FLUORIDE

Quarterly Journal of The International Society for Fluoride Research Inc.

Exploring Geographic Patterns of Fluoride Contamination and Their Role in Environmental Disaster Preparedness

Unique digital address (Digital object identifier [DOI] equivalent):
https://www.fluorideresearch.online/epub/files/288.pdf

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Accepted: 2024 Sept 24.
Published as e288: 2024 Sept 25

ABSTRACT

Purpose: The aim of this study was to examine the complex relationships between environmental monitoring efforts (EME), community engagement (CE), and environmental risk perception (ERP) in the context of improving environmental disaster preparedness (EDP) in the specific case of fluoride pollution. Using the Theory of Planned Behavior (TPB) as a conceptual framework, the study examines the effect of several variables on disaster preparation behavior in communities exposed to environmental risks.

Methods: The data was collected from people living in Shanxi Province, China, an area that suffers from severe fluoride contamination.

Results: The results of structural equation modeling (SEM) indicate that community engagement significantly improves the perception of environmental risk, which, in turn, positively impacts the preparation for disasters. Moreover, environmental monitoring efforts were shown to be a mediator of the association between community participation and disaster preparation, underscoring the crucial role that systematic monitoring plays in disaster management. The results indicate that including social and environmental elements is crucial for improving the ability of communities to withstand and recover from environmental catastrophes.

Conclusion: The findings emphasize that there is an urgent need to consider social, and environmental aspects if the resilience of communities to, and their recovery from, environmental disasters is to be improved.

Key-words: Fluoride, Monitoring Efforts, Risk Perception, Disaster Preparedness, Community engagement

1. INTRODUCTION

Access to sufficient levels of water, which is clean and safe, is essential for life. However, in recent decades population expansion, urban district and industrial revolution as well as incorrect use of resources have caused soil and water pollution in various parts of the world [1]. Groundwater plays a vital role in the socio-economic development of human life and in the production of hydropower and irrigation [2]. While developed nations have sustainable access to safe drinkable water, but this is not true in case of developing nations. Globally, groundwater supplies are decreasing, particularly in Asia, Africa, and North America. More than 2.5 billion people rely on groundwater for their drinking water supplies, with over 0.5 billion people living in 106 countries affected by groundwater contamination due to arsenic [3]. UNESCO reports indicate that nearly 80 percent of diseases in emerging countries are caused by water pollution making it essential to evaluate the quality of groundwater in order to determine whether it is suitable for domestic, industrial, and agricultural use [4].

Groundwater quality is adversely affected by human activities, and it is primarily determined by changes in chemical parameters such as fluoride concentration [5], which are influenced by the decomposition of soluble particles and their disintegration over time and space [6]. In recent years, it has become increasingly evident that excessive exposure to environmental fluoride increases the risk of fluorosis among individuals living in polluted areas. Fluoride pollution of groundwater is one the most pressing global concerns due to its toxic effects on human health, particularly in communities with limited access to safe water sources [7, 8]. High levels of fluoride in groundwater have been linked to serious health problems, most notably dental, skeletal, and nonskeletal fluorosis. Fluorosis is prevalent in 25 countries, with the highest incidence occurring in India, China, and various African regions [9, 10]. However, fluoride contamination is not limited to these regions; it also affects regions like Pakistan, Sri Lanka, the North and West African countries (Tunisia, Libya, Sudan, Senegal, Ghana, Ivory Coast), Kenya, Tanzania, Ethiopia, Uganda, Rwanda, South Africa, central Argentina, northern Mexico and Pakistan [3]. Most groundwater pollution is caused by natural sources, such as weathering of F-rich minerals, fumarolic gases, hydro-geothermal vents, and marine aerosols [11]. Fluoride concentrations in these regions increase due to the interaction between natural geological processes and human activities, including groundwater over-extraction. Further, the variability of fluoride levels across different geographical areas complicates the management of water resources and the development of public health interventions [12].

The existing literature has acknowledged that chronic exposure to fluoride can lead to significant issues with the physical and cognitive development of children [13]. Furthermore, it has been noted that, people from poor socioeconomic status are more prone to the uplift of excessive amounts of fluoride due to the unavailability of other safe water facilities and lack of basic knowledge [14, 15]. The scientific studies on this research have only looked at adverse health outcomes caused by the fluorides, as well as researching on the instances where the pollution was present. Still, it remains important to understand how the geographic patterns of fluoride toxicity and community engagement interrelate [16]. While there are agreements on the advances in environmental monitoring systems as well as environmental monitoring policies and strategies, little is known about how all these initiatives work towards the most expected outcome of increased community preparedness for disasters [15]. Literature on environmental monitoring and literature on disaster preparedness have been studied in isolation as different heads, with little attempt to examine their relationship. There is an absence of investigation concerning the social and cognitive processes which can influence the relationship between environmental monitoring and disaster preparation, for instance, community participation and environmental risk perceptions. A large part of this gap is found in the low income or rural communities in which both engagement and perception of risk are likely to vary significantly thus impacting on the effectiveness of environmental management programs.

Considering these gaps, it is necessary to position this study in relation to these complex relationships of environmental monitoring, risk perception, community engagement and disaster preparedness in fluoride regulation. This research addresses the following questions: What is the role of the community engagement and perception of environmental risks on the preparedness for disasters by the community? What is the impact of community engagement on environmental disaster preparedness and how does environmental monitoring efforts (EME) act as a mitigating factor? How does the relationship between environmental risk perception and community engagement address environmental monitoring efforts towards improvement of environmental disaster preparedness?

This study attempts to answer this questions by focusing on the practical environmental management practices on one hand and the social dynamics of the community on the other hand that climatizes their level of preparedness to face possible environmental crises. This research addresses these questions by the Theory of Planned Behavior (TPB) where control beliefs about Environmental Monitoring Efforts (EME), subjective norms regarding Community Engagement (CE) and presently held attitudes of Environmental Risk Perceptions (ERP) are all perceived as being instrumental in explaining the channels through which EME influences disaster preparedness. In supporting this strategy, the objectives of the present analysis add to the environmental health and disaster risk literature in responding to the questions of geography and society as determinants of the effectiveness of fluoride management strategies against health-related risks.

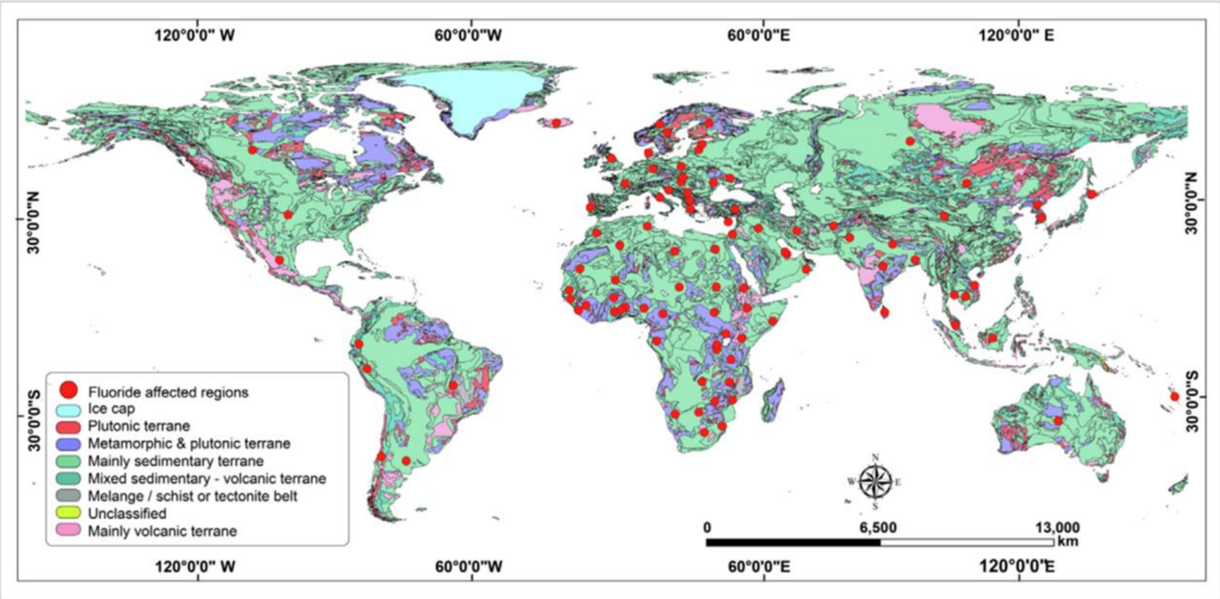

Figure 1: Fluoride-affected countries of the world with geological settings. Note that Africa, Asia, and European regions are the worst affected.
Source: Shaji, Sarath [3]

2. THEORETICAL BACKGROUND

From the 1970s, after consideration of the environmental pollution which has occurred, environmental monitoring has developed with various measures to regulate natural resources and deal with emergency situations involvingdisasters .

Efforts for management of the environment: EME have been useful to prepare for any possible calamities and take appropriate actions in case disaster strikes. Though these activities are about monitoring disasters, transforming them to make disaster preparedness plans has never been easy. Most of the research done in the existing literature forgets social psychology that acts as a bridge in the correlational relationship between environmental monitoring and community disaster preparedness [17]. In addressing such issues, this paper employs the Theory Of Planned Behaviour (TPB).

The Theory Of Planned Behavior looks at the impact of intentions and actual behavior on the aspects of subjective norms and perceived behavioral control of an individual [18]. According to the TPB, these three factors contribute to the formation of behavioral intentions, which can then be used to predict actual behavior. Disaster preparedness can be greatly enhanced by using

TPB to gain a deeper understanding of how environmental monitoring can influence community engagement and risk perception [19]. In numerous public health and environmental contexts, TPB has been extensively used to analyze behavior. The foundational work of Ajzen (1991) [20] on TPB stated that behavior is determined by both individual and collective perceptions and norms. A similar approach has been applied in environmental management to understand how communities respond to environmental risks and how they engage in protective behaviors. It is particularly relevant to examine how environmental monitoring efforts enable communities to act in the event of disasters when TPB places an emphasis on perceived behavioral control.

Through two key mediators: community engagement (CE) and environmental risk perception (ERP), TPB provides a framework for understanding how environmental monitoring influences disaster preparedness. In the context of disaster preparedness, CE refers to how much community members are involved in monitoring activities [21]. TPB suggests that higher engagement levels are likely to result in stronger subjective norms and greater collective efficacy, which are both critical to disaster preparedness. As opposed to ERP, ERP reflects community awareness and perception of environmental risks, which TPB identifies as an essential determinant of behavior.

TPB is used in this study to examine the relationship between community engagement (CE) and environmental risk perception (ERP) and how these factors influence disaster preparedness (EDP). In accordance with TPB, CE and ERP are interconnected, reinforcing the community's ability to prepare for disasters by using the information provided by environmental monitoring efforts (EME). A higher level of engagement, for example, may result in a perception of greater control over disaster outcomes, which TPB identifies as an important motivator for proactive behavior. Several studies have demonstrated the effectiveness of TPB for predicting a wide range of behaviors, including health-related behaviors [22], environmental conservation [23], and disaster preparedness [24]. However, it should be taken into consideration that most of the research has focused on individual behaviors rather than community responses. In order to bridge this gap, present research advances work in collective disaster preparedness by exploring how CE and ERP mediums are incorporated within Environmental monitoring efforts. Disasters are a result of an interplay of environmental threats and social vulnerabilities as substantiated by the research findings drawn by Hewitt [25]. Hewitt concluded that mere geological analysis is misplaced since other spatial factors, other than the seismic hazard, cannot be overlooked since they influence the level of disaster occurrence and the effects that the disaster has. Furthermore, it has been reported that more sophisticated environmental monitoring methods, like multi-directional change detection (MDCD) algorithm using SAR imagery, can improve the efficiency of forecasting environmental change prior to a disaster. Thus, through the inclusion of these new monitoring techniques as part of the TPB, this study seeks to explore the various components in EME in relation to the community and how attitudes, subjective norms and perceived behavioral control impact on community EME VT.

This study also attempts to broaden the use of TPB constructs in considering perceived behavioral control and subjective norms by integrating environmental monitoring as a construct. It is proposed that this recognition would enable a detailed analysis of how effective technological environmental protection measures may be integrated with social processes, in order to enhance the socio-psychological resilience of the community to environmental catastrophes. The TPB Theory suggests that there is an appropriate model to investigate the interactions of environmental monitoring efforts, participation of the community, and risk perception around other interactions such as disaster preparedness. By utilizing TPB, this research seeks to address how the community preparedness response to disaster can be enhanced through proper understanding of how to incorporate the issues of environmental management into the community’s disaster preparedness plans.

3. MODELS AND HYPOTHESES

3.1 Research Model

This study aims at understanding how Environmental Monitoring Efforts (EFE), Community Engagement (CE) and the

Environmental Risk Perception (ERP) interrelate in determining the preparedness of individuals in relation to fluoride regulation and the overall Environmental Disaster Preparedness (EDP). Applying Theory of Planned Behavior to contextualize this study, it seeks to understand how these factors interrelate to affect environmental attitudes and behaviors. The variables identified to be: (1) Environmental Monitoring Efforts, (2) Community Engagement, (3) Environmental Risk Perception, and (4) Environmental Disaster Preparedness, all referred to endogenous constructs in the model, were devised to illustrate the nature responses on fluoride removing behaviors among the subjects considering the environmental risks involved. These two variables were further determined as the independent variables whereby community engagement and environmental monitoring efforts combine with environmental risk perception to predict environmental disaster preparedness. Rather drawing from the work done by Patrisina et al. [26] on recent trends in environmental psychology, this study also posits that environmental disaster preparedness is also chained mediated by environmental monitoring efforts and environmental risk perception.

3.2 Hypotheses

Community Engagement (CE) is one of the constructs incorporated within the Theory of Planned Behavior (TPB) which is said to mean the initially described active involvement of community members in various activities to improve disaster preparedness and readiness [27]. Chong et al. [28] explains further that the reason for establishing owned processes over preparation is important is that there is a likelihood to enhance the disaster response and recovery processes as a result of shared accountability and ownership. On the contrary, members of the active, environmental monitoring communities are able to participate in, and therefore, should be protected by, such elements which will in turn enhance their disaster preparedness [29]. Based on the above, the present study posits the following hypothesis:

H1: *Community Engagement (CE) significantly influences Environmental Disaster Preparedness (EDP).*

Using the framework of TPB, Environmental Risk Perception (ERP) can be understood as a judgment about the reasons and impacts of any possible environmental threats, which is derived by either individuals or groups from their surroundings [30]. This environmental risk perception is actually very useful in helping to promote disaster preparedness behaviors. It has thus been noted that precautionary actions tend to be elicited by an individual when there is a high level of perceived risk because the person seeks to avoid the probable risks. The scholars Zeng et al. [30] demonstrated that in the event of diseases such as Ebola, individuals with high levels of risk perception are always prepared to avert such by preparedness measures. Therefore, this study puts forth the following hypothesis:

H2: Environmental Risk Perception ERP has a significant relationship with Environmental Disaster Preparedness EDP.

3.3 Mediation Hypotheses

The term Environmental Monitoring Efforts (EME) encompasses formal activities undertaken by communities or institutions to assess and monitor the status of the environment and its adverse impacts [31]. EME assists in decision making and planning to adopt preparedness measures. As explained by Que et al.[32], not only will early warnings be generated via efficient monitoring, but also, the community will be involved in the readiness stage to such warnings in the event they occur. This is to guarantee that the concerns of the general populace are addressed so that in the event of an emerging threat, the people will know how to react. A poll in geological disaster-prone areas in China found that areas where monitoring activities were done had high disaster preparedness levels. Given these circumstances, the current study proposed to hypothesis:

H3: Environmental Monitoring Efforts (EME) mediates the relationship between Community Engagement (CE) and Environmental Disaster Preparedness (EDP).

The idea of Environmental Disaster Preparedness (EDP) is an adequate level of preparedness to deal with environmental hazards with the purpose of reducing the impact that such hazards may have on the community [33]. According to Muir, the Emergency Preparedness Program includes different types of activities such as planning and developing of emergency's procedures, organization of training drills, and creation of early warning systems [34]. Several studies have indicated that well-prepared communities are better able to mitigate disaster effects and recover more quickly. Ning et al. [35] highlighted that in terms of emergency preparedness behaviors, attitudes toward preparedness were the most strongly correlated. It has also been elucidated that with COVID-19 being one of the most recent challenges relating to emergency and disaster management, preparedness, and planning (EDMPP), the importance of EDMPP is ever increasing [36]. Hence, this present study proposes the following hypothesis:

H4: The interaction between Community Engagement (CE) and Environmental Risk Perception (ERP) positively influences the effectiveness of Environmental Monitoring Efforts (EME) in enhancing Environmental Disaster Preparedness (EDP).

This set of hypotheses is a useful heuristic tool in order to develop an understanding grounded on the Theory of Planned Behavior (TPB) how environmental monitoring efforts (EMEs), community engagement (CE) and environmental risk perception (ERP) interrelate with regard to the enhancement of environmental disaster preparedness in the specific case of fluoride pollution; in particular, it concentrates on both social behavior and social cognition models.
All of these different types of factors need to be taken account for in order to create a better plan on how best replicate and sustain fluoride programs at the national level. The detail diagramitic view of hypotheses are given below in Figure 2.

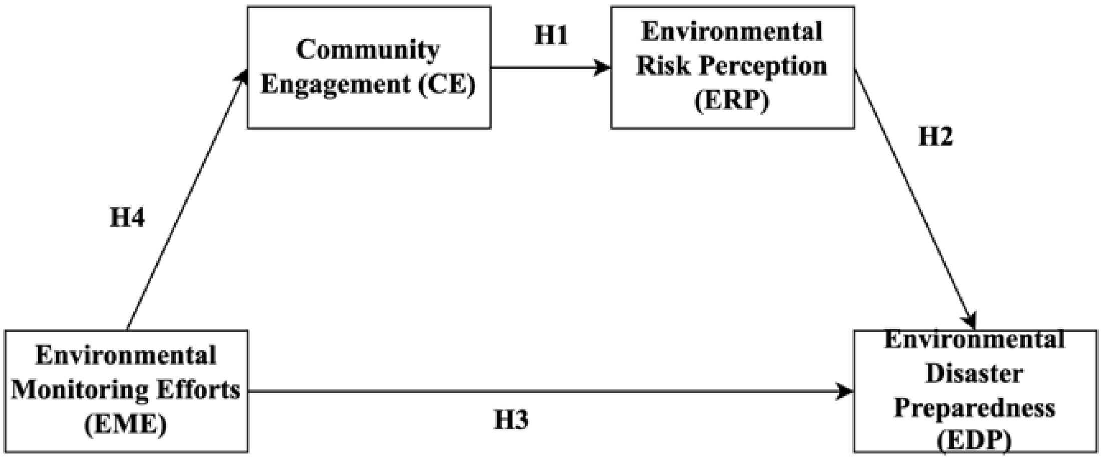

Figure 2: Path model

4. METHODOLOGY

4.1 Measures

The data for this study was collected online on an extensive survey to test the proposed research model. Due to the high fluoride level, this study was performed with residents in Shanxi Province in China through direct communication. We selected this region because they are particularly germane to the study of fluoride regulation and public health. The upcoming part describes the measurements, the sample and how data was collected.

To ensure the content validity of these constructs, the authors adapted most of the items in this survey from previous studies on which the scale was grounded. Table 1 summarizes the items adapted. Generally, the scale for Environmental Monitoring Efforts, EME, was adapted from George and Anilkumar [33], while that for Community Engagement, CE, was adapted from Wells et al.[27]. Moreover, the scale for Environmental Risk Perception (ERP), was adjusted from Zeng et al.[30]. Noting the Environmental Disaster Preparedness (EDP) was adopted from Perry and Lindell [35]. The survey adopted a seven-point Likert scale that provided responses as (1) Strongly disagree to (7) Strongly agree.

Table 1. Measures of Construct

Variable	Items	Source
Environmental Monitoring Efforts (EME)	EME: My community frequently conducts environmental monitoring activities (e.g., checking air/water quality).	[33]
	EME2: I have access to environmental monitoring data (e.g., pollution levels, weather alerts) in my community.	
	EME3: My community regularly updates and reviews environmental monitoring systems to ensure accuracy and reliability.	
	EME4: Environmental monitoring data is actively used in disaster preparedness planning in my community.	
Community Engagement (CE)	CE1: I regularly participate in disaster preparedness activities organized by my community.	[27].
	CE2: My community frequently collaborates with local authorities to enhance disaster preparedness	
	CE3: I am actively involved in monitoring environmental risks in my community.	
Environmental Risk Perception (ERP)	ERP1: I believe it is likely that my area will experience an environmental disaster (e.g., floods, earthquakes).	[30]
	ERP2: I am concerned about the severity of potential environmental disasters in my area.	
	ERP3: I worry about the safety of my community regarding environmental hazards.	
	ERP4: I actively seek information about potential environmental risks in my area.	
Environmental Disaster Preparedness (EDP)	EDP1: My community has a well-developed emergency plan for environmental disasters.	[35]
	EDP2: I regularly participate in disaster preparedness drills.	
	EDP3: There are sufficient resources (e.g., shelters, medical supplies) available in my community for responding to an environmental disaster.	
	MC2: Our organization works with media outlets to disseminate information on fluoride.	
	MC3: Media portrayal of fluoride issues aligns with our organizational stance.	

4.2 Sample and Data Collection

We used the online survey method and provided questionnaires in local languages (Chinese). A pilot study was first conducted, in which 20 participants from Shanxi Province in China were invited to participate in the survey. The participants were local residents, and their answers to the questionnaire included feedback, which was used to refine the measurement items. The modified questionnaire was distributed in March to May 2024 over a period of two months. We communicated with local community leaders and public health officials and requested them to distribute the link for the online survey to residents in their areas. Participants were assured of the confidentiality of their information and were requested to volunteer in the study by completing a questionnaire that explored their opinions on fluoride regulation.

4.3 Demographic Variables

Table 2 summarizes the demographics of the respondents in the final sample. The age of most respondents ranged from 25 to 50 years. Male and female respondents comprised 45% and 55% of the sample, respectively. Respondents who have lived in areas with high fluoride levels for more than 10 years comprised 60% of the sample. Most of the surveyed population had at least a secondary education level (70%) and was aware of local public health policies (65%).

Table 2: Demographic Characteristics of Respondents

Category	Percentage
Age (25-50 years)	76%
Male	45%
Female	55%
Lived in high-fluoride areas >10 years	60%
Secondary education or higher	70%
Aware of local public health policies	65%

4.4 Data Collection Process

The link to the questionnaire was distributed to 900 residents, of whom 750 returned the questionnaires. A total of 50 responses were discarded due to incomplete information, resulting in a final sample consisting of 700 valid responses. We checked for non-response bias by comparing the responses from the questionnaires completed earlier with those completed later. The results did not show any significant difference between the two groups. Hence, we conclude that our sample is not influenced by non-response bias.

5. DATA ANALYSIS AND RESULTS

To assess our measurement and structural model, we applied the structural equation modeling using the SmartPLS version 4.0. SmartPLS is a highly operational method that combines the principal components analysis to establish CFA and regression to estimate both the measurement and structural model. It has also been very beneficial in dealing with formative measures and moderating relationships. According to Purwanto [37], SmartPLS is not only capable of developing a formative model for the latent constructs but also does not make specific assumptions about the distribution of data and can manage complex models very well. Therefore, we used SmartPLS 4.0 software to run CFA and structural model testing in our study.

5.1 Measurement Model

5.1.1 Reliability and Validity

We performed exploratory factor analysis using Smart PLS version 4 to test whether the measures’ indicators can show factor loadings higher than 0.4. Results are shown in the provided Table 3. EFA is typically used to check the accuracy of item-factor matching and prepare for factor relationship analysis. The EFA results indicate that the indices for the overall fit of the proposed model are valid because the resulting values fall within the desired cut-off for loading values. All values are above the recommended level, indicating a lack of cross-loading issues.

Table 3: Construct Reliability and Validity

	PRE3	0.873			
Constructs	Items	Loadings	Cronbach Alpha	CR	AVE
Eff of Fluriode mgt Prog	EFPM1	0.974	0.986	0.987	0.947
	EFPM2	0.967			
	EFPM3	0.986			
	EFPM4	0.969			
	EFPM5	0.970			
Public Awarness	PA1	0.980	0.977	0.977	0.957
	PA2	0.977			
	PA3	0.977			
Public Engagement	PE1	0.958	0.956	0.959	0.883
	PE2	0.942			
	PE3	0.918			
	PE4	0.941			
Political Support	PS1	0.966	0.98	0.985	0.927
	PS2	0.975			
	PS3	0.944			
	PS4	0.965			
	PS5	0.963			
Social media Rep	SMR1	0.928	0.962	0.962	0.867
	SMR2	0.943			
	SMR3	0.913			
	SMR4	0.926			
	SMR5	0.944			
Stakeholder Pressure	SP1	0.953	0.929	0.93	0.876
	SP2	0.917			
	SP3	0.939			

Convergent validity was assessed by testing the value of the factor loadings, Cronbach's alpha, composite reliability (CR), and average variance extracted (AVE). The CFA results show that all item loadings are above 0.7. Next, we assessed the reliability and validity of the data using Cronbach's alpha, CR, and AVE. Cronbach's alpha is considered acceptable if it is 0.70 or higher, the variables in this study range between 0.723 and 0.892, which are considered satisfactory. The values for CR and AVE should be 0.70 and 0.5, respectively, or higher [38]. In this study, CR values range between 0.823 and 0.925, and those for AVE range between 0.608 and 0.755. Both results are above the recommended values, thereby indicating valid measures as shown in Table 3.

The discriminant validity of the measurement model is assessed by comparing the square root of AVE for each construct with the inter-construct correlations shown in Table 4. Such a conclusion arises since the AVE square root for each of the constructions, when compared with all correlated inter-constructs, was higher. For instance, the Community Engagement (CE) Square root of AVE is 0.897 which is above the correlation with Environmental Disaster Preparedness (EDP) at 0.879, Environmental Monitoring Efforts (EMF) at 0.846 and Environmental Risk Perception (ERP) at 0.826. Comparable trends can be seen in the other constructs as well demonstrating that each construct accounts for more variance in its indicators rather than the other constructs.

Table 4: Fornell-Larcker criterion

	Community Engagement (CE)	Environmental Disaster Preparedness (EDP)	Environmental Monitoring Efforts (EME)	Environmental Risk Perception (ERP)
Community Engagement (CE)	0.897			
Environmental Disaster Preparedness (EDP)	0.677	0.879		
Environmental Monitoring Efforts (EME)	0.633	0.645	0.846	
Environmental Risk Perception (ERP)	0.584	0.709	0.587	0.826

Meanwhile, the scores for variance inflation factor (VIF) were examined to assess the possible concerns of multicollinearity among the constructs. The resulting VIF scores range from 1.223 to 2.502, which are below the recommended threshold value of 10 [37]. Thus, multicollinearity is not an issue in this study as shown in Table 5.

Table 5: HTMT Ratios

	Community Engagement (CE)	Environmental Disaster Preparedness (EDP)	Environmental Monitoring Efforts (EME)	Environmental Risk Perception
Community Engagement (CE)				
Environmental Disaster Preparedness (EDP)	0.760			
Environmental Monitoring Efforts (EME)	0.796	0.749		
Environmental Risk Perception (ERP)	0.738	0.834	0.689	

Next, the structural model is tested using the data collected for the validated measures. Overall fit indices for the proposed model were calculated using SmartPLS 4. The resulting values are within the commonly accepted range. RMSEA is 0.057, which is lower than the suggested value of 0.10. CMIN/DF is 2.770, which is also within the accepted range. Moreover, IFI is 0.926, TLI is 0.914, and CFI is 0.926; these values are all above the suggested estimates of 0.90. Thus, the results show a valid model fit.

In addition, given that all questions in the survey were answered by the same individual, the extent of common method bias was evaluated using Harman's one-factor test (Podsakoff et al., 2003). The threat of common method bias in the test is considered high if a single factor accounts for more than 50% of the variance (Harman, 1976). The results show that none of the factors significantly dominate the explanation of the variance, in which the most influential factor accounts for 36.9% of the variance. Other evidence of common method bias includes exceptionally high correlations (r > 0.90) among variables. The inter-construct correlation matrix shows that the unusually high correlation in the sample is non-existent. Thus, common method bias is not a serious concern in this study.

The structural model was tested with the data collected for the validated measures. The overall fit indices for the proposed model are acceptable because the results are within the commonly accepted values. Chi-square/df is 1.832, RMSEA is 0.032, NFI is 0.931, IFI is 0.9420, TLI is 0.941, and CFI is 0.941. Considering that the results show acceptable model fit, we proceed to calculate the path coefficient.

The results show that the calculated path coefficients are significant. The results indicate that Community Engagement (CE) has a strong positive impact on Environmental Risk Perception (ERP) (H1:β = 0.584, p < 0.000). Similarly, Environmental Risk Perception (ERP) has a significant positive association with Environmental Disaster Preparedness (EDP) (H2: β = 0.504, p < 0.000). Moreover, Environmental Monitoring Efforts (EME) plays a mediating role in relation with Community Engagement and Environmental disaster Preparedness (EDP). Particularly, the path from EME to EDP shows a strong Significant effect (H3: β = 0.349, p < 0.000), and the path from EME to CE to EDP also shows a strong Significant effect (H4: β = 0.633, p < 0.000). The findings further show that, CE has significant effect on EDP as evidenced by a strong Positive path coefficient (H4: β = 0.584, p < 0.000). For this reason, we accept the verification of the assumed model (Fig. 3).

5.2 Structural model

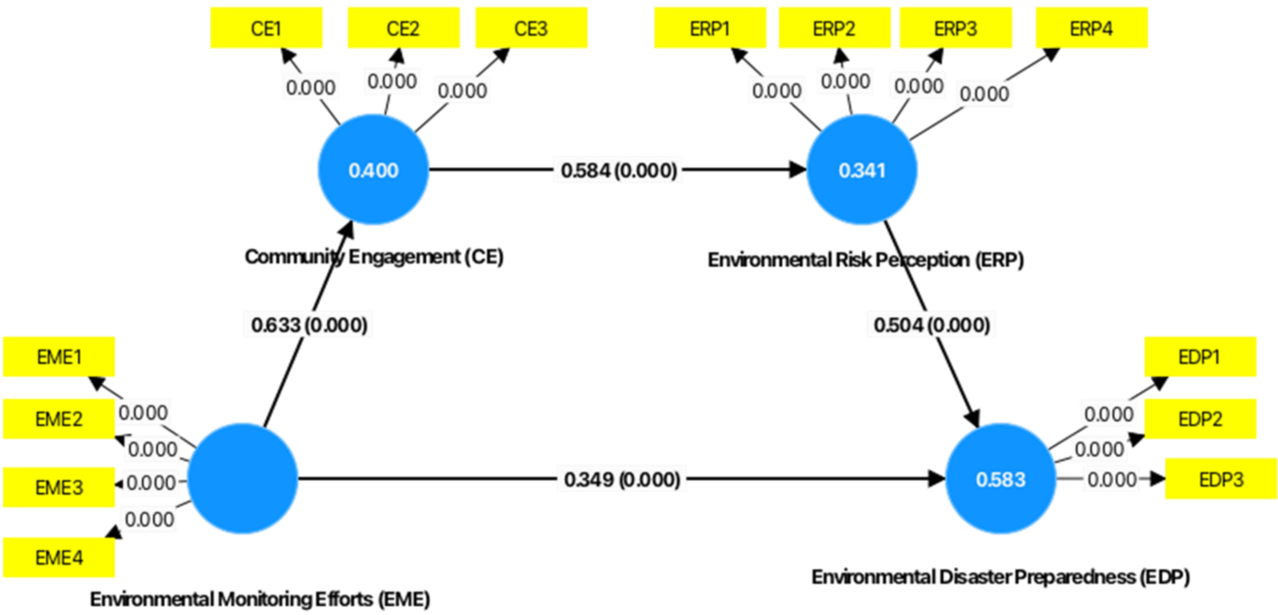

Figure 3: Measurement Model

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Mediation analysis

In this regard, the mediation effects of public awareness were assessed on relation between public engagement & social media representation and stakeholder pressure as well to effectiveness fluoride as shown in Table 6.

Table 6: Mediation analysis showing path coeficients.

	Eff of Fluriode mgt Prog	Political Support	Public Awarness	Public Engagement	Social media Rep	Stakeholder Pressure
Eff of Fluriode mgt Prog	0.973					
Political Support	0.405	0.963				
Public Awarness	0.311	0.281	0.978			
Public Engagement	0.435	0.452	0.414	0.940		
Social media Rep	0.386	0.342	0.451	0.484	0.931	
Stakeholder Pressure	0.342	0.226	0.473	0.421	0.447	0.936

DISCUSSION AND CONCLUSIONS

This study applied the Theory of Planned Behavior (TPB) and investigated the relationship between community engagement (CE), environmental risk perception (ERP) and environmental monitoring efforts (EME) on environmental disaster preparedness (EDP) with acute fluoride toxicity in consideration. Exploring the interrelationship of these factors, this current study seeks to explain the behavioral intentions and perceived control which reside in communities and determine the level of mobilization toward effective disaster preparedness.

These findings highlight the importance of social and environmental factors in building community resilience to environmental risks, with a particular focus on fluoride affected areas. According to the results of this study, community engagement significantly and positively elevates environmental risk perception (H1: $\beta = 0.584$, $p < 0.000$) which further leads to more preemptive disaster preparedness behavior. These results suggest that a greater engagement of community and reorganization environmental risks contribute to individuals improved preparedness for disasters. Our results are in line with the previous research by Que et al. [32] identifying attitudinal factors influencing community engagement in disaster preparedness. Similarly, Environmental risk perception has direct significant influence on environmental disaster preparedness (H2: $\beta = 0.504$, $p < 0.000$) which indicates that individual with higher awareness or sense of environmental risks, are more inclined to take precautions and improve an attitude of environmental disaster preparedness. These results further align with the current literature Kirschenbaum [39] and Bourque, et al.[40]. Furthermore, the mediating role of environmental monitoring efforts between community engagement and environmental disaster preparedness emphasizes the importance of systematic environmental monitoring in disaster management strategies. The finding of current study suggests that monitoring efforts not only prove essential data but also enhance the impacts of community engagement on disaster preparedness outcomes. A synergy between community participation and risk perception adds more value to the monitoring efforts as it is assumed that communities that are aware of the risks and participate will be efficient in utilizing the monitoring information to better their preparedness against environmental disasters.

One of the primary conclusions of this research stresses the importance of developing an integrated framework for preparedness with respect to environmental disasters that includes social engagement and risk assess logging as well as effective monitoring practices. This is quite critical in areas such as the region affected by fluoride pollution where mainstreaming water quality management with social empowerment policy vectors normalizes the effect. There is the potential of increasing the resilience of communities to environmental disaster by increasing the public participation in environmental monitoring practices and making them aware of the environmental concerns.

Theoretical and Practical Implications

This study contributes in a big way to the existing literature primarily in the possible linkages of environmental monitoring, community and risk perception, and disaster preparation, particularly where fluoride exposure is involved. Therefore, firstly, the study has offered fresh insight in rising body of knowledge since the Theory of Planned Behavior (TPB) is further stretched to the area of disaster preparedness in relation to the environment and specifically relating to fluoride pollution. Secondly, there is a special significance as to why there is this study emphasis because it shows that community engagement (CE), environmental risk perception (ERP) and environmental monitoring efforts (EME) cumulatively assist in the developing of the environmental disaster preparedness (EDP) that abate every natural calamity. It is relevant and useful to look at the pre-disaster preparation processes with reference to their scope among the communities and social & psychological components with the aim of how such processes influence the preparation for disasters. The most important part is, as the study shows how important it is to monitor the environment in such a way which promotes the integration of technological and behavioral aspects and thereby supports the readiness for a disaster. This theoretical extension of TBP underscores that when looking at reactions directed at environmental risks, social aspects need to be included to address the issue of community resilience to disasters more effective

The conducted research has some implications which are worth noting not just by the community mental health experts, but also the policymakers, public health practitioners, and community leaders. The findings retain the position that Community Engagement (CE) and environmental risk perception (ERP) do contribute to Improving disaster preparedness (EDP). This implies that the additional measures that can be taken to increase disaster preparedness should be associated with enhancing the level of community engagement and the population's awareness of risks as a means for enhancing disaster preparedness efforts. Concerning the level of probable involvement, participation in environmental monitoring projects can help raise people's awareness of issues such as fluoride pollution and therefore assist further community participation directly or indirectly in such programs. In addition, the results of the study state that there is a necessity for measures and systems of the environmental view that will be quick and clear to the user. With the help of these systems, the communities will also be able to help themselves by taking the necessary precautions to natural calamities expected to happen.

These findings need to be integrated into planning for disaster risk reduction through enhancement of community-based monitoring activities and communication of environmental risk to the community. There should be further enhancement of the disaster preparation project through various trainings and education programs that focus on the community and risk awareness. The application of technical measures of environmental management with attempts at the participation of the community in such measures should lead to sustainable development of the community in their ability to withstand environmental hazards and mitigate the effects of disasters.

Limitations and Future Research Directions

Despite the value of this research to new understanding, there are some other aspects that could be improved upon in the analysis of the data. The nature of the design makes it impossible to demonstrate causality between the important elements of CE, ERP, EME, and EDP, all of which are community engagement (CE), environmental risk perception (ERP), and environmental monitoring efforts (EME) respectively. These are temporal strains, and the conduct has no timelines in order to ascertain order of events in the phenomenon and additional no touch in how all these will in sequential order influence the preparedness on a disaster. In addition, the concentrations of fluoride pollution at a specific site and its vegetation may limit the applicability of the findings to other situations or other types of ecological hazards. For further understanding that might aid in the generalizability of the findings, more work in the future should look into how far these observations can be valid in other areas and even with different environmental threats. Furthermore, although there are some influential variables that may drive the so called 'disaster preparedness' behavior, this approach does not mention these: cultural, economical or legislative differences, for instance. Future studies should take a step further by looking into integrating these variables for the most complete understanding of the parameters influencing disaster preparedness in communities.

Further conclusions concentrate on extending the above mentioned limitations to suggest additional fruitfulness for the standing research. First of all, it is necessary to conduct a longitudinal study concerning the change of the community participation, the perception of the environmental risk, and the participation in environmental monitoring over a certain time period. Such research will also determine how these changes will impact preparation for environmental disasters. Such research would provide better understanding on such interaction and testify the need of formulating longitudinal disaster risk preparedness strategies. In addition, extending the study further to other places and types of environmental hazards will also improve the generalizability of the findings in many contexts. Using a comparative analysis where regions with different environmental challenges, or rural and urban developments are compared, is likely to reveal how more resources communities allocate towards disaster readiness. Last, future research should analyze the contribution of all other factors such as culture, economic status and policy in disaster readiness. Gaining knowledge on how these variables interact with the line dimensions captured in this study would enhance the delivery of well targeted and effective strategies on building resilience in the community.

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