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Targeted Education for Microplastic Risk: A Community-Based Intervention in Industrial Thailand

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Research Article

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Abstract

Background/purpose. Microplastics (MPs) pose major health risks, yet public awareness is critically low in high-risk areas, such as Thailand's Map Ta Phut Industrial Estate, leading to hazardous behaviors. This study assessed residents' knowledge, attitudes, and practices (KAP) regarding MPs exposure and subsequently designed a targeted, theory-driven health education program to empower the community.

Materials/methods. A three-phase research and development design was applied. Phase 1 involved a cross-sectional survey (n=382) assessing KAP. Phase 2 involved in-depth interviews (n=30) to explore perceptions and barriers. In Phase 3, mixed-methods data were synthesized to develop a four-session health education intervention grounded in Nutbeam's health literacy model and Thailand's V-SHAPE framework.

Results. The baseline assessment revealed profound knowledge deficits, with over 50.00% of participants unaware of MPs and their health implications. The majority (78.50%) engaged in moderate-risk behaviors, while attitudes were predominantly neutral (50.30%). The qualitative findings identified critical barriers, including misinformation, structural impediments (such as economic reliance on local seafood), and widespread apprehension about contamination. The developed intervention directly addressed these issues through sessions on awareness, media literacy, risk communication, and self-management skills.

Conclusion. This study identified significant gaps in microplastic knowledge and high-risk behaviors within a Thai community. An educational intervention was developed that integrates established health literacy frameworks to address these deficits. The findings demonstrate that enhancing environmental health literacy is an effective strategy for promoting positive behavioral change in at-risk populations. Future research should evaluate the program's long-term impact and scalability to inform policy and community engagement initiatives.

1. Introduction

Microplastics (MPs) have emerged as pollutants of global concern due to their pervasive distribution across all aqueous environments and their confirmed ingestion by a variety of aquatic organisms (Guerranti et al., 2019). Defined as plastic particulates smaller than 5 millimeters, MPs originate from the degradation of larger plastic materials and from primary sources such as microbeads found in cleaning products, cosmetics, and textile fibers (Joint Group of Experts on Scientific Aspects of Marine Environmental Protection (GESAMP), 2015). Their small size, high surface area, and hydrophobic properties enable them to absorb and transport hazardous substances, including persistent, bioaccumulative, and toxic substances (PBTs) and chlorinated hydrocarbons (Ahmad et al., 2025; Tang, 2021). MPs are commonly found not only in plastic raw materials but also in contaminated ambient media, such as air, water, and food sources, carrying pollutants that pose potential risks to human health (Yarahmadi et al., 2024).

In Thailand, plastics are heavily utilized across industrial sectors, resulting in MPs being commonly released during production and consumption. Due to their buoyancy and resistance to biodegradation, MPs can bypass conventional wastewater treatment systems and enter natural water bodies, eventually accumulating in rivers, canals, seas, and sediments, and being ingested by aquatic organisms (Saelee et al., 2021). Alarmingly, seafood—particularly shellfish products, which are consumed whole—has been found to be contaminated, with substantial MPs contamination in mussels and oysters sold in major Thai fish markets, where there have been levels reported of 9±3.55 pieces/gram in mussels and 9.5±0.71 pieces/gram in oysters, indicating the consumption of MPs through the food chain by the general population.

The Map Ta Phut Industrial Estate in Rayong Province, Thailand, is one of the largest petrochemical and heavy industrial zones in Southeast Asia. the Pollution Control Department (PCD) of Thailand has reported recurrent environmental incidents in the area, including chemical leaks and emissions, which contribute to MPs dispersion in both terrestrial and marine ecosystems (Pollution Control Department, 2023).

Additionally, Chokejaroenrat et al. (2024) investigated the degradation of MPs using heat-activated persulfate and its impact on antibiotic adsorption and environmental toxicity. Their findings highlighted the complex interactions between MPs and other pollutants, such as antibiotics, in industrial areas. Their study underscored the potential risks associated with MPs pollution, particularly in regions with intensive industrial activities such as Map Ta Phut.

Although MPs are omnipresent—detected in salt, water, human tissues, and aquatic ecosystems—public awareness remains relatively limited. Nonetheless, when informed about potential health impacts, 75% expressed major concern. This gap between awareness and concern highlights the need to integrate human dimensions—knowledge, perception, and behavior—into public health and environmental strategies. Furthermore, Janzik et al. (2024) emphasized that an individual's understanding of MPs risks was shaped by personal values, attitudes, and societal context, while Fian et al. (2025) demonstrated that public risk perceptions were key to driving support for plastic-reduction policies and behavior change.

Addressing microplastic pollution effectively requires not only environmental and industrial interventions but also a deep understanding of the behavioral responses and psychosocial dynamics of affected populations. The KAP model (Knowledge, Attitude, and Practice) serves as a valuable framework in this context, positing that enhancing knowledge can lead to positive shifts in attitudes and, consequently, promote healthier practices. This approach has been applied successfully in various studies to assess and improve public understanding and behavior related to environmental health issues, including MPs exposure (Alizadeh et al., 2024; Somerwill, L., & Wehn, U, 2022). By evaluating the knowledge, attitudes, and risk behaviors of residents near the Map Ta Phut Industrial

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Estate—a high-risk industrial zone in Thailand (Rangkadilok, 2015) —the current study aimed to inform the development of a tailored health education program. Such a program would be designed to encourage behavioral change and to mitigate the health risks associated with MPs in vulnerable communities.

2. Literature Review

The current body of research, as synthesized by Andrady (2011), affirms the dual threat posed by MPs: their physical presence and their chemical function as carriers for toxins. It has been thoroughly documented that weathering processes generate these particles, which subsequently adsorb high concentrations of POPs from seawater. The subsequent consumption by marine organisms serves as a distinct entry point into the food web. Notably, the review points out that the process after ingestion remains a "black box"—the extent to which these pollutants are emitted into an organism's tissues and biomagnify through the food chain has not yet been sufficiently modeled or quantified.

Cverenkárová K et al., (2021) demonstrated clearly that MPs, resulting from widespread plastic production and waste, have significantly polluted the environment and infiltrated the food chain, especially in marine organisms. Nonetheless, the full scope of this contamination across different food commodities and the related public health risks have not been thoroughly explored and require more in-depth research.

As research on MPs has expanded, the existing literature has highlighted a notable gap in understanding nanoplastics, especially in terms of their environmental fate across various ecosystems, their function as carriers for contaminants and pathogens, and the pressing necessity for future investigations to prioritize the behavior of naturally-aged particles over synthetic beads to effectively evaluate their real-world risks (Wang L, et al., 2021).

MPs pollution is an increasing environmental issue resulting from the buildup of enduring plastic waste that negatively impacts aquatic organisms. Due to heightened plastic production and inadequate waste management, plastics infiltrate ecosystems through pathways such as industrial discharges, agriculture, and wastewater discharges. Particles are now present in human food and the air, posing potential health risks and prompting global regulatory measures. This study explores the prevalence, origins, and health effects of MPs, with a distinct focus on how human psychology and cognitive skills can help to address this environmental issue. Karbalaei, S., et al., (2018).

Lamoree, M. H., et al. (2025) reported increasing evidence of micro- and nanoplastics (MNPs) in the human body, raising important health concerns. Research indicates that MNPs could traverse biological barriers such as the gut and lungs, subsequently enter the bloodstream and access delicate organs. Initial studies associate MNPs exposure with negative consequences, such as impacts on the immune system, reproductive health, and cardiovascular function. Nonetheless, human studies are constrained by insufficient exposure assessment methods, hindering conclusive risk evaluation. Developing these analytical tools is essential for accurately assessing the health impacts of MNPs and guiding effective public health strategies.

3. Methodology

A research and development design was conducted between March to May 2024 in the area surrounding the Map Ta Phut Industrial Estate, Rayong Province, Thailand. The study was implemented in three distinct phases:

Phase 1:

A quantitative approach was used to assess MPs-related knowledge, attitudes, and risk behaviors among Thai residents living near the Map Ta Phut Industrial Estate. Data was collected using

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structured questionnaires based on the Knowledge, Attitude, and Practice (KAP) framework to achieve the initial research objectives.

Phase 2:

A qualitative approach was undertaken in three steps:

1. Socio-demographic data and in-depth semi-structured interviews (approximately 20–30 minutes per participant) were conducted with key informants to gain deeper insight into their perceptions and practices related to MPs exposure.

2. A comprehensive literature review was carried out to identify best practices in health education programs focused on reducing MPs intake.

3. Based on the findings from both the qualitative data and literature review, a prototype health education program was developed.

Phase 3:

This phase focused on the construction and refinement of a health education program designed to enhance public KAP concerning MPs hazards. Specifically, the program targeted residents living near the Map Ta Phut Industrial Estate.

3.1. Study Population and Sampling

Phase 1:

This study focused on residents living near the Map Ta Phut Industrial Estate in Rayong Province, Thailand. The target population consisted of 76,138 residents within Map Ta Phut Municipality (Maptaphut City Municipality, 2023). In total, 382 participants were selected using multi-stage random sampling, based on the Krejcie & Morgan (1970) sample size determination table, with a 95% confidence level and a 5% margin of error. Participants were recruited from three key communities located within the vicinity of the industrial estate: 1) Takuan-Ao Pradu community, 2) Wat Sophon community, and 3) Ruam Pattana community. These communities were chosen strategically for their geographical proximity to the industrial zone, making them particularly relevant for studying environmental health impacts, such as MP exposure. This community-based sampling approach ensured representation from areas likely to be affected by industrial activities, supporting the study's objective of assessing MPs-related health awareness and behaviors within at-risk populations.

Table 1. Phase 1 Statistics for Participants Based on General Characteristics

Data	n=382	
	Frequency	Percentage
Sex		
Male	134	35.10
Female	247	64.60
LQBTQ+	1	0.30
Age		
< 20 years	9	2.40
21–30 years	72	18.80

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Data	n=382	
	Frequency	Percentage
31–40 years	81	21.20
41–50 years	62	16.20
51–60 years	89	23.30
> 60 years	69	18.10
Marital Status		
Single	140	36.60
Married	202	52.90
Divorced	10	2.60
Separated	8	2.10
Widowed	22	5.80
Religion		
Buddhism	377	98.70
Christianity	2	0.50
Islam	2	0.50
Other	1	0.30
Educational Level		
No formal education	10	2.60
Primary education	137	35.90
Lower secondary education	74	19.40
Upper secondary education	73	19.10
Diploma	40	10.50
Bachelor's degree	45	11.70
Postgraduate degree	3	0.80
Occupation		
Wage laborer	182	47.70
Merchant	82	21.50
Fisherman/Fisherwoman	4	1.00
Government official	10	2.60

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Data	n=382	
	Frequency	Percentage
Student	12	3.10
Gardener	11	2.90
Housewife/Househusband	55	14.40
Other	26	6.80
Monthly Income (THB)		
Less than or equal to 5,000	49	12.80
5,001–10,000	129	33.80
10,001–15,000	110	28.80
15,001–20,000	59	15.40
20,001–30,000	26	6.80
More than 30,000	9	2.40
Housing characteristics		
Own house	196	51.30
Relative’s house	26	6.80
Rented house	145	38.00
Dormitory	7	1.80
Other	8	2.10
Household size		
1 persons	72	18.80
2–3 persons	149	39.00
4–5 persons	121	31.70
More than 5 persons	40	10.50

Based on the results in Table 1, of the 382 respondents, the majority were female (64.60%), followed by males (35.10%) and one LGBTQ+ participant (0.3%). The largest proportion of participants were aged 51–60 years (23.30%), followed by 31–40 years (21.20%) and 21–30 years (18.80%). Only 2.40% were aged under 20 years and 18.1% were aged over 60 years. Over one-half (52.90%) were married, while 36.6% were single. Some were widowed (5.80%), divorced (2.60%), or separated (2.10%). Most people practiced Buddhism (98.70%), with small percentages of Christians, Muslims, and others (0.30%). Most had completed primary school (35.90%), followed by lower secondary (19.40%) and upper secondary (19.10%). Diplomas and (10.50%), bachelor's (11.70%), and postgraduate (0.80%) degrees were held by smaller proportions, while 2.60% had no formal education. The most common occupations were wage laborer (47.70%), merchant (21.50%), and

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housewife/househusband (14.40%). Other occupations were students (3.10%), gardeners (2.90%), government officials (2.60%), fishermen (1.00%), and others (6.80%). One-third (33.80%) earned THB 5,001–10,000 per month, while 28.80% earned THB 10,001–15,000 per month. Fewer earned less than THB 5,000 per month (12.80%) or more than 30,000 (2.40%). Over one-half (51.30%) owned their homes, while others rented (38.00%) or lived with relatives (6.80%). Few lived in dormitories (1.80%) or other housing (2.10%). Most households had 2–3 members (39.00%), followed by 4–5 (31.70%). Households with 1 member comprised 18.80%, while those with 5+ members comprised 10.50%.

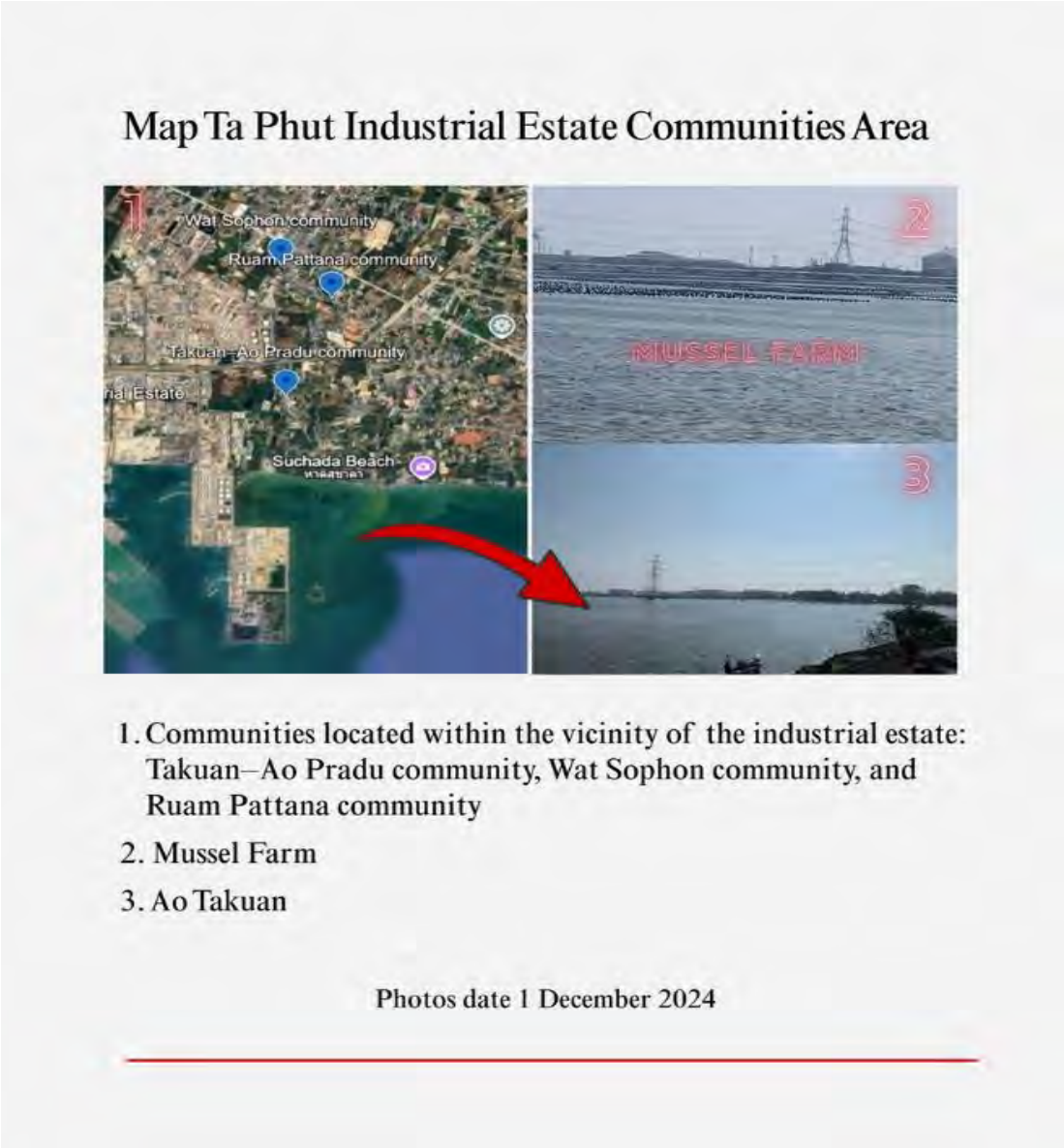

Figure 1. (1) Locations of sampling sites in coastal area adjacent to Map Ta Phut Industrial Estate in Rayong Province, Thailand (Google Earth, 2024); (2) Mussel farm; and (3) Ao Takan. (Photography taken by the authors on 1 December 2024)

Phase 2:

This phase engaged 30 key informants residing in the vicinity of the Map Ta Phut Industrial Estate in Rayong Province, Thailand, specifically from three communities: Takuan-Ao Pradu, Wat Sophon, and Ruam Pattana. The participants were selected purposively based on predefined criteria to ensure relevant contextual insights into MPs-related KAP. The participants' socio-demographic profile revealed a diverse range of contextual variables. Ages ranged from 26 to 80 years, and marital status

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included single, married, and widowed individuals. The majority were Buddhist. Education levels varied from primary education (Grade 6) to vocational and bachelor's degrees. Participants were engaged in a variety of occupations, including manual labor, government contract work, retirement, and informal commercial activities. Reported income varied widely, with some providing specific monthly figures. Living situations included both rented housing (such as boarding houses and apartments) and privately owned homes, with differing numbers of co-residents. Several participants disclosed pre-existing health conditions such as HIV, diabetes, hypertension, hyperlipidemia, and allergies. These socio-biological characteristics provide essential context for understanding the community's vulnerability and behavioral responses to microplastic exposure.

Data Collection

Prior to any data collection, informed consent was obtained from all participants in phase 1 and from key informants in phase 2, and each participant was informed that withdrawal from the study would be allowed at any point without penalty.

Phase 1: Quantitative Tool

Self-designed questionnaire to collect sociodemographic information. The questionnaire consisted of 6 parts: 1) demographic data (gender, age, marital status, religious, education level, occupation, income, current residential characteristics, number of residents living in the same house as the respondent; 2) MPs knowledge; 3) knowledge on health effects of MPs; 4) attitude toward the dangers of MPs; 5) Behavior regarding risk of MPs ingestion.

Phase 2: Qualitative tool

Face-to-face interviews to collect data. The key informant participants were interviewed at separate times of their choosing. Each interview began with friendly conversation. The demographic data were collected before the in-depth interview, and the remaining parts of the questionnaire were completed afterward. Each participant had a 20–30-minute in-depth interview.

Six questions were developed based on the in-depth interviews. These questions were used to assess knowledge, attitudes, and risk behaviors of the targeted residents near the Map Ta Phut Industrial Estate: Question 1) What are microplastics? Please answer in detail. Question 2) Do microplastics harm your health? Why? 3) Can you avoid microplastics in daily life? If so, how? 4) Is your seafood microplastic-contaminated? 5) Is your neighborhood microplastic-contaminated? 6) do you have any congenital diseases? What types of disease do you have?

Statistical Analysis

The quantitative data were analyzed using descriptive statistics (frequencies and percentages) to summarize participants' responses.

Qualitative data, QDA Miner Lite version 3.0—a free, user-friendly qualitative data analysis software developed by Provalis Research—was used to facilitate thematic coding and data visualization. This software allows researchers to import textual data, organize code hierarchically, and generate visual representations, such as code frequency charts and tag clouds, to enhance the efficiency and clarity of qualitative analysis (Provalis Research, 2025).

The qualitative analysis followed a systematic content analysis approach, as outlined by Kuckartz (2014), encompassing eight steps: (1) preparing the data; (2) defining units of analysis; (3) developing categories and a coding scheme; (4) testing the scheme on a sample of text; (5) coding all text; (6) assessing coding consistency; (7) drawing conclusions from the coded data; and (8) reporting methods and findings. This structured methodology ensured a rigorous and transparent analysis process, enabling the researchers to effectively identify and interpret key themes within the data.

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4. Results

Phase 1:

Table 2. Frequency and Percentage Distribution of Respondent's Knowledge About Microplastics.

Knowledge about microplastics	n=382	
	Frequency	Percentage
High level	69	18.10
Moderate level	122	31.90
Low level	191	50.00

The analysis of participants' knowledge about MPs (Table 2) revealed that one-half of the respondents (50.00%) had low knowledge, approximately one-third (31.90%) had moderate knowledge, and only 18.10% had high knowledge. These findings indicated that most of the sample population had limited awareness or understanding of MPs-related issues, underscoring the need for targeted educational interventions to improve health literacy and environmental awareness.

Table 3. Frequency and Percentage Distribution of Knowledge About Health Impacts of Microplastics.

Knowledge about health impacts of microplastics	n=382	
	Frequency	Percentage
High level	98	25.70
Moderate level	90	23.60
Low level	194	50.80

The findings on participants' knowledge regarding the health impacts of MPs (Table 3) indicated that the majority (50.80%) had a low level of understanding, approximately one-quarter of respondents (25.70%) had a high level of knowledge, and 23.60% had a moderate level. Based on these results, over one-half of the participants lacked sufficient awareness of the potential health risks associated with MPs exposure, highlighting a critical gap in public health literacy and the need for enhanced educational initiatives focused on MPs-related health effects.

Table 4. Frequency and Percentage Distribution of Attitudes Toward Microplastics.

Attitudes toward microplastics	n=382	
	Frequency	Percentage
Positive attitude	24	6.20
Neutral attitude	192	50.30
Negative attitude	166	43.50

Analysis of the participants' attitudes toward MPs (Table 4) indicated that the majority held neutral attitudes (50.30%), indicating a general lack of strong opinions or engagement with the issue.

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A substantial proportion (43.50%) expressed negative attitudes, suggesting concern or unfavorable perceptions regarding MPs. In contrast, only a small number (6.20%) had a positive attitude toward MPs. These findings reflected a predominantly ambivalent or critical stance among the population, which may have stemmed from their limited knowledge or awareness of MPs-related risks and might influence behavioral responses to environmental health interventions.

Table 5. Frequency and Percentage Distribution of Risk Behaviors Related to Microplastic Exposure.

Risk behaviors related to microplastic exposure.	n=382	
	Frequency	Percentage
High-risk behavior	29	7.60
Moderate-risk behavior	300	78.50
Low-risk behavior	53	13.90

The distribution of risk behaviors associated with MPs exposure (Table 5) indicated that most participants (78.50%) engaged in behaviors classified as moderate risk. A smaller proportion (13.90%) demonstrated low-risk behaviors, while only 7.60% exhibited high-risk behaviors. These findings suggested that although overtly hazardous practices are relatively uncommon, the prevalence of moderate-risk behaviors might contribute to cumulative microplastic exposure over time, emphasizing the importance of targeted behavioral interventions to shift practices toward lower-risk profiles and promote sustainable, health-conscious habits.

Table 6. Multiple Linear Regression of Knowledge About Microplastic, Knowledge About Health Impacts of Microplastic and Attitudes Toward Microplastic with Risk Behaviors Related to Microplastic Exposure

Variable	Unstandardized coefficients		Standardized coefficients	t	p-value
	B	SE	β		
Constant value	3.14	.16		18.72	.00*
Knowledge about MPs	-.01	.02	-.14	-2.51	.01*
Knowledge about health impacts of MPs	-.01	.02	-.11	-2.01	.04*
Attitudes toward MPs	-.04	.05	-.05	-.91	.35

Note. R = .13, R^2 = .01, Durbin-Watson = 1.77, *p-value < .05

The regression model (Table 6) explained 1% of the variance in risk behaviors related to MPs exposure (R^2 = .01). Two predictors emerged as significant negative contributors: knowledge about MPs (β = –.04, p < .05) and knowledge about the health impacts of MPs (β = –.11, p < .05). In contrast, attitudes toward MPs (β = –.05, p = .355) were not a significant predictor, suggesting that attitudinal factors alone may not influence behavioral outcomes in this context. The Durbin–Watson statistic (1.77) indicated no concerns regarding autocorrelation.

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Table 7. ANOVA Table About Knowledge About Microplastic, Knowledge About Health Impacts of Microplastic, Attitudes Toward Microplastic, and Risk Behaviors Related to Microplastic Exposure on Age

Variable	Source	SS	df	MS	F	p-value
Knowledge about MPs	Between Groups	211.83	9	23.53	.28	.97
	Within Groups	30980.57	372	83.28		
	Total	31192.41	381			
Knowledge about health impacts of MPs	Between Groups	109.34	9	12.14	.78	.63
	Within Groups	5781.25	372	15.54		
	Total	5890.59	381			
Attitudes toward MPs	Between Groups	12.20	9	1.35	2.95	.00*
	Within Groups	170.64	372	.45		
	Total	182.85	381			
Risk behaviors related to MPs exposure	Between Groups	8.11	9	.90	2.36	.01*
	Within Groups	141.63	372	.38		
	Total	149.74	381			

* p-value < .05

The ANOVA results (Table 7) indicated no significant age-related differences in knowledge about MPs ($F = .28$, $p > .05$) or knowledge of their health impacts ($F = .78$, $p > .05$). In contrast, significant differences were observed in attitudes toward MPs ($F = 2.95$, $p < .05$) and MPs-related risk behaviors ($F = 2.36$, $p < .05$).

Table 8. ANOVA Table about knowledge about microplastic, knowledge about health impacts of microplastic, attitudes toward microplastic, and risk behaviors related to microplastic exposure on education level

Variable	Source	SS	df	MS	F	p-value
Knowledge about MPs	Between Groups	1145.99	6	191.00	2.38	.02*
	Within Groups	30046.41	375	80.12		
	Total	31192.41	381			
Knowledge about health impacts of MPs	Between Groups	217.61	6	36.27	2.39	.02*
	Within Groups	5672.97	375	15.12		
	Total	5890.59	381			
Attitudes toward MPs	Between Groups	2.63	6	.43	.91	.48
	Within Groups	180.22	375	.81		
	Total	182.85	381			
Risk behaviors related to MPs exposure	Between Groups	1.91	6	.32	.81	.56
	Within Groups	147.82	375	.39		
	Total	149.74	381			

* p-value < .05

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The ANOVA results (Table 8) showed that education level was significantly associated with knowledge about MPs ($F = 2.38$, $p < .05$) and knowledge about the health impacts of MPs ($F = 2.39$, $p < .05$). These findings indicate that participants with different educational backgrounds demonstrated different levels of knowledge. In contrast, attitudes toward MPs ($p > .05$) and risk behaviors related to MPs exposure ($p > .05$) did not differ significantly across education levels.

Phase 2:

Table 9. Key Questions and Responses from Key Informants of in-depth Interviews (n=30) from Three Communities, Consisting of: 1. Takuan-Ao Pradu (n=10); 2. Wat Sophon (n=10); and 3. Ruam Pattana (n=10).

Research Question	Key Findings	Major Themes	Policy Implications	Limitations
Q1: Awareness of Microplastics	- 40% could define microplastics - 40% had no prior knowledge - 20% heard of but lacked understanding	-Size/source awareness -Media influence - Misconceptions (chemicals/dust)	- Targeted public education - Improved science communication	- Small sample size - Limited scientific depth in responses
Q2: Health Risk Perceptions	- 60% felt at risk - 23% uncertain - 17% saw no risk	- Food packaging concerns - Long-term accumulation fears - Cancer speculation	- Clearer risk communication - Focus on high-exposure sources	- Self-reported perceptions - No clinical correlation
Q3: Avoidance Possibility	- 67% saw avoidance as difficult - 23% attempted partial avoidance - 10% confident in avoidance	- Structural barriers - Substitution strategies - Fatalism vs empowerment	- Plastic packaging regulations - Alternative product promotion	- Urban bias - Social desirability bias
Q4: Seafood Contamination	- 73% believed seafood contaminated - 17% uncertain - 10% believed safe	- Visible pollution evidence - Food chain concerns - Proximity effects	- Fisheries management - Consumer labeling systems	- Coastal respondent bias - Anecdotal evidence
Q5: Residential Contamination	- 73% believed homes contaminated - 17% uncertain - 10% believed safe	- Industrial proximity - Household sources - Waste management issues	- Localized monitoring - Community education	- Limited rural representation

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Research Question	Key Findings	Major Themes	Policy Implications	Limitations
Q6: Health Conditions	- 40% hypertension - 23% hyperlipidemia - 10% diabetes - 33% no conditions	- Metabolic syndrome cluster - Age-related patterns - Unique autoimmune cases	- Vulnerable population focus - Medication interaction studies	- Small clinical sample - No treatment data

According to table 9:

Cross-Cutting Findings:

1. Knowledge-Action Gap: High awareness (Q1) doesn't translate to effective avoidance (Q3)
2. Structural Barriers: Market dominance of plastics hinders behavioral change (Q3)
3. Health Connections: Chronic conditions (Q6) may compound microplastic risks (Q2)
4. Localized Concerns: Proximity to industry/coast drives perceptions (Q4, Q5)

Recommended Action Items:

1. Tiered education campaigns addressing specific knowledge gaps
2. Policy interventions targeting food packaging and fishing gear
3. Longitudinal health studies of high-risk subgroups
4. Community-based monitoring programs

The examination of the comprehensive interview data revealed consistent patterns across modalities. Key informants identified activities that would aid in developing a health education program model to effectively prevent risky behaviors linked to MPs. The data must encompass educational content, as most participants lacked familiarity with definitions of microplastics (MPs), their effects on human health, food products contaminated with MPs, and strategies for mitigating everyday exposure to MPs. The activities may encompass competitions, the dissemination of information on MPs' contamination results and their health implications.

Responses from key informants:

Question 1: Do you know about microplastics? Please give the answer that you know.

Example from key informants

“I'm not very familiar with it, but I've come across it on television previously. I simply can't recall the specifics, so I'm unsure about the exact information.”

"I understood that microplastics are like things that aren't supposed to be there and could make you sick or even cause serious diseases." The informant says that we get these microplastics from things we use every day, like cups, bowls, drinking glasses, water bottles, and other plastic containers. When used to hold hot food, the plastic may leak into our bodies without our knowing it.”

“I know that microplastics are small pieces of plastic. I once went to a factory where they told me how they recycle plastic cups and other stuff. They explained that some kinds of plastic contain harmful substances, but this depends on the type of plastic. I understood it since I had observed the process of making it.”

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Question 2: Do you think that microplastics could cause health issues for you? Why?

Example from key informants

"I think that the things around us probably have microplastics in them. These chemicals can be found in many things we use every day, such as detergents, and bridges and public places may be polluted. Microplastics could even come from the plastic and coffee cups we use every day."

"I suppose there might be microplastic pollution because the location where people live is next to an industrial plant, and the environment is good for this kind of pollution."

"At this time, I don't feel impacted by microplastics because I haven't noticed any evident effects in my daily life. So, I don't think these pollutants will influence me right now."

Question 3: Do you think you can keep microplastics out of your regular life? How?

Example from key informants

"It's hard to avoid because I can't tell where microplastics are unless we are attentive every day. I don't eat seafood very often, especially shellfish, because it contains many things that can make you sick. There are additional things besides microplastics that we don't know how safe they are."

"Plastic isn't dangerous, in my opinion. I've used it for years without issues. I don't think it's hazardous because we've always used it without any side effects. Can I quit using plastic? I think so. I can drink water from a little water filter at home if we don't buy plastic bottles. I used to buy one from Hi-Way for guests and morning alms. I tried not to use plastic bags at the market. Though I carried cloth bags, I sometimes forgot. Without bags, it was difficult, so I bought new ones. Many stores use plastic bags again. They used to campaign well without giving out bags, but now I have to buy one at the minimart. Some marketplaces don't sell plastic bags, but little shops in small residences do."

Plates, bowls, glasses, and plastic water bottles are just a few examples of plastic items that people use every day. Many people don't know that these items can become contaminated with microplastics when reused. They say that you can prevent plastic by knowing things, like using glass bottles instead of plastic ones. But many items that are sold a lot still contain plastic. Microplastics can come from products we use every day, such as toothpaste, soap, and items with beads. They say most individuals don't know because they are used to using plastic and lack sufficient knowledge. Even though there are efforts to encourage people to use fewer plastic bags, these enterprises eventually become businesses that sell bags rather than give them away for free. So, they think that cutting down on plastic consumption is possible, but it has a lot of problems, such as market systems, convenience, and people not knowing enough about it."

Question 4: Do you believe that the seafood you eat contains contaminants with microplastics?

Example from key informants

"I avoid seafood due to my allergy to it. However, if you're inquiring about the possibility of microplastics contaminating the seafood in this area, it's quite probable. When I purchased shellfish to prepare for my family, I noticed there were small pieces of string attached. It resembled the cord employed to lift shellfish. As it aged, it detached and blended with the shellfish. We had to handle the cleanup ourselves. It was quite evident. This served as concrete proof that plastic was indeed present."

"I believe that seafood may have some microplastics or other harmful substances in it. There was a period when oil or trash made its way into the water, and sea creatures ate it. You can occasionally smell the oil when you eat shellfish, especially clams or mussels that were pulled up from

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the sand. Some clients even say they don't like the greasy smell, which makes you think that seafood from some places could not be safe."

"Indeed, there are times when we are unaware of what we consume, especially since we reside near industrial zones and do not have access to deep-sea fish or seafood sourced from distant locations. Typically, we purchase it from the beach. We are uncertain about the cleanliness of items brought to us by others or whether the animals have consumed anything that may have been contaminated beforehand. A risk remains."

Question 5: Do you think that the area where you live has microplastics in it?

Example from key informants

"Microplastics may be contaminating the area surrounding our home due to its proximity to a location where people dispose of their trash. Trash cans and heaps of litter can also be found in the vicinity. At times, individuals also incinerate their waste in that location. They dispose of it and set it ablaze. Plastic fragments can disperse, linger in the air, or settle on the ground or in nearby water sources, often without our awareness of their proximity. At times, we inhale them, or they blend into our drinking water."

"I suspect that the residential area could be affected by microplastics, potentially transported by wind or dust from the surroundings. This is particularly evident when an unpleasant smell occasionally drifts in. I have a feeling it originates from a factory. While I'm uncertain about the specific type of industrial plant, I am convinced that the odor originates from the factory's emissions."

"There is a factory close to my residence. There must be some chemicals in there. This kind of factory obviously has a chance."

Phase 3:

Develop a Health Literacy Enhancement Program to reduce MPs' intake into the human body

Based on the results from phases 1 and 2, there was a need to develop a health literacy enhancement program aimed at reducing MPs' intake into the human body. The program was designed for the experimental group based on a review of the relevant literature and integrated theoretical frameworks, including Nutbeam's health literacy model (2008) and the V-SHAPE concept by the Department of Health (2019). The intervention consisted of four weekly sessions, each lasting 50 minutes, focusing on different aspects of MPs' awareness and self-management. The sessions consisted of: (1) understanding microplastics; (2) media literacy and decision-making; (3) communication and behavioral change; and (4) self-management and sustainable practices. Learning activities encompassed lectures, demonstrations, group brainstorming, and discussions to develop key competencies such as information access, media literacy, communication skills, decision-making, and self-management. The program aimed to promote knowledge, attitudes, and behaviors that would reduce MPs' exposure to environmental health risks, thereby enhancing individual health literacy.

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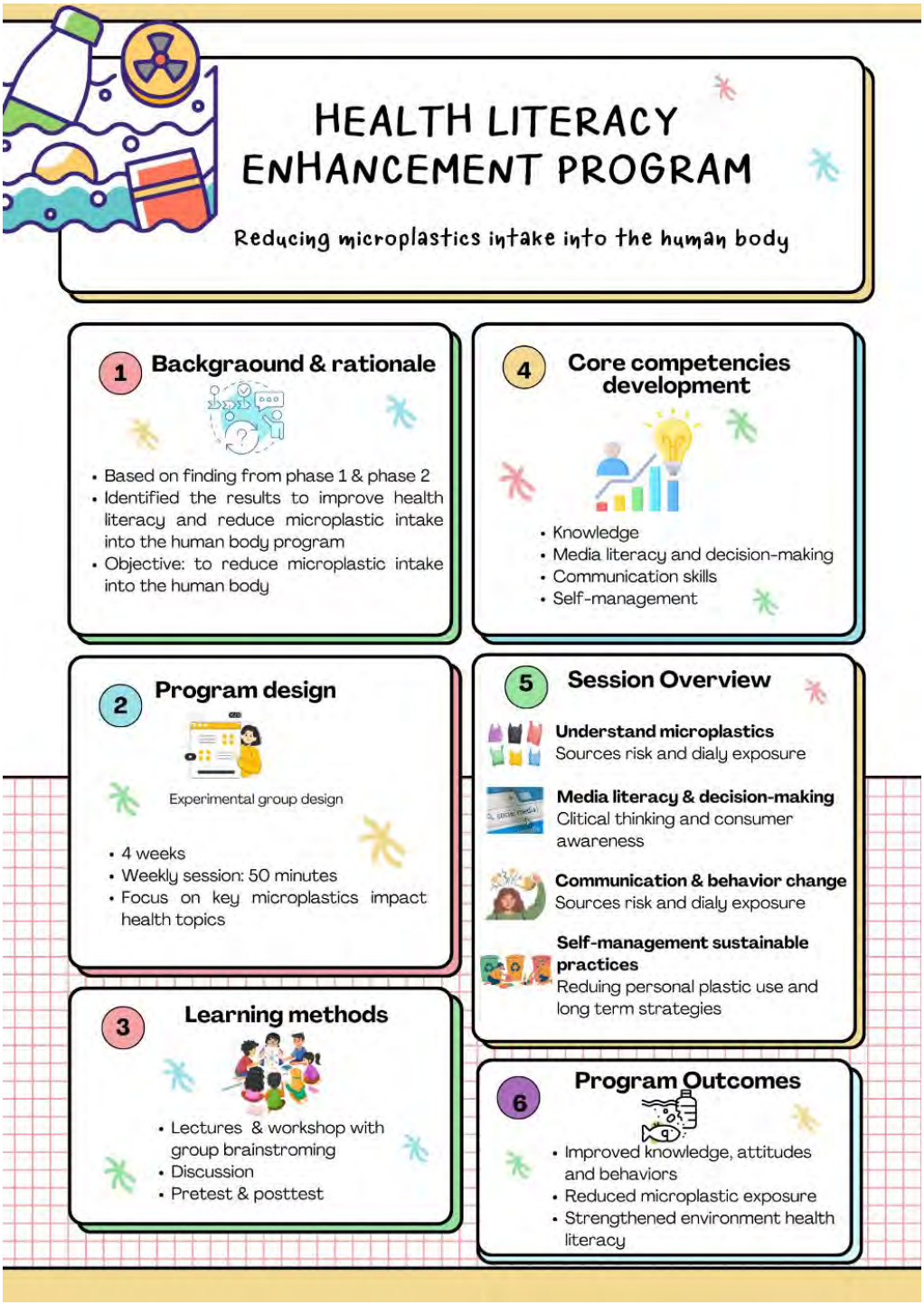

Figure 2. Health Literacy Enhancement Program: Reducing Microplastics Intake into the Human Body (Designed by Authors)

The findings from this study revealed important gaps in knowledge, attitudes, and behaviors related to MPs' exposure among residents living near the Map Ta Phut Industrial Estate. Based on the quantitative data, one-half of the participants (50.00%) had low knowledge about microplastics, with 50.80% unaware of their health impacts. Attitudinal responses were largely neutral (50.30%), while 78.50% exhibited moderate-risk behaviors. The analysis of the qualitative interviews confirmed these trends, revealing misconceptions regarding MPs, structural barriers to avoidance, and a high level of concern over seafood and residential contamination. A strong knowledge-action gap emerged—while many participants recognized the risks, few adopted protective behaviors. Furthermore, vulnerability was heightened by chronic health conditions, such as hypertension and hyperlipidemia. These findings underscore the urgent need for health literacy interventions tailored to socio-cultural

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and environmental contexts. Accordingly, a structured four-week educational program was developed, guided by Nutbeam's Health Literacy Model (Nutbeam, 2008), Thailand's V-SHAPE model (Department of Health, 2019), and Tanasugarn (2018). The program addressed cognitive, behavioral, and self-management dimensions to reduce MPs' exposure and to improve community resilience. Future efforts should integrate policy-level changes, community monitoring, and longitudinal studies to address cumulative risks and enhance sustainable behavior change.

5. Discussion

Phase 1:

This study investigated the knowledge, attitudes, and risk behaviors regarding MPs exposure among the residents of Map Ta Phut Municipality in Rayong Province, which is located near a high-risk industrial area. According to Ramakul et al. (2018), the Map Ta Phut area has been designated as a heavy chemicals industrial zone. Currently, residents of the Map Ta Phut subdistrict, situated in the central district of Rayong province, are expressing concerns about respiratory tract diseases, allergies, and cancer linked to environmental pollution from nearby chemical manufacturing.

Based on applying multi-stage random sampling with a 95% confidence level and a 5% margin of error, 382 participants were recruited from Takuan-Ao Pradu, Wat Sophon, and Ruam Pattana in the Map Ta Phut Municipality of Rayong Province. Residents in the vicinity of Map Ta Phut Industrial Estate face a major risk of MPs exposure. The demographic profile comprised 64.60% women and 35.90% individuals who had graduated from primary school. The average age of participants was 31–60 years, with 47.70% identifying as wage laborers, indicating a level of socioeconomic vulnerability. Overall, the results showed important gaps in public awareness and a tendency toward moderate-risk behavior, underscoring the need for focused public health initiatives.

Inadequate Understanding of Microplastics:

Fifty percent of the participants reported having low knowledge. This aligned with international research trends, including the findings of Deng et al. (2020) in China, which indicated that microplastics are not as widely recognized as other pollutants. Cammalleri (2020) reported that 25% of participants were unaware of microplastics. Even with low ratings, the awareness of MPs' pollution underscores the necessity for future public health professionals to enhance their knowledge to effectively convey essential information to the public. Enhancing public awareness would elevate risk perception and inspire collective efforts to mitigate microplastics pollution. The SAPEA (2019) European survey revealed that although there were widespread concerns regarding plastics, the sources and consequences of MPs were not adequately understood. In addition, the findings of the current study supported those of Alizadeh (2024), which identified a deficiency in MPs' knowledge in print and public media.

A lack of understanding regarding health risks influences perception, as one-half of the respondents (50.80%) were unaware of them. The influence of perceived health risks on behavior modification makes this topic essential. The current study's findings aligned with those of Campanale et al. (2020), indicating that the public remains unaware of the amount of comprehensive scientific research on MPs. The intricacies of toxicological pathways, such as endocrine disruption, oxidative stress, and inflammation, contribute to the uncertainty. Understanding the need to modify one's behavior for self-protection can be challenging without awareness of the potential consequences.

Risky Daily Behaviors and Unclear Attitudes:

As a result of this knowledge gap, most participants held neutral (50.30%) or negative (43.50%) perspectives on MPs. Often, neutral views suggest a lack of awareness or uncertainty, while negative attitudes reflect that certain groups are starting to express their concerns, albeit without taking

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action. This suggests that the population is at a pivotal juncture, presenting relevant authorities with a major opportunity to implement educational programs that foster change. This underlying issue can be tackled proactively. This finding was linked to Tang (2023), who emphasized that plastic-avoidance habits and hassles represented the greatest barriers to behavior change. Therefore, the government needs to encourage green alternatives by implementing stringent policies and providing support.

Based on the current research, 78.50% of participants exhibited moderate risk behaviors. Indicating that MPs were obtained through everyday activities, such as using plastic food containers, consuming bottled water, and using personal care products containing microbeads. This observation raises concerns, as consistent daily exposures can lead to serious long-term cumulative effects, even if the immediate risk seems low. This result was linked to the findings of Prata et al. (2020), indicating that chronic low-level exposures to various environmental health issues presented a major public health risk. Education should focus on removing unconventional, high-risk activities and promoting the adoption of sustainable, low-risk lifestyles among individuals.

The analysis of phase 1 highlighted the importance of interventions tailored to specific contexts. Communication strategies rooted in culture, such as the use of local dialects, engagement with community leaders, and the incorporation of visuals, have effectively heightened awareness of MPs and diminished harmful behaviors in industrial areas. These findings aligned with the advocacy of Orchaiyapoom et al. (2024) for clear and accessible messages tailored to diverse audiences. It is essential to address systemic factors, such as packaging regulations and enhancements in waste management infrastructure, to encourage and maintain individual behavior changes.

Determinants of Risk Behaviors Related to Microplastic Exposure:

The regression findings offer important insights into how knowledge and attitudes operate within the broader context of community-based health and environmental behavior. Although both general knowledge about microplastics and knowledge of their health impacts were statistically significant predictors of risk behaviors, their effect sizes remained small. This pattern reflects a well-documented knowledge–behavior gap in public health education, where increased awareness does not automatically lead to behavioral change among community members. Prior studies have similarly emphasized that microplastic exposure poses potential health risks, yet knowledge alone does not translate into protective practices (Prata et al., 2019; Sharma & Chatterjee, 2017). Many individuals may understand these risks, but their actions continue to be shaped by ingrained daily routines, socioeconomic constraints, limited access to safer alternatives, and environmental conditions within their communities.

Notably, attitudes toward microplastics were not a significant predictor of behavior, suggesting that attitudinal shifts alone are insufficient to drive meaningful behavioral modification in real-world community settings. The very low explanatory power of the model ($R^2 = .01$) further highlights the complexity of microplastic-related behaviors and underscores that cognitive and affective factors represent only a small portion of the determinants involved. These findings align with Nutbeam's (2008) health literacy framework, which posits that effective health behavior change requires more than functional knowledge—it demands interactive and critical health literacy, enabling individuals to critically assess environmental risks, evaluate available options, and make informed decisions within the structural limitations they face. In this regard, interventions must go beyond information dissemination to include skill-building, empowered decision-making, and environmental support mechanisms. Collectively, the results underscore the need for educational and community-based approaches that integrate health literacy development, environmental restructuring, and practical support systems to promote sustainable behavior change among the general population.

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Phase 2:

This qualitative phase of the study examined the community's perceptions and offered detailed, contextual data to enhance the quantitative survey findings. The thorough interviews with the 30 key informants revealed a complex interaction among limited scientific understanding, heightened risk perception, and a sense of powerlessness regarding MPs' exposure. These findings highlighted the importance of comprehensive treatments that tackle both personal understanding and systemic environmental deficiencies.

The in-depth interviews revealed an 'awareness paradox': while 40 percent of the participants were unable to accurately define MPs, a substantial majority regarded them as a serious threat, with 60 percent expressing safety concerns and 73 percent being apprehensive about the effects on their seafood and community environments. The gap between scientific knowledge and risk perception corresponded with insights from wider environmental health studies. Alizadeh et al. (2024) found that Southeast Asian countries face considerable risks from high levels of MPs contamination in water supplies, sediments, and biota.

The current findings indicated that media narratives and observable pollution evidence have a greater impact on public risk perception than scientific literacy. The "dread risk" aspect of risk perception theory indicates that, frequently, unseen, persistent threats provoke intense emotional reactions. In the current study, the fears expressed by informants were associated with visible pollution emanating from the nearby industrial estate and the long-term accumulation of such pollutants, indicating that communication strategies must address these concerns and misunderstandings (including the speculative link to cancer), alongside information. The study by Pop et al. (2023) indicates that “Media narratives about plastic and MPs pollution have increased over time, influencing the perception of this risk.” The findings from the current study emphasize the importance of precise and fair media coverage of MPs to mitigate misinformation and guarantee that the public comprehends the risks associated with MPs. Additionally, a detailed analysis of individuals' perceptions reinforces the development of suitable interventions to reduce plastic consumption, which in turn mitigates the risks associated with microplastic pollution, yielding benefits for both human health and the environment.

The interviews conducted in the current study illustrated the community's sense of helplessness and the institutional barriers to avoiding MPs compellingly. Due to the prevalence of plastic packaging and the lack of alternatives, 67% of the respondents found avoidance difficult or impossible. Fatalism obstructs the possibility of behavioral change. The "attitude-behavior gap" refers to contextual elements, such as infrastructure and market options, that hinder the implementation of pro-environmental intentions, as discovered by Hartmann et al. (2019). Change is not solely the responsibility of the individual when the system complicates the process of making the "right" decision. The informants in the current study indicated it was essential to have robust policy interventions, such as laws on plastic packaging and government support for affordable and accessible alternatives.

Informants linked the Map Ta Phut Industrial Estate to their strong belief in local seafood and residential contamination, with both factors cited by 73% of respondents. An understanding of localized risk perception, shaped by lived experiences and environmental degradation, is essential, as it contrasts with the location-independent issues found in national surveys. The study by Poboon (2017) indicated that environmental justice research had identified that populations near industrial zones faced a disproportionate burden of pollution. This finding aligned with Janmimool (2024), highlighting the development of heightened and specific environmental risk perceptions. The findings from the interviews in the current study highlighted the importance of focused surveillance and tailored instructional activities for specific communities.

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While the current study did not establish a causal link, careful examination of the self-reported health conditions of informants, particularly those related to metabolic syndrome, such as hypertension (40%) and hyperlipidemia (23%), is warranted. A toxicological study examined the potential effects of MPs and their chemical additives on metabolism (Deng et al., 2020). The current findings are correlational and constrained by the small, non-clinical sample; however, they highlight concerns about a potentially vulnerable population and emphasize the need for future epidemiological studies to investigate the relationship between long-term environmental exposure in industrial areas and the prevalence of chronic diseases.

Phase 3:

The insights gained from Phases 1 and 2 indicated the necessity for a thorough, theory-based intervention strategy to address the gaps in knowledge and behavior regarding microplastic exposure. The KAP (Knowledge, Attitudes, Practices) framework from Phase 1 effectively outlined residents' initial awareness and behavioral trends surrounding the Map Ta Phut Industrial Estate. However, it was evident that these areas were interrelated aspects of a broader health literacy gap.

Considering these constraints, the health literacy approach in Phase 3 was both intentional and necessary. Nutbeam's (2008) multidimensional model of functional, interactive, and critical health literacy enhances knowledge, decision-making, self-regulation, and community engagement. Health literacy encompasses the essential skills required to acquire, interpret, evaluate, and apply knowledge for informed health decision-making, in contrast to KAP, which focuses on fixed constructs.

Thailand's V-SHAPE model, as outlined by the Department of Health (2019) and Tanasugarn (2018), highlights the importance of culturally grounded competencies such as self-care, media discernment, and community-based resilience, which serve to enhance Nutbeam's paradigm. The foundation of this four-session educational intervention involved knowledge acquisition (Session 1), media literacy and decision-making (Session 2), communication and behavior change (Session 3), and self-management for sustainable practice (Session 4).

The Phase 3 program combined these frameworks to illuminate and empower, connecting the cognitive, behavioral, and motivational gaps from the previous phases. This approach aligned with the global agreement that environmental risk education should include skill development and critical engagement, particularly for marginalized groups facing industrial hazards. The promotion of free reusable bags and education proved to be effective components of the MPs' pollution policy. Furthermore, a lack of environmental knowledge and insufficient management have impeded the reduction of MPs emissions (Alizadeh et al, 2024).

Nonetheless, Kaushik et al. (2022) found, through a preliminary survey of Indian students' understanding, attitudes, behaviors, and opinions on plastic and MP pollution, that educational qualifications and fields of study had significant, directly proportional effects. Even with sufficient awareness of plastic pollution, understanding of MPs remained limited. In line with Dowarah (2022), awareness of MPs' pollution was statistically associated with anti-plastic attitudes and behaviors. A decrease in plastic and microplastic contamination could result from implementing structured educational programs and mass media campaigns, enforcing strict policies, and using eco-friendly polymers.

6. Conclusion

Based on the results of the current study, there were major gaps in knowledge, attitudes, and risk behaviors related to microplastics among Thai residents living near the Map Ta Phut Industrial Estate. The quantitative data showed limited understanding and moderate-risk behaviors, while the qualitative findings highlighted misconceptions and structural barriers to change. In response, a four-

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session health education program was developed using Nutbeam's health literacy framework and Thailand's V-SHAPE model. The program emphasized knowledge, media literacy, communication, decision making, and self-management to build functional, interactive, and critical health literacy. Through empowering individuals to assess and act on environmental risks, the intervention offers a scalable, community-based model for reducing microplastic exposure. These findings underscore the importance of environmental health literacy in promoting behavioral change among at-risk populations. Future studies should evaluate the program's long-term impact, explore its adaptability across diverse settings, and integrate policy-level strategies to support sustained community engagement.

7. Suggested Future Study

Future research should focus on understanding the long-term health impacts of MPs ingestion, particularly in high-risk industrial communities such as Thailand's Map Ta Phut Industrial Estate. While the current findings highlighted major knowledge gaps and hazardous behaviors, further investigation is needed to quantify the biomagnification of MPs and associated toxins through the food chain. Additionally, research should explore the effectiveness of advanced wastewater treatment technologies in reducing pollution MPs and assess the socio-economic factors that perpetuate reliance on contaminated seafood. Investigating the role of microplastics and their interactions with other pollutants, such as antibiotics, could provide critical insights into the environmental and health risks of microplastics. Finally, longitudinal studies evaluating the sustained impact of community-based health education programs, such as the one developed in the current study, would be invaluable for refining interventions and informing policy decisions globally.

Declarations

Author Contributions.

Tharisara Chirasatienpon: Authorship, main idea, methodology, data analysis, conceptualization, ethical submission, and revisions.

Phubate Napatpittayatorn: Corresponding author; co-author, methodology, data analysis, and editorial assistants.

Chanakarn Sakulthaew: Co-author, editorial assistant.

Conflicts of Interest. The authors declare no conflict of interest.

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Ethical Approval. In this research, the researcher determined the sample's rights using clear inclusion and exclusion criteria. Each participant in the sample group signed a consent form before beginning the study. This research project was submitted for ethics review by the Central Research Ethics Committee (CREC) and was approved by the Central Research Ethics Committee (CREC for phase 1, with approval number CREC018/66SR-SBR1on February 6, 2024, and by the Human Research Ethics Committee Nakhonratchasrima, with approval number SBR1HE-021-2567 on 31 January 2024, for phase 2. Each participant could opt out of the study without affecting their studies. No data were recorded for name, address, or identity. The tape recordings will be destroyed once the research report has been published successfully.

Data Availability Statement. Some data are not publicly available due to [legal/ethical restrictions] but are available from the corresponding author on reasonable request and with permission from Ethics Committee/Institutional Policy.

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