

Article

PFAS Risk-Mitigation Messaging: Achieving a More Sustainable and Healthier Living Environment

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Abstract

Per- and polyfluoroalkyl substances (PFAS) are persistent “forever chemicals” associated with environmental and public health risks. Despite increasing concern, policies and mitigation strategies often lag behind PFAS contamination, and many communities lack accessible solutions for reducing exposure. Effective risk communication is needed to develop public awareness of, engagement with, and adoption of PFAS mitigation practices. This study examined how risk message framing may influence behavioral intentions to reduce PFAS contamination in everyday living environments. A between-subjects experiment ($N = 296$) exposed participants to one of four PFAS messages varying in threat (high vs. low) and efficacy (high vs. low) levels. Participants reported very limited prior exposure to PFAS risk messaging. High-threat messages generated greater fear than low-threat messages, but high-efficacy messages did not produce significantly greater perceived efficacy than low-efficacy messages. The interaction between threat and efficacy significantly predicted emotional flow, with the high-threat/high-efficacy condition generating greater emotional flow than the low-threat/low-efficacy condition. Fear, perceived efficacy, and emotional flow were significant positive predictors of PFAS mitigation behavioral intentions. Findings suggest that PFAS risk communication should pair credible threat information with actionable efficacy cues that help audiences move from fear toward agency, hope, and protective intentions.

Keywords: PFAS contamination; PFAS risk mitigation; Extended Parallel Process Model; emotional flow; environmental risk communication

1. Introduction

Per- and polyfluoroalkyl substances (PFAS), also known as “forever chemicals,” are synthetic compounds that persist in water, soil, and food supplies [1,2]. PFAS contamination has been detected in drinking water, soil, and food supplies, raising concerns about the long-term impacts of these chemicals on the ecological system and human health [3–6]. PFAS exposure has been linked to a range of health risks, including cancer, hormone disruption, immune system suppression, and organ toxicity [7,8].

Mitigation technologies (e.g., granular activated carbon, plasma oxidation, and supercritical water treatment) are technical in nature and difficult to communicate to the public [9–11]. Hence, evaluating the proposed mitigation actions [12] and communicating about PFAS with readability, understandability and actionability [13] can be challenging. Notably, official PFAS health messages tend to emphasize uncertainty, dismiss legitimate concerns in affected communities, and rarely offer useful intervention approaches [14].



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According to a 2023 national survey, 45.1% of U.S. respondents had never heard of PFAS, 31.6% had heard of PFAS but did not know what it was, and 97.4% did not believe their drinking water was impacted [15]. These findings suggest that adequate environmental literacy is needed for shaping attitudes and behavioral intentions toward environmental sustainability [16,17]. Recent PFAS research has suggested the need for solution-focused communication that can help the public understand feasible exposure reduction and mitigation strategies [18].

A potentially effective solution-focused messaging approach involves using efficacy cues to counter perceived threat and motivate protective action [19–22]. Because threat perceptions are likely to elicit fear, messages that shift emotions from fear to hope through efficacy-building cues may strengthen protective behavioral intentions [23–25]. Yet past research has not explored these factors to explain PFAS mitigation intentions.

For instance, survey research has demonstrated that PFAS risk perception, personal efficacy, subjective norms, information seeking and systematic processing were positively related to mitigation intentions, but not negative emotion [26]. Experimental research has also shown that perceived information insufficiency interacts with perceived information-gathering capacity to influence systematic processing and information-seeking intentions [27]. Separate experimental work found that high-efficacy messages elicited stronger intentions to reduce PFAS exposure in drinking water than low-efficacy messages [28].

To address the aforementioned gap in understanding how efficacy and emotional factors influence mitigation intentions, the current experimental study is guided by the Extended Parallel Process Model (EPPM) [19] and the emotional flow construct [23], which provide the respective theoretical foundations for the investigation. The study investigates the effects of bi-level threat and efficacy information cues on fear, perceived agency, and the negative-to-positive emotional flow, as well as their influence on PFAS mitigation intentions.

2. Literature Review

2.1. Environmental Sustainability and Risk Communication

Environmental communication plays a critical role in shaping how the public interprets environmental hazards and responds to mitigation efforts [29–31]. Recent research highlights how environmental risk communication influences public awareness, engagement, attitudes, and understanding of sustainability challenges [16,32]. A face-to-face survey (N = 27,057) conducted among European Union citizens found that the use of communication materials—including books, scientific papers, websites, blogs, web-based forums, newspapers, films, and televised documentaries—was a significant predictor of pro-environmental behavior [16].

A U.S. study similarly showed that exposure to environmental risk via offline news channels, online news outlets, and mobile communication platforms facilitated perceived personal risk vulnerability and risk information-seeking behavior, leading to self-protective responses and willingness to engage in community- and municipality-led collaborative sustainability initiatives [33]. Importantly, Chen [34] reported that psychological proximity to climate change increased environmental concern but did not directly predict pro-environmental behavior.

By implication, as sustainability transitions require reducing exposure to environmental contaminants, it is necessary to convince individuals to adopt sustainable practices and support positive environmental policies [35–38]. To accomplish such objectives, it would be crucial for risk communication to influence information-seeking and interpersonal communication in ways that will facilitate environmentally responsible and collective actions [16,30,31].

Because audience characteristics may also shape responses to environmental risk communication, gender was considered as a potential control variable. Prior research indicates that women tend to report stronger environmental concern, pro-environmental attitudes and pro-environmental behaviors than men [39]. Gender has also been associated with perceived risk and affective responses to environmental and health hazards, with men often reporting lower perceived risk than women [40,41]. Recent health risk research has similarly found gender differences in fear responses, with women reporting greater fear of COVID-19-related health risks than men [42]. Gender was therefore included as a control variable because it may influence affective responses to PFAS risk messages.

The extant research thus suggests that public perceptions of environmental risks are influenced not only by objective hazard information but also by social, psychological, and communicative processes [43–45]. These dynamics are aligned with the theoretical perspective of the Extended Parallel Process Model (EPPM) [19], which suggests that individuals' responses to risk communication depend on both perceived threat and beliefs about the effectiveness of potential protective actions.

2.2. *Extended Parallel Process Model*

The Extended Parallel Process Model (EPPM) posits that behavioral responses to risk communication depend on two key cognitive evaluations: perceived threat (severity and susceptibility) and perceived efficacy (response efficacy and self-efficacy) [19]. When individuals perceive both threat and efficacy as high, they are more likely to adopt protective behaviors to mitigate the risk. In contrast, when perceived threat is high but perceived efficacy is low, individuals may respond with denial, message rejection, or avoidance [46,47].

Meta-analytic evidence suggests that fear appeals can influence attitudes, intentions, and behaviors under nearly all circumstances, particularly when messages include strong efficacy information and clear descriptions of susceptibility and severity [22]. However, a critical re-analysis of fear appeal theory cautions that threatening communication should be used carefully and is most defensible when messages also strengthen perceived efficacy [48]. Research has also found that when fear outpaces individuals' efficacy beliefs, they may retreat to a maladaptive defensive strategy such as denial, avoidance, fatalism, wishful thinking, or hopelessness [19,49,50].

Past work examining climate change attitudes demonstrates that risk perception and environmental knowledge are closely linked to mitigation and adaptation intentions [17,51,52]. Research on sustainability decision-making also indicates that individuals' perceptions of environmental risks and responsibilities influence their willingness to engage in environmentally protective actions [53]. In a similar vein, awareness of local PFAS exposure was found to be associated with heightened concern and stronger intentions to adopt protective behaviors in environmental health contexts [15].

Environmental risk messages that emphasize catastrophic consequences without providing actionable solutions can sometimes backfire by producing emotional overload, mistrust, or disengagement [54]. Conversely, messages that combine credible threat information with practical and achievable solutions can enhance perceived efficacy, strengthen message effectiveness and promote engagement in mitigation behaviors [17,31]. By implication, threat-based messages tend to be most persuasive when accompanied by strong efficacy cues that provide clear pathways for protective action [55].

Given the limited experimental research on PFAS risk communication, the current study tests whether threat framing generates fear and whether efficacy framing strengthens perceived efficacy. Specifically, it examines whether high-threat messages evoke greater fear than low-threat messages and whether high-efficacy messages generate greater perceived

efficacy than low-efficacy messages. Two hypotheses are proposed below to test these theoretical assumptions.

H1. *High-threat message conditions will generate greater perceived fear than low-threat message conditions.*

H2. *High-efficacy message conditions will generate greater perceived efficacy than low-efficacy message conditions.*

2.3. Emotional Flow

In the context of environmental sustainability, emotional responses to risk information may also play an important role in shaping public engagement with environmental issues. For instance, environmental hazards can evoke emotional reactions such as fear, concern, or hope, which in turn influence how individuals process risk information and evaluate potential actions [30,31,56,57]. Understanding how risk communication messages evoke emotional responses and shape perceptions of environmental threats may help inform risk message designs that strengthen efficacy and support mitigation actions.

Tannenbaum et al. [22] found that fear appeals can influence attitudes, intentions, and behaviors, with their effectiveness depending partly on threat and coping appraisals. Further, similar research in vaccine risk communication has demonstrated that efficacy cues may help audiences manage threat-induced fear by shifting their emotional response toward hope [58]. This emotional shift can be explained by the emotional flow construct, which conceptualizes how shifts in emotional tone across a message may influence an individual's attention, cognitive processing, and message persuasiveness [23].

Emotional flow research suggests that rather than eliciting a single dominant emotional response, persuasive messages may guide audiences through a sequence of emotional states over time and increase receptivity to persuasive appeals [24]. Peinado and Nabi [59] found that messages shifting from negative emotions such as fear toward positive emotions such as hope produced greater self-efficacy, stronger protective intentions, and more interpersonal discussion. Similarly, Alam and So [25] found that emotional flow in narrative messages enhanced audience engagement and persuasive processing. Recent measurement research further demonstrates that audiences can reliably identify emotional transitions within persuasive content [60].

Taken together, this literature suggests that negative-to-positive emotional movement may reduce defensive responses, deepen message processing, and increase receptivity to recommended protective actions. In the current study, emotional flow is conceptualized as a sequence beginning with awareness of the PFAS threat and the resulting fear or concern. Efficacy cues may then shift the response toward emotional relief, hope, and agency. Accordingly, PFAS risk communication messages may create an emotional arc that moves audiences from concern or fear toward agency and protective intentions.

Integrating EPPM and emotional flow suggests that high-threat and high-efficacy information cues will trigger greater fear before shifting toward a more hopeful emotional state. This emotional flow should be stronger than that produced by low-threat and low-efficacy messages. Accordingly, the following hypothesis is proposed:

H3. *Messages embedded with the high-threat/high-efficacy condition will generate greater perceived emotional flow than the low-threat/low-efficacy message condition.*

2.4. Fear, Efficacy, and Behavioral Intentions

Dong and Yang [26] found that perceived information insufficiency, risk perception, and efficacy beliefs significantly shaped how individuals seek, process, and respond to PFAS messages. Although threat information could increase negative emotions such as fear, it did not predict behavioral intentions in the absence of efficacy cues. When messages contained actionable efficacy information, such as community mobilization, technological solutions, or policy interventions, participants reported stronger engagement and support for mitigation policies.

In a related study [27], efficacy beliefs and perceived capacity to effectively respond to PFAS risk were also strong predictors of information seeking, policy support, and willingness to engage in community action. These findings are consistent with EPPM, which suggests that threat is more likely to motivate adaptive responses when accompanied by efficacy information [19].

Research on environmental risk communication also underscores the importance of perceived control and affective responses. For instance, when individuals experience fear or anxiety but believe they can respond effectively to the risk, they are more likely to seek information and support mitigation efforts [61]. This process of shifting from a negative to a hopeful emotional state is consistent with the thesis of emotional flow [23,24,59,62]. Chu and Yang [63] observed that the relative weight of risk versus efficacy information for climate change engagement shifts with psychological distance, suggesting that for diffuse threats like PFAS, clearly communicated efficacy pathways may be especially critical for motivating action.

Together, the literature suggests that fear, efficacy, and emotional flow may each contribute to protective behavioral intentions. On this basis, we propose the following hypotheses:

H4a–c. *Perceived (a) fear, (b) efficacy, and (c) emotional flow will be positively related to behavioral intentions to engage in PFAS-mitigation behaviors.*

A proposed conceptual model (Figure 1) is shown below to illustrate the interrelations between the theoretical constructs tested in the experiment and proposed research hypotheses.

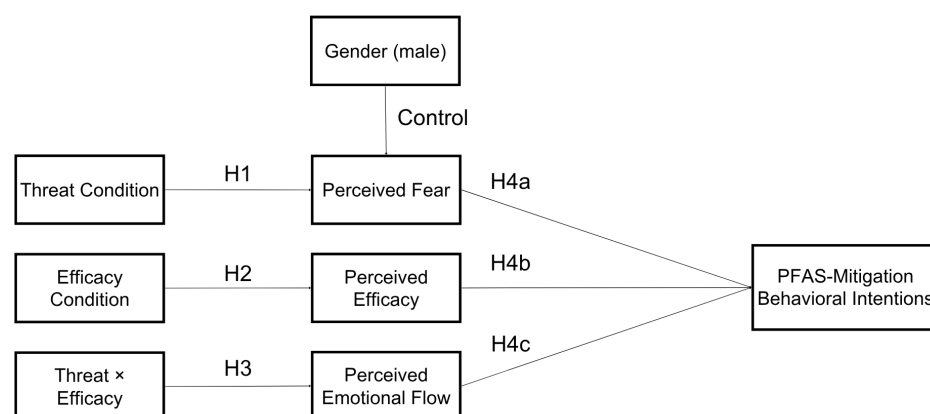


Figure 1. Proposed conceptual model.

2.5. Prior Risk Information Exposure

PFAS contamination shares features with other “invisible hazards” such as microplastics, where the risk is diffuse, chronic and not directly perceptible, making it harder for communication to convey urgency and efficacy simultaneously [64,65]. Because only 23.3%

of U.S. survey respondents knew what PFAS were [15], prior PFAS information exposure may shape how they interpret and evaluate subsequent risk messages [43,44].

Examining the frequency and sources of prior PFAS message exposure may establish a baseline for future risk communication strategies designed to increase public awareness and knowledge. Moreover, this baseline assessment can also help explain how the public may evaluate the experimental PFAS messages tested in the current study. To explore these message exposure patterns, the following research questions are tested.

RQ1a,b. *What are the prior (a) levels of PFAS risk message exposure and (b) types of PFAS risk message exposure?*

RQ2a,b. *Will the prior (a) levels of PFAS risk message exposure and (b) types of PFAS risk message exposure be positively related to participants' evaluations of the experimental message?*

3. Materials and Methods

3.1. Methodology

This post-test-only study used a between-subjects experimental design with four message conditions to examine the effects of threat (high vs. low) and efficacy (high vs. low) framing in PFAS environmental communication. Participants were undergraduate students enrolled in an introductory-level course that fulfilled a general course requirement at a large Northeastern university in the United States. Students were compensated with extra course credit for their participation. The initial dataset contained 365 responses. Cases with missing data on variables required for analysis or evidence of straightlining were excluded, resulting in the removal of 69 cases and a final analytic sample of 296 participants. An a priori power analysis was conducted in G*Power 3.1.9.7 (Heinrich Heine University Düsseldorf, Düsseldorf, Germany) [66] for a fixed-effects ANOVA testing main effects and interactions, using a medium effect size ($f = 0.25$), $\alpha = 0.05$, power = 0.80, numerator $df = 1$, and four groups. Results indicated that a minimum sample size of 128 participants was required. The final analytic sample of 296 participants exceeded this minimum requirement.

3.2. Participants

Participants' average age was 19.2 years ($SD = 2.93$); their gender identity indicated 54.7% female, 44.3% male, and 1% "other" or unreported. In terms of racial/ethnic makeup, participants were asked to self-identify with one or more racial/ethnic categories. Percentages may exceed 100% because participants could select more than one category. The breakdown showed 69.2% White, 7% Hispanic/Latino (non-White), 17.5% Asian, 6.7% Black or African American, 1.6% Native American or Alaska Native, 0.6% Native Hawaiian or Pacific Islander, and 1.3% Other/unreported.

3.3. Procedure and Stimuli

The study was conducted online. Participants were first instructed to log in to the study's Qualtrics XM Platform (web-based platform; Qualtrics LLC, Provo, UT, USA) webpage to review the consent form. Upon expressing informed consent, they were asked to answer questions associated with demographic characteristics, prior PFAS message exposure frequency and sources of prior PFAS message exposure. Participants were randomly assigned through the Qualtrics Survey Flow randomizer to one of four experimental message conditions. The randomizer was configured to distribute participants approximately evenly across conditions. Participants were then shown one of four short narrative videos, each approximately 60–90 s in length. Afterward, participants completed post-exposure measures assessing perceived threat, perceived efficacy, perceived emotional flow, perceived fear, message evaluation, and PFAS mitigation behavioral intentions. The perceived

fear and perceived efficacy scales were also used to evaluate the threat and efficacy manipulations, respectively. The entire study procedure had a median completion time of 6.3 min.

The four video stimuli were presented as simulated television news segments, using consistent narrative style and delivery structure across conditions. The visual presentation was also consistent across conditions, as each video used the same broadcast-style graphics, newsroom backdrop, and simulated newscaster. The videos contained spoken narration delivered by the simulated newscaster but did not display captions or the complete narrative text on screen. Figure A1 provides a representative screenshot of the experimental stimuli. The newscaster's appearance was generated using Leonardo AI Phoenix 1.0 (Leonardo Interactive Pty Ltd, North Sydney, NSW, Australia), while the animation and voice were generated using HeyGen Avatar III (HeyGen Technology Inc., Los Angeles, CA, USA). The four videos represented four conditions: high-threat/high-efficacy (90 s), high-threat/low-efficacy (75 s), low-threat/high-efficacy (70 s), and low-threat/low-efficacy (72 s).

In terms of the narrative (see Table A1), the high threat level described the cancer and other health threats associated with PFAS found in drinking water, non-stick pans, product packaging, and common plastic materials. In contrast, the low-threat condition described how people may be exposed to trace amounts of PFAS in drinking water without emphasizing severe health consequences. The high-efficacy level message illustrated how government action, available mitigation technology, and PFAS-free product use can help reduce PFAS contamination, including specific examples of PFAS mitigation in multiple U.S. cities. By comparison, the low-efficacy level message emphasized the difficulty, cost, and uncertainty of reducing PFAS exposure.

3.4. Measures

The definition for each variable is described below. All theoretical constructs were assessed with 7-point Likert-type items (1 = strongly disagree to 7 = strongly agree), unless otherwise noted. To ascertain each variable's conceptual dimensionality, principal component analysis (PCA) with varimax rotation was conducted, followed by a calculation of Cronbach's α to assess internal consistency. Across scales, item communalities ranged from 0.43 to 0.88, and factor loadings ranged from 0.66 to 0.94, indicating an acceptable factor structure. Cronbach's α coefficients also indicated acceptable to excellent internal reliability across measures (below). A confirmatory factor analysis (CFA) was also conducted to validate the measurement structure. The CFA model demonstrated acceptable fit, $\chi^2(153) = 312.90$, $p < 0.001$, $\text{CMIN}/df = 2.05$, $\text{NFI} = 0.93$, $\text{IFI} = 0.96$, $\text{TLI} = 0.95$, $\text{CFI} = 0.96$, and $\text{RMSEA} = 0.06$, 90% CI [0.05, 0.07]. Standardized factor loadings ranged from 0.63 to 0.90, and all loadings were statistically significant at $p < 0.001$. These results supported the use of the refined composite measures in the subsequent analyses. Table 1 summarizes the study measures, operationalization, and reliability estimates.

Perceived emotional flow was measured using six items adapted from Fitzgerald et al. assessing perceived shifts in emotion while processing the PFAS message [60]. These items asked, for example, when the participant was viewing the message, whether they felt "a series of shifts in my emotions" and "negative emotions (e.g., fear) at times and positive emotions (e.g., hope) at other times." Five items loaded on one factor. The sixth item ("I felt calm the entire time") loaded on a second factor and was removed. The five items were averaged to create the emotional flow variable ($\alpha = 0.90$).

Table 1. Study measures, operationalization, and reliability.

Variable	Operationalization	Reliability (α)
Perceived Emotional Flow	5-item composite	0.90
Perceived Fear	3-item composite	0.85
Perceived Efficacy	3-item composite	0.79
Perceived Threat	3-item composite	0.86
PFAS Mitigation Behavioral Intentions	6-item composite	0.94
PFAS Message Exposure Frequency	1 item, 5-point frequency scale	—
PFAS Message Source Types	12-item check-all-that-apply index	—
Message Evaluation	5-item composite	0.90

Note. All multi-item theoretical constructs were measured on 7-point Likert-type scales ranging from 1 = strongly disagree to 7 = strongly agree. PFAS message exposure frequency was measured on a 5-point scale ranging from 1 = never to 5 = very often. PFAS message source types were measured using a check-all-that-apply format and summed to create a source-count index.

Perceived fear was measured by three items adapted from Xie et al. and Osman et al. [67,68]. These items asked how participants would feel if exposed to PFAS contamination, using the emotional descriptors (a) worried, (b) afraid, and (c) terrified. The three items loaded onto a single factor and were averaged to create a PFAS-specific fear variable ($\alpha = 0.85$). This composite also served as the post-exposure manipulation check for the threat condition because fear represented the proximal affective response expected from the high-threat message under H1.

Perceived efficacy was initially measured using four items adapted from Xie et al. and Warkentin et al. [67,69]. These items assessed participants' beliefs that the following strategies would effectively reduce PFAS exposure: (a) installing water treatment systems at water treatment plants, (b) implementing public policy changes, (c) changing personal behaviors, and (d) undertaking community-level actions such as cleanups and advocacy efforts. The four items loaded on a single factor; these items were averaged to create a perceived efficacy variable ($\alpha = 0.80$). The confirmatory factor analysis supported a modified three-item construct after the item "Changing personal behaviors is an effective way of reducing PFAS exposure" was removed. The final three items were averaged to create the perceived efficacy variable used in the analyses ($\alpha = 0.79$). This final three-item composite also served as the post-exposure manipulation check for the efficacy condition.

Perceived threat was measured using four items adapted from Xie et al. and Warkentin et al., capturing beliefs about the severity of and susceptibility to PFAS exposure [67,69]. Example items included "PFAS exposure is a threat to me" and "I am at risk of being exposed to PFAS contamination." The four items loaded on a single factor; these items were averaged to create a perceived threat variable ($\alpha = 0.86$). The confirmatory factor analysis supported an improved three-item construct after one item was removed. The final three items were averaged to create the perceived threat variable used in the analyses ($\alpha = 0.86$).

Behavioral intentions were measured using six items adapted from Xie et al. and Warkentin et al. to indicate potential engagement in PFAS-mitigating behaviors and to encourage others to do so [67,69]. Sample items include "I would be willing to change my personal habits to reduce PFAS contamination" and "I am likely to support PFAS mitigation policies in my community." These items resulted in a single-factor solution; they were averaged to create a composite variable ($\alpha = 0.94$).

Risk-message exposure frequency was indicated by a single item on a five-point scale (1 = Never; 5 = Very Often) via the following question: "Within the last 12 months, how frequently have you seen advertisements or messages about per- and polyfluoroalkyl substances (PFAS), also known as 'forever chemicals'?"

Risk message types. Participants selected all applicable sources in response to the question "What types of PFAS-related messages have you seen?" The 12 categories were

out-of-home advertisements, television advertisements, sponsored social media advertisements, social media influencer or activist posts, websites, news articles, radio or podcast advertisements, community meetings, local government messaging, environmental group communications, information campaigns, and word-of-mouth communication.

Message evaluation was assessed using eight items adapted from Mutti-Packer et al. to evaluate whether the experimental message was attention-grabbing, relevant, believable, effective, informative, and useful [70]. The eight items initially loaded onto a single factor; however, one item, “This message was frightening,” was removed to improve reliability. The remaining seven items were averaged to create a composite variable ($\alpha = 0.91$). Following subsequent item refinement, two additional items, “This message grabs your attention” and “This message is relevant to me,” were removed. The final five items were averaged to create the message evaluation variable used in the analyses ($\alpha = 0.90$).

4. Results

4.1. Manipulation Checks

A one-way ANOVA indicated that participants in the high-threat condition ($M = 5.30$, $SD = 1.14$, $n = 145$) reported greater perceived fear than participants in the low-threat condition ($M = 4.86$, $SD = 1.15$, $n = 151$), mean difference = 0.44, 95% CI [0.18, 0.71], $F(1, 294) = 11.01$, $p = 0.001$, $\eta^2 = 0.036$. The threat manipulation was therefore successful.

Participants in the high-efficacy condition ($M = 5.45$, $SD = 0.85$, $n = 150$) reported slightly greater perceived efficacy than participants in the low-efficacy condition ($M = 5.26$, $SD = 0.95$, $n = 146$). However, the difference was not statistically significant, mean difference = 0.19, 95% CI [−0.01, 0.40], $F(1, 294) = 3.35$, $p = 0.068$, $\eta^2 = 0.011$. Thus, the efficacy manipulation did not produce a statistically reliable difference in perceived efficacy.

Levene’s tests were nonsignificant for both perceived fear, $F(1, 294) = 0.33$, $p = 0.568$, and perceived efficacy, $F(1, 294) = 2.08$, $p = 0.151$, indicating that the homogeneity-of-variance assumption was satisfied for both analyses.

4.2. Descriptive Statistics and Correlations

Table 2 presents descriptive statistics and zero-order correlations among the major study variables. Participants reported a mean PFAS message exposure frequency of 1.64 ($SD = 0.84$) during the previous 12 months, measured on a 5-point scale. They reported an average of 1.26 PFAS information source types ($SD = 1.36$, observed range = 0–8 of 12). Among the study constructs measured on 7-point scales, perceived efficacy ($M = 5.35$, $SD = 0.90$), perceived threat ($M = 5.25$, $SD = 1.01$), perceived fear ($M = 5.08$, $SD = 1.17$), and message evaluation ($M = 5.05$, $SD = 1.10$) had the highest mean values. Behavioral intentions were positively correlated with perceived threat ($r = 0.52$, $p < 0.001$), perceived fear ($r = 0.51$, $p < 0.001$), perceived efficacy ($r = 0.48$, $p < 0.001$), message evaluation ($r = 0.39$, $p < 0.001$), perceived emotional flow ($r = 0.29$, $p < 0.001$), and the number of PFAS message source types ($r = 0.15$, $p = 0.009$). The maximum variance inflation factor was 2.24, indicating no problematic multicollinearity.

4.3. Hypothesis Testing

To test the proposed conceptual model, an observed-variable path analysis was conducted in IBM SPSS Amos version 31.0 (IBM Corp., Armonk, NY, USA), using maximum likelihood estimation. The model included threat condition, efficacy condition, the interaction term between threat and efficacy, perceived fear, perceived efficacy, perceived emotional flow, and behavioral intentions. Gender was included as a control variable predicting perceived fear in the path model. The modeling demonstrated acceptable fit,

$\chi^2(15) = 26.08, p = 0.037, \text{CMIN}/df = 1.74, \text{NFI} = 0.96, \text{IFI} = 0.98, \text{TLI} = 0.95, \text{and CFI} = 0.98$ (see Figure 2).

Table 2. Descriptive statistics and zero-order correlations.

	1	2	3	4	5	6	7	8	9
1 Perceived Threat	--								
2 Perceived Efficacy	0.60 **	--							
3 Message Evaluation	0.55 **	0.44 **	--						
4 PFAS Message Exposure	−0.003	−0.08	−0.07	--					
5 Message Source Total	0.01	−0.05	0.00	0.68 **	--				
6 Perceived Emotional Flow	0.22 **	0.09	0.37 **	0.07	0.10	--			
7 Gender	−0.14 *	−0.19 **	−0.09	0.22 **	0.21 **	−0.05	--		
8 Fear	0.59 **	0.43 **	0.43 **	−0.09	−0.04	0.39 **	−0.22 **	--	
9 Behavioral Intentions	0.52 **	0.48 **	0.39 **	0.06	0.15 **	0.29 **	−0.24 **	0.51 **	--
Mean	5.25	5.35	5.05	1.64	1.26	3.57	0.45	5.08	4.91
Standard Deviation	1.01	0.90	1.10	0.84	1.36	1.32	0.50	1.17	1.14

* $p < 0.05$ (2-tailed); ** $p < 0.01$ (2-tailed).

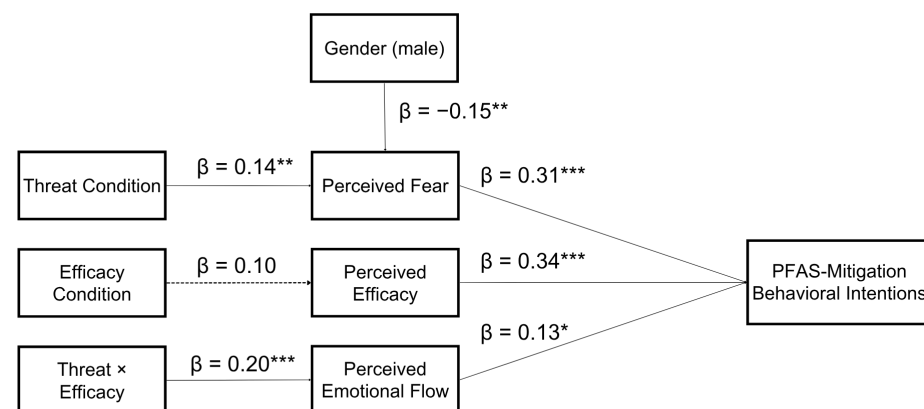


Figure 2. Conceptual model testing results. Note. Dashed line indicates a nonsignificant path. * $p < 0.05$; ** $p < 0.01$; *** $p < 0.001$.

Table 3 presents the summary results for the path analysis that tested the proposed research hypotheses. H1 predicted that high-threat message conditions would generate greater perceived fear than low-threat message conditions. The path model results showed that threat condition positively predicted perceived fear ($\beta = 0.14, p = 0.007$); therefore, H1 was supported. Gender was also significantly associated with perceived fear ($\beta = -0.15, p = 0.003$).

H2 asserted that high-efficacy message conditions would generate greater perceived efficacy than low-efficacy message conditions. The association between efficacy condition and perceived efficacy was not statistically significant ($\beta = 0.10, p = 0.055$); thus, H2 was not supported.

H3 expected that messages embedded with the high-threat/high-efficacy condition would generate greater perceived emotional flow than messages with the low-threat/low-efficacy condition. The threat $\times$ efficacy interaction significantly predicted perceived emotional flow ($\beta = 0.20, p < 0.001$); therefore, H3 was supported.

H4 predicted that perceived fear, perceived efficacy, and perceived emotional flow would be positively related to behavioral intentions to engage in PFAS-mitigating behaviors. Perceived fear ($\beta = 0.31, p < 0.001$), perceived efficacy ($\beta = 0.34, p < 0.001$), and perceived

emotional flow ($\beta = 0.13$, $p = 0.013$) each significantly predicted behavioral intentions. Hence, H4a–c were supported.

Table 3. Hypothesized path model predicting PFAS mitigation intentions.

Hypothesis	<i>B</i>	<i>SE</i>	Standardized β	95% CI for <i>B</i>	<i>p</i>	Result
H1	0.31	0.11	0.14	[0.09, 0.53]	0.007	Supported
H2	0.18	0.10	0.10	[−0.003, 0.37]	0.055	Not supported
H3	0.61	0.17	0.20	[0.27, 0.94]	<0.001	Supported
H4a	0.31	0.06	0.31	[0.20, 0.42]	<0.001	Supported
H4b	0.43	0.07	0.34	[0.30, 0.56]	<0.001	Supported
H4c	0.11	0.05	0.13	[0.03, 0.20]	0.013	Supported
Control	−0.33	0.11	−0.15	[−0.55, −0.11]	0.003	Significant

Note. Model fit: $\chi^2(15) = 26.08$, $p = 0.037$, $\text{CMIN}/df = 1.74$, $\text{NFI} = 0.96$, $\text{IFI} = 0.98$, $\text{TLI} = 0.95$, $\text{CFI} = 0.98$. Unstandardized estimates (*B*), standard errors, 95% confidence intervals for *B*, and standardized coefficients (β) are reported. Gender was coded such that higher values represented male participants and was included as a control variable predicting perceived fear.

4.4. Research Question Testing

RQ1a examined the frequency of prior exposure to PFAS-related risk information. The results indicated generally low levels of prior exposure. Among the 296 respondents who answered this question, 54.7% reported never having encountered PFAS-related messages within the past 12 months, while 31.1% reported rarely encountering such messages. Only a small proportion of respondents (14.1%) reported seeing PFAS-related messages sometimes, often, or very often. The mean level of PFAS message exposure was 1.64 ($SD = 0.84$).

RQ1b investigated the type of information sources that participants encountered to learn about PFAS. On average, participants reported 1.26 PFAS message source types ($SD = 1.36$). Reported PFAS information sources included sponsored social media advertisements (28.4%), followed by television advertisements (15.9%), word-of-mouth communication from friends or family members (15.5%), social media influencers or activists (14.9%), and websites (14.9%). Less frequently reported sources included out-of-home advertisements (11.1%), news articles (9.8%), environmental group communications (6.8%), radio or podcasts (2.7%), local government messaging (2.4%), information campaigns (3.0%), and community meetings (0.7%).

RQ2a,b examined whether PFAS message exposure frequency and the number of PFAS-message source types were positively related to participants' evaluation of the experimental message. Neither PFAS message exposure frequency ($r = -0.07$, $p = 0.211$) nor the number of source types ($r = -0.003$, $p = 0.949$) was significantly correlated with message evaluation.

5. Discussion

This study demonstrated that a high-threat PFAS message frame had a greater effect on participants' fear response than a low-threat message frame. Importantly, the effect of the threat appeal is consistent with EPPM, as threat appraisal is central to protection motivation [19–21]. Gender was also a significant control variable in the path model, with male participants reporting lower perceived fear than female participants. This finding mirrors prior risk perception and health risk research showing that men often report lower perceived risk and fear responses than women [40–42]. PFAS threat messages may therefore elicit different affective responses across audience groups.

In contrast, the high-efficacy message frame did not generate a stronger efficacy response than the low-efficacy message frame, contrary to the assumption of EPPM. This finding suggests that the brief efficacy cues used in the stimulus may need to be repeated

to elicit the intended differences in individuals' agency for coping with the perceived PFAS threat. These efficacy cues may also need to be presented in a more forceful or believable manner. In addition, participants' limited awareness or knowledge of PFAS may have influenced their acceptance of the highly technical and unfamiliar mitigation solutions. This explanation is consistent with a 2023 national survey which found that 76.7% of U.S. adults were either unfamiliar with PFAS or had heard of PFAS but did not know what they were [15]. It is also possible that the threat content overshadowed the efficacy cues, although this explanation requires further testing. Participants in the high- and low-efficacy conditions may therefore have formed relatively similar efficacy appraisals.

Consistent with the interaction between threat and efficacy cues, the high-threat/high-efficacy message condition generated significantly greater perceived emotional flow than the low-threat/low-efficacy condition. However, perceived emotional flow did not differ significantly between the high-threat/low-efficacy and low-threat/low-efficacy conditions. This pattern suggests that emotional flow may be most likely to emerge when threat information is paired with high efficacy-oriented cues, rather than when threat information is presented with low-efficacy cues. By implication, when people experience a high level of threat, strong efficacy cues may help temper fear and shift the emotional response from negative affect toward hope, agency, and protective motivation, as suggested by the emotional flow construct [23,24,59,62].

Emotional flow was also a modest but significant predictor of PFAS mitigation behavioral intentions. This finding aligns with Hominski and Lin [58], who found that emotional flow positively predicted HPV vaccination intentions. These findings also reinforce the importance of pairing threat cues with efficacy cues in PFAS risk communication. Together, these results suggest that credible efficacy cues may redirect threat-induced fear toward hope, agency, and adaptive action [23,24,59,62].

These findings also suggest that individuals were more likely to report intentions to engage in PFAS mitigation when they believed that personal, community, or policy actions could reduce PFAS exposure. The mitigation intentions measure in the current study reflected willingness to reduce PFAS exposure through personal consumption choices and support for community-level initiatives and local government policies. It therefore represented both individual and collective forms of mitigation. The combination of fear and efficacy as facilitating factors to motivate PFAS mitigation intentions also supports prior research showing that fear, threat appraisal, and efficacy appraisal can jointly contribute to recommended behavioral responses [22].

Although PFASmessage exposure frequency and the number of PFAS information source types were generally low, neither was significantly associated with participants' evaluations of the experimental message. The low exposure levels observed here are consistent with prior research documenting limited public awareness of PFAS [15,71].

Together, the low frequency and limited range of PFAS information exposure observed in the present study suggest that existing communication efforts also had limited reach among this college student sample. Although prior research suggests that Gen Z consumers are attentive to sustainable consumption [72] and motivated by several factors when making environmentally friendly choices [73], the current findings suggest that awareness of PFAS may remain limited within this population. These findings also suggest that existing PFAS communication efforts may have limited visibility across both digital and nondigital channels [13,14].

5.1. Study Limitations

Several limitations should be considered when interpreting the current findings. First, the sample consisted of undergraduate students at a single university, most of whom

were 18–20 years old, non-Hispanic, and White. Thus, the findings should not be generalized to the broader U.S. population or to communities most directly affected by PFAS contamination. The current study was exploratory in nature, and the selection of college students allowed us to examine how young adults, whose sustainable consumption [72] and environmentally friendly choices [73] have received increasing research attention, might respond to our experimental stimuli. A Pew Research study (N = 13,729) indicated that Gen Z reported relatively high levels of concern about climate change, personal action, interpersonal discussion, and engagement with climate-related social media content [74]. Similarly, another report described how addressing environmental literacy in K-12 and higher education is necessary to promote civic engagement, as Gen Z students lack guidance on what actions are needed to prevent environmental disasters in the future [75]. To expand generalizability, future research should recruit more diverse population samples, including residents of PFAS-affected communities facing elevated exposure or health risks.

Second, this exploratory experiment relied on a single message exposure and self-reported responses. Future research should adopt repeated-exposure, longitudinal, or field-based designs to examine whether PFAS risk messages produce sustained changes in efficacy perceptions, emotional responses, mitigation intentions, or actual protective behaviors. Third, the study did not include a pretest of the message stimuli. Although post-exposure manipulation checks were conducted, the efficacy manipulation did not significantly increase perceived efficacy. Future studies should pretest PFAS efficacy messages to ensure that proposed mitigation actions are perceived as clear, credible, and feasible before full experimental implementation.

Fourth, the study measured behavioral intentions rather than actual mitigation behavior. This distinction is important because intentions do not necessarily translate into direct action. PFAS mitigation may require financial resources, access to filtration technologies, institutional support, community initiatives, and coordinated government action. Future research should explore how an individual's PFAS mitigation intentions may contribute to actual collective action at the community, government, and policy levels.

Finally, additional research should continue refining measures of emotional flow and integrating them with threat and coping appraisals to improve the effectiveness of PFAS risk message design. Mixed-methods research that includes qualitative interviews with affected community members could help clarify why some efficacy cues are perceived as believable or actionable while others are not. The use of biometric measures could also complement self-reported responses by capturing affective and cognitive processing during message exposure.

5.2. Practical Implications

The current study findings offer several practical implications for PFAS risk communication. Environmental and public health agencies should communicate the seriousness of PFAS contamination without leaving audiences in a state of helplessness. Messages should pair threat information with credible efficacy cues, including individual, household, community, and policy-level actions. For PFAS campaigns, these efficacy cues may include guidance about water filtration, PFAS-free product substitution, community testing, regulatory action, and available remediation technologies.

Because the efficacy manipulation did not significantly increase perceived efficacy, future campaigns should carefully design efficacy cues that are accessible to audiences with limited PFAS awareness and knowledge. This means that PFAS communication messages should be tailored to accommodate the environmental, scientific, and health literacy levels of their intended audiences. In other words, PFAS risk communication practitioners should consider adopting social marketing campaign techniques that combine

audience targeting with content tailoring to better meet the information and learning needs of diverse stakeholder groups.

Moreover, participants most often reported encountering PFAS information through sponsored social media advertisements, television advertisements, word-of-mouth communication, social media influencers or activists, and websites. Future campaigns should test platform-matched messages across these channels. However, reported exposure should not be interpreted as evidence of message effectiveness. For this reason, formative, process, and summative evaluation should be conducted to evaluate message reach and effects as part of the social marketing campaign design and implementation.

6. Theoretical Implications and Conclusions

This exploratory study contributes to the limited theoretical understanding of how PFAS risk communication may help motivate the public's mitigation intentions. The findings suggest that increasing public understanding of PFAS may require making the threat concrete, evidence-based, and personally relevant. Because human and environmental health are closely interconnected, PFAS is an important sustainability issue. For example, while the U.S. Environmental Protection Agency [76] is conducting studies to detect PFOA and PFOS in biosolids and drinking water, the U.S. Food and Drug Administration is currently testing for PFAS in bottled water, seafood, and baby formula [77].

A recent large-scale modeling study by Brausmann and Edilian [78] suggested the use of science-based public information campaigns, environmental health education, disclosure requirements, or chemical risk labeling to create public awareness of environmental risks. Their findings indicated that public concern about personal health can strengthen support for environmental policies that improve environmental quality. However, communicating the implications of PFAS for environmental and human health can be challenging because scientific research associated with PFAS is ongoing and constantly evolving.

Another challenge is making the threat directly relevant to the public. For instance, theory-based risk communication research on local flood risk management leveraged coastal residents' awareness of and experiences with storm and flood risks. This approach was used to motivate participation in community-based, government-led mitigation initiatives [32,33]. By comparison, PFAS are colorless, odorless, tasteless, and undetectable by human senses. PFAS exposure may be associated with outcomes such as cancer, thyroid disorders, and infertility. Therefore, risk communication must not only explain these potential relationships but also acknowledge that these conditions may have multiple causes.

Based on the discussion about PFAS communication challenges, it would be reasonable to assume that an individual's risk perceptions, emotional responses, and protective behaviors associated with PFAS may be influenced by their psychological distance from these invisible chemical compounds. The four dimensions of psychological distance identified by construal level theory (CLT) [79]—temporal, spatial, social, and hypothetical distance—may therefore provide a useful theoretical framework for a follow-up study. These four different types of psychological distance could be examined to clarify how they shape individuals' perceptions of the contamination threat [80,81].

Specifically, from the perspective of temporal distance, PFAS may not be perceived as an immediate threat because contamination is often invisible, diffuse and difficult for individuals to detect directly. Perceived spatial and social distance may also shape PFAS risk perceptions, as some communities face heavier PFAS contamination burdens while others may perceive the threat as more remote. As for hypothetical distance, individuals may differ widely in their perceptions of the likelihood that PFAS may negatively affect their health. In this theoretical context, the effectiveness of PFAS communication may

depend on how individuals understand both the seriousness of the threat and the relevance of individual, community, and policy-level mitigation actions.

In conclusion, this exploratory study is among the few to experimentally examine how PFAS messages that vary in threat and efficacy framing shape fear, perceived efficacy, emotional flow, and mitigation intentions. Future research should validate the current study's framework across more diverse populations and social settings. Additional research could also draw on CLT or protection motivation theory (PMT) [82] to clarify how psychological distance and coping appraisals shape responses to PFAS communication. Continued research is needed to advance theoretically sound PFAS risk communication, while providing practitioners with useful, evidence-based practices.

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Appendix A



Figure A1. Representative screenshot of the experimental video stimuli.

Table A1. Experimental stimuli scripts.

Condition	Duration	Complete Script
High-threat/ High-efficacy	90 seconds	Our lead story this evening: Per- and polyfluoroalkyl substances (PFAS)—often called “forever chemicals”—are synthetic compounds used for decades to make coatings that resist water and heat. PFAS have contaminated thousands of drinking-water systems across the United States. These chemicals build up in the body and have been linked to cancer, thyroid disease, and developmental effects in children. These chemicals are found in non-stick pans, packaging, and even rainwater. PFAS have spread into nearly every water source in the country. Once they enter the body, they remain for years, increasing risks of cancer and immune problems. Scientists call PFAS “forever” for a reason—they do not break down naturally, and removing them from water is extremely difficult and expensive. The good news is that communities can take action. Cities such as Wilmington, Delaware and Ann Arbor, Michigan are already removing PFAS with upgraded filtration systems. State and federal agencies are banning industrial releases, and households can choose PFAS-free products. Each action—policy, technology, or personal choice—reduces contamination. PFAS are persistent, but they are not unstoppable. Working together, we can protect our water and our health.
High-threat/ Low-efficacy	75 seconds	Our lead story this evening: Per- and polyfluoroalkyl substances (PFAS)—often called “forever chemicals”—are synthetic compounds used for decades to make coatings that resist water and heat. PFAS have spread into nearly every water source in the country. Once they enter the body, they remain for years, increasing risks of cancer and immune problems. These chemicals are found in non-stick pans, packaging, and even rainwater. Scientists call PFAS “forever” for a reason—they do not break down naturally, and removing them from water is extremely difficult and expensive. Many communities have no realistic way to filter them out. PFAS contamination is everywhere, and avoiding exposure may be nearly impossible.
Low-threat/ High-efficacy	70 seconds	Our lead story this evening: Per- and polyfluoroalkyl substances (PFAS)—often called “forever chemicals”—are synthetic compounds used for decades to make coatings that resist water and heat. Trace amounts may appear in drinking water, but most people are exposed at very low levels. Government agencies continue to monitor PFAS in the environment. The good news is that communities can take action. Cities such as Wilmington, Delaware and Ann Arbor, Michigan are already removing PFAS with upgraded filtration systems. State and federal agencies are banning industrial releases, and households can choose PFAS-free products. Each action—policy, technology, or personal choice—reduces contamination. PFAS are persistent, but they are not unstoppable. Working together, we can protect our water and our health.
Low-threat/ Low-efficacy	72 seconds	Our lead story this evening: Per- and polyfluoroalkyl substances (PFAS)—often called “forever chemicals”—are synthetic compounds used for decades to make coatings that resist water and heat. Trace amounts may appear in drinking water, but most people are exposed at very low levels. Government agencies continue to monitor PFAS in the environment. Because these chemicals are found in so many products, eliminating them completely would be challenging. For now, experts recommend staying informed as research continues.

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