



The precautionary behavior against PM 2.5 exposure

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Abstract

This article presents an integrated theoretical framework combining Protection Motivation Theory (PMT), Precautionary Principles (PP), and the Precaution Adoption Process Model (PAPM) to analyze precautionary behavior in response to PM2.5 exposure. The framework examines how various information channels influence decision-making processes, from awareness to action, through cognitive assessments and stages of precaution adoption behaviors. By incorporating a public attention index based on internet searches, the framework links individual-level processes and population-level indicators of concern regarding PM2.5 issues. This integration offers insights for environmental health research and risk communication, informing targeted strategies to promote protective behaviors against air pollution and other environmental threats. The framework suggests that effective interventions should be tailored to different stages of awareness and decision-making, considering various information sources and their impacts. Potential applications include enhancing risk communication strategies, targeting specific demographic groups, and addressing barriers to the adoption of protective behaviors.

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Introduction

In recent years, PM2.5 (fine particulate matter with a diameter of 2.5 micrometers or less) has emerged as a serious environmental and public health concern, particularly in developing countries experiencing rapid population growth. PM2.5 can remain suspended in the air for long periods and penetrate deep into the respiratory system (Thangavel et al., 2022).

Long-term exposure to PM2.5, even at low levels leads to premature mortality and other adverse health effects (Pope et al., 2002; Pope & Dockery, 2006). PM2.5 originates from diverse sources, both outdoor and indoor environments, meaning that even areas with seemingly clean air can have high PM2.5 levels due to indoor activities such as burning wood or coal for heating and cooking (Liu & Salvo, 2018; Kummetha, 2022).

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In 2019, Thailand ranked as the 28th most polluted country among 98 countries, with an annual average PM2.5 concentration of 24.3 micrograms per cubic meter. By 2020, an annual average PM2.5 concentration was recorded at 18.1 micrograms per cubic meter, moving Thailand to 57th place in the rankings. Thailand's PM2.5 level, while improved, remained four times above the WHO's recommended annual air quality guideline value (IQAir, 2022).

To reduce the negative effects of PM2.5 exposure, individuals take preventive actions to manage their exposure levels. These range from short-term proactive defensive behaviors (such as using indoor air purifiers or wearing protective masks outdoors) to longer-term passive avoidance strategies (such as avoiding outdoor activities during high PM2.5 periods or relocating to areas with better air quality) (Ward & Beatty, 2016).

This article presents a pertinent literature on the integration of Protection Motivation Theory (PMT), Precautionary Principles (PP), and the Precaution Adoption Process Model (PAPM) to develop a conceptual framework for analyzing precautionary behavior in response to PM2.5 exposure. The framework examines how various information channels influence decision-making processes, from awareness to action through cognitive assessments, stages of precaution adoption behaviors. In addition to incorporating a public attention index based on internet searches, the framework links individual-level processes and population-level indicators of concern on PM2.5 issue.

This integrated framework offers insights for environmental health research, risk communication, and informs targeted strategies to promote protective behaviors against air pollution and other environmental threats, suggesting that the effective interventions should be tailored to different stages of awareness and decision-making, considering various information sources and their impacts. Policies could focus on enhancing risk communication strategies, targeting specific demographic groups, and addressing barriers to adoption of protective behaviors.

Literature Review

Theories and principles provide a comprehensive framework for understanding how individuals perceive and respond to environmental and health risks. Protection Motivation Theory (PMT) explains the cognitive processes behind threat assessment and coping strategies. Precautionary Principles advocates for preventive action

despite the threat, which can be observed in both proactive defensive and passive avoidance behaviors. Precaution Adoption Process Model (PAPM) outlines the stages individuals go through when deciding to take protective action. Public Attention Index to PM2.5 Exposure offers a practical measure of public engagement with PM2.5 issues through internet search behavior.

Protection Motivation Theory (PMT)

The PMT, a psychological framework developed by Rogers (1975), explores the cognitive processes involved in threat appraisal and coping appraisal, providing insights into how people perceive threats and how threats motivate individuals to adopt protective behaviors. The theory is widely used in health psychology, risk communication, and behavior change interventions.

Threat Appraisal: The cognitive process by which individuals evaluate the level of danger posed by a particular threat, involves: Perceived severity, which refers to individuals' assessment of how serious or severe the consequences of the threat would be if it occurred. Perceived vulnerability refers to an individuals' belief about their personal likelihood of experiencing the threat.

Coping Appraisal: The cognitive process by which individuals assess their ability to cope with a threat and the effectiveness of the recommended protective action, involves: Response efficacy, which refers to belief that the recommended protective action will be effective in reducing or eliminating the threat. Self-efficacy refers to individuals' confidence in their ability to perform the recommended protective action. Response cost refers to perceived costs associated with taking protective action such as money and time, which are crucial factors to consider.

The theory determines the level of protection motivation. A high perceived severity and vulnerability of threat appraisal tend to increase protection motivation leading to a higher likelihood of adopting protective behaviors of coping appraisal. Understanding threat appraisal is key for promoting protective behaviors through effective interventions and messaging whereas coping appraisal complements threat appraisal by ensuring individuals feel capable of addressing perceived threats.

Precautionary Principles (PP)

The PP defines a new standard of risk management when the existence of risk is subject to some scientific uncertainty. It was introduced at the 1992 Rio Conference

in Article 15, which stated that “where there are threats of serious or irreversible damage, lack of full scientific certainty shall not be used as a reason for postponing effective measures to prevent environmental degradation” (Treich, 2001). The concept of precautionary is strongly linked to the effect of arrival of information over time in sequential models as well as to the situations in which there is ambiguity over probability distributions (Courbage et al., 2013). Therefore, the principle as applied to individuals’ behavior can be understood through *proactive defensive* and *passive avoidance behavior*, which provide a framework for analyzing how individuals respond to potential risks when faced with the threats.

Proactive Defensive Behavior: This refers to actions that individuals take to actively protect themselves from perceived threats. The purpose is to seek control or mitigate the risks while still actively engaging with the risk. This involves investing in protective equipment or technology, making backup plans, actively seeking information and expertise, or engaging in developing skills for effective risk management.

Passive Avoidance Behavior: This refers to avoiding situations or activities perceived as potentially risky. The purpose is to reduce the risk by limiting exposure to potential threats. This involves avoiding certain activities or environments, opting out of decisions with uncertain outcomes, or maintaining the plan even if the change presents potential risks.

PP has become a key approach in risk management that has been widely adopted and applied across various fields (Courbage et al., 2013; Treich, 2001). It is often discussed in relation to policies and environmental contexts and can also be applied to studying individual behavior. The principle emphasizes the dynamic nature of sequential decision-making with evolving information. Importantly, it is worth noting that individuals employed proactive defensive and passive avoidance behavior at the same time.

Precaution Adoption Process Model (PAPM)

The PAPM is a stage-based model that describes the process individuals go through when deciding whether to take protective action against a health threat. The model illustrates a series of stages aiming to explain how an individual comes to decisions to act and how individuals translate the decision into action. Unlike other health behavior models, such as the Health Belief Model, the model explicitly includes unawareness and inaction stages and also provides a more detailed description of the process leading up to action (Weinstein et al., 2020).

PAPM proposes that individuals’ decisions can be categorized into discrete stages. Each stage is characterized by specific patterns of beliefs, behaviors, and informational needs. Stage 1: Unaware, individuals have no knowledge of the health issue or any related precautionary measures. They are completely unaware of the potential risks or the need for preventive action. Stage 2: Unengaged, individuals have become aware of the health issue but have not yet considered taking action. They recognize the existence of the problem but remain detached from it personally. Stage 3: Undecided, individuals actively consider the advantages of taking precautionary action. They weigh the pros and cons but have not reached a conclusion. This stage is marked by uncertainty and information-seeking behavior. Stage 4: Decided not to act, some individuals make a conscious decision not to take any precautionary action. This decision is based on their assessment of the situation, which may include perceived low risk, high costs of action, or other personal factors. Stage 5: Decided to act, some individuals have made a firm decision to adopt precautionary behavior. They have moved past the phase of consideration and are now committed to making a change, although they have not yet begun implementing it. Stage 6: Act, this final stage represents the crucial transition from intention to actual behavior change. In this stage, individuals initiate taking precautionary behavior.

The transition through stages is not always linear, individuals can move backward as well as forward or skip stages. Importantly, awareness of the treats does not always lead to engagement or action. PAPM addresses the overlooked early stages and the gap between deciding to act and taking action, enabling more targeted interventions and communication strategies in public health efforts.

Public Attention Index to PM2.5 Exposure (PAI_PM2.5)

The Public Attention Index for PM2.5 exposure (PAI_PM2.5) is a proxy measure designed to quantify public attention to PM2.5 issues through online search behavior in Thailand, which reflects the public’s threat appraisal and information-seeking in response to perceived PM2.5 risks. Individuals’ expressions of concern toward the risk from PM2.5 exposure could be detected by online search to locate the resolutions to the problem (internet search behavior) such as reading media news online or searching for relevant information about PM2.5 exposure. The index estimates public attention to PM2.5 issues in Thailand by analyzing internet search data across 77 provinces.

The methodology involves collecting monthly search data, selecting terms most correlated with actual PM2.5 levels, and calculating the index using a formula that normalizes search volumes. The resulting index is then validated against actual PM2.5 levels, economic and social costs, and willingness to pay for pollution reduction. This method provides a comprehensive understanding of public reactions to air quality changes, enabling policymakers to assess perceptions and develop effective interventions for environmental health.

Public attention

Public attention refers to the time and effort that citizens, special-interest groups, and the media dedicate to publicly debated issues. For citizens, attention primarily centers on issues that personally impact them, with concern levels directly influencing the focus given to an issue. Special-interest groups benefit by promoting issues aligned with their specific agendas. Meanwhile, the media seeks to maximize profits by emphasizing issues that capture audience interest. Public attention includes both qualitative and quantitative aspects. Qualitatively, it captures the issues society focuses on, as opposed to society's underlying attitudes. Quantitatively, it measures the resources allocated to an issue over time, representing an intensity that reflects resource usage per unit of time (Newig, 2004).

Notably, Public attention and public attitude are distinct concepts. Public attitude reflects a learned predisposition toward a subject, while attention involves the active allocation of resources. Public attention shifts more rapidly and dramatically than public attitude, both in magnitude and rate of change (Newig, 2004; White, 2013).

Determinant factors of public attention

Public attention is primarily influenced by the severity of the environmental situation and the availability of problem-solving resources. These two key factors work synergistically to shape how much attention the public gives to various environmental problems.

Public attention is closely linked to the severity of the environmental situation as explained by the Problem-Reaction Model described by Newig (2004). The higher the costs caused by the environmental problem, the greater the stakeholders being dissatisfied with the situation and their interest in embarking on measures to improve the deficient situation, and thus, the greater the attention of all stakeholders towards the issue (Jamali, 2008).

Furthermore, the Capacity Model (Newig, 2004) highlights the importance of available resources or

capabilities to solve the problem at stake. The deteriorations in environmental conditions remain unperceived unless they are or become technically solvable at economically viable costs explained by the theory of cognitive dissonance (Festinger et al., 1957). As problem-solving resources become more accessible, public awareness and attention are likely to increase.

Measuring public attention

The development of mass media came into being by enabling virtually everyone to receive and disseminate common interesting and relevant information (McQuail, 1987). As a result, public attention has become a major area of research. Public attention suggests at least a basic level of shared focus; otherwise, it would just refer to individual attention. In general, one way to conceptualize public attention is by equating it to the aggregate of individual attentions, which could be measured through random polling or interviews, mass media analysis, and internet search data.

Polls and interviews measure public attention the most direct and accurate compared to other approaches, but their reliability may turn into the contrary when respondents provide inaccurate responses, especially on socially sensitive issues. These methods are costly and can only address select topics at specific times. Respondents are either asked to choose from a list of issues, limiting the range of possible answers, or they may name issues freely, risking the omission of important ones (Bauske et al., 2022; Keeter, 1984; Mayone Stycos, 1996).

Mass media (such as newspapers, television, radio) enables the exploration of a wide range of issues or subjective opinions across virtually any time frame, indirectly revealing individuals' preferences in devoting their attention. As a result, mass media analysis tends to produce less biased outcomes compared to poll and interview approaches. For example, the corpus of published newspapers provides ex-post analyses of issues, whereas polls and interviews are limited to topics covered at the time of their conduct. Mass media analysis approach is more cost-effective and time-efficient than conducting polls and interviews.

Internet search data opens a novel research frontier by directly measuring public attention to unexpected events, providing real-time and dynamic feedback. The internet data source offers immediacy and broad coverage, capturing a large and diverse range of respondents. Internet search data is generated as a byproduct of routine online activity, eliminating the need for individuals or organizations to respond to questions post-event.

This approach can mitigate issues related to non-response or inaccurate answers. Furthermore, it allows for continuous information gathering on a broader spectrum of topics, rather than being limited to a few predetermined questions (Maurer & Holbach, 2016; Nghiem et. al., 2016; Wu et. al., 2022).

Public attention on environmental policy

Public attention significantly influences government actions on politically relevant issues, as illustrated by Newig (2004) rational choice model. This model emphasizes the importance of understanding issue-attention cycles and their role in shaping policy responses through public discourse.

Recent studies have raised concerns regarding the efficacy of environmental policies in general practice, particularly those targeting air quality improvement. Zhang & Mu (2018) critically evaluated interventions such as refined oil price adjustments, suggesting these measures may yield only limited short-term improvements in air quality. Extending this analysis, Lu et al. (2018) and Yang and Geng (2022) identified key indicators of environmental concern within the Chinese public, emphasizing the roles of regulatory measures and public education in fostering heightened awareness and engagement.

Public understanding and interpretation of air quality information present significant challenges. There are studies that revealed a limited awareness of air pollution's health impacts, particularly among individuals without pre-existing respiratory conditions (Arshad et. al., 2024; Chen et. al., 2024; Ghorani-Azam et. al., 2016; Vichit-Vadakan et. al., 2011). Although urban sources of pollution, such as traffic emissions, were widely recognized, there was less awareness regarding rural pollutants, with many individuals often mistakenly perceiving rural areas as pollution-free. The study

also identified a gap in understanding the connection between air pollution and climate change. These studies recommended revising the Air Quality Index (AQI) to incorporate specific health guidance and adopt a more detailed grading system, emphasizing the need for clear communication strategies to bridge the gap between scientific knowledge and public comprehension of air quality issues.

Methodology

Conceptual Framework

Figure 1 is the study's conceptual framework which presents an integrated conceptual framework of the Precaution Adoption Process Model (PAPM), Protection Motivation Theory (PMT), Precautionary Principles (PP), and Public Attention Index to PM_{2.5} Exposure (PAI_PM_{2.5}). This integration demonstrates how external factors (PM_{2.5} exposure levels and information availability) and internal processes (threat perception and coping strategies) work together to move individuals through stages of awareness and action regarding PM_{2.5} exposure. It shows both the cognitive progression through the PAPM stages, and the factors influencing this progression in the determinants section.

The PAPM section outlines stages from “Unaware” to “Act” which illustrate the progression of awareness toward decision-making. The determinant section outlines the specific determinants related to PM_{2.5} exposure that influence progression through the PAPM stages, starting with the severity of PM_{2.5}, leading through threat appraisal, internet search, and public attention index for PM_{2.5} exposure, to coping appraisal, precautionary behavior, and future intention.

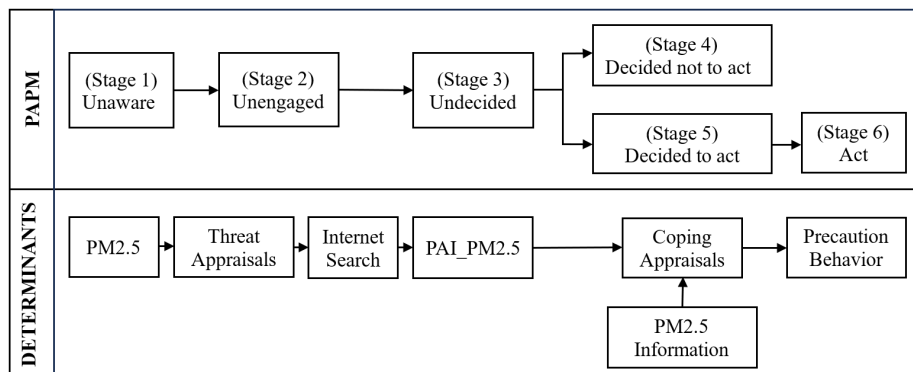


Figure 1 Conceptual Framework

The framework highlights the crucial roles of internet searches, news and information on the issue of PM2.5 exposure in shaping public attention, and subsequent decision-making stages. It demonstrates the effects of information sources on precautionary behaviors. Table 1 and Table 2 provide detailed information on how each component in the framework is defined and measured.

Table 2 illustrates the stages of the PAPM in relation to public awareness and response to PM2.5 pollution threats. The table integrates key concepts from PMT, including threat appraisals and coping appraisals, while also considering internet search behavior and precautionary actions. Each of the six stages is clearly defined and associated with specific determinants, providing a comprehensive view of how people progress in their understanding and response to PM 2.5 exposure risks.

Econometric Model

Logit regression is a statistical method used for examining the relationship between a binary dependent variable and a set of independent predictor variables that can be continuous or categorical (Lechner, 1991). Let there be N observations and k characteristics (exogenous variables) on each observation, ($n = 1, \dots, N$). The dichotomous qualitative response model is defined as:

$$y_n^* = X_n \beta + u_n \quad ; (n = 1, \dots, N)$$

$$y_n = \begin{cases} 1 & \text{if } y_n^* \geq 0 \\ 0 & \text{if } y_n^* < 0 \end{cases} \quad (1)$$

Table 1 The Notation and Definition of Variables in Conceptual Framework

Notation	Definition
PM2.5	The 24-hour average of PM2.5 concentration levels in micrograms per cubic meter. This reflects the actual severity of PM2.5.
Threat Appraisals	A combination of perceptions regarding the severity of potential harm (perceived severity) and the likelihood of experiencing that harm (perceived vulnerability) contributes to the perceived severity of the risk from PM2.5 exposure. This is derived from PMT.
Internet Search	Internet search terms related to PM2.5 issue, collected as secondary data from Google Trends across 77 provinces of Thailand. The data reflect information-seeking behavior concerning PM2.5.
PAI_PM2.5	Public attention index for PM2.5. This reflects the attention on the issue of PM2.5.
Coping Appraisal	An assessment of precaution action according to the concept of PMT involves assessing the effectiveness of potential actions (response efficacy) and ability to successfully implement these actions (self-efficacy).
PM2.5 Information	Channels of news and information on the issue of PM2.5 which can be categorized according to the source (formal and informal) and types (on-line and off-line). This categorization helps assess the perceived reliability and accessibility of perceived information.
Precautionary Behavior	An action on how people respond to the threat of PM2.5 exposure. This encompasses proactive defensive behavior such as wearing masks and passive avoidance behavior such as avoiding polluted areas.

Table 2 Description of Conceptual Framework.

PAPM Stages	Determinant	Definition
Stage 1: Unaware	- PM 2.5	In this initial stage, individuals have no knowledge or awareness about the harmful effects of PM2.5 exposure or how to protect themselves from it. The only relevant factor here is the actual PM2.5 level which is defined as the 24-hour average of PM2.5 concentration levels in micrograms per cubic meter. At this point, despite being exposed to PM2.5, individuals have not formed any opinions about it due to the lack of awareness.
Stage 2: Unengaged	- Threat Appraisals - Internet Search	As individuals move into this stage, they develop some knowledge and awareness about the harmful effects of PM2.5 and potential protective measures, remaining unengaged with the issue because an individual may believe that the issue is irrelevant to them. After perceiving the risk from PM2.5 exposure (called Threat Appraisals in PMT), individuals express of concern toward the risk from PM2.5 that could be detected by online search to locate the resolutions to the problem (called Internet Search Behavior) such as reading media news online or searching for relevant information about PM2.5 exposure. The Public Attention Index for PM2.5 (PAI_PM2.5) is formed at this stage, reflecting the level of public attention to the PM2.5 issue as measured by internet search behavior.

Table 2 Continued

PAPM Stages	Determinant	Definition
Stage 3: Undecided	- PM 2.5 Information - PAI_PM 2.5	Individuals have knowledge and awareness about harmful and protective measures but are uncertain about taking action due to limited knowledge. Therefore, individuals in this stage actively seek information which is influenced by public attention for PM2.5 (PAI_PM 2.5) and news on the issue of PM2.5 (PM2.5 Information).
Decision making (Stage 4 and 5)	- Coping Appraisal	Once individuals perceive harm and engage with the problem of PM 2.5, they will decide whether or not to act in such precautionary activities based on their preference to cope with the PM2.5 risk. This decision-making process is known as Coping Appraisals in PMT.
Stage 4: Decided not to act		Individuals being aware and engaged, some decide not to take protective action against PM 2.5 exposure. This could be due to low perceived threat, low response efficacy, or low self-efficacy. The decision in this stage is influenced by their assessment of coping strategies.
Stage 5: Decided to act		Individuals being aware and engaged, some decide to take preventive action against PM2.5 exposure, which is based on adopted precautionary preference. This decision is influenced by their evaluation of effective coping strategies.
Stage 6: Acting	- Precautionary Behavior	In this final stage, where decisions turn into actions, individuals have taken precaution action to protect themselves against PM 2.5. These precaution behaviors, shape their future intentions regarding PM 2.5 exposure response choices.

where; β denotes the $k \times 1$ vector of unknown coefficients. u_n denotes the error term. X_n denotes the $1 \times k$ vector of exogenous variables. y_n^* denotes the unobservable dependent variable. The observable dependent indicator variable y_n takes the value 1 with probability p_n and the value 0 with probability $1 - p_n$. Due to the assumption on error term being *i.i.d* of logit regression, thus, the logistically distributed p_n is given by:

$$p_n = \frac{1}{1 + \exp(-X_n \beta)} \quad (2)$$

Empirical Model

For the empirical analyses, this study employs the Logit regression to analyze precautionary behavior in response to PM2.5 exposure, with an emphasis on how various information channels influence these behaviors. The models are defined as:

$$\begin{aligned} BEHAVIOR_n^k &= \beta_1 PAI_PM25_n + \beta_2 PM25_n \\ &\quad + \beta_3 INFO_SOURCE_n^k + \beta_4 INFO_TYPE_n^k \\ &\quad + \beta_5 DEMOGRAPHIC_n + \beta_6 CONTROL_n + u_n \end{aligned} \quad ; (n = 1, \dots, N)$$

$$BEHAVIOR_n^k = \begin{cases} 1 & \text{if } BEHAVIOR_n^k \geq 0 \\ 0 & \text{if } BEHAVIOR_n^k < 0 \end{cases} \quad (3)$$

where $BEHAVIOR_n^k$ denotes group of variables that represents types k of precautionary behavior against PM2.5 exposure as precaution practice of individual n . PAI_PM25_n denotes public attention index for PM2.5 issue of individual n . $PM25_n$ denotes the 24-hour average of PM2.5 concentration levels in micrograms per cubic meter of the province in which individual n resides. $INFO_SOURCE_n^k$ denotes PM2.5 information from source of type k as perceived by individual n . $INFO_TYPE_n^k$ denotes PM2.5 information from type k media as perceived by individual n . $DEMOGRAPHIC_n^k$ denotes group of variables that represents demographic characteristic of individual n , consists of gender, age, health condition, highest education attainment level, and occupation type. $CONTROL_n^k$ denotes group of control variables of individuals n that consists of total income, total income of individuals' household, co-residency with elderly aged 60 and over, presence of children under 12 years, and any respiratory patients within the household. u_n denotes the error term (Table 3).

Table 3 Variable summary for logit regression

Category	Variable	Description	Value
Precautionary Behavior	$DEFENSIVE_n^D$	Individual n adopts proactive defensive behavior as precaution practice against PM2.5 exposure	1 if yes, and 0 if no
	$AVOIDANCE_n^D$	individual n adopts passive avoidance behavior as precaution practice against PM2.5 exposure	1 if yes, and 0 if no
	$NOACTION_n^D$	individual n takes any precaution action as precaution practice against PM2.5 exposure	1 if yes, and 0 if no
Public Attention for PM2.5 PM2.5 Concentration Level	PAI_PM25_n	Public attention index for PM2.5 issue of individual n	Numeric value of 0 to 100
	$PM25_n$	24-hour average of PM2.5 concentration levels for individual n 's province	Numeric value in micrograms per cubic meter
Perceived Sources of PM2.5 Information	$INFO_SOURCE_{n_n}^{formal}$	Sources of PM2.5 information as perceived by individual n	1 if individuals n perceive PM2.5 news from formal source (e.g. government departments and agency, news agency, media broadcasting, etc.) and 0 if individual n perceives PM2.5 news from informal source (e.g. friends and relatives, community leader, influencer, youtuber, etc.)
Types of Media for PM2.5 News	$INFO_TYPE_{n_n}^{online}$	Media types of PM2.5 information as perceived by individual n	1 if individual n perceives PM2.5 news from on-line media, and 0 if individual n perceives PM2.5 news from off-line media
	$MALE_n^D$	Gender of individual n	1 if individual n is male, and 0 if individual n is female
Demographic Characteristics	AGE_n	Age of individual n	Numeric value
	$SICKNESS_n^D$	Individual n is a respiratory patient	1 if yes, and 0 if no
	$MARRIED_n^D$	Marital status of individual n	1 if individual n is currently married, and 0 if no
	$EDUCATION_{n_n}^{no}$	Highest education attainment level of individual n is no educational attainment	1 if yes, and 0 is no
Control Variables	$EDUCATION_{n_n}^{Primary}$	Highest education attainment level of individual n is primary school	1 if yes, and 0 is no
	$EDUCATION_{n_n}^{Secondary}$	Highest education attainment level of individual n is secondary school	1 if yes, and 0 is no
	$EDUCATION_{n_n}^{High}$	Highest education attainment level of individual n is high school	1 if yes, and 0 is no
	$EDUCATION_{n_n}^{undergrad}$	Highest education attainment level of individual n is undergraduate	1 if yes, and 0 is no
	$EDUCATION_{n_n}^{graduate}$	Highest education attainment level of individual n is graduate	1 if yes, and 0 is no
	$OCCUPATION_{n_n}^{student}$	Occupation of individual n is student	1 if yes, and 0 is no
	$OCCUPATION_{n_n}^{servant}$	Occupation of individual n is public servant	1 if yes, and 0 is no
	$OCCUPATION_{n_n}^{fulltime}$	Occupation of individual n is full-time employee	1 if yes, and 0 is no
	$OCCUPATION_{n_n}^{parttime}$	Occupation of individual n is part-time employee	1 if yes, and 0 is no
	$OCCUPATION_{n_n}^{self}$	Occupation of individual n is self-employed	1 if yes, and 0 is no
	$OCCUPATION_{n_n}^{former}$	Occupation of individual n is farmer	1 if yes, and 0 is no
	$OCCUPATION_{n_n}^{retired}$	Occupation of individual n is retired	1 if yes, and 0 is no
	$OCCUPATION_{n_n}^{unemploy}$	Occupation of individual n is unemployed	1 if yes, and 0 is no
	$LN(INCOME_R)_n$	Log total income of individual n	Numeric value
	$LN(INCOME_HH)_n$	Log total income of individual n 's household	Numeric value
	$CORES(ELDERLY)_n^D$	Individual n lives with elderly aged 60 years and over	1 if yes, and 0 is no
	$CORES(CHILDREN)_n^D$	Individual n lives with children aged below 12 years	1 if yes, and 0 is no
	$CORES(SICKNESS)_n^D$	Individual n lives with respiratory patient	1 if yes, and 0 is no

Discussion

The analyzing of human cognition and behavior of are inadequate under the explanation by a single theory, necessitating multiple perspectives for comprehensive understanding more efficiently. This article presents an integrated framework of Protection Motivation Theory (PMT), Precautionary Principles (PP), and the Precaution Adoption Process Model (PAPM) that provides a comprehensive view of how various information channels influence individuals' perceptions, motivations, and adoption of precautionary action throughout the decision-making process. PAPM explains the transition process of how individuals adopt precautionary behavior, from being unaware of a risk (PM_{2.5} exposure) to taking or not taking precautionary action while PMT explains how individuals assess PM_{2.5} threats and protective measures based on perceived severity, vulnerability, and coping ability in determining their adoption of precautionary behaviors.

Contributions of the integrated framework in combining cognitive processes of the risk from PMT offer insights into why some take action against PM_{2.5} risks while others do not, the response against the risk from PP, and behavior change stages from PAPM. Firstly, this reveals how differences in information types and sources impact behavior across different awareness and decision-making stages, which helps identify critical points for more targeted and effective public health communication to promote health protective policies related to the risk from environmental issues, especially from PM_{2.5} exposure and potentially other environmental health-related behavior. Second, it enables a more dynamic analysis of behavior change, examining how factors such as risk perception and efficacy beliefs evolve over time and influence progression through the PAPM stages. Third, this framework also corporates contextual factors, demographic characteristics, to illustrating their potential impact on both cognitive processes and stage progression. Last, the integration bridges individual-level cognitive processes (PMT) with population-level indicators (public attention index for PM_{2.5} exposure), offering a more comprehensive view of public response to the risk from PM_{2.5} exposure. This novel integration contributes to the theoretical framework of health behavior change and potentially informs future research in environmental health and related fields.

Conclusion and Recommendation

This article presents an innovative integrated theoretical framework combining Protection Motivation Theory (PMT), Precautionary Principles (PP), and the Precaution Adoption Process Model (PAPM) to comprehensively understand precautionary behavior against PM_{2.5} exposure. This integration offers key contributions to environmental health behavior research, including comprehensive behavioral analysis, insights into information impact across awareness stages, dynamic behavior change analysis, incorporation of demographic influences, and bridging individual and population-level indicators.

The framework enhances the understanding of how individuals respond to environmental health risks, particularly PM_{2.5} exposure, from initial awareness to taking preventive action. This offers a foundation for future research in environmental health, potentially informing more effective public health interventions and policy development. Therefore, understanding how individuals progress from unawareness to action on PM_{2.5} risks can inform strategies for promoting protective behaviors and policies addressing air quality and other environmental health concerns.

Conflict of Interest

The authors declare that there is no conflict of interest.

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