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Health Literacy and Environmental Health Behaviors Related to Potential Microplastic Exposure Among Urban Residents in Thailand: A Cross-Sectional Study

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Abstract

Microplastic contamination has become a major environmental health concern because of its widespread occurrence and potential risks to human health. Although environmental health literacy (EHL) is recognized as an important determinant of health-related decision-making, evidence regarding its influence on behaviors that reduce potential microplastic exposure remains limited, particularly in riverine communities of developing countries. This study assessed EHL, environmental health behaviors associated with potential microplastic exposure, and factors associated with these behaviors among urban residents living along the Mekong River in Thailand. A community-based cross-sectional study was conducted among 420 adults in Mueang Nakhon Phanom District, Thailand, between October and December 2024 using multistage random sampling. Face-to-face interviews were performed using a content-validated questionnaire assessing six EHL domains and environmental health behaviors related to microplastic exposure. Multivariable logistic regression was used to examine factors associated with poor environmental health behaviors. Overall, 41.7% of participants demonstrated good environmental health behaviors, whereas 58.3% exhibited poor behaviors. Participants had a moderate level of EHL (mean score, 2.30 $\pm$ 0.46), with decision-making representing the weakest domain. Insufficient EHL was strongly associated with poor environmental health behaviors (AOR = 8.06, 95% CI: 2.86–10.04; $p < 0.001$). Additional factors associated with poor environmental health behaviors included consumption of untreated river or other water sources, no physician visit during the previous month, age older than 60 years, and obtaining aquatic foods through self-capture, whereas trade occupation was associated with lower odds of poor behaviors. These findings support community-based EHL programs led by local authorities and public health practitioners that strengthen critical appraisal and decision-making skills, provide accessible and evidence-based information on microplastic risks, and promote practical actions such as reducing single-use plastics and improving household waste management.

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1. Introduction

Plastic pollution has become one of the most pressing environmental challenges worldwide, driven by rapid industrialization, population growth, urbanization, and increasing dependence on plastic-based products. Global plastic production has increased exponentially over the past decades, resulting in substantial accumulation of plastic waste across terrestrial and aquatic ecosystems. Although plastic materials provide important benefits for modern society, their persistence and fragmentation into smaller particles have raised significant concerns regarding ecological integrity and human health [1,2]. Among these emerging pollutants, microplastics (MPs), generally defined as plastic particles smaller than 5 mm, have attracted increasing scientific and public health attention because of their widespread distribution, environmental persistence, and potential biological effects [3].

Microplastics have been detected in various environmental compartments, including marine and freshwater systems, sediments, soil, air, and food chains. Recent evidence indicates that humans may be exposed to microplastics through multiple pathways, particularly ingestion of contaminated food and water, inhalation of airborne particles, and dermal contact [4,5]. Emerging evidence also suggests that children may be particularly vulnerable to environmental risk factors because of their unique developmental and physiological characteristics. This may be relevant to potential microplastic exposure, given the growing recognition of microplastics as an emerging environmental health concern [6]. These populations may therefore warrant specific attention in future research on potential microplastic exposure and environmental health literacy. However, the present study focused exclusively on adults, and further research is needed to investigate these issues in children and other vulnerable groups. Studies have reported the presence of microplastics in commonly consumed food products, drinking water, and human biological samples, suggesting that exposure is widespread and difficult to avoid in contemporary environments [7,8]. Although the long-term health consequences of potential microplastic exposure remain incompletely understood, experimental and epidemiological evidence suggests potential biological mechanisms, including oxidative stress, inflammation, endocrine disruption, immune responses, and cellular damage associated with plastic particles and their chemical additives [9,10].

The potential health implications of potential microplastic exposure have shifted the focus of research beyond environmental contamination assessment toward understanding human behaviors, risk perception, and preventive practices. Individual and community behaviors play an important role in reducing plastic pollution and minimizing potential exposure pathways. Practices such as reducing unnecessary plastic consumption, appropriate waste segregation, responsible disposal, and informed choices regarding plastic-related products may contribute to lowering environmental plastic accumulation and associated health risks [11]. However, the adoption of these behaviors depends not only on environmental awareness but also on individuals' ability to access, understand, evaluate, and apply relevant health and environmental information.

Health literacy has increasingly been recognized as a critical determinant influencing health-related decision-making and preventive behaviors. According to Nutbeam's framework, health literacy encompasses functional, interactive, and critical capacities that enable individuals to obtain, interpret, and use information to improve health outcomes and participate in health-promoting actions [12]. Previous studies have demonstrated that

individuals with higher levels of health literacy are more likely to engage in preventive behaviors, adopt healthier lifestyles, and make informed decisions regarding environmental and health risks [13,14]. Therefore, applying a health literacy perspective may provide important insights into how communities understand microplastic-related risks and translate environmental information into protective behaviors.

In the Asian region, plastic pollution has become a particularly important environmental and public health concern. Rapid economic development, increasing urbanization, and inadequate waste management infrastructure have contributed to high levels of plastic leakage into terrestrial and aquatic environments across many Asian countries [2]. Southeast Asia has been identified as one of the major contributors to global plastic pollution, with rivers serving as important pathways transporting plastic debris from land-based sources into marine ecosystems [15]. Freshwater systems in this region are particularly vulnerable because they support dense human settlements, agricultural activities, fisheries, and domestic water use.

The Mekong River represents one of the most important transboundary freshwater systems in Southeast Asia, supporting the livelihoods and daily activities of millions of people across multiple countries. However, increasing population pressure, urban development, and waste generation along the river basin have raised concerns regarding plastic contamination and potential microplastic accumulation in aquatic environments [16]. Recent environmental investigations have detected microplastics in various components of the Mekong River ecosystem, highlighting the need for greater understanding of potential human exposure pathways and community-level responses to this emerging environmental health issue [17].

Thailand has experienced substantial growth in plastic consumption over recent decades, accompanied by increasing challenges related to plastic waste generation and management. Despite ongoing efforts to improve waste reduction and recycling systems, plastic leakage into natural environments remains a significant concern, particularly in densely populated areas and regions dependent on aquatic ecosystems. Previous environmental assessments in Thailand have demonstrated the widespread occurrence of microplastics in freshwater environments, coastal areas, sediments, and aquatic organisms, indicating that plastic contamination has become an emerging environmental health issue requiring multidisciplinary approaches [18,19].

Freshwater ecosystems in Thailand serve as important resources for domestic activities, agriculture, fisheries, and local economies. The Mekong River, which flows through northeastern Thailand, provides essential ecological and socioeconomic functions for communities located along its banks. Nakhon Phanom Province is one of the major riverine areas along the Mekong River in northeastern Thailand, where local populations maintain close interactions with the river environment through daily activities, food consumption, recreation, and community livelihoods. These interactions may influence perceptions of environmental risks and the adoption of protective behaviors related to environmental contaminants, including microplastic pollution.

Although increasing evidence has documented the presence and distribution of microplastics in Thai aquatic environments, most existing studies have primarily focused on environmental monitoring, including the identification, abundance, composition, and spatial distribution of microplastic particles in water, sediment, and aquatic organisms [17,19]. However, evidence regarding the human dimensions of microplastic pollution remains limited, particularly regarding how communities perceive microplastic-related risks, access environmental health information, and adopt preventive behaviors to reduce potential exposure. Understanding these behavioral and cognitive dimensions is essential because

individual actions, household practices, and community engagement represent important components of environmental pollution prevention.

Environmental health literacy provides a useful framework for understanding how individuals interpret environmental risks and translate knowledge into appropriate actions. In the context of microplastic contamination, individuals require not only awareness of plastic pollution but also the ability to evaluate information sources, understand potential health implications, and make informed decisions regarding consumption patterns, waste management, and plastic use reduction. However, current evidence regarding environmental health literacy related to microplastic contamination remains scarce, especially among populations living in riverine communities in low- and middle-income countries.

Although several environmental health literacy instruments have been developed [20], existing measures vary substantially in their conceptual scope, target populations, and environmental contexts. Many available instruments focus on general environmental knowledge, awareness, perceptions, or specific environmental hazards and may not adequately capture the functional, interactive, and critical health literacy capacities required to understand and respond to microplastic exposure [21]. In particular, there is limited evidence of validated instruments specifically designed to assess environmental health literacy related to potential microplastic exposure among adults living in riverine communities in Thailand. Therefore, rather than directly adopting an existing instrument developed for a different environmental or population context, we developed a context-specific environmental health literacy questionnaire based on Nutbeam's Health Literacy Framework [11]. The questionnaire was designed to assess individuals' abilities to access, understand, appraise, and apply information related to potential microplastic exposure and environmental health behaviors within the local community context. To enhance its methodological rigor, the instrument underwent expert assessment of content validity and pilot testing before administration in the main study. This approach was intended to ensure that the questionnaire was conceptually grounded in an established health literacy framework while remaining relevant to the specific environmental and sociocultural context of communities along the Mekong River.

Furthermore, while previous studies have examined health literacy in relation to disease prevention and health promotion behaviors, limited research has explored its role in environmental health behaviors associated with emerging pollutants such as microplastics. This knowledge gap is particularly relevant for communities along major freshwater systems, where daily interactions with aquatic environments may influence both perceived risk and preventive practices. Generating evidence on the relationship between health literacy and environmental health behaviors may support the development of targeted risk communication strategies and community-based interventions for microplastic pollution prevention.

Therefore, this study aimed to assess health literacy and environmental health behaviors related to potential microplastic exposure among residents living in communities along the Mekong River in Mueang Nakhon Phanom District, Nakhon Phanom Province, Thailand. The study also examined factors associated with environmental health behaviors, including sociodemographic characteristics, environmental factors, and health literacy domains, to identify key determinants that may inform future public health interventions addressing microplastic-related risks.

2. Methods

2.1. Study Design

A community-based cross-sectional study was conducted among residents living in riverine communities along the Mekong River in Mueang Nakhon Phanom District,

Nakhon Phanom Province, northeastern Thailand. The study communities were purposively selected based on their proximity to the Mekong River and their relevance to the study objectives. The study area is located within the lower Mekong River basin, where the river serves as an important ecological and socioeconomic resource for local communities, supporting household activities, fisheries, agriculture, and other daily livelihoods.

The riverine environment in this area has raised concerns regarding plastic waste accumulation and potential microplastic contamination associated with domestic activities, urbanization, and environmental transport processes. Therefore, these communities provided an appropriate setting for investigating environmental health literacy and behaviors associated with potential microplastic exposure. The purposive selection of communities should be considered when interpreting the findings, as it may introduce selection bias and limit the generalizability of the results to other populations with different environmental and sociodemographic characteristics.

The study was designed to evaluate health literacy and environmental health behaviors related to microplastic contamination among residents in Mekong River communities. Sociodemographic characteristics, environmental factors, and domain-specific dimensions of health literacy were assessed to explore factors associated with preventive behaviors.

2.2. Study Population

The study population consisted of adults aged 18 years and older who had lived in communities along the Mekong River in Mueang Nakhon Phanom District, Nakhon Phanom Province, northeastern Thailand. The selected communities represented urban and peri-urban riverine settings where residents maintain regular interactions with the Mekong River through household activities, local commerce, recreation, and consumption of aquatic resources.

Adults residing in these communities were considered an appropriate population for assessing health literacy and environmental health behaviors related to microplastic contamination, as their daily activities may involve varying degrees of contact with river-associated environments. The study population provided insights into how sociodemographic characteristics, environmental perceptions, and health literacy dimensions may influence preventive behaviors concerning potential microplastic exposure.

2.2.1. Sample Size Estimation

The sample size was determined a priori based on the requirements for multivariable logistic regression analysis in a community-based cross-sectional study. The primary analysis aimed to identify factors associated with environmental health behaviors related to potential microplastic exposure among adults living in communities along the Mekong River. Because empirical evidence specifically examining the association between environmental health literacy and microplastic-related preventive behaviors in riverine communities remains limited, the assumptions for sample size calculation were informed by theoretically meaningful effect sizes and evidence from previous studies of health literacy and preventive health behaviors in community and health-related settings.

An odds ratio (OR) of 2.0 was specified a priori as the minimum meaningful effect size. This value was considered to represent a moderate association that would be epidemiologically relevant for identifying differences in preventive behaviors according to levels of environmental health literacy. Previous studies have reported meaningful associations between health literacy and health-related outcomes and preventive practices, supporting the use of a moderate effect size for sample size planning [19,21]. Because no sufficiently specific effect estimate was available for microplastic-related behaviors in the target popu-

lation, an OR of 2.0 was used as a theoretically meaningful planning assumption rather than as an estimate derived from a microplastic-specific study.

An anticipated prevalence of 45% for inadequate environmental health behaviors was specified a priori. This value was selected as a plausible planning estimate based on previous community-based research examining health literacy and preventive health behaviors [22]. Although these studies were not specifically focused on microplastic exposure, their findings provided a relevant basis for estimating the proportion of adults who might demonstrate inadequate preventive behaviors in a community setting. Thus, the 45% prevalence was used as a contextually appropriate planning estimate rather than as a direct estimate of microplastic-related behaviors in the target population.

Using a two-sided significance level (α) of 0.05 and 80% statistical power, the minimum required sample size was estimated to be 350 participants. To account for potential non-response, incomplete questionnaires, and exclusions during data quality assessment, an additional 20% was added, resulting in a target sample size of 420 participants. All 420 recruited participants were included in the final analysis.

2.2.2. Eligibility Criteria

Participants were eligible for inclusion if they met the following criteria: (1) adults aged 18 years or older; (2) currently residing in communities located along the Mekong River in Mueang Nakhon Phanom District, Nakhon Phanom Province, Thailand; (3) having lived in the study area for at least 1 year, an operational criterion used to ensure sufficient familiarity and experience with the local environmental and community context, consistent with previous community-based studies [23]; (4) being able to understand and communicate in Thai; and (5) voluntarily agreeing to participate by providing written informed consent. Participants were excluded if they were unable to complete the questionnaire due to severe cognitive or communication difficulties, were temporary visitors or non-residents of the study area, or submitted questionnaires with substantial missing information (>20% of required items). Questionnaires with incomplete key variables required for the statistical analysis were also excluded from the final dataset.

2.2.3. Sampling Method

A multistage sampling technique was applied to recruit participants from communities located along the Mekong River in Mueang Nakhon Phanom District, Nakhon Phanom Province, northeastern Thailand. This approach was used to ensure adequate representation of residents from different community areas within the riverine urban and peri-urban setting.

In the first stage, communities located along the Mekong River within the predefined study area were identified in collaboration with local administrative authorities. Communities were selected based on their geographic location within the study area, population distribution, and accessibility for field data collection. These criteria were applied to ensure that the selected communities represented the target riverine population and provided a feasible sampling frame.

In the second stage, household lists obtained from community administrative records were used as the sampling frame. Households were selected using a probability-based simple random sampling method to minimize selection bias and provide an equal opportunity for eligible households to be selected.

In the third stage, eligible adults aged 18 years or older from the selected households were invited to participate in the study. When more than one eligible adult was available in a household, one participant was selected using a simple random selection procedure to avoid preferential selection of participants within households.

Before data collection, interviewers received standardized training on the study objectives, participant eligibility criteria, questionnaire administration, interview procedures, and ethical considerations. The same questionnaire and standardized instructions were used for all participants. Interviewers were instructed to read the questions as written, avoid leading questions or personal interpretations, and maintain a neutral manner throughout the interviews to minimize interviewer-related bias.

Data quality was maintained by checking completed questionnaires for completeness and consistency immediately after each interview. Participants were interviewed individually, where feasible, to provide privacy and reduce the potential for social desirability bias. These standardized procedures were implemented to improve consistency across interviewers, reduce information and interviewer bias, and enhance the quality and reliability of the collected data.

This multistage sampling strategy was designed to obtain a representative sample of adults living in Mekong River communities and to facilitate the assessment of health literacy and environmental health behaviors related to potential microplastic exposure in an urban riverine context.

2.3. Outcome Measures

Data were collected using a structured questionnaire developed based on previous literature on health literacy, environmental health behaviors, and microplastic-related health risks. The questionnaire was guided by the Nutbeam Health Literacy Framework, which conceptualizes health literacy as the capacity to access, understand, evaluate, and use health information to make appropriate health-related decisions [11]. The questionnaire consisted of three main sections.

2.3.1. Sociodemographic, Environmental, and Health-Related Characteristics

Sociodemographic characteristics included sex, age, educational attainment, occupation, monthly household income, household size, and duration of residence in the study area. Environmental and lifestyle-related characteristics included household water sources, drinking water practices, exposure to plastic products in daily life, household waste management practices, and patterns of aquatic food consumption. These variables were included to characterize factors potentially related to environmental interactions and behaviors associated with microplastic contamination. Health-related characteristics included self-reported illness within the previous month, healthcare utilization, and other relevant health information, comprising 30 items.

2.3.2. Environmental Health Literacy Related to Potential Microplastic Exposure

Environmental health literacy (EHL) was assessed using a newly developed 56-item questionnaire based on Nutbeam's Health Literacy Framework and adapted to the environmental health context of microplastic contamination among community-dwelling adults. The framework was operationalized into six context-specific domains to capture the complementary capacities required to understand, access, communicate, evaluate, apply, and use environmental health information in decision-making related to potential microplastic exposure. These domains comprised: (1) cognitive understanding (16 items), assessing basic understanding of microplastic-related environmental and health information; (2) access to health and environmental information (8 items), assessing the ability to obtain relevant information from available sources; (3) communication and information exchange (8 items), reflecting the ability to communicate, discuss, and exchange environmental health information with others; (4) self-management and application of knowledge (8 items), assessing the ability to apply relevant knowledge to everyday practices; (5) appraisal of information credibility (8 items), reflecting the ability to evaluate the reliability

and relevance of environmental health information; and (6) decision-making based on environmental health information (8 items), assessing the ability to use evaluated information to make appropriate decisions concerning potential microplastic exposure and preventive behaviors. Thus, the six domains represented a context-specific operationalization of Nutbeam's functional, interactive, and critical health literacy concepts rather than six original domains of the framework. The questionnaire was specifically contextualized to the environmental and sociocultural characteristics of communities along the Mekong River. To the best of our knowledge, this specific instrument has not previously been validated or published elsewhere. Each item was rated on a 3-point Likert scale, with higher scores indicating higher EHL. Existing environmental health instruments were considered during questionnaire development [24]. The present questionnaire was consequently developed to capture the functional and critical dimensions of EHL relevant to community residents and the prevention of potential microplastic exposure. For interpretation, mean scores for each domain and the overall EHL score were categorized as low (1.00–1.66), moderate (1.67–2.33), or good (2.34–3.00).

To classify the level of environmental health literacy (EHL), the total score was converted to a percentage of the maximum possible score. Based on previous health literacy research, including a general health literacy scale developed for the Thai population that classified scores of ≥80% as proficient health literacy, and other population-based studies that used ≥80% of the maximum score to indicate adequate health literacy, a cutoff of ≥80% was adopted as the operational criterion for sufficient EHL in the present study [25]. Importantly, this cutoff was applied as an operational criterion for the newly developed EHL instrument rather than as a universally established threshold for environmental health literacy.

2.3.3. Environmental Health Behaviors Related to Potential Microplastic Exposure

Environmental health behaviors related to potential microplastic exposure were assessed using a 30-item self-reported questionnaire designed to measure the frequency and consistency of preventive practices in daily life. The items were developed to capture behaviors relevant to potential pathways of microplastic contamination and exposure, rather than to directly measure individual microplastic exposure. The assessed behaviors included reducing unnecessary plastic use, selecting environmentally preferable products, appropriately segregating and disposing of household waste, avoiding improper handling of plastic waste, adopting safer consumption practices, and engaging in behaviors that may help reduce plastic contamination in the environment. These practices were considered relevant to microplastic exposure because reducing unnecessary plastic use and improving the segregation, handling, and disposal of plastic waste may reduce the generation, accumulation, and environmental dissemination of plastic materials that can contribute to microplastic contamination.

Each item was rated on a 3-point Likert scale: 2 = regularly practiced, 1 = sometimes practiced, and 0 = never practiced, with higher scores indicating more appropriate environmental health behaviors. The total score was calculated by summing the scores across all 30 items, yielding a possible range of 0–60 points. The resulting score therefore represents the extent to which participants reported engaging in preventive environmental health practices relevant to potential microplastic exposure, rather than a direct measurement of microplastic exposure or exposure reduction.

The total score was subsequently expressed as a percentage of the maximum possible score. Following the criterion used in a previous study [25], an 80% cutoff of the maximum possible score was adopted for the primary analysis. Participants who achieved a score of ≥80% (≥48 points) were classified as having "good" environmental health be-

haviors, whereas those who scored <80% (<48 points) were classified as having "poor" environmental health behaviors.

2.4. Instrument Content Validity and Reliability

Content validity and internal consistency reliability were subsequently assessed before the questionnaire was used in the main survey. A structured questionnaire was developed through a review of relevant literature on health literacy, environmental health behaviors, and public awareness related to microplastic contamination. The development of the instrument was guided by the Nutbeam Health Literacy Framework and adapted specifically to the environmental health context of potential microplastic contamination and exposure in communities living along the Mekong River. The items were designed to assess knowledge, access to information, communication, self-management and application, appraisal of information credibility, and decision-making related to potential microplastic contamination and exposure, rather than general environmental knowledge alone.

The content validity of the questionnaire was evaluated by experts using the Index of Item-Objective Congruence (IOC), and internal consistency was assessed using Cronbach's alpha. These procedures provided evidence of the content relevance and internal consistency of the instrument but did not constitute a formal assessment of construct validity. The limited psychometric validation of the newly developed instrument, including the absence of construct validity and test–retest reliability assessment, is acknowledged as a limitation of this study.

The questionnaire comprised four sections: (1) sociodemographic characteristics, (2) environmental and health-related characteristics, (3) health literacy related to microplastic contamination, and (4) environmental health behaviors associated with microplastic prevention. The complete structured data abstraction form and questionnaire are provided as Supplementary Materials.

Content validity was evaluated by a multidisciplinary panel of three experts with expertise in public health, environmental health, and epidemiology. Each questionnaire item was independently reviewed using the Item-Objective Congruence (IOC) index to assess the alignment between item content and study objectives. The IOC values ranged from 0.67 to 1.00, indicating satisfactory content validity. Items that did not meet the acceptable criteria were revised based on expert recommendations before implementation in the field survey. All experts voluntarily participated in the validation process and provided informed consent prior to evaluation.

A pilot test was conducted among 30 adults from a community with demographic and environmental characteristics comparable to those of the study population but not included in the main study. Internal consistency reliability was assessed using Cronbach's alpha coefficient. The health literacy scale demonstrated good internal consistency, with an overall Cronbach's alpha coefficient of 0.87, and domain-specific coefficients ranging from 0.72 to 0.85. The environmental health behavior scale also showed acceptable reliability, with a Cronbach's alpha coefficient of 0.79, indicating adequate consistency for use in the main survey.

2.5. Data Collection Procedures

Data were collected from October to December 2024 through face-to-face interviews using a structured questionnaire administered during household visits in communities along the Mekong River in Mueang Nakhon Phanom District, Nakhon Phanom Province, Thailand. Data collection was conducted by trained research assistants who followed a standardized field protocol to ensure consistency and minimize variability across study areas.

Before the commencement of fieldwork, all research assistants participated in a comprehensive training session covering the study objectives, questionnaire administration procedures, interviewing techniques, participant communication, and ethical principles for human research. Practice sessions and simulated interviews were conducted to improve familiarity with the questionnaire and reduce potential interviewer-related bias.

Before data collection, eligible participants received detailed information about the study purpose, procedures, potential benefits, and confidentiality measures. Written informed consent was obtained from all participants prior to participation. Data were collected using anonymous questionnaires with unique identification codes, and no personally identifiable information was recorded to protect participant privacy.

To ensure data quality, completed questionnaires were reviewed daily by field supervisors for completeness, internal consistency, and potential data entry errors. Questionnaires with missing or incomplete responses were identified during this review and, where feasible, clarified with the field team before data entry. Approximately 10% of completed questionnaires were randomly selected for verification through re-check procedures. In addition, double data entry and cross-validation were performed to identify and resolve discrepancies before statistical analysis. For the statistical analyses, participants with missing data for variables required for a specific analysis were excluded from that analysis (complete-case analysis).

2.6. Statistical Analysis

All statistical analyses were performed using IBM SPSS Statistics version 26 (IBM Corp., Armonk, NY, USA). Descriptive statistics were used to summarize participants' characteristics, including frequencies and percentages for categorical variables and means with standard deviations (SDs) for continuous variables. The distributions of health literacy scores and environmental health behavior scores related to microplastic contamination were also described.

The overall environment health literacy and environmental health behavior scores were calculated according to the scoring criteria described previously and categorized into sufficient/insufficient environment health literacy and adequate/inadequate environmental health behaviors using the predefined 80% cutoff point.

For bivariate analyses, differences in mean scores between groups were assessed using independent samples *t*-tests or one-way analysis of variance (ANOVA), as appropriate. Associations between categorical independent variables and levels of environmental health behaviors were examined using the chi-square test or Fisher's exact test when expected cell counts were insufficient.

Binary logistic regression analysis was performed to identify factors associated with adequate environmental health behaviors related to microplastic contamination. Variables with a p-value < 0.25 in the bivariate analyses were considered candidates for inclusion in the multivariable logistic regression model. In addition, variables considered theoretically relevant based on previous literature and conceptual frameworks regarding health literacy and environmental health behaviors were retained regardless of their statistical significance.

Before multivariable analysis, categorical variables were transformed into dummy variables, and reference categories were determined a priori based on theoretical and epidemiological considerations. Multicollinearity among independent variables was assessed using the variance inflation factor (VIF), with values <5 indicating no substantial multicollinearity. A purposeful variable selection approach was applied by considering statistical significance, confounding effects, and theoretical relevance during model development.

The results of logistic regression analyses were presented as crude odds ratios (CORs), adjusted odds ratios (AORs), and corresponding 95% confidence intervals (CIs). Model fit

was assessed using the Hosmer–Lemeshow goodness-of-fit test, and Nagelkerke R^2 was reported to indicate the explanatory power of the logistic regression model. All statistical tests were two-sided, and a p-value < 0.05 was considered statistically significant.

2.7. Ethical Considerations and Informed Consent

The study protocol was approved by the Human Research Ethics Committee of Mahasarakham University (Approval No. 273/2566). All participants were informed about the study objectives, procedures, potential risks, and benefits prior to participation, and written informed consent was obtained from all participants. Participant confidentiality was ensured through the use of anonymized data, and all methods were carried out in accordance with relevant guidelines and regulations.

3. Results

3.1. General Characteristics of the Participants

A total of 420 participants were included in the study, of whom 175 (41.7%) demonstrated good environmental health behaviors associated with potential microplastic exposure and 245 (58.3%) demonstrated poor behaviors. Females accounted for 60.7% of the study population, with no significant difference in sex distribution between the two behavioral groups ($p = 0.577$). The overall mean age was 51.6 ± 15.8 years, with participants demonstrating good behaviors being significantly older than those with poor behaviors (55.9 ± 15.5 vs. 48.6 ± 15.2 years, $p < 0.001$). Consistently, older adults (>60 years) were more prevalent in the good-behavior group, whereas younger adults (18–45 years) were more prevalent in the poor-behavior group ($p < 0.001$).

Occupational status and educational attainment also differed significantly between the two groups ($p = 0.007$ and $p = 0.008$, respectively). Agriculture was the most common occupation overall (39.8%) and was more prevalent among participants with good behaviors, whereas labor occupations were more common among those with poor behaviors. Monthly income, religion, and household size did not differ significantly between groups ($p > 0.05$). Participants with good behaviors had resided in their communities for a significantly longer period than those with poor behaviors (48.2 ± 22.1 vs. 44.1 ± 18.2 years, $p = 0.038$).

Significant differences were observed in drinking water sources ($p < 0.001$), with filtered water more commonly reported among participants with good behaviors and bottled water more frequently reported among those with poor behaviors. Household water source did not differ significantly between groups ($p = 0.106$). Participants with good behaviors were also more likely to report illness during the previous month (20.6% vs. 13.1%, $p = 0.039$) and physician visits during the previous month (22.3% vs. 13.5%, $p = 0.018$). In contrast, illness type and aquatic food consumption during the previous month were not significantly associated with behavioral status (both $p > 0.05$).

The source of aquatic foods differed significantly between the groups ($p < 0.001$). Participants with good behaviors were more likely to obtain aquatic foods from markets, whereas those with poor behaviors more frequently consumed self-caught aquatic foods or foods obtained from friends or relatives. No significant difference was observed in the type of aquatic foods consumed ($p = 0.807$).

Environmental health literacy showed the strongest observed association with environmental health behaviors ($p < 0.001$). Sufficient EHL was more common among participants with good behaviors (69.4%), whereas insufficient EHL predominated among those with poor behaviors (37.7%), indicating a significant association between EHL and environmental health behaviors associated with potential microplastic exposure (Table 1).

Table 1. General characteristics of participants according to environmental health behaviors related to potential microplastic exposure (n = 420).

Factors	Behaviors Good (*n* = 175)		Poor (*n* = 245)		Total (*n* = 420)		*p*-Value Exact Test/*t*-Test
	n	(%)	*n*	(%)	*n*	(%)	
Gender							
Male	66	(37.7)	99	(40.4)	165	(39.3)	0.577
Female	109	(62.3)	146	(59.6)	255	(60.7)	
Age (year)							
Mean (SD)	55.9	(15.5)	48.6	(15.2)	51.6	(15.8)	0.000 **
18–45 years	36	(20.6)	92	(37.6)	128	(30.5)	0.000 **
46–60 years	66	(37.7)	99	(40.4)	165	(39.3)	
>60 years	73	(41.7)	54	(22.0)	127	(30.2)	
Occupation							
Agriculture	85	(48.6)	82	(33.5)	167	(39.8)	0.007 **
Trade	16	(9.1)	35	(14.3)	51	(12.1)	
Labor	38	(21.7)	79	(32.2)	117	(27.9)	
Government/State enterprise/Others	36	(20.6)	49	(20.0)	85	(20.2)	
Income per Month (Bath)							
Mean (SD)	6030.1	(5177.1)	6764.2	(5687.3)	6460.7	(5485.9)	0.180
≤8340 Bath	133	(76.0)	169	(69.0)	302	(71.9)	0.115
>8340 Bath	42	(24.0)	76	(31.0)	118	(28.1)	
Duration of Residence (years)							
Mean (SD)	48.2	(22.1)	44.1	(18.2)	45.8	(19.9)	0.038 *
≤10 years	17	(9.7)	15	(6.1)	32	(7.6)	0.194
>10 years	158	(90.3)	230	(93.9)	388	(92.4)	
Religion							
Buddhist	169	(96.6)	241	(98.4)	410	(97.6)	0.234
Others	6	(3.4)	4	(1.6)	10	(2.4)	
Education Level							
No formal education:	3	(1.7)	4	(1.6)	7	(1.7)	0.008 **
Primary	119	(68.0)	123	(50.2)	242	(57.6)	
Secondary	34	(19.4)	73	(29.8)	107	(25.5)	
Vocational	8	(4.6)	21	(8.6)	29	(6.9)	
Bachelor's or higher	11	(6.3)	24	(9.8)	35	(8.3)	
Household Size							
Small (1–2 persons)	42	(24.0)	39	(15.9)	81	(19.3)	0.087
Medium (3–4 persons)	66	(37.7)	93	(38.0)	159	(37.9)	
Large (≥5 persons)	67	(38.3)	113	(46.1)	180	(42.8)	
Drinking Water Source							
River	1	(0.6)	6	(2.4)	7	(1.7)	0.000 **
Tap water	24	(13.7)	24	(9.8)	48	(11.4)	
Filtered water	103	(58.9)	92	(37.6)	195	(46.4)	
Bottled water	45	(25.7)	115	(46.9)	160	(38.1)	
Others	2	(1.1)	8	(3.3)	10	(2.4)	
Household Water Source							
River	12	(6.9)	27	(11.0)	39	(9.3)	0.106
Tap water	137	(78.3)	167	(68.2)	304	(72.4)	
Filtered water	18	(10.3)	30	(12.2)	48	(11.4)	
Bottled water	3	(1.7)	3	(1.2)	6	(1.4)	
Others	5	(2.9)	18	(7.3)	23	(5.5)	
Illness in the past month							
Yes	36	(20.6)	32	(13.1)	68	(16.2)	0.039 *
No/Unsure	139	(79.4)	213	(86.9)	352	(83.8)	

Table 1. *Cont.*

Factors	Behaviors Good (n = 175)		Poor (n = 245)		Total (n = 420)		p-Value Exact Test/t-Test
	n	(%)	n	(%)	n	(%)	
Physician visits in the past month							
Yes	39	(22.3)	33	(13.5)	72	(17.1)	0.018 *
No/Unsure	136	(77.7)	212	(86.5)	348	(82.9)	
Type of Illness in the past month							
Respiratory system	11	(6.3)	14	(5.7)	25	(6.0)	0.055
Digestive system	17	(9.7)	9	(3.7)	26	(6.2)	
Circulatory/neurological	15	(8.6)	16	(6.5)	31	(7.4)	
None	132	(75.4)	206	(84.1)	338	(80.5)	
Aquatic foods consumption (past month)							
Yes	170	(97.1)	234	(95.5)	404	(96.2)	0.389
No/Unsure	5	(2.9)	11	(4.5)	16	(3.8)	
Source of aquatic foods							
Self-caught	27	(15.4)	56	(22.9)	83	(19.8)	0.000 **
Market	145	(82.9)	162	(66.1)	307	(73.1)	
From friends/relatives	3	(1.7)	27	(11.0)	30	(7.1)	
Type of Aquatic foods Consumed							
Fish	168	(96.0)	234	(95.5)	402	(95.7)	0.807
Others:	7	(4.0)	11	(4.5)	18	(4.3)	
Health literacy							
Sufficiency	170	(69.4)	66	(37.7)	236	(56.2)	0.000 **
Insufficiency	75	(30.6)	109	(62.3)	184	(43.8)	

* $p < 0.05$; ** $p < 0.01$.

3.2. Environmental Health Literacy Regarding Microplastic Exposure

The levels of environmental health literacy regarding microplastic exposure across six dimensions. Overall, participants demonstrated a moderate level of environment health literacy, with a mean overall score of 2.30 ± 0.46. Among the six dimensions, appraisal achieved the highest mean score (2.34 ± 0.51) and was the only domain classified as being at a good level. In contrast, the decision-making dimension had the lowest mean score (1.70 ± 0.41), although it remained within the moderate category.

The remaining dimensions, including cognitive (2.30 ± 0.46), access to health information and services (2.13 ± 0.41), communication (2.27 ± 0.46), and action (2.30 ± 0.42), were all classified as demonstrating moderate levels of environmental health literacy. These findings indicate that while participants generally possessed an adequate capacity to understand, access, communicate, and apply information related to microplastic exposure, their ability to make informed decisions based on environmental health information related to potential microplastic exposure remained comparatively limited, as shown in Table 2.

Table 2. Environmental health literacy level with 6 components for Microplastics exposure (n = 420).

Environmental Health Literacy Components	Mean	SD.	Level
Cognitive	2.30	0.46	Moderate
Access to health information and service	2.13	0.41	Moderate
Communicate	2.27	0.46	Moderate
Action	2.30	0.42	Moderate
Appraisal	2.34	0.51	Good
Decision	1.70	0.41	Moderate
Overall	2.30	0.46	Moderate

3.3. Factors Associated with Insufficient Environmental Health Literacy:

The factors associated with insufficient environmental health literacy related to microplastic exposure. In the bivariable analysis, age, occupation, duration of residence, drinking water source, household water source, and the source of aquatic foods were significantly associated with insufficient environmental health literacy (all $p < 0.05$).

After adjustment for potential confounding factors using multivariable logistic regression, several variables remained independently associated with insufficient environmental health literacy. Compared with participants aged >60 years, those aged 18–45 years had significantly higher odds of insufficient environmental health literacy (adjusted odds ratio [AOR] = 2.39, 95% confidence interval [CI]: 1.25–4.56, $p = 0.008$), whereas the association among participants aged 46–60 years was not statistically significant (AOR = 1.72, 95% CI: 0.98–3.01, $p = 0.059$). Occupation was also an independent factor associated with environmental health literacy. Compared with agricultural workers, participants engaged in trade were significantly less likely to have insufficient environmental health literacy (AOR = 0.20, 95% CI: 0.10–0.37, $p < 0.001$). No significant associations were observed among labor/other occupations or government/state enterprise employees ($p > 0.05$). Participants who had resided in their communities for more than 10 years were more likely to have insufficient environmental health literacy than those with a shorter duration of residence (AOR = 3.34, 95% CI: 1.38–8.04, $p = 0.007$). Household water source also remained a significant factor associated with insufficient environmental health literacy, with participants using tap water showing lower odds of insufficient environmental health literacy than those relying on river water or other untreated water sources (AOR = 0.36, 95% CI: 0.18–0.73, $p = 0.004$). In contrast, drinking water source was not independently associated with environmental health literacy after adjustment (all $p > 0.05$). Regarding the source of aquatic foods, participants who primarily purchased aquatic foods from markets were significantly less likely to have insufficient environmental health literacy than those who consumed self-caught aquatic foods (AOR = 0.37, 95% CI: 0.20–0.70, $p = 0.001$). In contrast, obtaining aquatic foods from friends or relatives was not significantly associated with environmental health literacy ($p = 0.507$), as shown in Table 3.

Table 3. Factors associated with insufficient environmental health literacy related to potential microplastic exposure ($n = 420$).

Factors	Health Literacy				COR	*p*-Value	AOR	*p*-Value	95% C.I. for AOR	
	Insufficiency ($n = 174$)		Sufficiency ($n = 246$)							
	n	(%)	*n*	(%)					Lower	Upper
Age (year)										
18–45 years	36	(20.7)	92	(37.4)	3.04	0.000	2.39	0.008 **	1.25	4.56
46–60 years	69	(39.7)	96	(39.0)	1.65	0.034	1.72	0.059	0.98	3.01
>60 years *	69	(39.7)	58	(23.6)	1	0.000	1	0.026		
Occupation										
Agriculture	102	(58.6)	65	(26.4)	1	0.000	1	0.000 **		
Trade	14	(8.0)	37	(15.0)	4.15	0.000	0.20	0.000 **	0.10	0.37
Labor/other	32	(17.4)	85	(34.6)	4.17	0.000	0.92	0.860	0.39	2.19
Government/State enterprise	26	(14.9)	59	(24.0)	3.56	0.000	0.92	0.830	0.46	1.88
Duration of Residence (years)										
≤10 years *	16	(9.2)	16	(6.5)	1	0.012	1	0.000 **		
>10 years	158	(90.8)	230	(93.5)	1.46	0.038	3.34	0.007 **	1.38	8.04
Drinking water source										
River/Others *	4	(2.3)	13	(25.3)	1	0.002	1	0.045		
Tap water	25	(14.4)	23	(9.3)	0.28	0.049	0.48	0.288	0.12	1.86
Filtered water	95	(54.6)	100	(40.7)	0.32	0.056	0.56	0.365	0.16	1.96
Bottled water	50	(28.7)	110	(44.7)	0.68	0.513	1.68	0.430	0.46	6.12

Table 3. *Cont.*

Factors	Health Literacy				COR	*p*-Value	AOR	*p*-Value	95% C.I. for AOR	
	Insufficiency (*n* = 174)		Sufficiency (*n* = 246)							
	n	(%)	*n*	(%)					Lower	Upper
Household Water Source										
River/Others *	17	(9.8)	45	(18.3)	1	0.053	1	0.029 *		
Tap water	138	(79.3)	166	(67.5)	0.45	0.010	0.36	0.004 **	0.18	0.73
Filtered water	17	(9.8)	31	(12.6)	0.68	0.369	0.55	0.224	0.21	1.43
Bottled water	2	(1.1)	4	(1.6)	0.76	0.758	0.77	0.805	0.10	5.87
Source of Aquatic foods Consumed										
Self-caught *	29	(16.7)	54	(22.0)	1	0.015	1	0.001 **		
Market	139	(79.9)	168	(68.3)	0.65	0.093	0.37	0.001 **	0.20	0.70
From friends/relatives	6	(3.4)	24	(9.8)	2.15	0.135	1.43	0.507	0.46	4.48

Variable(s) entered on step 1: Age, Occupation, Duration, Religion, Household size, Drink water source, Household Water Source, Illness in the past month, Visited Doctor in the past month, Source of Aquatic Animals Consumed, Aquatic Animals Consumed. Hosmer and Lemeshow Test Chi-square = 8.88, *p*-value = 0.353, Nagelkerke R Square = 0.29, Overall Percentage = 69.8. COR = crude odds ratio; AOR = adjusted odds ratio; CI = confidence interval. AORs were estimated from the multivaria-ble binary logistic regression model adjusted for all variables included in the model. * $p < 0.05$; ** $p < 0.01$.

3.4. Factors Associated with Poor Environmental Health Behaviors Related to Potential Microplastic Exposure

In the bivariable analysis, age, occupation, drinking water source, physician visit during the previous month, source of aquatic foods, and environmental health literacy were significantly associated with poor environmental health behaviors related to potential microplastic exposure (all $p < 0.05$). Variables with $p < 0.25$ in the bivariable analysis were subsequently entered into the multivariable binary logistic regression model.

After adjustment for potential confounding factors using multivariable logistic regression, several variables remained independently associated with poor environmental health behaviors related to microplastic exposure. The adjusted odds ratios (AORs) presented in Table 4 were derived from the multivariable model after adjustment for all variables included in the model. Compared with participants aged >60 years, those aged 46–60 years were significantly less likely to report poor environmental health behaviors (AOR = 0.28, 95% CI: 0.11–0.75, $p = 0.011$), whereas the association among participants aged 18–45 years was not statistically significant (AOR = 0.55, 95% CI: 0.25–1.22, $p = 0.144$).

Occupation was also independently associated with poor environmental health behaviors. Compared with agricultural workers, participants engaged in trade were significantly less likely to report poor environmental health behaviors (AOR = 0.22, 95% CI: 0.07–0.66, $p = 0.007$). No significant associations were observed among participants in labor/other occupations or government/state enterprise employees (all $p > 0.05$).

Drinking water source remained significantly associated with poor environmental health behaviors. Compared with participants who consumed bottled water, those who consumed river water or other untreated water sources were significantly more likely to report poor environmental health behaviors (AOR = 3.85, 95% CI: 1.82–8.14, $p = 0.001$). In contrast, tap water and filtered water were not independently associated with poor environmental health behaviors after adjustment (all $p > 0.05$).

Physician visits during the previous month were also significantly associated with poor environmental health behaviors. Participants who had not visited a physician during the previous month were more likely to report poor environmental health behaviors than those who had visited a physician (AOR = 3.11, 95% CI: 1.30–7.41, $p = 0.010$).

Table 4. Factors associated with poor environmental health behaviors related to potential microplastic exposure (n = 420).

Factors	Behavior				Bivariable Analysis		Multivariable Analysis			
	Poor (n = 245)		Good (n = 175)						95% C.I. for AOR	
	n	(%)	n	(%)	COR	p-Value	AOR	p-Value	Lower	Upper
Age (year)										
>60 years	92	(37.6)	36	(20.6)	1	0.001	1	0.039		
46–60 years	99	(40.4)	66	(37.7)	0.28	0.001 **	0.28	0.011 *	0.11	0.75
18–45 years	54	(22.0)	73	(41.7)	0.49	0.003 **	0.55	0.144	0.25	1.22
Occupation										
Agriculture	82	(35.5)	85	(48.6)	1	0.001	1	0.032		
Trade	35	(14.3)	16	(9.1)	0.44	0.016 *	0.22	0.007 **	0.07	0.66
Labor/other	79	(32.2)	38	(21.7)	0.46	0.002 **	0.67	0.552	0.18	2.53
Government/State enterprise	49	(20.0)	36	(20.6)	0.71	0.200	0.82	0.719	0.29	2.36
Drinking water source										
Bottled water	115	(46.9)	45	(25.7)	1	0.007	1	0.002		
Tap water	24	(9.8)	24	(13.7)	0.55	0.362	0.57	0.547	0.10	3.45
Filtered water	92	(37.6)	1.3	(58.9)	2.86	0.001 **	2.76	0.074	0.91	8.42
River/Others *	14	(5.7)	3	(1.7)	2.56	0.006 **	3.85	0.001 **	1.82	8.14
Physician visits in the past month										
Yes	33	(13.5)	39	(22.3)	1	0.001	1	0.001		
No	212	(86.5)	136	(77.7)	1.84	0.019 *	3.11	0.010 *	1.30	7.41
Source of aquatic foods consumed										
Self-caught *	56	(22.9)	27	(15.4)	1	0.000	1	0.004		
Market	162	(66.1)	145	(82.9)	0.23	0.024 *	0.11	0.023	0.11	0.74
From friends/relatives	27	(11.0)	3	(1.7)	0.12	0.001 **	0.06	0.002	0.01	0.34
Health Literacy										
Sufficiency	170	(69.4)	66	(37.7)	1	0.001	1	0.001		
Insufficiency	75	(30.6)	109	(62.3)	3.75	0.001 **	8.06	0.001 **	2.86	10.04

Variable(s) entered on step 1: Age, Occupation, Income, Duration, Religion, Household size, Drinking water source, Household Water Source, Illness in the past month, Visited Doctor in the past month, Type of illness, Source of Aquatic Animals Consumed, Health Literacy. Hosmer and Lemeshow Test Chi-square = 9.96, p-value = 0.268; Nagelkerke R Square = 0.711; Overall Percentage = 89.0. COR = crude odds ratio; AOR = adjusted odds ratio; CI = confidence interval. AORs were estimated from the multivariable binary logistic regression model adjusted for all variables included in the model. * $p < 0.05$; ** $p < 0.01$.

Regarding the source of aquatic foods, participants who primarily obtained aquatic foods from markets were significantly less likely to report poor environmental health behaviors than those who consumed self-caught aquatic foods (AOR = 0.11, 95% CI: 0.11–0.74, p = 0.023). Likewise, participants obtaining aquatic foods from friends or relatives were significantly less likely to report poor environmental health behaviors (AOR = 0.06, 95% CI: 0.01–0.34, p = 0.002).

Environmental health literacy demonstrated the strongest association with poor environmental health behaviors. Participants with insufficient environmental health literacy were more likely to report poor environmental health behaviors related to potential microplastic exposure than those with sufficient environmental health literacy (AOR = 8.06, 95% CI: 2.86–10.04, $p < 0.001$).

The final multivariable logistic regression model demonstrated good model fit (Hosmer–Lemeshow χ^2 = 9.96, p = 0.268), with a Nagelkerke R^2 of 0.711 and an overall classification accuracy of 89.0%, as shown in Table 4.

4. Discussion

The present study provides novel evidence regarding the relationship between environmental health literacy and environmental health behaviors related to microplastic

exposure among residents living in communities along the Mekong River in northeastern Thailand. Although microplastic pollution has become an emerging global environmental and public health concern, studies investigating how environmental health literacy influences community-level environmental health behaviors related to potential microplastic exposure remain limited, particularly in low- and middle-income countries. The present findings demonstrated three principal observations. First, more than half of the participants exhibited poor environmental health behaviors related to potential microplastic exposure despite residing in communities with long-term dependence on freshwater ecosystems. Second, participants generally demonstrated a moderate level of environmental health literacy, although substantial variation was observed across individual environmental health literacy domains, particularly decision-making. Third, insufficient environmental health literacy was the strongest independent factor associated with poor environmental health behaviors related to potential microplastic exposure after adjustment for multiple sociodemographic and environmental factors. Collectively, these findings emphasize that improving environmental health literacy may represent one of the most effective public health strategies for reducing human exposure to microplastics and promoting environmental health behaviors that minimize potential microplastic exposure [26–28].

One of the most important findings of this study is that environmental health literacy demonstrated the strongest association with environmental health behaviors related to potential microplastic exposure. Participants with insufficient environmental health literacy had more than eight times higher odds of reporting poor environmental health behaviors related to potential microplastic exposure than those with sufficient environmental health literacy. This strong association should be interpreted cautiously because the two constructs are theoretically related, and some conceptual overlap between the literacy and behavior measures may have contributed to the observed magnitude of the association. This finding also highlights that environmental health literacy extends beyond simply possessing factual knowledge about environmental pollution. Rather, environmental health literacy encompasses the ability to obtain, understand, critically evaluate, and appropriately apply information when making decisions related to environmental health. The observed association may reflect the role of these literacy-related capacities in recognizing environmental risks, identifying reliable sources of information, critically evaluating relevant evidence, and engaging in appropriate environmental health practices related to potential microplastic exposure [29,30]. However, given the cross-sectional design, these findings should not be interpreted as evidence that higher environmental health literacy directly leads to better environmental health behaviors. Similarly, the relatively high Nagelkerke R^2 (0.711) and classification accuracy (89.0%) should be interpreted cautiously. These values indicate relatively strong model fit and classification performance within the study sample but should not be interpreted as evidence of validated predictive performance. The relatively high model performance may partly reflect the strong association and potential conceptual overlap between environmental health literacy and behavioral measures. In addition, because the model was developed and evaluated using the same cross-sectional dataset and no external validation sample was available, the possibility of overfitting cannot be completely excluded. Future studies using independent samples and appropriate internal or external validation approaches are warranted to assess the stability and generalizability of the findings.

The present findings are highly consistent with Nutbeam's conceptual framework, which proposes that environmental health literacy progresses from functional literacy to interactive and critical literacy. Functional environmental health literacy enables individuals to access and understand environmental health information, whereas interactive and critical environmental health literacy facilitate active participation in environmental health

promotion, critical appraisal of information, and informed decision-making. In the context of microplastic exposure, these higher-order competencies are particularly important because the scientific evidence continues to evolve rapidly. Individuals must therefore interpret complex and sometimes conflicting information regarding exposure pathways, potential health effects, and strategies for reducing microplastic exposure. The strong relationship identified in the present study suggests that interventions focusing solely on increasing environmental health knowledge may be insufficient unless accompanied by efforts to strengthen critical appraisal and decision-making skills, thereby promoting environmental health behaviors related to potential microplastic exposure [31,32].

Our findings also support the emerging Environmental Health Literacy (EHL) framework, which integrates principles of environmental health literacy, environmental science, toxicology, environmental epidemiology, and risk communication. Environmental health literacy recognizes that environmental health challenges often involve complex exposure pathways, requiring individuals to understand the interactions among environmental contaminants, human behaviors, and health outcomes. Recent international studies have demonstrated that higher environmental health literacy is associated with greater environmental risk perception, stronger environmental responsibility, and increased adoption of environmental health behaviors that reduce environmental exposures. Similar relationships have been reported for exposures to heavy metals, pesticides, air pollution, and endocrine-disrupting chemicals, suggesting that environmental health literacy represents a common mechanism through which scientific knowledge is translated into health-protective actions [8,33,34].

An additional explanation for the strong relationship between environmental health literacy and environmental health behaviors related to potential microplastic exposure may be the increasing complexity of information surrounding microplastic exposure. During the past five years, scientific evidence has expanded considerably, documenting the presence of microplastics in drinking water, seafood, table salt, human blood, placental tissue, breast milk, lung tissue, and cardiovascular tissues. However, despite growing concern regarding their potential adverse health effects, substantial uncertainty remains regarding toxicological thresholds, biological mechanisms, and effective strategies for reducing microplastic exposure. Such uncertainty may create confusion among community members, particularly those with insufficient environmental health literacy, thereby reducing confidence in environmental health decision-making. Individuals with higher environmental health literacy, particularly stronger critical literacy skills, are more likely to critically evaluate emerging scientific evidence and adopt environmental health behaviors that reduce potential microplastic exposure despite ongoing scientific uncertainties [2,5,35].

Furthermore, our findings indicate that environmental health literacy should be considered a modifiable public health resource rather than a fixed individual characteristic. Unlike age or sex, environmental health literacy can be improved through structured educational interventions, community participation, effective risk communication, and increased access to understandable environmental health information. Recent intervention studies have demonstrated that environmental education programs designed according to environmental health literacy principles significantly improve environmental knowledge, risk perception, self-efficacy, and environmental health behaviors related to microplastic exposure. These observations suggest that strengthening environmental health literacy may represent one of the most cost-effective approaches for reducing population exposure to potential microplastic exposure while simultaneously promoting broader environmental sustainability objectives [36,37].

Another important finding concerns the distribution of environmental health literacy across its individual domains. Although participants demonstrated a moderate overall level

of environmental health literacy, decision-making had the lowest mean score among all assessed domains. This observation deserves particular attention because decision-making represents the highest level of cognitive processing within environmental health literacy frameworks. Effective environmental health decision-making requires individuals to compare alternative information sources, evaluate scientific credibility, balance competing risks and benefits, and translate scientific recommendations into feasible household practices. Previous studies investigating environmental health literacy have similarly reported that decision-making consistently represents one of the weakest domains despite relatively high levels of environmental awareness. This pattern suggests that future educational interventions should extend beyond information dissemination and instead prioritize practical problem-solving, critical thinking, and evidence-based environmental health decision-making skills to promote environmental health behaviors related to potential microplastic exposure [38].

4.1. Factors Associated with Environmental Health Literacy

Beyond the overall association between health literacy and preventive behaviors, the present study identified several sociodemographic and environmental determinants independently associated with insufficient environmental health literacy related to potential microplastic exposure. Specifically, age, occupation, duration of residence, household drinking water sources, and aquatic food sources remained significant associated with insufficient environmental health literacy after controlling for potential confounding factors. These findings support the concept that environmental health literacy is shaped by complex interactions among individual characteristics, environmental experiences, social contexts, and access to trustworthy environmental information, rather than being determined solely by formal education or demographic characteristics [26,27].

Age emerged as one of the strongest factors associated with insufficient environmental health literacy in this study. Younger adults (18–45 years) were significantly more likely to have insufficient literacy levels compared with older participants. Although this finding may appear contrary to previous evidence suggesting that younger generations generally have greater digital literacy and easier access to online information, environmental health literacy involves more than the ability to obtain information through digital platforms. According to the concept of critical health literacy, individuals must be able to evaluate the credibility of information sources, interpret scientific evidence, recognize misinformation, and apply relevant knowledge to make appropriate decisions within their specific environmental contexts. Therefore, increased access to information does not automatically result in higher environmental health literacy unless individuals possess the cognitive skills necessary to critically appraise and apply rapidly evolving scientific knowledge [28,29].

One possible explanation for the higher environmental health literacy observed among older participants is the accumulation of environmental experience over time. Individuals who have lived for several decades along the Mekong River may have experienced long-term changes in river ecosystems, fisheries, seasonal flooding patterns, agricultural activities, and the increasing accumulation of plastic waste. Such repeated exposure to environmental changes may enhance risk perception and facilitate a better understanding of the interconnected relationships between environmental degradation and human health. Previous studies in environmental psychology have demonstrated that direct personal experiences with environmental hazards often have a stronger influence on environmental awareness and risk perception than indirect exposure through media campaigns or formal education alone [30,31]. Therefore, experiential learning may partially offset limitations in formal education among older adults living in rural communities and contribute to the development of environmental health literacy.

Occupation was also independently associated with environmental health literacy. Compared with agricultural workers, individuals engaged in commercial occupations had significantly higher odds of insufficient environmental health literacy. This finding may reflect differences in patterns of interaction with environmental resources rather than occupation itself as a direct determinant. Agricultural workers typically maintain closer and more frequent contact with natural ecosystems through crop production, irrigation activities, fisheries, and livestock management. These routine interactions may increase their awareness of environmental changes, exposure pathways, and potential consequences of environmental contamination, thereby encouraging greater interest in environmental health information. Similar patterns have been reported among agricultural communities exposed to pesticide contamination, groundwater pollution, and climate-related environmental changes, where dependence on ecosystem services was associated with increased environmental awareness and stronger engagement in protective behaviors [32,33].

Interestingly, longer duration of residence was associated with insufficient environmental health literacy after adjustment for potential confounders. Although longer residence duration would theoretically be expected to enhance local environmental knowledge, several mechanisms may explain this unexpected finding. One possible explanation is the influence of the shifting baseline syndrome, whereby individuals adapt their perceptions of environmental conditions to the state they have experienced during their lifetime and gradually perceive deteriorating conditions as normal. As environmental changes often occur incrementally, long-term residents may underestimate emerging environmental risks despite accumulating scientific evidence of contamination and ecological disruption [8].

Second, one possible explanation is that long-term residents may rely predominantly on traditional ecological knowledge developed through personal experiences, observations, and community practices. Although such knowledge represents an important resource for understanding local ecosystems and adapting to environmental changes, it may not always incorporate emerging scientific evidence regarding newly recognized contaminants, including microplastics, nanoplastics, and plastic-associated chemicals. However, this explanation remains speculative. Duration of residence may also act as a proxy for age, education, socioeconomic characteristics, migration history, or other unmeasured factors that may be related to environmental health literacy. In particular, without information on migration history, it is difficult to determine whether the observed association reflects the duration of residence itself or differences in migration background and environmental experiences. These factors may also interact with length of residence and shape access to environmental health information and community knowledge. Therefore, the observed association should be interpreted cautiously and not as evidence of an independent effect of duration of residence on environmental health literacy. Bridging traditional ecological knowledge with contemporary scientific knowledge may represent an important opportunity for environmental health promotion initiatives, particularly in communities experiencing long-term environmental change [34]. Qualitative and longitudinal studies incorporating migration history and repeated assessment of environmental health literacy are needed to further clarify these relationships over time.

Household drinking water sources also emerged as an important determinant of environmental health literacy. Participants using treated tap water had significantly lower odds of insufficient environmental health literacy compared with those relying on untreated water sources. This association may not directly reflect differences in potential microplastic exposure levels but may instead indicate broader disparities in environmental awareness, socioeconomic circumstances, access to health information, and engagement with public health services. Previous studies have consistently shown that households adopting safer water management practices tend to demonstrate higher health literacy, greater confidence

in public health guidance, and stronger participation in preventive health behaviors [5]. These findings suggest that drinking water practices may serve as an indicator of broader environmental health awareness within communities.

The source of aquatic food consumption was another significant factor associated with environmental health literacy. Participants who purchased aquatic products from markets demonstrated higher environmental health literacy than those who consumed self-caught aquatic animals. One possible explanation is that purchasing aquatic products through formal supply chains provides greater opportunities to receive food safety information, product-related communication, and public health messages. In contrast, individuals who rely on self-caught aquatic resources may perceive locally harvested food as safe due to long-standing familiarity and cultural connections with the surrounding environment. This pattern may reflect familiarity bias, in which repeated exposure to a particular environmental setting reduces perceived vulnerability to contamination despite evidence of potential environmental risks [5].

Collectively, these findings indicate that environmental health literacy should not be conceptualized solely as an individual cognitive capacity but rather as a multidimensional construct influenced by cumulative environmental experiences, occupational contexts, community interactions, environmental communication systems, and access to reliable scientific information. This interpretation aligns with recent conceptual frameworks suggesting that environmental health literacy develops through dynamic interactions between individuals and their social, cultural, and ecological environments rather than through formal education alone [2,36].

Importantly, the present findings provide valuable implications for the design of targeted public health interventions. Younger adults, newly established residents, and individuals who depend directly on untreated environmental resources may represent priority groups for environmental health literacy interventions aimed at enhancing critical appraisal skills, improving environmental risk communication, and promoting evidence-informed decision-making. Intervention strategies should integrate practical approaches for reducing potential microplastic exposure with accessible explanations of emerging scientific evidence regarding environmental contamination. Furthermore, meaningful community participation, culturally appropriate communication approaches, and collaboration among healthcare professionals, environmental scientists, and local administrative organizations will be essential for achieving sustainable improvements in environmental health literacy [37,38].

4.2. Factors Associated with Environmental Health Behaviors Related to Potential Microplastic Exposure

The present study demonstrated that preventive behaviors against potential microplastic exposure were associated with multiple individual and contextual factors, including environmental health literacy related to microplastic exposure, sociodemographic characteristics, environmental awareness, and access to reliable environmental information. These findings reinforce the growing recognition that addressing plastic pollution requires not only technological solutions and policy-level interventions but also behavioral changes at individual and household levels. Because human exposure to microplastics can occur through multiple pathways, including ingestion of contaminated food and water, inhalation of airborne particles, and contact with plastic-containing materials, preventive behaviors represent an important component of exposure reduction strategies and environmental health protection [26,27].

A key finding of this study was the significant association between environmental health literacy and preventive behaviors. Participants with higher levels of microplastic-related environmental health literacy were more likely to engage in protective behaviors, suggesting that cognitive skills and the ability to interpret environmental

health information may facilitate the translation of knowledge into action. This finding is consistent with the broader health literacy framework, which proposes that individuals who can access, understand, critically evaluate, and apply health-related information are better equipped to make appropriate decisions regarding risk prevention and health promotion [5,36]. In the context of microplastic exposure, individuals with higher environmental health literacy may have a better understanding of exposure pathways, recognize potential health implications, and adopt preventive practices such as reducing single-use plastic consumption, minimizing unnecessary plastic packaging, and improving household waste management.

The observed relationship between environmental health literacy and preventive behaviors may also be explained through the environmental health literacy framework. Unlike established environmental health risks with well-defined preventive recommendations, potential microplastic exposure represents an emerging challenge characterized by scientific uncertainty regarding long-term human health consequences. Therefore, individuals require not only factual knowledge but also critical appraisal skills to interpret evolving scientific evidence, assess potential risks, and make informed decisions. Previous studies have demonstrated that environmental health literacy can influence pro-environmental behaviors by strengthening risk perception, motivation, self-efficacy, and engagement in protective actions [27,30].

Environmental risk perception may represent another important pathway linking knowledge with preventive behaviors. Individuals who perceive potential microplastic exposure as a meaningful threat to human health may be more motivated to adopt protective actions, particularly when they believe their behaviors can contribute to reducing personal exposure or environmental harm. Previous research has shown that perceived environmental risks are important factor associated with public engagement in pollution prevention behaviors [2,37]. However, developing appropriate risk perception regarding microplastics remains challenging because these contaminants are largely invisible, individual exposure levels are difficult to estimate, and scientific evidence regarding health effects continues to evolve. Therefore, effective communication strategies should aim to increase awareness while maintaining scientific accuracy and avoiding unnecessary fear or misinformation.

Sociodemographic characteristics may also contribute to variations in preventive behaviors against microplastic exposure. In this study, differences according to age, educational attainment, and socioeconomic characteristics suggest that individuals with greater educational opportunities may have advantages in accessing, interpreting, and applying environmental health information. Education has consistently been identified as an important determinant of environmental behaviors because it can enhance awareness, problem-solving capacity, and participation in sustainability-related actions [5,32]. Individuals with higher educational backgrounds may also be more familiar with concepts related to plastic reduction, recycling practices, and circular economy principles.

Age-related differences in preventive behaviors may reflect variations in environmental awareness, social experiences, and lifestyle patterns across generations. Younger individuals may receive greater exposure to environmental sustainability campaigns through digital platforms and social networks, potentially increasing awareness and participation in plastic reduction initiatives [37,38]. Conversely, older adults may have established consumption habits that are more resistant to change, although their accumulated environmental experiences and community-based practices may provide valuable knowledge for environmental conservation. These findings suggest that interventions should incorporate age-specific approaches rather than applying a uniform strategy across different population groups.

Access to reliable environmental information was another important factor associated with preventive behaviors. Participants who received information from credible sources, including educational institutions, government agencies, healthcare providers, and environmental organizations, may have been more likely to adopt appropriate preventive practices. However, the increasing availability of information through digital and social media platforms creates both opportunities and challenges. While online communication can rapidly improve public awareness, it may also facilitate the dissemination of inaccurate or exaggerated claims regarding microplastic risks [29,31]. Strengthening scientific communication and improving individuals' ability to evaluate information credibility are therefore essential components of effective environmental health interventions.

Preventive behaviors related to potential microplastic exposure may also depend on environmental opportunities and broader social contexts. Individual actions are influenced not only by personal motivation and awareness but also by the availability of alternatives, economic conditions, and community infrastructure. For example, reducing plastic consumption may be difficult when reusable products are inaccessible, relatively expensive, or unsupported by local systems. Therefore, improving preventive behaviors requires integration of individual-level education with supportive environmental policies, including improved waste management systems, plastic reduction initiatives, and regulations promoting sustainable production and consumption [2,37].

The feasibility of adopting recommended environmental health behaviors may also depend on structural and economic conditions. Although individuals with higher environmental health literacy may have greater capacity to understand and apply environmental health information, knowledge alone may not be sufficient when safer or more sustainable choices are more expensive or less accessible. Household income, availability and affordability of alternatives to single-use plastics, access to safe drinking water, local waste-management infrastructure, and availability of appropriate products may influence individuals' ability to adopt recommended behaviors. These structural barriers are particularly relevant in community settings where environmental health choices may be constrained by household resources and local infrastructure. Therefore, interventions should not place responsibility solely on individuals but should also address the social and economic conditions that shape the feasibility of behavior change. Community programs and local policies could support behavior change by improving access to affordable alternatives, strengthening waste-management systems, and providing practical options that are feasible within local socioeconomic contexts.

The findings have important implications for clinical practice, primary care, and public health policy. Interventions should extend beyond increasing awareness and emphasize practical skills, critical appraisal, and environmental empowerment. Primary care providers and public health practitioners could incorporate environmental health literacy (EHL) into routine health education and counseling, focusing on practical issues such as plastic use, drinking water sources, food preparation, household waste management, and feasible alternatives to single-use plastics. Brief, context-specific counseling and accessible educational materials may be particularly useful for individuals with lower EHL.

At the community and policy levels, EHL could be integrated into existing health promotion services rather than implemented as stand-alone programs. School-based EHL activities with age-appropriate content could target children and adolescents, particularly given the poorer environmental health behaviors observed among younger participants in this study. Because this study included adults only, future research should examine children and adolescents to better understand how EHL and related behaviors vary across developmental stages and how environmental health knowledge and practices may be transmitted between generations. Family-oriented risk communication could help parents

and caregivers reinforce appropriate environmental health practices at home, while maternal and child health services could incorporate brief environmental health counseling into routine antenatal, postnatal, and child health visits. Community health workers, local health-promoting hospitals, schools, and local authorities could collaborate to provide consistent and locally relevant information through educational materials, community campaigns, and practical demonstrations.

At the policy level, local authorities could also address structural barriers to behavior change by improving access to affordable alternatives to single-use plastics and strengthening household waste-management infrastructure. These approaches may be particularly relevant in communities where economic and environmental conditions constrain the feasibility of recommended behaviors. Given the cross-sectional design, however, these recommendations represent potential strategies for health promotion rather than evidence that such interventions would directly improve behaviors or reduce microplastic exposure. Future intervention studies should evaluate their feasibility and effectiveness, particularly among children, adolescents, and families with potentially distinct patterns of environmental exposure.

Overall, the findings suggest that environmental health behaviors related to potential microplastic exposure are associated with multiple individual and contextual factors, including EHL, sociodemographic characteristics, access to information, and environmental conditions. Public health strategies may therefore benefit from combining EHL education with supportive community and policy environments that facilitate feasible environmental health practices. Such approaches should be evaluated using longitudinal and intervention designs to determine whether improvements in EHL and environmental conditions are accompanied by changes in environmental health behaviors and, where feasible, objectively assessed exposure.

Future research should address several specific areas. First, longitudinal studies are needed to examine temporal changes in environmental health literacy and environmental health behaviors and to clarify whether changes in EHL are associated with subsequent changes in behavior. Second, studies should incorporate objective exposure assessment, including environmental sampling and biomarker-based or biomonitoring approaches where feasible, to complement self-reported behaviors and better characterize individual exposure to microplastics. Third, intervention studies should evaluate the feasibility and effectiveness of specific EHL improvement strategies, such as school-based education, primary care counseling, family-oriented risk communication, and community-based programs. Future studies should also consider including children and adolescents, collecting migration history, and examining socioeconomic and structural factors that may influence the feasibility of recommended environmental health behaviors. These approaches would provide stronger evidence for developing context-specific strategies to address environmental health risks associated with plastic pollution.

5. The Strength and Limitation of the Study

This study has several important strengths. First, it addresses an emerging environmental health concern by simultaneously examining environmental health literacy related to potential microplastic exposure and preventive behaviors against microplastic exposure. This approach provides valuable insights into how individuals perceive environmental risks, process environmental health information, and translate knowledge into protective actions within a community context. Second, the use of a structured questionnaire and multivariable analytical approach enabled the identification of factors independently associated with preventive behaviors while accounting for potential confounding variables. These findings contribute important evidence for designing targeted environmental

health education programs, improving risk communication strategies, and promoting evidence-informed behavioral interventions for reducing microplastic exposure.

Several limitations of this study should be considered. First, the cross-sectional design limits the ability to establish temporal relationships or causal inferences between environmental health literacy and environmental health behaviors. Second, self-reported questionnaires may have introduced recall and social desirability biases, as participants may have overreported desirable environmental health behaviors or underreported less desirable behaviors. Third, the study assessed self-reported behaviors related to potential microplastic exposure, but actual exposure was not directly measured through environmental sampling, biological specimens, or biomonitoring. In particular, the absence of biological measurements means that internal potential microplastic exposure or body burden could not be objectively quantified. Therefore, the findings should not be interpreted as evidence of actual potential microplastic exposure or exposure reduction. Fourth, the study communities were purposively selected based on their proximity to the Mekong River, which may have introduced selection bias and limited the generalizability of the findings to communities with different environmental, geographic, and sociodemographic characteristics. Therefore, the findings should be interpreted within the specific context of communities along the Mekong River in Mueang Nakhon Phanom District and should not be directly generalized to other regions or the broader Thai population. Further studies involving diverse communities and geographic settings are needed to assess the consistency and generalizability of these findings. Fifth, migration history was not collected, limiting our ability to determine whether the observed association between duration of residence and EHL reflects the duration of residence itself or differences in age, education, socioeconomic characteristics, migration background, environmental experience, or other unmeasured factors. Therefore, residual confounding cannot be excluded. Finally, questionnaire validation was limited to content validity and internal consistency; test–retest reliability, criterion validity, and construct validity through factor analysis were not assessed. Inter-observer agreement was not applicable because the questionnaire was self-administered. Future studies should incorporate migration history, comprehensive psychometric validation, objective exposure assessment and biomonitoring, and longitudinal designs to better clarify the relationships among EHL, preventive behaviors, and potential microplastic exposure.

6. Conclusions

This study found that environmental health literacy and environmental health behaviors related to potential microplastic exposure were associated with several individual and contextual factors among adults living in communities near the Mekong River. Higher environmental health literacy was associated with more appropriate environmental health behaviors, whereas insufficient environmental health literacy was associated with higher odds of reporting poor behaviors. Age, occupation, drinking water source, physician visits, and sources of aquatic foods were also associated with environmental health behaviors.

These findings suggest that environmental health literacy, access to reliable environmental health information, and contextual factors may be relevant to understanding behaviors related to potential microplastic exposure. Community-based public health strategies may consider integrating environmental health literacy education, risk communication, and accessible evidence-based information into community and primary healthcare services. However, given the cross-sectional design, reliance on self-reported measures, and absence of objective exposure assessment, the observed associations should not be interpreted as causal relationships or as evidence of actual microplastic exposure reduction. Future longitudinal and intervention studies incorporating objective behavioral and exposure measures are warranted to further clarify these relationships and evaluate

strategies for promoting appropriate environmental health behaviors related to potential microplastic exposure.

Supplementary Materials: The following supporting information can be downloaded at: https://www.mdpi.com/article/10.3390/environments13090490/s1, File S1: Questionnaire.

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