in part, to their ability to organize and pre-package scientific information, which is often not as easy for ad-hoc and community organizations (Duan and Miller 2021; Comfort, Tandoc, and Gruszczynski 2020; Hedding and Riffe 2016; Benson and Wood 2015; Takahashi and Meisner 2013). Our findings further underscore this; 32.8% and 44.8% of the articles include a claim or claims made by the Virginia Department of Environmental Quality (DEQ) and the Radford Army Ammunition Plant, respectively. It is clear that journalists heavily rely on government and corporate sources when reporting on environmental risks. However, this may not necessarily reflect the ability to provide scientific information. Our logistic regression shows that when articles quote claims made by the Virginia Department of Environmental Quality (DEQ), they are 4.5 times more likely to include scientific information. Meanwhile, quoting claims made by the Radford Army Ammunition Plant does not make a significant difference. This shows that there might be a gap between the perceptions of corporations as eloquent scientific information providers and the actual use of their scientific claims. However, it is difficult to conclude it with the case of a single facility.

The DEQ is a key regulatory agency overseeing the RAAP, as well as the major producer of scientific information regarding the plant's environmental risks, including the TRI data and quarterly lead concentrations monitoring. The department also plays an intermediary role in providing information about the plant by posting and translating scientific documents about the RAAP's risks on its website. For instance, the department's website provides answers to frequently asked questions about the plant's open burning, which cannot be found on the plant's website. Another example is a technical report about the multi-pathway risk assessment of the plant's incinerators (BAE Systems 2020) posted on the DEQ website. While RAAP operator BAE Systems prepared and revised the technical document, the DEQ is the agency that reviewed it, asked for revisions, approved it, and posted it for public access. State officials and documents are the major claims-makers providing scientific information, even when generated by the plant.

In contrast, the logistic regression found that articles including community activists' claims are 84% less likely to include scientific information. This does not necessarily mean that community activists are less scientific or default to non-scientific claims by choice. Community activists in the area have regularly proposed the installation of air and drinking water monitors at the local elementary school to investigate the impact of chemical releases and open burning (Gangloff 2017; Mastrangelo 2017). This suggests that they are very aware of the importance of scientific information for understanding and addressing environmental risks but do not have access to the information or the capacity to produce it by themselves. Unequal access to scientific information—or the means to generate it—may be rectified through the provision of scientific assistance or support for community activists. There is significant room to improve the ability and capacity of stakeholders—and in particular community groups—to contribute scientific and technical information, which can both generate new data and richer understandings and elevate such organizations' voices given the journalistic norms of pursuing factuality and neutrality. More robust community or citizen science programs could go a long way toward helping groups to generate the scientific information necessary to advance their advocacy work. Involving community members and organizations can expand discussions about scientific evidence, generate new data, and contribute to evidence-based decision-making (Riesch and Potter 2014; Elwood and Ghose 2001). A study examining citizen science initiatives found that well-designed processes for involving communities and providing resources to assist them are vital in generating scientific information and impactful results (Cox et al. 2015).

However, an increase in the provision and sources of scientific and technical information in news media may not be sufficient if the overarching goal is to not only improve public understanding but also provide venues for deliberation and sense-making. In fact, a laser focus on increasing technical information may have unintended negative consequences; if the conveyance of scientific information becomes the sole best criterion for evaluating environmental news, it may come at the cost of the already unequal access other claims-makers have to news coverage. Beyond its role in conveying ostensibly factual information from government agencies and other stakeholders to the broader public, the media plays a critically important role as an arena for indirect and public deliberation among actors (Peters 1994). That is, the media must balance its roles in fostering both more informed and democratically-derived perceptions of environmental risks. This underscores the tug-of-war between the informing and public arena functions of journalism on environmental risks.

A re-examination of the centrality of traditional environmental risk frames could also contribute to improving the real-world risk communication reflected in news coverage by altering journalistic practices and activists' strategies. In this study, articles are 12 times more likely to include scientific information when they explicitly assert the existence of environmental risks. This concurs with previous studies' conclusions that adopting risk frames correlates with the inclusion of scientific information in environmental news reports. When environmental news is framed as a story of risk, reports are more likely to concentrate on explaining the wider background and implications of those risks. In contrast, when framed as an accident story, coverage is more likely to focus on what happened in the immediate course of the incident (Ryan, Dunwoody, and Tankard 1991). The application of a risk lens by the media can precipitate more comprehensive and informative coverage of issues associated with environmental risks.

However, as noted previously, community activists, such as those concerned with the RAAP, are more likely to be under-resourced and thus could be excluded from news coverage if risk frames are adopted, even though they are the major claims-makers asserting the existence of those risks. Instead of adopting a risk frame in an evidential way to prove how risky a situation is, community activists and other under-resourced claims-makers could use alternative or overlapping frames to draw attention to risks. Corner, Richardson, and Fenton (1990) found that audience responses to media messages about nuclear power are informed by not only the evidential frame, assessing arguments and evidence, but also other overlapping interpretative frames, including the civic frame, which judges according to balance and fairness. In other words, claiming risks does not always have to be underwritten with scientific evidence to prove those risks. Even if the RAAP's discharge of toxic chemicals is within regulatory standards, procedural violations, unreliable actions, and insufficient communication efforts may still be framed as potential threats by overlapping risk and civic frames.

Overall, the findings of this study largely concur with the findings of previous studies on governmental and risk frames. This study is significant in adding an empirical case to the small number of existing studies about the coverage of environmental risk in the news media. In addition, the results of this study give researchers caution that focusing on the provision of scientific information in the media to foster better public understanding can come at a cost, particularly when there is a lack of well-established environmental organizations or the capability of communities to access and produce risk knowledge. The disparities between governmental and industry claims-makers and community groups in their ability to generate scientific information imply that enhancing risk information in the media could stymie the inclusion of community voices and diverse perspectives.

One limitation of this study is the lack of establishment of causality. In particular, this study cannot verify whether journalists explicitly seek scientific information and obtain it most readily from the government or seek information from governments and that happens to be scientific information. That is, are government officials often regarded as the most credible and reliable sources due to the nature of their claims providing scientific information and evidence, or are they inherently viewed as more credible and happen to provide information that is scientific in nature? This limitation suggests a need for future studies that include qualitative interviews with environmental journalists to better understand their practices when reporting on environmental risks.

Furthermore, news coverage of scientific information is seemingly affected by a variety of journalistic elements ranging from macro-level factors, such as ownership and cultural atmosphere, to micro-level factors, such as the practices of particular journalists (Hansen 1994). Understanding how journalistic factors and the provision of scientific information on environmental risks are intertwined can support better risk communication through the media.

Future research is also needed to identify the needs of community activists and organizations to increase their access to scientific and technical information or the ability to generate that information. Better knowledge of how to support claims-makers who are pushed out of the news representation of scientific arguments can benefit public communication and understanding of environmental risks by strengthening the role of media as a venue for both knowledge-building and social deliberation.

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Appendix: News Article Codebook

Code Name	Definition
Inclusion of scientific information	
Yes	The claims made in the article refer to scientific information and data 1. Reference to general scientific knowledge or facts about causal relationships 2. Reference to data 3. Reference to scientific studies/literature 4. Reference to expert knowledge 5. Any other scientific information
No	None of above
Source of scientific information	
Expert interviews	Scientific information provided by interviews from individual experts
Academic research	Scientific information cited from academic literature
Government announcements & publications	Scientific information provided by government officials' interviews, announcements, and publications
Other	Other sources of scientific information
Missing	No explicit source

Claims-makers	
Radford Amy Ammunition Plant	The article quotes claims made by the Radford Army Ammunition Plant: Plant spokesperson, plant officials, plant operating company
Virginia State Government	The article quotes claims made by the Virginia Department of Environmental Quality
Community Activists	The article quotes claims made by community members who claim themselves as community activists or those who affiliated with environmental organizations
Other	The article quotes claim from claims-makers other than the plant, State government, and community activists
Risk assertion	
Risk-claiming only	The article includes claims asserting the existence of any actual or potential harm posed by the plant
Risk-denying only	The article includes claims denying the existence of any actual or potential harm posed by the plant
Both claiming and denying risk	The article includes both claims asserting risk and denying risk
No claiming	No risk claims made in the article
Etc.	
Date	Date of the article published

Word count	The number of words in the article
Headline/title	Headline/title of the article
Author	Author of the article

3 Influence of EPA's GenX Toxicity Assessment on News Media Topics

3.1 Introduction

The U.S. Environmental Protection Agency (EPA) published a draft toxicity assessment for GenX chemicals in November 2018 in response to growing concerns about PFAS contamination, particularly in regions affected by incidents related to GenX exposure. The publication of the EPA's toxicity assessment coincided with a period of heightened media coverage and public discourse surrounding PFAS contamination. Unlike traditional academic knowledge, regulatory science determining the acceptability of risks associated with synthetic chemicals is constructed through negotiations among scientists, policymakers, stakeholders, communities, and the public as they are expected to affect social, governmental, and regulatory actions (Demortain, 2017; Dendler & Böl, 2021; Jasanoff, 1994). Understanding the dynamics between newly generated risk assessment knowledge, media coverage, and public discourse is essential for informing effective risk communication strategies and regulatory decision-making processes.

This study employs structural topic modeling to analyze news media coverage of PFAS contamination during the timeframe surrounding the publication of the EPA's toxicity assessment for GenX chemicals. By examining changes in topic prevalence and content before and after the publication of the assessment, the study aims to elucidate the influence of risk assessment knowledge on media discourse and identify key themes and concerns in public narratives surrounding PFAS contamination. Through this analysis, the study seeks to contribute to a better understanding of how risk assessment knowledge shapes media coverage and public discourse on environmental risks, ultimately informing efforts to address PFAS contamination and protect public health and the environment.

3.2 Literature Review

3.2.1 Government-produced Toxic Chemical Risk Assessment

Government risk assessments are critical tools for informing public policy and protecting public health and the environment from the adverse effects of industrial chemicals found in food, water, air, and consumer products. The U.S. Environmental Protection Agency's Office of Pollution Prevention and Toxics (OPPT) conducts chemical risk assessments under the Toxic Substances Control Act (TSCA), significantly revised by the Frank R. Lautenberg Chemical Safety for the 21st Century Act in 2016. This revision provides OPPT with increased authority to regulate pre-existing chemicals and introduces tighter deadlines for risk evaluation processes (Vandenberg, 2016).

The risk evaluation process under TSCA includes several steps in order to inform regulatory actions and public safety measures: prioritization of chemicals, risk evaluation to determine if a chemical presents an unreasonable risk, and risk management (National Academies of Sciences, 2021). In contrast to many fields of basic research, environmental toxicology has frequently been shaped and prompted by public policy articulated in legislation (Landis et al., 2005). Many countries, like the U.S., Canada, and Europe, have mandated toxicity testing or toxicity risk assessment. In the United States, the EPA is commonly regarded as establishing significant regulations. However, numerous states may impose even more rigorous standards for various chemicals. States may vary in their methodologies for establishing toxicity limits or conducting risk assessments.

3.2.2 Roles and Impacts of Government-generated Risk Assessment

Desired Roles of Risk Assessment

Government-produced risk assessments serve several critical roles for the public, government, and broader legislative and decision-making contexts. These assessments are foundational for creating evidence-based policies and regulations, providing guidance at various administrative levels, and ensuring public transparency and engagement.

Risk assessments are essential for crafting policies aimed at protecting public health from the adverse effects of industrial chemicals found in air, water, food, and consumer products. These assessments guide federal decision-making to regulate chemical exposure and ensure safety standards are met to mitigate health risks (EPA, 2018).

Comprehensive federal risk assessment frameworks provide broad guidance for federal and state-level decisions (Vandenberg, 2016). Risk assessments conducted by federal agencies serve as vital sources of authoritative information for guiding public health policies and decisions across different administrative levels (Effio et al., 2013). For instance, risk assessments under TSCA influence legislative reforms, enhancing the EPA's authority to regulate chemicals and prompting updates to risk evaluation procedures to align with current scientific and industrial practices (National Academies of Sciences, 2021).

Additionally, risk assessments facilitate effective risk communication for informing the public about the risks associated with chemical exposures by enhancing scientific credibility (Balog-Way et al., 2020; Heath & O'Hair, 2010). This transparency helps build trust and enhances public engagement in the regulatory process.

Limited Studies on the Impact of Risk Assessment

While the legal basis for risk assessment of toxic chemicals pursues several public and regulatory benefits, there have been limited studies bridging these normative benefits and actual practices (Shaffer, 2021). While there are studies on the implications of scientific revision of risk assessment methods, scopes, and settings (Chen & Li, 2007; Mishra et al., 2022), research on roles and social and regulatory impacts of risk assessment is limited to theoretical explorations.

Shaffer (2021) highlighted that there are almost 30 distinct federal risk evaluation and assessment procedures across various federal agencies, mandated by statute, focusing on the toxicity of chemicals in areas such as food and drug, consumer products, hazardous waste sites, and ecology. However, it is noteworthy that fewer than half of these procedures directly lead to risk management actions or regulatory measures. The dynamics among the availability of risk assessment knowledge, public understanding and awareness of risk assessment, and social and regulatory actions have not been empirically documented, other than with historical reviews or theoretical lenses (Sexton, 2013; Stanton & Harvey, 2017).

On the other hand, the impact of risk assessments does not have a direct link to social and regulatory actions to explore. Risk assessments as regulatory knowledge sometimes trigger public and government actions, while other times no significant impact. Meanwhile, some actions are taken without concrete risk knowledge provided by federal or state agencies, or even against them. In the post-modern view of science and policy, risk assessment is sometimes considered knowledge that can be produced and transmitted by communities and civil societies without being confined to expert systems (Garlick & Levine, 2017). In this light, risk assessments produced by governments are neither readily prioritized nor directly translated into public policy (Richter et al., 2018). Instead, risk knowledge is recognized as a new type of resource that can be mobilized to influence or elicit social and regulatory changes when pursued by communities and civil societies (Hess, 2016).

3.2.3 Effective Communication of Risk Assessment in News Media

To serve their desirable roles, government-produced risk assessments need to be engaged with stakeholders affected by said risks and deliberated or accepted. Studies have claimed that the communication of risks derived from governmental assessments requires an understanding of public perceptions and the ethical responsibilities involved rather than standing alone (Jasanoff, 1987; Lee, 1986; Lyytimäki et al., 2009). This includes framing scientific data and risk assessments within narratives that are comprehensible and relevant to the public (Henwood & Pidgeon, 2016). When communication of risk fails, this does not only facilitate public understanding or engagement but also impedes public risk perception (Cohen Hubal et al., 2010; Lu, 2017).

News media is one of the most accessible methods for communication of risk assessment. The news media plays a pivotal role in shaping public perception of environmental risks. Studies have shown that news coverage can significantly influence public understanding and policy regarding environmental and health risks associated with chemical exposures (Andrews & Caren, 2010; Jenner, 2012; Wakefield & Elliott, 2003). Media attention, combined with scientific understanding of chemical risks, can drive policy changes, especially at the state and local levels (Matus & Bernal, 2020). Despite the declined influence of news media, recent studies and surveys still discover that news media is still the most used channel for risk knowledge and information for the public (Newman et al., 2021; Zhang et al., 2022).

However, there have been struggles to communicate risks in news in a more reflective and inclusive manner of different societal perspectives while still keeping scientific accuracy and credibility (Beck et al., 2016; Giulio et al., 2008; Heath & O'Hair, 2010; Lee, 1986; Lyytimäki et al., 2009; Neris et al., 2019; Ramondt & Ramírez, 2020).

DiMaggio et al. (2013) detail two important reasons for studying news texts to understand how certain issues are discussed in society. First, news coverage reproduces representations about an issue from elites, such as institutional actors or public intellectuals, and embodies the assumptions and narratives those authorized speakers employ to frame the current topic with quotes or paraphrases from what they speak (DiMaggio et al., 2013). Second, news media influences the views of the reading public and contributes changes in the views of the public by setting agendas about the issue (DiMaggio et al., 2013).

3.3 Research Method

Based on the existing literature or lack of, this study explores the dynamics among newly generated risk assessment knowledge, communication of risk and risk knowledge in media, and social and regulatory actions elicited by the new assessment. I will examine these two research questions:

1) What topics are discussed in news texts about environmental risks during the timeline surrounding the production of the new risk assessment?
2) What is the effect of newly available risk knowledge on the prevalence of these topics?

3.3.1 Structural Topic Modeling

To answer the research questions, this study employs Structural Topic Modeling (STM). Structural Topic Modeling (STM) is a statistical technique used to discover the latent thematic structure in a large corpus of text data. This method extends traditional topic modeling by incorporating metadata that might influence the topical content of documents. Structural Topic Modeling (STM) has a strength in its availability to examine the relationship between topics identified and metadata of each document. Metadata can include information such as author details, publication date, document type, or any other categorical or continuous variables relevant to the study (Roberts et al., 2013). I will generate a 'risk assessment' variable with binary values (before and after the publication of the EPA's toxicity assessment) and examine the effect on topics.

To better understand topics and high-probability words identified by structural topic modeling, random 15 news articles corresponding to each topic will be analyzed line-by-line and documented. Topic labels will be assigned based on the analysis of news documents. In addition, an excerpt example related to the topic label and containing high-probability words will be provided.

3.3.2 Data Collection and Processing

I use two databases—Newsbank’s Access World News and Factiva—to include as many digital-native news outlets as possible, in addition to traditional print-based news outlets. According to Gilbert & Watkins's (2020) comparison of different news data aggregators, Access World News has the most coverage of digital-native news outlets although it is not exhaustive. However, Access World News lacks major news organizations like The New York Times, The Los Angeles Times, and The Washington Post (Gilbert & Watkins, 2020), which are available in Factiva. Hence, I will use both databases as best practices to capture news articles from both born-digital outlets as well as major news companies.

I will collect every article that contains any reference to PFAS and family chemicals from the databases between August 2018 and February 2019 because the EPA published a new draft toxicity assessment for GenX chemicals on November 15, 2018. While covering a longer timeframe allows researchers to better understand broader topics and trends over time, this involves too many external events and factors difficult to isolate from the effects of new risk assessments on the topic. Due to the lack of best practices for time period selection, this study covers three months before and after November 2018.

I include virtually any article (including news stories, news analysis, and opinion pieces) that referred however marginally to the PFAS and their family chemicals in forms of their chemical names (PFAS, PFOS, PFOA, forever chemical(s), GenX).

The near-duplicate articles overlapping more than 90% were removed using the Jaccard index, remaining longer news texts. Each news article will serve as a unit of analysis. Texts will be prepared for the topic model by removing common English stop words, which are words that provide no information about the content of the text. The next step is model specification and implementation. In this step, the number of topics needs to be decided. In addition, I will review trends of news articles to identify external factors affecting the number of articles and topic prevalence.

3.4 Case: EPA's Draft Toxicity Assessment for GenX Chemicals

The EPA's Draft Toxicity Assessment for GenX Chemicals was published as a response to the GenX drinking water crisis in eastern North Carolina. The chemicals named GenX are Hexafluoropropylene oxide-dimer acid (HFPO-DA) and its ammonium salt, which was considered a safer substitute to ammonium perfluorooctanoate, known as PFOA (Hopkins et al., 2018). GenX is one of the Per- and polyfluoroalkyl substances (PFASs), so-called 'forever chemicals' that are persistent organic pollutants that can pose health risks to exposed individuals, including liver damage, increased risk of thyroid disease, cancer, and a decrease in fertility (Fenton et al., 2021). The GenX drinking water crisis began when the chemical was detected in drinking water sourced from the lower Cape Fear River near the Chemours Fayetteville Works complex in North Carolina. The Chemours complex is a spin-off from DuPont, which had been discharging GenX as a byproduct of its manufacturing process since at least 1980, according to North Carolina Governor Roy Cooper's press office (North Carolina Governor Roy Cooper's Press Office, 2017).

In Fayetteville, North Carolina, the Chemours Facility produced GenX and stated that all wastewater from the plant would be captured and shipped off-site for disposal purposes (Hopkins et al., 2018). However, in 2015, GenX was identified downstream from the facility in their wastewater discharge (Strynar et al., 2015). In 2016, concentrations in drinking water 90 miles downstream were found to be up to 4,500 ng, which is almost 100 times greater than the EPA's health advisory level (Sun et al., 2016). GenX was subsequently reported in the drinking water surrounding the Cape Fear River, affecting more than 200,000 residents (Hopkins et al., 2018). The state was able to stop the Chemours facility from releasing any more GenX in their wastewater, and drinking water concentrations have since declined enough to meet the state's health goals (Hopkins et al., 2018). However, the community's serious concerns about GenX risk remain and raise questions about how long Chemours (and DuPont) released GenX and similar compounds, and whether people have been harmed by drinking water tainted by these chemicals. At the heart of the debate is uncertain scientific and regulatory knowledge of the environmental risks posed by these chemicals. Multiple studies have reported on the detection of GenX in the Cape Fear River and describe the potential risks posed by them, in addition to the growing body of academic studies that indicate that PFAS compounds are more toxic than previously believed (Fenton et al., 2021).

The detection of the chemical in drinking water elicited a series of reactions from communities, civil societies, stakeholders, and experts, including collective claims and actions. High uncertainty about the health impacts posed by GenX led these reactions to focus particularly on the availability of and demand for scientific and regulatory knowledge to determine the level of harm the chemical potentially poses. Facing uncertainty about what scientific knowledge could be used to determine whether the level of GenX in the drinking water causes serious harm, the community made significant efforts, from petitions to lawsuits, to pursue better knowledge about the risk by pressing regulatory agencies and the State department. In response to the growing concerns, the

U.S. Environmental Protection Agency published a draft toxicity assessment of these chemicals, which indicated that the chemicals pose more health risks than previously believed (U.S. Environmental Protection Agency, 2021).

3.5 Results and Discussions

3.5.1 Article Trends over Time

Between August 2018 and February 2019, for a 7-month period, there were a total of 1,175 news articles containing the search strings published. Figure 3-1 shows noticeable surges in late October 2018 and Mid February 2019. On October 23-24, 2018 there were increased articles about election campaigns including candidates' campaigns about addressing environmental risks of PFAS which bring attention back to some high-profile PFAS contamination across the nation. The surge in February 2019 is due to the EPA announcing its first-ever comprehensive nationwide Per- and Polyfluoroalkyl Substances (PFAS) Action Plan. Based on the review, I created control variables indicating 1) election news (containing election-related keywords) and 2) PFAS action plan (containing the keyword "PFAS" and "action plan*").

Table 3-1 Monthly Number of Articles

Month-Year	Number of articles
August 2018	173
September 2018	122
October 2018	196
November 2018	141
December 2018	172
January 2019	139
February 2019	232
Total	1,175

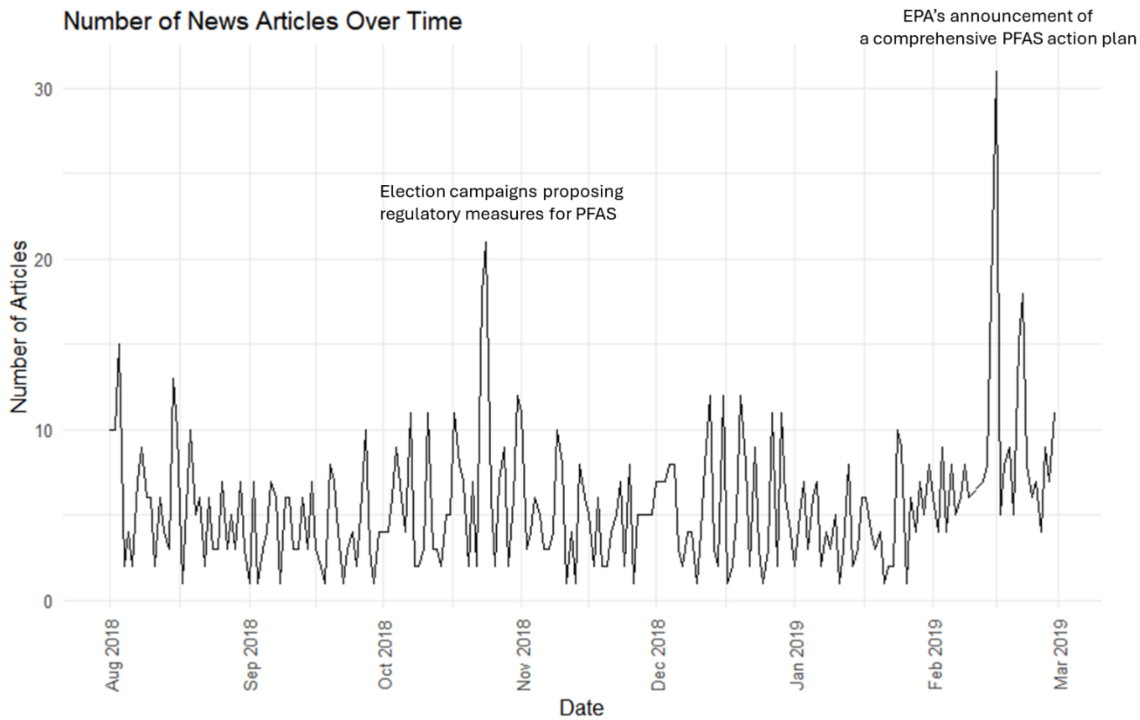

Figure 3-1 Number of News Articles over Time (Aug 2018 - Feb 2019)

3.5.2 Optimal Number of Topics

To determine the number of topics, diagnostic values by the number of topics are created. Results provide several metrics to evaluate how well different numbers of topics model your data (Figure 3-2).

Held-Out Likelihood is a measure of how well the model predicts unseen data. The graph shows that the curve is leveling off as the number of topics increases. An "elbow" in the curve, which is the point after which there are diminishing returns in likelihood improvement with additional topics appears around 10 to 15 although there is no dramatic change.

Residuals graph shows how the residuals decrease as the number of topics increases. The graph flattens approaching 20 topics, indicating that increasing topics beyond this doesn't substantially improve the residuals.

Semantic Coherence measures how semantically consistent the high-probability words in each topic are. Higher (closer to 0) is generally better. The semantic coherence appears to be decreasing as the number of topics increases, suggesting that the topics are becoming less coherent. A higher number of topics is not yielding more coherent topics, so a smaller number of topics might be more meaningful in this context.

Lower Bound graph shows the variational lower bound on the per-word log likelihood. Generally, the higher (closer to 0), the better the model. The lower bound is increasing with the number of topics, but this should be balanced against the other metrics, especially semantic coherence.

The Held-Out Likelihood suggests an improving model fit up until around 15 topics, where the curve begins to plateau. This implies that after 15 topics, the model is not gaining much additional predictive power.

The Residuals are consistently decreasing, but the rate of decrease slows as adding more topics, and it flattens out past 20 topics. This indicates that adding more topics isn't necessarily providing a better fit for the data.

Semantic Coherence shows a clear downward trend as the number of topics increases. This suggests that while the model technically gets a better fit with more topics, the interpretability of the model is suffering. Coherence is crucial for ensuring the topics are meaningful and distinct.

The Lower Bound plot shows improvement as the number of topics increases, but this metric should be balanced against semantic coherence for interpretability.

Given these observations, while 15 topics might offer a slightly better model fit according to the held-out likelihood and lower bound, the decrease in semantic coherence suggests that the topics might become less interpretable and meaningful. Thus, I determined to use 10 topics to strike a balance between a reasonable model fit and maintaining topic coherence, making the topics more likely to be interpretable and distinct.

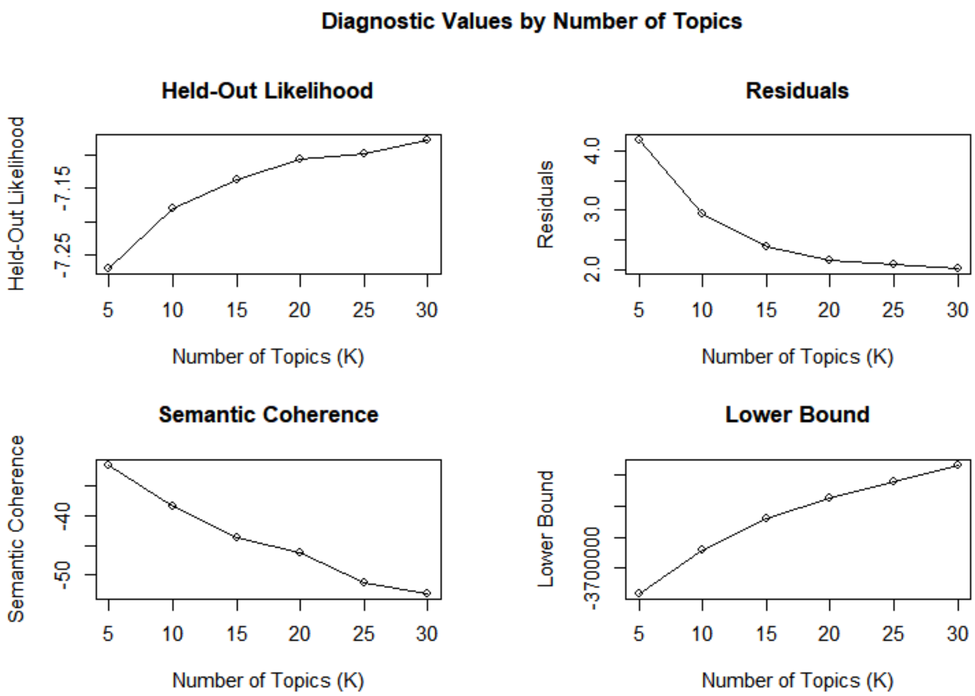

Figure 3-2 Diagnostic Values by Number of Topics

3.5.3 Topic Prevalence

Table 3-2 shows the highest probability words and FREX words. FREX weights words by their overall frequency and how exclusive they are to the topic (Roberts et al., 2019).

Table 3-2 Topic Identified with Highest Probability Words

Topic		Highest Probability	FREX	Proportion
1	EPA Regulatory Actions on PFAS	water, pfas, chemic, epa, drink, health, level	wheeler, epa, pfoa, exposur, blood, pfna, mcl	22.65%
2	Vermont Landfill Controversies	landfil, wast, state, vermont, dump, leachat, water	leachat, casella, newport, coventri, memphremagog, quebec, anr	6.67%
3	Michigan School PFAS Water Contamination	school, grand, township, haven, robinson, place, michigan	robinson, pinckney, huizenga, haven, ottawa, elementari, grand	4.87%
4	PFAS Contamination in Various Local Communities	pfas, water, test, well, contamin, use, health	wurtsmith, parchment, foam, airport, vike, mdeq, bottl	19.56%
5	New Hampshire's Pease Tradeport PFAS Contamination	new, hampshir, state, work, health, peopl, peas	peas, portsmouth, upton, shaheen, amico, hassan, longjohn	8.36%
6	Michigan Election Campaigns	michigan, educ, elect, state, top, goal, offic	macomb, occup, bachelor, top, questionnair, wayn, onlin	2.78%
7	Public Oversight of Politicians	counti, year, order, can, domest, say, one	murkowski, carey, pfa, domest, haggerti, violenc, bradi	6.77%
8	North Carolina GenX Contamination	water, chemour, genx, state, pfas, fear, chemic	chemour, genx, cape, fayettevill, wilmington, cfpua, bladen	8.32%
9	Michigan Environmental Legislation and Government Actions	state, michigan, fund, bill, work, water, year	whitmer, snyder, legislatur, pipelin, schumer, gov, budget	11.53%
10	Water Management in Cities with PFAS Contamination	water, citi, system, treatment, well, council, contamin	marana, gaylord, steglitz, city', marinett, johnson, lazi	8.49%

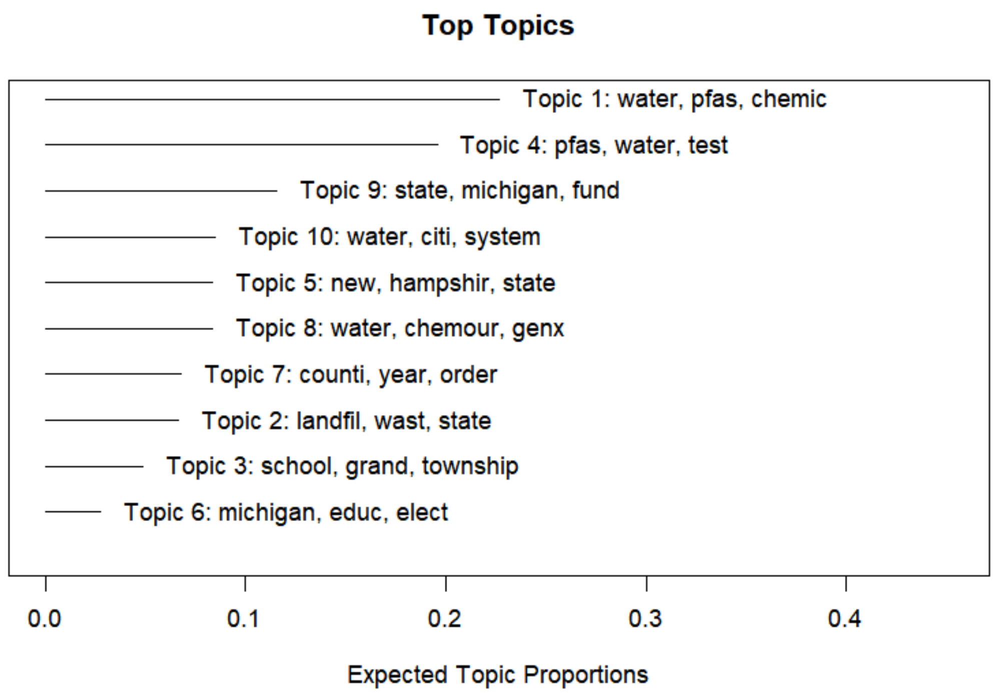

Figure 3-3 Expected Topic Proportions

3.5.4 Topic Analysis

Topic 1: EPA Regulatory Actions on PFAS

News articles corresponding to Topic 1 are regarding the EPA's environmental policies and regulatory actions or lack of them regarding the public health concerns tied to PFAS, particularly in drinking water. The articles are not specifically bound to specific geographies but on a national scale.

The articles specifically discuss the urged or expected regulatory actions for EPA, including proposing regulatory determinations, developing new methods for detecting PFAS, and considering listing PFAS as hazardous substances under the Superfund program to facilitate cleanups. Many articles criticize the EPA for moving slowly.

Articles repeatedly mention the health risks associated with PFAS, including cancer, thyroid disease, and other serious health problems. The persistence of these chemicals in the environment and their nickname as "forever chemicals" highlight the severity and longevity of the contamination issue.

Various senators and EPA administrators are mentioned as key figures in the struggle to regulate PFAS. The transition from EPA chief Scott Pruitt to Andrew Wheeler is noted, with a continuity of concerns regarding PFAS regulation during their tenures.

Excerpt:

> […] the Environmental Protection Agency said Thursday it would move toward setting safety limits for a class of highly toxic chemicals contaminating drinking water around the country. […] Acting EPA Administrator Andrew Wheeler released an "action plan" for dealing with the long-lasting substances, which have been linked to health threats ranging from cancer to decreased fertility. The perfluoroalkyl and polyfluoroalkyl substances, known collectively as PFAS, have turned up increasingly in public water systems and private wells. Wheeler said the agency's plan would help communities monitor, detect and address PFAS pollution. But environmentalists and some members of Congress said the strategy wasn't aggressive enough on dealing with the chemicals […]. (Flesher and Knickmeyer, 2019)

Topic 2: Vermont Landfill Controversies

News articles corresponding to Topic 2 discuss environmental and community concerns related to landfill expansions in Vermont, particularly regarding the environmental and health impacts of leachate and PFAS contamination. The articles primarily cover debates, regulatory actions, and community responses.

Multiple environmental groups, particularly DUMP (Don't Undermine Memphremagog's Purity), and city councils have been mentioned regarding their engagement in significant opposition to the landfill's expansion due to concerns over PFAS concentration in leachate affecting water quality and health. Community efforts focus on preventing landfill leachate from entering Lake Memphremagog, a critical water source for both Vermont and Quebec residents. Specific entities such as Casella (landfill operating company) and ANR (Agency of Natural Resources) and locations in Vermont like Newport or Coventry are involved in the discussions and regulatory processes reported in the news.

Excerpt:

> Newport City and a local group called DUMP have joined an international appeal […] [regarding] the expansion of the Casella landfill in Coventry, in the watershed of international Lake Memphremagog.
> […] The Vermont Department of Environmental Conservation issued a solid waste permit on Oct. 12 allowing the expansion of the landfill. The permit requires both the state and Casella to research how to remove "emerging contaminants" called per- and polyfluoralkyl substances (PFAS) and other chemicals that have an effect on human health from the leachate from the landfill's double liners. They also are to research how to stop or reduce those chemicals from entering the landfill. (Smith, 2018)

Topic 3: Michigan School PFAS Water Contamination

News articles in Topic 3 explore public concerns, government and political responses, and policy discussions following the discovery of PFAS in the drinking water at Robinson Elementary School in Grand Haven, Michigan. These articles include keywords about geographies like Michigan, Robinson township, Grand Haven, Pinckney, Ottawa, as well as the name of a politician like Huizenga.

Excerpt:

> Huizenga praised the state of Michigan's response to PFAS substances found in water supplies across the state. The chemicals linked to cancer and other diseases were discovered Monday in Robinson Elementary School's water supply. Davidson said the issue stems from deregulation of corporations, and said he would work in Congress to implement measures to prevent the "next PFAS." Low levels of the substances were also discovered in August in the water system that serves the remainder of Grand Haven schools and Spring Lake Public Schools. No traces were detected in sampling this month. (Sinn, 2018)

Topic 4: PFAS Contamination in Local Communities

Articles in Topic 4 discuss the widespread concern about PFAS (per- and polyfluoroalkyl substances) contamination across various communities, detailing governmental responses, community impacts, and individual case studies. While these contamination cases are not limited to specific geographies, some cases in Michigan are salient such as the cases associated with a former paper mill in Parchment, Viking Corp. property, or former Wurtsmith Air Force Base in Michigan which led to the MDEQ (Michigan Department of Environmental Quality) as one of the FREX words.

The news coverage records the various communities' responses to PFAS findings in the water system and drinking wells and demands for more comprehensive testing. They also report State and local governments' efforts to address PFAS contamination by distributing bottled water and filters to affected residents or collecting outdated and toxic firefighting foam.

Excerpt 1:

> Thirteen residential wells were found to contain toxic compounds that exceed a federal health advisory for drinking water. On Friday, the Michigan Department of Environmental Quality released results of private well tests in Cooper Township, which show 86 homes are contaminated with some amount of per- and polyflouroalkyl substances known as PFAS. Private wells in Parchment and the township were tested after high amounts of PFAS were found entering Parchment's water supply July 26. Homes within a 1-mile radius of Parchment's contaminated groundwater wells were tested. Most are within a wellhead protection area established in 1994. Results for 107 homes were released Friday, while the DEQ waits for results to come back for an additional 40. All homes in the study area are being supplied with bottled water. (Barrett, 2018)

Excerpt 2:

> […] Concentrations of perfluoroalkyl and polyfluoroalkyl substances (known as PFAS) above the U.S. Environmental Protection Agency's advised limits — in some places up to 371 times above it — have been found in wells located on and off [Cannon Air Force] base, according to a Tuesday news release from the New Mexico Environment Department and New Mexico Department of Agriculture. Two types of PFAS — known as PFOS and PFOA — were present in firefighting foams used at Cannon to extinguish petroleum-based fires […]. (Hayden, 2018)

Topic 5: New Hampshire's Pease Tradeport PFAS Contamination

The news articles in Topic 5 discuss PFAS contamination in New Hampshire, particularly focusing on the contamination found in Pease International Tradeport. Significant amounts of news coverage report political leaders push for stricter regulations and better environmental protections. These also cover discussions about legislative efforts to tackle PFAS contamination, including testimony before Congress, local advocacy by residents, and the involvement of national groups aiming to influence policy changes to protect public health. This led to the FREX words specifically highlight individuals central to the Pease contamination case, such as Andrea Amico, a prominent community advocate in Portsmouth, or politicians like Jeanne Shaheen, Maggie Hassan, Matt Longjohn, and Fred Upton.

Excerpt:

> Portsmouth Environmental activist Andrea Amico […] co-founded Testing for Pease and has advocated for years for state and federal environmental regulators to set more protective measures to protect people from PFAS exposure, like the one at the former Pease Air Force Base. Two of her children and her husband drank water from a contaminated city-owned well at the Pease International Tradeport before it was shut down.
> […] As much as she enjoyed the State of the Union, Amico's favorite part of the night was attending a Senate dinner with Shaheen. […] "She introduced me to so many other senators and it was nice to see members of the government where you could talk to them in a more relaxed setting […]. Almost every single senator I met had issues with PFAS in their state and could relate to the work I was doing," Amico said. (McMenemy, 2019)

Topic 6: Michigan Election Campaigns

The articles in Topic 6 discuss detailed coverage of various elections within Michigan, including races for governor, attorney general, and other state and local offices, particularly focusing on candidate platforms including PFAS as one of the frequently discussed policy proposals along with other State policy goals such as education and vocational training initiatives. This topic is identified due to the heavy political concerns about PFAS contamination in Michigan, leading to relevant policies suggested by candidates. The highest probability words and FREX words are across the candidate platforms.

Excerpt:

> If elected, Jim Stamas would bring 10 years of experience to the Legislature. The Republican was elected to the Michigan House in 2008 and has served three terms. He began serving his first term in the Michigan Senate in 2014. Should the Midland native gain election on Nov. 6, he would be serving his second and final four-year term in the Senate […].
>
> A growing concern in the 36th District and across the state has been PFAS contaminated water. Oscoda and Alpena, both cities in the 36th have PFAS contaminated water. (Kennett, 2018)

Topic 7: Public Oversight of Politicians

Articles related to Topic 7 cover news about public and media oversight of general or specific state-elected officials. They encompass letters addressed to these individuals or indirectly to news editors, interviews and comments, and news coverage of annual addresses. This topic is identified due to consistent word choices across these types of news articles, often mentioning PFAS and environmental regulations as part of proposed laws or regulations by these politicians. The highest probability words and FREX words encompass other policy-related terms that may not directly relate to PFAS and environmental regulations as they appear simultaneously in articles with PFAS keywords.

Excerpt:

> […] Expecting us to believe that Whitmer was singularly responsible for job losses and tax increases in Michigan is senseless and insulting. […] The Flint water crisis, under Republican jurisdiction, is still not ratified. Wolverine products, again under their watch, continue to pollute. […] And, now, we have statewide PFAS contamination […]. (DeWaard, 2018)

Topic 8: North Carolina GenX Contamination

The articles from Topic 8 discuss the ongoing environmental issues related to PFAS (per- and polyfluoroalkyl substances) contamination in North Carolina, focusing particularly on the actions of the Chemours Company and its handling of GenX contamination, which affected the Cape Fear River and surrounding areas like Wilmington or Bladen. The coverage illustrates the regulatory, community, and legal responses to the contamination.

Excerpt:

> Despite Chemours' efforts to prevent additional contamination of water and air around its Fayetteville Works facility, Cape Fear River Watch and the Southern Environmental Law Center filed suit Wednesday in federal court alleging long-term contamination of groundwater seeping from beneath the complex means the company remains in violation of the federal Water Act.
> The suit also alleges violations of the Toxic Substances Control Acts centered around the air emissions of GenX and other per- and polyfluoroalkyl substances (PFAS) at the company's Fayetteville Works plant about 100 miles up the Cape Fear River from Wilmington […]. (Wagner, 2018)

Topic 9: Michigan Environmental Legislation and Government Actions

The articles corresponding to Topic 9 focus on the legislative actions and governmental policies, particularly highlighting the roles of key figures such as Governors Gretchen Whitmer and Rick Snyder, and discussing the impact of legislation on state environmental policies, including those related to environmental policies concerning PFAS.

Excerpt:

> Michigan governor Gretchen Whitmer delivered her first State of the State address at the capitol in Lansing on Tuesday, Feb. 12. The governor addressed many important issues during her speech […].
> "[…] We also have issues with PFAS contamination throughout the state. There are lots of communities who are struggling to figure out how to get clean water to their constituents, and I think the state has a role in helping assist them in finding ways to pay for it, creating some regulatory clarity around what's required of those water providers, then assisting people who have wells or private water sources in figuring out whether or not their water is safe to drink and then helping them fix that problem if it's not. […]. (McAllister, 2019)

Topic 10: Water Management in Cities with PFAS Contamination

The articles in Topic 10 cover a range of issues primarily associated with water management regarding PFAS contamination in various cities, especially focusing on the role of local councils and their decisions on water systems. The articles report various city councils' decisions on water system upgrades, treatment installations, and responses to public health concerns as well as infrastructure upgrades, like the installation of new water treatment systems and the renewal of water mains.

Topic 10 is differentiated from Topic 4, which also discusses water contamination issues affecting various communities, as it specifically focuses on water management and systems rather than contamination and concerns in general.

Excerpt:

> Ann Arbor officials are proceeding with plans to annex 88 more "township islands" into the city. The City Council voted 9-2 Monday to OK submitting the annexation petitions to the state boundary commission for approval, with 1st Ward reps Jeff Hayner and Anne Bannister opposed. It's a move that has been met with resistance from some township residents concerned about paying higher property taxes, tens of

> thousands of dollars in utility connection fees, and new bills for water and sewer services they say they don't need because they have functioning wells and septic systems.
>
> […] As for those concerned about threats to the city's municipal water supply, including toxic chemicals such as dioxane and PFAS, Ramlawi said he recently toured the city's water treatment plant and the city has exceptional staff taking a hard look at those issues.
>
> He said he's confident the city's drinking water coming from the Huron River, which has some PFAS in it both before and after treatment, is just as safe as anything anyone can get from a well […]. (Stanton, 2018)

3.5.5 Discussion of Topic Prevalence

National Topics Versus Specific Contamination Cases

Topic 2 (Vermont Landfill Controversies), Topic 3 (Michigan School PFAS Water Contamination), Topic 5 (New Hampshire's Pease Tradeport PFAS Contamination), and Topic 8 (North Carolina GenX Contamination) are tied to specific contamination cases while Topic 4 (PFAS Contamination in Various Local Communities) covers different cases across the country. High-profile PFAS contamination cases during the time period make independent Topics due to the salience of repeatedly mentioned geography and individual names tied to the cases while Topic 4 combines more general top words shared by multiple cases.

High Frequency of Topics Related to Michigan

Topic 3, 6, and 9 are specifically tied to the State of Michigan. This is likely to be due to the fact that during the period between May 2018 and April 2019 Michigan had the most contaminated sites according to EWG (Environmental Working Group) and the Social Science Environmental Health Research Institute at Northeastern University's

PFAS Contamination Site Tracker (Walker, 2019). According to the map, Michigan had 192 known contamination sites as of May 2019, followed by 47 cases in California and 43 cases in New Jersey. However, California and New Jersey did not make individual cases despite the second and third largest cases they have.

High Frequency of Topics Related to the November 2018 Election

The analysis time period includes the 2018 Gubernatorial Election and Midterm Elections, including various other state and local elections, such as for Michigan's state Senate and House of Representatives. PFAS environmental risks appeared during the time as one of the policy concerns, which resulted in Topic 6 (Michigan Election Campaigns) and Topic 7 (Public Oversight of Politicians) surrounding the election. Election campaigns about PFAS were particularly salient in Michigan due to the large number of contamination during the time as detailed above.

3.5.6 Estimated Effects of EPA’s Draft Toxicity Assessment for GenX Chemicals

Estimated Effects of Risk Assessment Publication

Figure 3-4 shows the topic proportion trends over time for each topic. The x-axis represents time by year and month, and the y-axis shows the average topic proportion, which is the average prevalence of topics across all articles for each month. While many are not salient enough or have no clear pattern, some topics show changes in topic proportion over monthly changes.

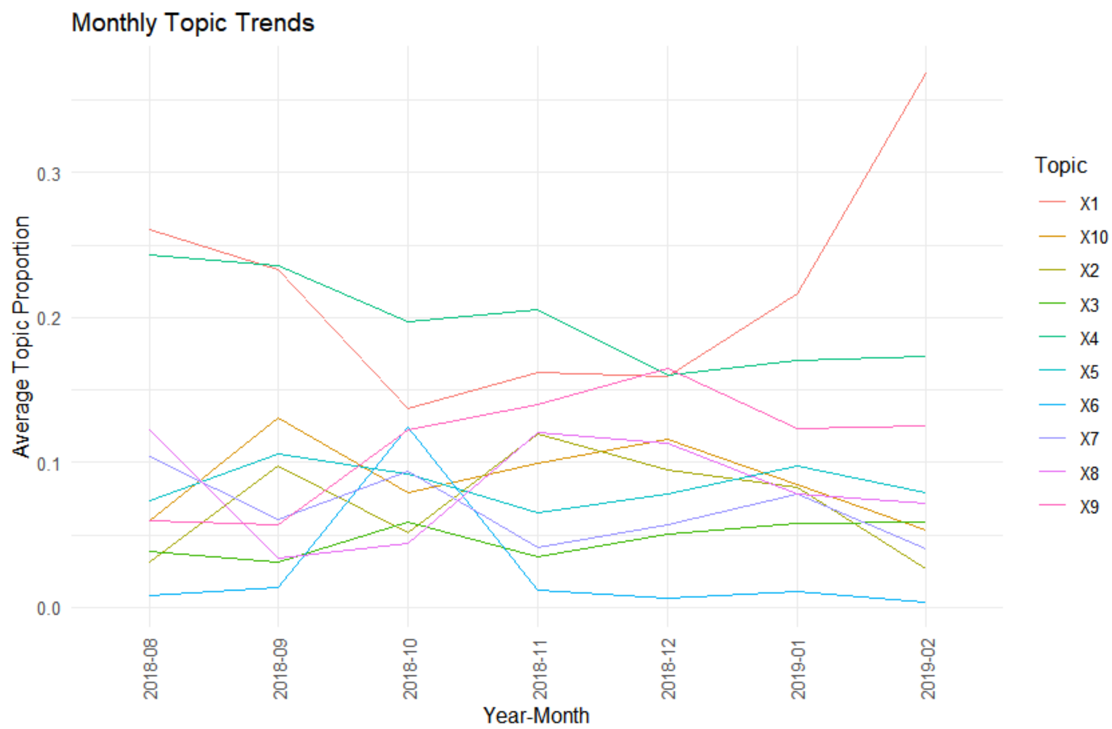

Figure 3-4 Monthly Topic Prevalence Trends over Time

I conducted an analysis of the estimated effect on topic prevalence to isolate the impact of toxicity assessment publication. This analysis is based on a logistic normal regression on the simplex of topic proportions, enabling the examination of how specific factors increase or decrease the prominence of topics (Roberts et al., 2016).

To control compounding factors that influence topic prevalence, I created metadata indicating whether the news article includes election campaigns or the EPA’s action plan announced in Feb 2019. Although the election was held on 8 November 2018, and the plan for creating an action plan was announced on February 14 2019, news articles including these keywords are not exclusively limited to this timeline as election campaigns and demands for action plan had been important topics regarding PFAS environmental risks. That said, there are clear surges closer to the time of November 9 2018, and February 14 2019 for each topic respectively as visible in Figure 3-4.

Table 3-3 shows the results of estimated effect analysis between the EPA's publication of a draft toxicity assessment for GenX and topic prevalence. Without control variables, Model 1 indicates that publications of the EPA's toxicity assessment increased the prevalence of Topic 1 and decreased the prevalence of Topics 6 and 7. However, the significance of these effects reduced once election campaigns and action plans are controlled in Models 2 and 3. Meanwhile, the publication of the toxicity assessment decreases the prevalence of Topic 4 and increases them of Topics 8 and 9 consistently across the models.

Table 3-3 Estimated Effects

	Topic	Toxicity Assessment	Election Campaign	Action Plan
	Model 1			
1	**EPA Regulatory Actions on PFAS**	**0.04677***	-	-
2	Vermont Landfill Controversies	0.011345	-	-
3	Michigan School PFAS Water Contamination	0.005582	-	-
4	**PFAS Contamination in Various Local Communities**	**-0.05520****	-	-
5	New Hampshire's Pease Tradeport PFAS Contamination	-9.484e-05	-	-
6	**Michigan Election Campaigns**	**-0.048977*****	-	-
7	**Public Oversight of Politicians**	**-0.035704****	-	-
8	**North Carolina GenX Contamination**	**0.03816***	-	-
9	**Michigan Environmental Legislation and Government Actions**	**0.04587****	-	-
10	Water Management in Cities with PFAS Contamination	-0.007914	-	-
	Model 2			
1	EPA Regulatory Actions on PFAS	0.03343	-0.14540***	-
2	Vermont Landfill Controversies	0.009269	-0.045011*	-
3	Michigan School PFAS Water Contamination	0.005087	-0.001920	-
4	PFAS Contamination in Various Local Communities	**-0.06415*****	-0.15287***	-
5	New Hampshire's Pease Tradeport PFAS Contamination	0.007782	0.106577***	-
6	Michigan Election Campaigns	-0.035799	0.189634***	-
7	Public Oversight of Politicians	-0.03250	0.02247	-
8	**North Carolina GenX Contamination**	**0.03373***	-0.04684*	-
9	**Michigan Environmental Legislation and Government Actions**	**0.05151*****	0.12789***	-
10	Water Management in Cities with PFAS Contamination	-0.008511	-0.054323*	-
	Model 3			
1	EPA Regulatory Actions on PFAS	0.007315	-0.139898**	0.369632***
2	Vermont Landfill Controversies	0.01393	-0.04371*	-0.06460*
3	Michigan School PFAS Water Contamination	0.0100406	-0.0006929	-0.0400101
4	PFAS Contamination in Various Local Communities	**-0.05733****	-0.15918***	-0.10394**
5	New Hampshire's Pease Tradeport PFAS Contamination	0.006474	0.101390***	0.026295
6	Michigan Election Campaigns	-0.035236	0.194427***	-0.008160
7	Public Oversight of Politicians	-0.02956	0.02474	-0.05104
8	**North Carolina GenX Contamination**	**0.03842***	-0.04583	-0.02078
9	**Michigan Environmental Legislation and Government Actions**	**0.05360*****	0.12846***	-0.07513*
10	Water Management in Cities with PFAS Contamination	-0.007792	-0.060359**	-0.033654

3.5.7 Discussion of Estimated Effects

Topic 8: North Carolina GenX Contamination

Increased topic prevalence in North Carolina GenX Contamination is likely to be because of a proposed consent order among stakeholders in the community, two weeks after the publication of the toxicity assessment. News articles reporting this consent order explicitly mention the EPA's toxicity assessment as the reason for the fast-paced progress with the order.

On November 21, 2018, collaborative efforts between state environmental regulators, Cape Fear River Watch, and Chemours resulted in a proposed consent order aiming to restrict the discharge of per- and polyfluoroalkyl substances (PFAS) such as GenX. The agreement also obligated Chemours to offer affected residents water or treatment solutions for mitigating high PFAS levels, alongside a substantial civil penalty.

Additionally, on November 27, 2018, the Department of Environmental Quality reached a consensus with Chemours and Cape Fear River Watch on another proposed consent order targeting PFAS contamination impacting wells and the Cape Fear River. This order further mandated Chemours to diminish GenX air emissions and ensure permanent replacement drinking water sources for specific regions.

Moving into December 2018, the North Carolina Department of Environmental Quality finalized their outlined measures to tackle GenX and other PFAS within the lower Cape Fear River, in accordance with the terms established on November 21. These actions notably included the ongoing capture of all process wastewater from operations at the Fayetteville Works facility for disposal off-site.

Topic 9: Michigan Environmental Legislation and Government Actions

Similar to the North Carolina GenX case, Michigan made governmental actions and environmental legislation addressing PFAS issues. While news articles reporting these actions did not attribute to the EPA toxicity assessment as the direct cause of these actions, they do mention the assessment to emphasize the significance of health risks from PFAS.

On December 13, 2018, there was an expansion of residential well testing for PFAS in Ottawa County, Michigan, prompted by initial tests indicating contamination. The Michigan Department of Environmental Quality initiated additional testing in the area to pinpoint the source and scope of the contamination.

A week later, on December 20, 2018, concerns surfaced regarding Michigan's standards for safeguarding drinking water from PFAS. Questions were raised about the adequacy of the existing standards in ensuring human health protection against PFAS exposure.

Towards the end of the month, on December 29, 2018, Governor Rick Snyder of Michigan signed a $1.3 billion budget legislation addressing various priorities, including environmental cleanup efforts. Although not directly targeted at PFAS mitigation, this legislation indirectly impacts the allocation of funds and resources towards addressing PFAS contamination and related cleanup initiatives.

Topic 4: PFAS Contamination in Local Communities

While it is not clear the link between the EPA's toxicity assessment and PFAS Contamination in local communities, this finding ties back to the literature review emphasizing that risk knowledge is not automatically translated into public policy or prompting legislative and government actions but needs to be recognized and mobilized to bring policy changes (Garlick & Levine, 2017; Hess, 2016; Richter et al., 2018). Although the assessment is likely to influence community concerns, whether communities are aware of the publication of new risk knowledge is not visible. In addition, even if they are aware, there are various levels of readiness across communities to make progress toward legislative and regulatory actions which may affect attention from news media to write news articles.

3.6 Limitations and Conclusion

This study conducts structural topic modeling to explore the dynamics between PFAS environmental contamination and media coverage, particularly regarding the influence of newly generated risk assessment knowledge on topic prevalence. Through structural topic modeling and estimated effect analysis, the study has identified key topics in news media related to PFAS contamination and examined how the publication of the EPA's toxicity assessment for GenX chemicals impacted their prevalence.

The findings indicate that the publication of the EPA's toxicity assessment appears to have influenced topic prevalence on certain PFAS contamination cases when it coincided with communities' concerns and discourses being mature enough to make progress toward legislative actions.

However, this study also highlights several limitations that warrant consideration. The reliance on news media data may introduce biases, and the use of structural topic modeling may not capture all nuances or emerging themes in the data. Additionally, while efforts were made to control for confounding variables, other factors may have influenced the relationship between the toxicity assessment and topic prevalence.

Despite these limitations, the findings contribute to a better understanding of public discourse surrounding PFAS contamination and the role of risk assessment knowledge in shaping media coverage. Moving forward, it is essential to continue monitoring media discourse on PFAS contamination, incorporating diverse sources of data such as EWG's contamination case database, and considering the broader socio-political context to inform effective risk communication and policy-making efforts.

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4 Toxics Release Inventory Database in the News

4.1 Introduction

This study aims to deepen our understanding of environmental regulation by information disclosure by looking at the U.S. Environmental Protection Agency's (EPA) Toxic Releases Inventory (TRI) program. TRI is a mandatory environmental regulation program that tracks and discloses designated toxic chemicals and is the most renowned information disclosure program in the United States. In this paper, I particularly examine informational intermediaries of the program who bridge the gap between data disclosed by the federal agency and the public in general. The users of the TRI data and their ways of invoking TRI data for making claims in the news media will be identified.

4.2 Literature Review

4.2.1 Regulation by Information Disclosure

Regulation by information disclosure (also known as "informational regulation" or "regulation by revelation") is generally defined as "rules requiring mandatory disclosure of information on […] operations or performance of regulated entities to third parties, such as workers, consumers, shareholders, or the public in general" (Case, 2001, p. 10775). Regulation by disclosure has two main components: making information accessible and supporting decision-making (Yadin, 2019). The ultimate goal of information disclosure is to support better decision-making by deterring undesired behavior (Cortez, 2018).

Many environmental laws explicitly place duties on federal agencies to make information available to the public, including the Clean Air Act, the Safe Drinking Water Act, the Emergency Planning and Community Right-to-Know Act, the National Environmental Policy Act, the Toxic Substances Control Act, and the Federal Insecticide, Fungicide, and Rodenticide Act (Cortez, 2018; Vladeck, 2007). The underlying assumption of these laws is that 'information can change behavior' according to EPA's former General Counsel (Cortez, 2018). Theoretically, the target for behavioral changes could be the recipients of information, regulated entities, or both. Recipients of information can decide where to live, what to eat, or what to drink to prevent exposure to pollution and toxins by considering given information about their surrounding environment. Taking collective actions to put pressure on regulated entities could be another decision they can make. Regulated entities can also make decisions about their manufacturing processes, waste discharge and treatment, and other environmental performance to avoid public pressures and negative impacts on their profits, market share, or reputation (Fung et al., 2007). In the context of environmental regulation, however, information disclosure broadly tries to leverage the threat of public pressure to change the undesirable behavior of regulated entities instead of narrowly helping general citizens to make better decisions (Craswell, 2013; Esty, 2004; Florini, 2013).

4.2.2 US EPA's Toxics Release Inventory (TRI) Program

The Toxics Release Inventory (TRI) is one of the most successful informational regulation programs in the United States (Fung & O'rourke, 2000; U.S. Environmental Protection Agency, 1997, 2000). TRI is a mandatory environmental regulation program that tracks and discloses the management of certain toxic chemicals listed as potential threats to human health and the environment. U.S. Facilities releasing the designated chemicals must report how much each chemical they release to the environment or manage through recycling, energy recovery, and treatment annually. The information submitted by facilities is compiled in the Toxics Release Inventory database open to the public to inform regulated facilities, federal, state, and local governments, researchers, and the public.

TRI stands as one of the key elements of the Emergency Planning and Community Right-To-Know Act (EPCRA). The EPCRA passed into law in 1986; it was precipitated by the Bhopal disaster in 1984, in which a gas leak accident at a pesticide plant in Bhopal, India, caused more than 5,000 deaths and 500,000 injuries (Sanjay Kumar, 2023). This notorious accident brought public focus to the potential chemical hazards and highlighted the gap in public knowledge regarding the utilization, emissions, and transfers of harmful chemicals, which prompted the creation of the EPCRA. The law seeks to provide information on hazardous chemical storage and release into the environment to protect human health and the environment, and help advance local preparedness for unexpected chemical emergencies.

As one of the earliest disclosure programs, the TRI has been applauded as an effective example of regulation via disclosure (Bui & Mayer, 2003; J. T. Hamilton, 1995; Khanna et al., 1998; Konar & Cohen, 1997; Patten, 2002; U.S. Environmental Protection Agency, 2000). Initially, the TRI program significantly impacted firm-level emissions (Cohen & Viscusi, 2012). Between its establishment in 1988 and 1995, it resulted in a 45% decrease in the discharge of toxic chemicals listed in the inventory (Fung & O'Rourke, 2000). Media interest in those early years and the resulting threat of negative publicity appeared to have a powerful impact on companies (Fung et al., 2007). As a result, TRI is recognized as one of the most successful policy instruments of environmental protection in the United States. The success of TRI inspired EPA as well as other federal agencies to adopt a range of disclosure policies and publish a variety of different information and data to enhance policy goals (Cortez, 2018; Robinson et al., 2009).

It is noteworthy that the original petitions for mandatory disclosure of toxic releases were not primarily focused on changing facilities' behaviors and reducing pollution (van den Burg & Mol, 2008). The primary rationales for EPCRA and the TRI program stressed the intrinsic value of knowing about community hazards attenuated after the Bhopal accident (Fung et al., 2007; Hamilton, 2005). The goal of the TRI program at the time was centered on meeting the public right to know about potential pollution exposures; hence it was not designed to pursue behavior changes of polluting facilities originally. Even though the unintended success in reducing toxic chemical emissions has made the program an “evolutionary bridge between the idea of information as a public right and information as a means of reducing risk,” how and why the TRI made the success remained relatively unclear other than anecdotal explanations (Graham, 2002, p. 17). There has been scant understanding of pathways through which information disclosed under the program makes its way to the public and has regulatory impacts (Cohen, 2001; Karkkainen, 2000; Kraft et al., 2011; Stephan, 2002). The limited knowledge about information dissemination makes it challenging to improve or modify the program for better regulatory outcomes despite concerns about the effectiveness of the program after the early shock phase (Bae et al., 2010; Esty, 2004; Fung et al., 2007).

4.2.3 Role of Intermediary Groups in Information Dissemination

Despite the earlier successes of TRI in fostering pollution reduction, researchers have gradually found flaws in the program's design, and curbed their enthusiasm that disclosure policies could be a panacea. The general public's knowledge of the TRI program and data is limited, and disclosed information about toxic pollution has remained relatively uninfluential in individuals' market decisions and community actions (Fung et al., 2007; Kraft et al., 2011; Lynn & Kartez, 1994).

Atlas's (2007) survey of 1,292 residents in two counties found that there was very low awareness among the public of the existence of TRI data, or even the existence of local TRI facilities or their release of toxic chemicals. About 50-70% of the TRI facilities were recognized by no one and each remaining facility was recalled by an average of only 0.8-2 percent of the 1,292 people surveyed (Atlas, 2007). Kraft et al.'s (2011) survey of TRI reporting facilities revealed that the facilities rarely or never receive any contact or inquiry from communities about their TRI information.

The limited public knowledge of TRI raises a question about the target recipients of information disclosed and the pathways through which disclosure programs make an impact. Scholars have found evidence that intermediary groups such as civil society organizations, community organizations, and independent research groups play critically important roles in facilitating the flow of TRI data to the public (Cortez, 2018; Esty, 2004; Hess, 2007; Leong & Hazelton, 2019; Lynn & Kartez, 1994; Sage, 1999; World Bank, 2000).

Translating voluminous TRI data into usable information requires specialized abilities to acquire, understand, and analyze the data, which individual citizens may not be equipped with (Kuh, 2021). In their study exploring the status of TRI usage in the public and private sectors, Lynn & Kartez (1994) concluded that effective public access to TRI information requires the efforts of intermediary actors who bridge individual needs and the data. The study found that TRI data is most useful when formatted as summary and interpretive reports prepared by citizen organizations rather than in the formats presented by the EPA (Lynn & Kartez, 1994). Community groups typically reorganize data to more directly address pertinent issues and problems, and incorporate additional information that gives meaning and context (Lynn & Kartez, 1994).

Targeting intermediary groups as the major users of information disclosure programs suggests a major shift in the government's role in information disclosure from controller to facilitator (Cortez, 2018). Craswell (2013) calls this "government-aided disclosures (GADs)," in which the government creates a baseline for disclosure but allows potential users to utilize the information dynamically or go beyond the baseline in some way. Although the agency's duties in gathering and publishing data do not drastically change, now much more weight should be on ensuring data quality and enabling the private and non-profit sectors to maximize its uses (Fung et al., 2007).

Leong & Hazelton (2019) point out that one of the conditions for mandatory disclosure programs to cause change is providing data appropriate for information intermediaries or other intended users. However, there is little consensus around what data are appropriate for intermediaries or not.

There has been no systematic exploration of who intermediary groups are, what information these intermediaries use, at which aggregation level data serves those users the best, and how this information needs to be presented. (Cortez, 2018; Leong & Hazelton, 2019). Although the EPA suggests academic institutions, community and citizen groups, government organizations, industry, financial firms, and media/journalists as current and potential users, these are more like a collection of anecdotes rather than a systematic list (U.S. Environmental Protection Agency, 2013).

4.2.4 News Media as a Channel for Augmenting Environmental Information Disclosure

There are different types of intermediary groups, including advocacy organizations, industries, research groups, state and local government agencies, but not all of them are equally bridging the gaps between TRI data and the public. News media has a unique place as one of the information intermediaries as well as a channel through which intermediaries can deliver information they translate from raw data.

The media has a strong advantage when it comes to increasing public knowledge about toxic chemical information due to its accessibility to the broader public, particularly when the level of public awareness about disclosed data is low. Mennemeyer et al. (1997) found that the mere releases of hospital mortality rates had no significant impact on patients' visits to the hospitals until newspapers reported the said mortality rates, which led to a 9% reduction in hospital visits. The authors speculate that public disinterest or unawareness in disclosed data happens when the way data is presented is inconsistent with what potential users value, or the presented data is too general to carry much value and weight. The public was largely unaware of or disinterested in the existence of mortality data until news media reconstructed it to be more personalized and relatable (Mennemeyer et al., 1997). News media played an active information intermediary role in this case.

However, the role of the news media in information disclosure goes beyond acting as intermediaries. Even if intermediary groups such as non-profit organizations or community groups process and repackage TRI data to provide meaningful information to the public, it is challenging to deliver that information without conduits. This is particularly the case with environmental and health-related coverage. Environmental information, in general, is often not easy for the public to access or understand due to its complex nature (Coyle, 2005; Hansen, 2013). Members of the wider public tend to rely on television and newspapers to evaluate environmental information instead of sorting through complex environmental data directly (Boykoff, 2009; Leiserowitz et al., 2010). Despite a decline in readership, news media still remain a significant and influential source for environmental information, leading to increased information-seeking behavior or activism, while social media does not show the same significance or shows mixed results (Chung et al., 2020; Santos & Wong-Parodi, 2022; Zhang & Skoric, 2018),

One phenomenon that explains this high influence of news media is the "more-and-more" phenomenon, originally suggested by Lazarsfeld et al. (1968). Contrary to the common belief that the increased number of social and alternative media platforms disperses public attention from traditional media, scholars have found that heavy consumption of news from social media is a significant indicator predicting higher consumption of legacy media as well (Bergström & Jervelycke Belfrage, 2018; Martin & Schoenbach, 2016; Martin & Sharma, 2022; Riffe et al., 2008). People receive information simultaneously or consecutively through different mediums, rather than subscribing to only one type. According to a recent study conducted by the Pew Research Center, social media does not replace traditional news consumption; instead, it serves as a primary avenue through which people access news (Walker & Matsa, 2021). Even if they access environmental information via social media, they verify the information with traditional news media. Social media users perceive news stories published by news outlets to be more credible than the same news shared by their social media friends (Tandoc, 2019). Traditional media are generally perceived as more credible than social media platforms for environmental and health topics (Johnson & Kaye, 2015; Viviani & Pasi, 2017).

The combination of these studies indicates not only that news media is still influential source of environmental information, but also information is perceived as credible when it makes the news. Even if intermediary groups produce and publish TRI-related information, it may only reach limited audiences unless released through news media, which narrows the impact of information disclosure.

4.3 Research Design

4.3.1 Research Questions

Previous research has not thoroughly examined how users utilize disclosed regulatory data and the best practices for federal agencies to provide and maximize the use of such information (Cortez, 2018; Fung et al., 2007; Graham, 2002). This paper aims to better understand users of the TRI program, one of the most renowned regulation-by-disclosure tools in the United States. Specifically, it examines informational intermediaries of the program and their methods of using TRI data to make claims in the news media, which serves as a channel for augmenting the impact of disclosure.

This study asks the following questions:

1) What is the current status of news coverage of TRI data?
2) Who are users of the TRI program that make claims in the news by using the disclosed data?
3) How do users invoke or present the TRI data?
4) Among the users, who are informational intermediaries of the TRI program based upon their use of the disclosed data?

4.4 Research Method

This study employs a content analysis of online and print newspaper articles that contain claims referring to the EPA's TRI data. The content analysis method is suitable for systematically examining patterns in news texts and exploring meanings attached to those patterns.

4.4.1 Data Collection

Online and print newspaper articles are the primary data in this study. Written news articles are chosen over television because they offer space for various stakeholders to make claims and provide richer contextual information.

This study considers two units of analysis: 1) individual newspaper articles and 2) individual claims in those news articles citing or quoting the TRI data. The research sample consists of news articles published from 2017 to 2021 that contain keywords related to the Toxics Release Inventory. Six search strings were used to collect news articles: "toxics release inventory," the original name of the TRI data, and "toxic release inventory," which is the widely used misnomer of TRI, ["toxics release" AND "Environmental Protection Agency"], ["toxic releases" AND "Environmental Protection

Agency"], ["toxics release" AND "EPA"], and ["toxic release" AND "EPA"], in case the word 'inventory' is replaced with other vocabularies such as data or information. Articles written in English and published in the United States were collected.

Both Factiva and Newsbank databases were searched to capture as many articles as possible. Factiva covers major national news publications, such as the New York Times, and independent news companies, such as ProPublica. Newsbank's strength is its inclusion of small and locally based newspapers. In total, 329 articles from Newsbank and 38 from Factiva were collected.

An initial review of the collected news raised concerns about significant amounts of duplicated or near-duplicated content. These vary from identical articles written by the same authors published in multiple outlets to syndicated papers reproduced using exact excerpts from the same press releases or national wire services with one or two original paragraphs added. These duplicates could distort content analysis by overrepresenting certain users, geographies, and methods of presentations when the total sample is relatively small. Thus, this study eliminates duplicated or near-duplicated articles. Filtering processes consist of two steps. First, I manually removed articles with the same titles published within a seven-day span and written by the same authors, only remaining the longest ones. Second, the Jaccard index is employed to measure lexical similarity among documents and detects reused passages (Pradhan et al., 2015; Qurashi et al., 2020). I used the textreuse R package to calculate the Jaccard index between pairs of documents and generate a matrix (Mullen, 2020). The Jaccard index ranges from 0 to 1 (no similarity to identical match). Although the similar previous study concluded that the pairs of documents with Jaccard index above 0.70 showed high similarity with only negligible differences, careful scrutiny in this study suggested that the threshold for near-duplicated articles in our data is 0.52. Paired articles with the Jaccard scores above 0.52 contain almost overlapping identical paragraphs whereas articles below score 0.52 have different sentences, passages, and structures. Even though some articles below 0.52 share one or two overlapping paragraphs likely from news syndicates, they have sufficient original paragraphs that are not negligible and distinct one from another. The news coverages with Jaccard scores higher than 0.52 are removed remaining the longest articles. This filtering processes left us with 222 articles.

4.4.2 Data Analysis

A content analysis of print and online news articles was conducted to identify major users and their ways of invoking TRI data. The content analysis systematically examined text data to discover significant patterns (Riffe et al., 1998). This analysis looked at the number of news articles reporting TRI data and trends by year to gain a comprehensive understanding of how claims invoking the TRI data are present in the news media, which serves as a channel to deliver the TRI information to the broad audience and enlarge the impact of information disclosure.

After that, exploratory coding was conducted to develop a coding scheme, as there is no exhaustive list of TRI users or their methods of presenting TRI data in prior literature. In the first round, all the users mentioning TRI-related information and the forms in which they present the data were coded with quick descriptions of methods without unified categories. After the first coding round, all the codes were reviewed, categorized, and organized into a code book. I used this codebook to code all of the news articles again and compare the results with the first time to readjust the categories. The final categories and codes developed through this process include: 1) Claims-makers (Environmental organizations, TRI reporting facilities, US EPA, Researchers and experts, State government, Investigative news from other outlets, and Others); 2) Geographic levels of TRI release aggregation (Facility, State, City/county, USA, Industry, Multi-states, Zip code, River, and Town levels); and 3) Forms of data presentation (Amount of releases, Trend over time, Incorporated with other data, Rank, Descriptions and implications of the TRI program, Errors and limitations of the TRI data, Particular facility's current and historical failure to report TRI, Share of releases accounted among peers, and Others).

4.5 Results

4.5.1 The Status of TRI News Coverage

There was relatively little TRI data coverage during the five-year research period, with an average of 44 articles per year and 222 articles in total. This is very little considering the number of facilities mandatorily reporting to the TRI; more than 22,000 facilities, which generated 3,426,433,844 lb of 490 designated toxic chemicals in 2019. However, only 56 news articles reporting on TRI data were published in 2021, which is the year in which the 2019 data was released.

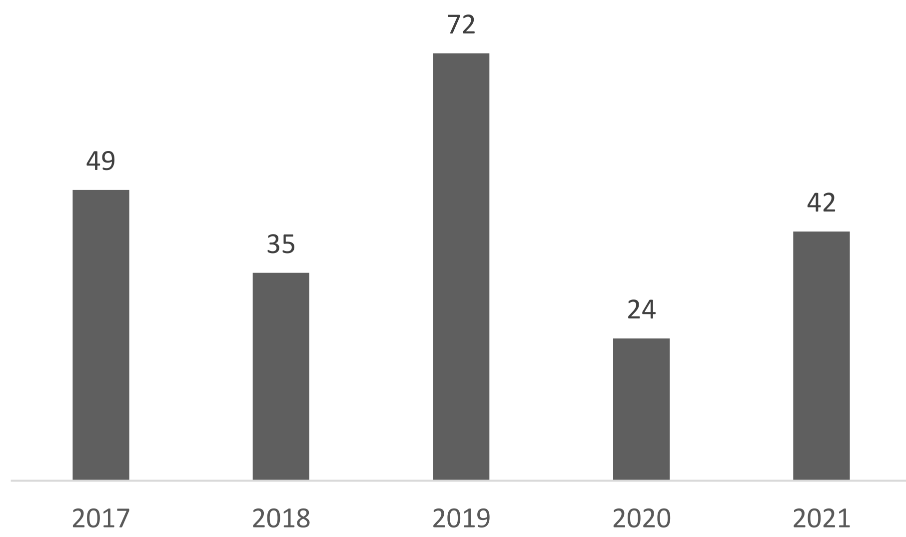

Figure 4-1 Total Numbers of TRI News Coverage (2017-2021)

4.5.2 Stakeholders Utilizing TRI Data to Make Claims in the News

Of the 222 articles containing information about TRI, 62.2% do not have quotes or citations from specific claims-makers. These articles refer to TRI data directly without referring to any intermediary claims-makers or sources.

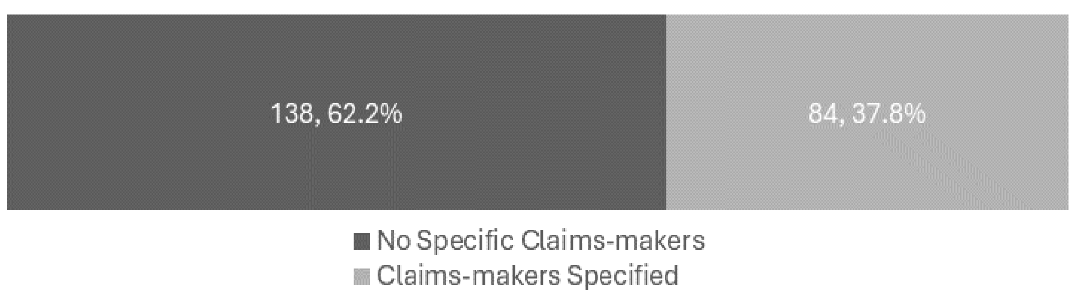

Figure 4-2 Explicit Claims-makers in TRI News Coverage

The remaining 37.8% of the articles cite at least one specific claims-maker. The most widely cited group of claims-makers are environmental organizations, whose claims regarding TRI data are included in 39.3% (33) of the articles with specified claims-makers. Environmental groups use TRI data primarily to underscore their concerns about sizeable toxic chemical releases in general, across the nation or concerned states, as well as to call out certain facilities.

EPA claims are included in 25.0% (21) of the articles that cite specific claims. EPA claims cited come from news briefs about annual TRI releases and trends and any other related comments.

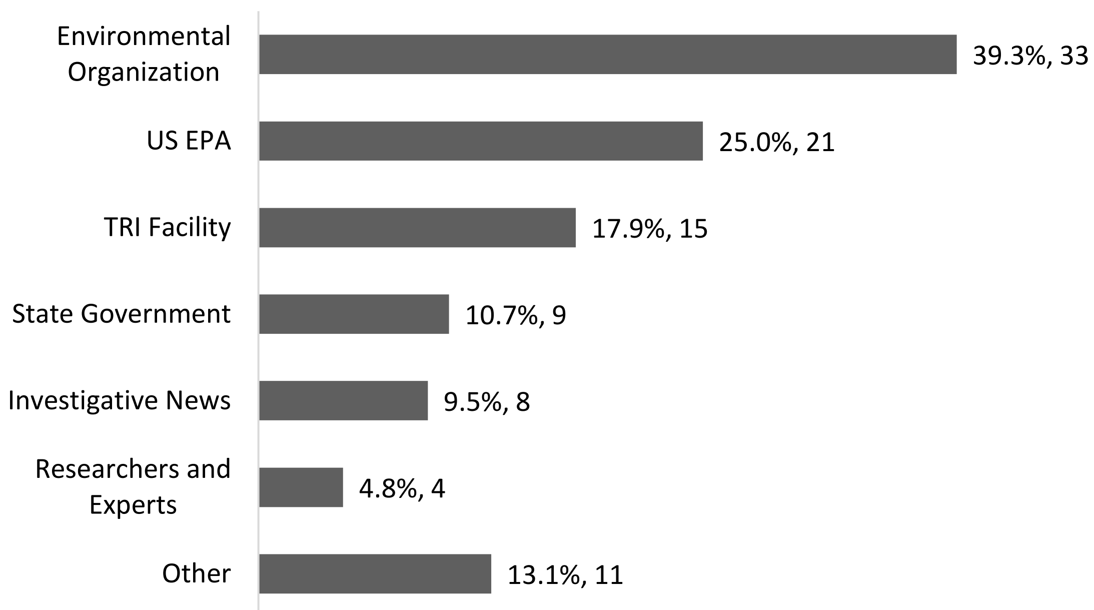

Figure 4-3 Claims-makers Quoted or Cited in TRI News Coverage

15 articles quote or cite TRI reporting facilities. In these articles, TRI facilities mainly provide explanations or excuses for their releases in response to accusations that they are significant polluters releasing large amounts of toxic chemicals.

State governments are quoted or cited in 10.7% (9) of the articles. Almost all the claims made by state governments are from officials in Departments of Environmental Quality, which typically manage and supervise facilities releasing toxic chemicals. State government officials are likely to provide comments to the news when facilities located in their states garner public attention due to high releases or their states are ranked low in environmental performance vis-à-vis toxic chemical releases among peers.

Other news outlets publishing independent analyses using TRI data are also key claims-makers, cited in 9.5% (8) of the articles. These include special editions in large news outlets such as the New York Times or investigative journals like Pro Publica analyzing TRI data and illuminating findings relevant to vulnerable populations or potential climate risks. News articles cite these findings, and some even endorse the informative aspects of these pieces and navigate the viewers toward them.

Researchers and experts were cited in 4.8% (4) of the articles. Researchers and experts make the news when their research uses TRI data or when they comment on specific topics regarding TRI data as experts.

Other groups quoted and cited in articles (13.1%, 11) include individual residents expressing concerns about the amount of toxics released into their communities, politicians mentioning TRI data and release amounts as a way to underscore environmental concerns, the Louisiana Chemical Association discussing how chemical releases have been reduced, a court mentioning a settlement around industrial wastewater discharge, and a data processing company advertising their technology adjusting data and neighbor-level geographies.

4.5.3 TRI Utilization in the News Stories

Geographic Level of Aggregation

About 54.5% of the total articles contain TRI information at the facility level. Many of these facilities are the nation or state's top polluters or the specific cause of concern for localities or populations nearby. The facility names are occasionally brought up due to the particular chemicals they release even if they are not necessarily the top polluters.

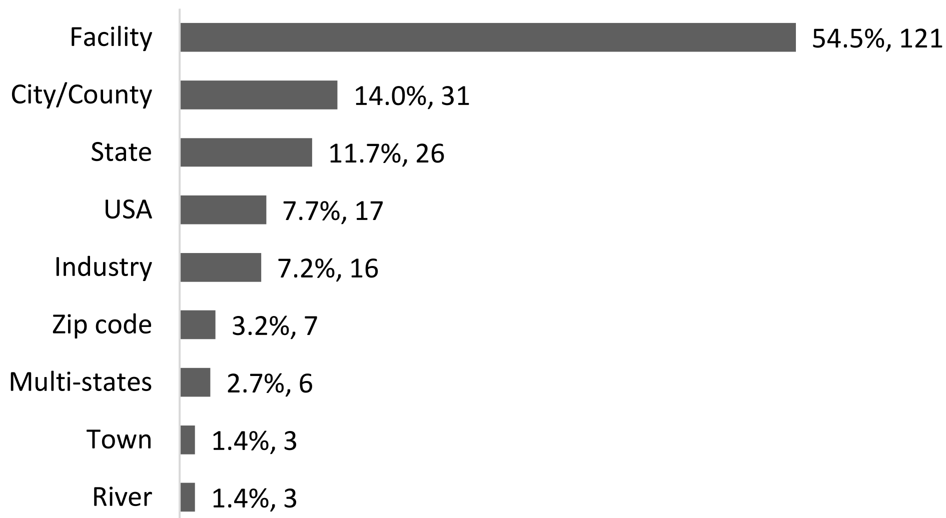

Figure 4-4 Graphic Level of Aggregation Presented in TRI News Coverage

County and city-level releases, which are the foci in 14.0% of articles, often make the news on local outlets geographically close to the localities. These articles mainly mention how much chemicals in total are released into the environment within regional boundaries.

11.7% of articles report state-level TRI data. These articles highlight the top polluting states in terms of chemical releases and their improvements or underperformance compared to previous records and their peers.

7.7% of the articles focus on the nation-wide level of releases. Some are a result of EPA press releases addressing TRI releases nationwide. These articles show the trend of the total release as a nation over past years, pointing out environmental improvement or sluggishness.

TRI data are sometimes aggregated at the industry level. Frequently appearing industries are mining and chemical manufacturing. General manufacturing, electric utility, and water disposal industries were occasionally mentioned.

TRI releases at the zip code level account for 3.2% of the articles. These articles use zip codes to provide detailed information about where certain high-profile facilities releasing chemicals are located.

2.7% of the articles cover TRI releases at the multi-state level. Most of these articles present toxic chemical releases data at the EPA region level (10 times), and a few use Bureau of Economic Analysis regions such as New England or Great Lakes or unofficial regions like the Pacific Southwest.

In addition, TRI releases were reported at the town and river levels. While TRI releases at the town level are brought up similarly to City and County are, the river is a unique aggregation level directly tied to a particular environmental group, Tennessee Riverkeeper. The organization reconstructs TRI data and presents all the facilities discharging chemicals into the Tennessee River.

Forms of TRI Utilization by Different Claims-maker

Unlike the previous analyses at the article level, this analysis uses quotes and citations as the unit of analysis. This unit of analysis is used to examine not only the frequencies of different methods of presenting TRI data but also which methods are employed by different groups of claims-makers. Since most articles include more than one claims-maker, counting the articles containing specific methods does not show the relationships between claims-makers and methods.

For environmental organizations, the two most frequent ways to present TRI data are showing the total amounts of releases and ranks. Environmental organizations use the absolute total amounts of chemical releases to demand that facilities, states, and other entities reduce their discharges into the environment, regardless of the release trends over time. Showing facilities and states' ranks among peers is also a recurrent technique environmental organizations use to call for actions to improve environmental performance.

The EPA refers to TRI data when the agency discusses how TRI data are reported, what the data look like, and the implications on environmental protection goals and missions. The agency also frequently uses trends over time to demonstrate environmental progress attributable to the agency.

TRI reporting facilities primarily mention TRI data to explain their high chemical release levels by highlighting the limitations or errors in the release data. For example, some facilities criticize the TRI program for focusing solely on the amount of releases rather than the actual harm caused, arguing that they should not be judged based on TRI data alone. In addition to pointing out these errors and limitations, facilities often highlight their release trends over time or compare them to previous years to demonstrate improvements, regardless of the absolute numbers.

State government officials similarly reference the errors and limitations of TRI data, mainly to counter criticisms that they are not adequately fulfilling their environmental protection responsibilities or effectively supervising top polluters within their states.

Table 4-1 Forms of TRI Presentation by Claims-maker

TRI Presentation	Env. Org.	EPA	TRI Facility	State Gov.	Investigative News	Researcher & Expert	Total
Trend over time	5	**10**	6	1	1	0	25
Amount of release	**12**	0	3	3	2	0	23
Errors or limitations of TRI data	3	1	**8**	6	0	2	21
TRI release rank	**7**	0	2	2	1	0	18
Descriptions or information about TRI program	2	**9**	0	0	0	0	13
Reconstructed with other data	5	1	0	0	3	2	11
Facility's current or historical failure to report TRI	1	4	0	0	1	0	7
Share of releases accounted among peers/comparison to peers	2	1	1	1	1	0	6
Designated TRI facility	2	0	0	0	0	0	2
Total	40	27	21	13	9	4	128

*Env. Org. = Environmental Organizations; State Gov. = State Government
**Frequency Shading Key: 1-3: 4-5: 6-8: 9-12:

Although it may not be their dominant method to present TRI data in the news, environmental organizations are the group that most frequently incorporate toxic releases with data such as demographic data or proximity to the coast or river. Contrary to popular belief, environmental organizations make more claims in the news based on their independent analyses than researchers, experts, or investigative news sources.

4.6 Discussions and Conclusions

4.6.1 Status of TRI Reporting in the News

This analysis shows a dearth of coverage of TRI data, despite the high number of TRI reporting facilities and the large volume of releases. This suggests that the impact of informational disclosure via news media is limited. This result is consistent with observations from previous studies about TRI reports and other environmental topics in the news. The amount of space or airtime that environmental topics are given has decreased since the mid-1990s, and media consolidation and downsizing throughout the 2000s worsened the situation (Friedman, 2015). Kraft et al.'s (2011) survey on the perspectives of TRI facilities found that only 8 percent of the surveyed facilities perceived that their toxic releases received extensive media coverage. The authors connected limited media attention to the decline in interactions between TRI facilities, environmental groups, and communities, speculating that the limited media coverage likely reflects a decline in public interest in TRI releases and interactions with releasing facilities.

The intricate and technical nature of TRI data likely hampers its coverage in the media. Studies have shown that even when environmental data, including TRI, is publicly available, its complexity can obscure the significance of the findings, making it challenging for media outlets to effectively communicate the information to a broader audience (Konar & Cohen, 1997; Ragothaman & Carr, 2008). Producing articles on TRI data requires reporters to understand the nature of toxic release data and possess data analysis and software skills. However, as traditional media has continued shrinking, there are very few news outlets with journalists specializing in environmental reporting across the United States (Friedman, 2015). Limited production resources and time render TRI a less appealing subject for news outlets to compose articles on. Khanna et al. (1998) note that the complexity of the data can diminish its perceived relevance and impact on investors and the public, leading to less media coverage.

Another possible reason for the lack of news reporting is a general lack of public awareness or interest in TRI facilities. Atlas's (2007) survey found that most participants do not recognize the names of TRI facilities in their neighborhoods and are unaware that these facilities release hazardous chemicals into the environment. Although public interest in the topic may not be the sole driver of media coverage, news media typically assigns space to topics with more salient public demand (Bakaki et al., 2020). The specialized nature of the data means that it is primarily of interest to a niche audience, rather than the general public, further limiting its media traction (Aerts et al., 2008).

Moreover, TRI data often lacks the immediacy and urgency that drives news coverage. The impacts of toxic releases are typically long-term and cumulative, rather than immediate and dramatic. This temporal disconnect reduces the newsworthiness of TRI data compared to more immediate environmental disasters or crises (Hamilton, 1995). Additionally, the gradual nature of pollution reduction reported in TRI updates does not provide the immediate, attention-grabbing headlines that the media often seeks (Bui & Mayer, 2003; Fung & O'Rourke, 2000).

The limitations of TRI data could also decrease public interest and lessen the concerns of corporations and facilities about negative publicity. TRI data primarily reports raw emissions without considering factors such as toxicity, exposure, and population vulnerability. The Risk-Screening Environmental Indicators (RSEI) model, which incorporates these factors, offers a more comprehensive assessment of potential health risks. This discrepancy can undermine the perceived importance of TRI data and its coverage in the media (Lutter et al., 2013). However, RSEI provides even more complex details about toxicity weights, which decreases public interest in the data or challenges the production of news coverage on the matter.

To increase the effectiveness of information disclosure, the EPA needs to balance the complexity, credibility, and immediacy of risk information about toxic chemicals. Providing contextual information regarding TRI data in their press releases in addition to general information about release quantities could be an option (Koehler & Spengler, 2007). The amount and depth of TRI coverage could also be improved by actively expanding and promoting training sessions that help TRI users analyze and comprehend TRI data.

4.6.2 Informational Intermediaries of the TRI program

By definition, informational intermediaries of the TRI program are processing, organizing, and presenting disclosed information to the general public. The results suggest that environmental organizations are the most frequent intermediary group invoking disclosed data, as predicted by other studies emphasizing the role of intermediary groups (Cortez, 2018; Esty, 2004). In addition to referring to release amounts or trends, environmental groups conduct their own in-depth analysis by incorporating TRI data with demographic data or coastal maps.

Moreover, environmental groups not only recurrently utilize TRI data to make claims, but their claims successfully make the news more than individuals do. This analysis shows that news articles reporting TRI releases rarely interview individual residents unaffiliated with organizations. The claims by individuals who make the news mostly revolve around their emotions and concerns. This does not necessarily mean that individuals do not invoke TRI as scientific evidence or fact to make data-driven claims. When an individual and prominent environmental organization make the same claims referring to TRI data, journalists are more likely to assign space to the environmental group’s claims, partially because it is relatively easier to identify such organizations and assess their credibility (Yang, 2004). This finding reinforces the importance of intermediary groups in distributing disclosed information via news media. It also indicates that individuals actively pursuing the spread of TRI-related claims may need to be assisted by intermediary organizations to meet the threshold of news coverage.

Along with the environmental organizations, this study identifies investigative news articles as intermediaries cited and quoted by journalists. This type of news article contributes to the impact of information disclosure by directly producing information based on TRI data and delivering them to the audience and indirectly appearing in other news as information sources. Most of the articles cited were published by large news publishers with nationwide readers or non-profit news outlets specializing in investigative journalism. Although they are less frequent, researchers and experts are also identified as another intermediary group. Researchers have long played intermediary roles. For instance, the Political Economy Research Institute (PERI) at the University of Massachusetts Amherst released the Toxic 100 Index, an interactive web-based tool identifying the top 100 corporate polluters in the United States, taking into account the toxicity and population exposure of emissions, and merging individual facilities' scores into corporation-level data (Ash et al., 2009; Cho & Roberts, 2010). PERI recently updated their interactive tool to track air pollution at the country's K-12 and higher education institutions. Researchers and experts' methods for processing and presenting TRI data are invaluable because they typically go beyond the raw data provided by the EPA. They produce new knowledge by incorporating toxic release data with other data and analytic methods that are not easily accessible to other players, thus advancing the public understanding of toxic chemical releases. However, the results show that there is little news coverage despite the value of their intermediary work.

4.6.3 Best Practices for Information Disclosure

The most frequent geographic level of aggregation and invocation of the TRI data by environmental organizations are facility-level and the amounts released; both are the default units of data collection and release used by the TRI program. Even though users may choose these aggregations and methods on purpose, it is hard to deny that the default forms of data presentation could affect TRI users' utilization of data.

TRI data at the facility level has both advantages and disadvantages. On the one hand, highly polluting facilities are likely to do damage control and improve their environmental performance to avoid bad reputations and impacts on profits when facility names are circulated in the news (Hamilton, 2005; Stephan, 2002). On the other hand, facility-level recognition may not have enough impact on the wider public unless those facilities are big national or international names, which hinders collective actions from communities. Residents sometimes do not recognize the names of low-profile local facilities discharging toxic chemicals or are unaware that those facilities are located within or close to their neighborhoods (Atlas, 2007). The names of polluters might need to be attached to geographic locations familiar to the general public to enhance the effects of information disclosure. The impact of geographic aggregation on public awareness or informational disclosure has been barely explored despite its significance (Leong & Hazelton, 2019).

Results show that facilities and state governments repeatedly claim that pounds of released toxic chemicals do not represent actual harm. Although many of these claims are used to justify high pollution, and these claims-makers rarely provide data to prove otherwise, the volume of TRI releases is not a reliable measure of exposure to toxic chemicals. In order to address the limitations of TRI data, EPA developed the risk-screening environmental indicator (RSEI) in the form of RSEI scores and RSEI toxicity-weighted concentrations at various geographic aggregation levels (Chakraborty et al., 2011). As per the EPA, the RSEI integrates data from the TRI regarding the quantity of hazardous chemicals released or transferred by facilities. It also considers variables such as the chemical's behavior and movement in the environment, its toxicity compared to other chemicals, and the likelihood of human exposure. However, the RSEI has barely been noticed by the media, let alone the general public, as the popularity of the TRI overshadows it. Even the claims-makers criticizing TRI data never invoke RSEI data, which fixes the limitations and errors that they point out. Although it has been actively utilized in academic research and projects, RSEI has to be proactively promoted and presented to the public since RSEI scores better estimate communities' and individuals' exposure to health risks more closely than the TRI amounts do.

Information disclosure programs require careful design and implementation choices regarding data outputs, and simple data publication has no significant policy impact (Bae et al., 2010; Craswell, 2013). To maximize the use of the TRI data and its disclosure impact, the EPA needs to revamp how data is presented and more actively consider utilization. In the meantime, intermediary actors will continue to play critical roles in translating this information into claims covered in the news media.

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5 Conclusion

5.1 Summary

This dissertation addresses the challenges associated with communicating environmental risks from toxic chemicals, which are often invisible and technically complex. The subsequent reliance on risk knowledge necessitates effective dissemination by government agencies, yet the public's engagement with this information remains unclear due to the dearth of real-world studies. This dissertation aims to bridge this gap through three papers, each focusing on different aspects of risk knowledge communication using news dialogues as data sources.

Chapter 1 explores the motivations for studying environmental risk knowledge communication, highlighting the challenges posed by the invisible and complex nature of toxic chemicals. It outlines the objectives and structure of the dissertation, which consists of three standalone papers examining different aspects of risk knowledge communication using news media as a data source. The chapter also provides an overview of relevant concepts and theories, setting the stage for the subsequent studies by establishing the importance of effective communication strategies for disseminating environmental risk knowledge to the public.

Chapter 2 explores the communication of location-specific risk information, using the Radford Army Ammunition Plant (RAAP) as a case study. It examines how scientific information about local environmental issues is presented in news articles and what factors influence its inclusion. The study employs content analysis and logistic regression to analyze local news articles, revealing that different stakeholder groups have varying capacities to access and use scientific information. The findings highlight the need for government agencies and research communities to support groups with limited resources.

Chapter 3 investigates chemical-specific risk knowledge, focusing on the communication of PFAS environmental risks in news texts in the United States. The study uses the US EPA's Draft Toxicity Assessment for GenX Chemical as a case study, employing a structural topic model (STM) to uncover thematic topics in news articles and a multinomial logistic regression to assess the impact of the GenX assessment on these topics. The results show that the influence of risk knowledge on news topics varies depending on community contexts, with the publication of the GenX risk assessment affecting topics related to specific contamination cases only when communities are prepared for governmental actions or legislation.

Chapter 4 examines the use of the US EPA's Toxics Release Inventory (TRI) database in news media. This study conducts an exploratory analysis to understand how different stakeholders utilize TRI data to make claims about environmental risks. The findings indicate that stakeholders use TRI data in various ways to suit their agendas, with environmental organizations being the primary users. These organizations often reconstruct TRI data to make it more relevant to the public, suggesting their potential role as intermediaries in risk communication.

5.2 Research Implications

This dissertation has explored the complexities and challenges of communicating knowledge of environmental risks through various lenses, including public communication of science, dialogical communications in news media, and dynamics within communities and among stakeholders.

This dissertation provides empirical evidence supporting findings from existing studies, including: 1) limited news coverage of environmental risk knowledge, including both scientific and non-scientific information; 2) risk framing increases the inclusion of scientific information in news communication regarding environmental issues; 3) dominance of government sources in communicating risk information about toxic chemical pollution; 4) disproportionate accessibility and utilization of risk knowledge among various stakeholders; and 5) the role of intermediary groups in bridging risk knowledge and the public.

Moreover, this study is among the few that empirically examine the impact of newly generated risk knowledge on public discourse and societal priorities as communicated through news media in real-world contexts. The findings highlight the intricate relationship between the publication of new risk assessments and community contexts, paving the way for future research opportunities.

This study highlights both the advantages and limitations of using news texts to explore risk knowledge communication. On the one hand, news data can enrich analysis by offering a vast array of real-time developments and historical events, providing researchers with a chronological archive of topics and shifts in claims-making patterns. On the other hand, these insights come with challenges. News data often filters and reconstructs risk knowledge communication, requiring a critical evaluation of the research findings (Altheide, 2010; Boholm, 2009; Dollbaum, 2021; Earl et al., 2004). For instance, Paper 1 reveals that community activists make the fewest scientific claims, despite their calls for scientific data collection and monitoring. This indicates that news production might gatekeep their scientific claims, viewing them as less credible sources of scientific risk knowledge.

Additionally, shifts in the audience accessing information via traditional news media must be considered alongside news data analysis findings. While news media continues to be a primary source of environmental information and influences risk perceptions, information-seeking behaviors, and environmental activism (Chung et al., 2020; Santos & Wong-Parodi, 2022; Zhang & Skoric, 2018), the decline in newspaper readership and the polarization of user segments impact how risk knowledge is communicated. News media may overlook significant dialogues occurring outside their scope, depending on the context, demographics, and characteristics of the concerned groups, such as age and internet access, as well as the issues involved. Without critical evaluation, accepting these findings at face value could lead to incorrect conclusions about real-world risk knowledge communication, underscoring the necessity of careful reflection.

5.3 Policy Implications

This dissertation suggests policy implications for government agencies and other risk knowledge producers to improve dissemination and communication strategies for risk data and information. The most prominent issue from the findings is the sheer volume of limited media reports communicating risk knowledge information.

Although increased coverage does not necessarily promise enhanced public understanding of environmental risks and benefits, it serves as a starting point for risk knowledge communication (Bucchi, 2008; Sousa et al., 2014). Scholars attribute the decreased volume of risk information coverage to the intricate nature of risk data

(Khanna et al., 1998; Konar & Cohen, 1997; Ragothaman & Carr, 2008), the lack of immediacy and urgency of some environmental risk information during non-crisis times (Bui & Mayer, 2003; Fung et al., 2007; Fung & O'rourke, 2000; Hamilton, 1995), and low public awareness and interest in risk knowledge (Atlas, 2007; Bakaki et al., 2020). The findings from this dissertation support these reasons by showing that scientific risk knowledge is not easily communicated among non-scientific groups, except for environmental organizations, and their impact on public discourse is only significant for communities with existing awareness and agendas regarding environmental risks.

There is a trade-off between the complexity of risk knowledge and public interest, affecting the dissemination of risk data and information. Scientific complexity and details sometimes conceal the significance and relevance of risk information, making it challenging to communicate in news media that prefer simple and clear descriptions of topics. The difficulty in media coverage could lead to a decrease in public awareness and interest in risk knowledge. Additionally, the intricate nature of risk knowledge could decrease public interest, leading to a lack of motivation for journalists to cover risk information. On the other hand, oversimplifying the scientific aspects of risk information could also decrease the effectiveness of risk knowledge communication, leading to misinterpretation, misunderstanding, and even distrust in risk information providers (Frewer, 2001; Grozdanov Christozov et al., 2012; Rothman & Kiviniemi, 1999).

To enhance the effectiveness of risk knowledge communication, government agencies responsible for producing and disseminating risk knowledge, such as the EPA, need to balance scientific details with contextual information that resonates with the public. Combining risk knowledge with contextual information in government agencies' press releases and risk information products could be an example of practical adjustments. Actively promoting training sessions or providing accessible guidelines and tutorials for potential users, including journalists, to help them better analyze and comprehend risk data and information could be another option. These policy implications and practical suggestions can also address other issues identified in this paper, such as the disparity in accessibility and utilization of risk knowledge among various stakeholders, and the need for engaging intermediary groups to bridge risk knowledge and the public.

5.4 Theoretical Implications

The challenging relationship between the technical complexity of risk knowledge and public interest, discussed in the policy implications section above, has significant implications for theoretical approaches in the field of public communication of science and technology. The complexity of risk information and public interest correspond to two critical components of science communication: credibility and salience. Credibility ensures that the information is trusted by the audience, while salience ensures that the information is relevant and engaging. Credibility and salience, along with legitimacy, comprise the attributes of how scientific and technical information are effectively communicated and used to inform decision-making processes (Cash et al., 2003; Dunn & Laing, 2017; Van Voorn et al., 2016). Trade-offs among these attributes make it crucial to balance them for the successful communication of technical information (Kunseler et al., 2015; Sarkki et al., 2014), which is also the case for risk knowledge communication as discovered in this dissertation.

The emphasis on balancing credibility and salience in this study underscores the limitations of the diffusionist model in public communication of science and technology

(Bucchi & Mazzolini, 2003; Dunwoody & Scott, 1982; Wynne, 1995). The diffusionist model, which focuses largely on the one-way provision of credible scientific knowledge of environmental risks does not serve as a sound theoretical framework encompassing its links to salience. The findings of this dissertation advocate for a shift from the traditional diffusionist model to a more interactive dialogic model in theoretical approaches to public communication of science and technology. This shift is expected to foster a deeper understanding of risk knowledge communication by ensuring that it addresses not only credibility and legitimacy but also salience, aligning with public interests and broader societal concerns.

More specifically, the research reinforces the utility of dialogic communication in news media as a theoretical lens for risk knowledge communication. Dialogic communication is valuable for its ability to integrate risk information and data with public discourse and societal priorities, providing a more comprehensive understanding of how risk knowledge is conveyed and communicated in the public sphere.

5.5 Limitations

This dissertation acknowledges the limitations and considerations inherent in the news data, methodologies, and analyses employed. These limitations include limited generalizability, imperfect reflection of reality in news data, potential oversight of variables, and limited precision in news coding.

5.5.1 Limited Generalizability

While some findings from this dissertation are consistent with existing evidence, its generalizability may be restricted. The limitation primarily stems from the case study approach focused on the Radford Army Ammunition Plant and Toxicity Assessment for GenX chemicals. The high-profile status of these cases may lead to their dynamics not being universally applicable and to the skewing of the results, limiting direct application to other contexts.

5.5.2 Inaccurate Reflection of Reality in News Data

An inherent limitation lies in relying solely on news texts to understand real-world events. Despite critical evaluation conducted in this dissertation, news data can be biased and selective, offering partial and distorted views. Thus, corroborating findings with diverse sources and evidence becomes imperative, a practice that may warrant more extensive exploration than undertaken in this study.

5.5.3 Potential Oversight of Variables

The complexity of news dynamics presents challenges in comprehensively addressing all influential variables. While this dissertation endeavored to encompass various factors, some may remain overlooked. Despite drawing from existing studies and practical data review, certain variables could evade scrutiny, impacting the interpretation of Papers 1 and 2.

5.5.4 Limited Precision in News Coding

The final limitation involves the precision of news coding due to the unstructured nature of news texts. For instance, the definition of scientific information in Paper 1 may differ across cases where risk knowledge communication is simplified versus when it involves highly detailed scientific information. The methods and coding criteria may not be applicable for cases in different contexts.

Additionally, this study's choice to analyze single news articles as the unit of analysis is driven by practical considerations to avoid potential biases and difficulties in isolating individual claims independently from other claims-makers. While this practical choice of unit of analysis reduced subjectivity, it may compromise the accuracy of statistical analysis compared to its full potential.

5.6 Recommendations for Future Research

Building on the insights and limitations identified in this dissertation, several avenues for future research are recommended to further advance the field of environmental risk communication. These recommendations aim to address gaps, overcome limitations, and enhance the overall understanding and effectiveness of risk knowledge dissemination.

5.6.1 Expanding Case Studies and Generalizability

Future research should consider expanding the range of case studies to include a more diverse set of environmental issues and geographic locations. While this dissertation focused on specific high-profile cases such as the Radford Army Ammunition Plant and GenX chemicals, exploring a broader array of cases will help determine whether the findings are universally applicable. Additionally, studying a variety of community contexts, including those with different socioeconomic and demographic characteristics, will provide a more comprehensive understanding of how risk communication strategies can be tailored to different audiences.

5.6.2 Integrating Multiple Data Sources

Given the limitations of relying solely on news media, future studies should integrate multiple data sources to corroborate findings and provide a more nuanced understanding of risk knowledge communication. Combining news texts with social media analysis, interviews with key stakeholders, and surveys of public perception can offer a more holistic view. This mixed-methods approach can help validate the findings from news data and provide deeper insights into the public's engagement with and response to risk information.

5.6.3 Assessing the Influence of Intermediary Groups

This dissertation highlighted the significant role of environmental organizations as intermediaries in risk communication. Future research should explore the influence of various intermediary groups, including non-governmental organizations, community organizations, technical assistance groups, and investigative news, in bridging the gap between risk knowledge and public understanding. Evaluating their strategies, effectiveness, and challenges will provide insights into how these groups can be better supported and utilized in risk communication efforts.

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