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RESEARCH ARTICLE

Examining Predictors of Preventive Behaviors for PM2.5 Exposure Among Upper Secondary Students in Bangkok: An Application of the Socio-Ecological Model

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Abstract

This study aimed to assess preventive behaviors for particulate matter (PM2.5) exposure and examined the factors influencing these behaviors among upper secondary school students in Bangkok. A descriptive research design was employed, involving 450 students selected through multi-stage random sampling. The researchers collected data using researcher-developed questionnaires during August-September 2024 and analyzed them using Chi-square, Pearson's correlation, and multiple regression analysis. The results showed that students demonstrated moderate preventive behaviors toward PM2.5 (M = 27.34, S.D. = 9.08). Individual factors showed no significant relationship with preventive behaviors, while interpersonal, institutional, community, and public policy factors played key roles in shaping students' preventive behaviors. Key influences included family support (r = 0.505), peer support (r = 0.578), teacher support (r = 0.459), perceived school environment (r = 0.214), and perceptions of school and community activities in addressing PM2.5 (r = 0.391 to r = 0.415). Multiple regression identified five significant predictors: peer support, family support, perceived Ministry of Education policies, school safety measures, and perceived school environment (β = 0.349 to 0.079, $p < 0.05$). This study underscores the importance of socio-environmental factors in shaping preventive behaviors, emphasizing the need for coordinated action among families, educators, and policymakers to reduce PM2.5 exposure among students.

Keywords: PM2.5, Predictive factor, Preventive behavior, Socio-ecological model, Student

Introduction

Particulate matter with a diameter of less than 2.5 microns (PM2.5) is a major environmental and public health problem that many countries worldwide are concerned about and are attempting to get this problem solved and alleviated (World Health Organization [WHO], 2022). Researchers have found that approximately 99.82% of the world's land area is exposed to PM2.5 levels exceeding the safety standards recommended by the World Health Organization (WHO), and that only 0.001% of the global population breathes air considered acceptable (Wenhua et al., 2023). Currently, the PM2.5 situation in many countries is exceeding the standard and affecting public health. The smaller the particle size, the more harmful it is to health throughout the human system (Greenpeace Thailand, 2023). Since it can go through tissues and organs into the circulatory system, affecting health and causing many diseases, especially irritation of the eyes, nose, and respiratory tract, it can also cause heart disease, cerebrovascular disease, chronic obstructive pulmonary disease, lung cancer, and respiratory tract infections (WHO, 2023). Moreover, the World Health Organization (WHO) discovered that environmental air pollution is the main cause of approximately 7 million deaths worldwide every year, with approximately 3.2 million deaths from air pollution from the use of natural fuels for household cooking each year and 4.2 million deaths from general outdoor air pollution each year (WHO, 2022). Similarly, Southeast Asia faces unsafe levels of air pollution, which has adverse health effects and reduces life expectancy by an average of 2 to 3 years for those living in areas with severe pollution levels in Southeast Asia (Greenstone & Hasenkopf, 2023). Thailand, one of the Southeast Asian countries, also faces air pollution, especially from PM2.5 (Clean Air Network, 2020).

In Thailand, people have been experiencing problems with smog and PM2.5 for many years (Ministry of Public Health, 2023). In the past 4 years, from 2020 to 2023, PM2.5 levels have consistently exceeded the standard of 50 micrograms per cubic meter (Department of Disease Control, 2023). It usually occurs from November to March every year, and the transition is period from winter to summer, especially in the upper northern part of the Bangkok Metropolitan Region (Pollution Control Department, 2021). Due to the context of Bangkok as the capital of Thailand, with the densest population in the country, Bangkok is the center of the country's development in terms of economy, business, finance, governance, education, and transportation (Bangkok Information Center, 2023). Therefore, Bangkok is a source of air pollution. Bangkok is also the province with a PM2.5 value exceeding the standard of 50 micrograms per cubic meter, ranked number 1 in the country. PM2.5 that exceed the standard posed an impact throughout the country, both in terms of health, economy, and environment, and tends to be more severe and affect people's quality of life more since people's lifestyles have changed with economic growth in industry, transportation, urban expansion, construction, and agriculture (Khaikham, 2023). Regarding health impacts, the data from the Health Data Center (HDC) over the past 3 years reveals that the number of people suffering from air pollution-related diseases has been increasing continuously every year, from 7,792,689 in 2021 to 10,361,085 in 2022 and 11,230,456 in 2023, respectively. Patients were found of all ages, including adolescents aged 15-19. In the past year, adolescent patients aged 15-19 have increased from 98,505 in 2022 to 303,665 in 2023. Therefore, adolescent patients have increased significantly (Health Data Center, 2024).

Regarding health problems of Thai adolescents, according to the population registration data for the fiscal year 2023, the Thai teenage population aged 15 to 19 years was 4,037,251 (Department of Provincial Administration, Ministry of Interior, 2023). Adolescents experience the same health problems as other age groups. Although experts consider adolescents the healthiest age group, they also face many significant risk factors for premature illness and death, including sexual behavior, tobacco use, alcohol and drug use, diet, physical activity, road accidents, mental health issues, and environmental pollution (Institute for Population and Social Research, Mahidol University, 2020). Specifically, environmental pollution–related risk factors align with World Health Organization (WHO) data showing that environmental conditions contribute to illness and death among adolescents. Adolescents experience rapid physical, mental, cognitive, and decision-making changes, increasing their risk and threat from the environment and pollution. Environmental pollution affecting the health of adolescents includes, for example, climate change, UV rays, chemicals, heavy metals, and air pollution (WHO, 2023). Also, the causes of adolescent illnesses caused by air pollution are consistent with data from the health database system that Thai people suffer from diseases related to air pollution (Health Data Center, 2024). Therefore, the public and private sectors realize the importance of health problems caused by PM2.5 and attempt to find methods to solve the problem (Ministry of Public Health, 2021).

In Thailand, actions to solve the pollution and PM2.5 problems have been carried out, such as spraying water droplets in the air, artificial rain, black smoke vehicle detection, campaigning to wear masks to prevent particulate matter, campaigning to stop burning incense and campaigning to use public transportation as solutions to the end of the cause. They are only short-term solutions and cannot sustainably solve the problem (Phanthuwongpakdee, 2019). Meanwhile, laws and regulations related to solving the pollution and PM2.5 problems could not solve the problem as much as they should due to a lack of cooperation and systematic coordination of relevant public and private agencies (Khaikham, 2023). Apart from cooperation from all sectors, the most important mechanism in solving the problem is the people since people can be both the cause of PM2.5 and affected by PM2.5. Therefore, people must also participate in behavior modification (Department of Health, 2020).

Based on the literature review on preventive behaviors for PM2.5, most studies focused on the sources and components of PM2.5 and adults or the general public. In contrast, a few studies were conducted on infants and adolescents (Sujaritpong & Voelker, 2023). The results of the study on knowledge of environmental health and preventive behaviors for PM2.5 of youth in highland areas during open field burning in Phayao discovered that the youth had mean preventive behaviors for PM2.5 at a low level (Sittiyos et al., 2023). Furthermore, the study conducted in Colombia found that students in grades 6 through 11 had an average air pollution knowledge score of only 33.8 percent and a preventive behavior score of just 28.6 percent. Moreover, only 11.6 percent of the students reported wearing masks on days with poor air quality. These findings underscore the urgent need to enhance air pollution knowledge and preventive behaviors among adolescent students (Marín et al., 2024). In addition, the study conducted in the United Kingdom on the health impacts of air pollution, utilizing individual semi-structured interviews with children and adolescents aged 7 to 17, found that 88 percent could identify outdoor sources of air pollution, such as traffic and industrial activities. However, only 52 percent were aware of indoor air pollution, and 44 percent believed exercising in highly polluted areas might be more harmful than beneficial (Jordan et al., 2024). Meanwhile, the study of perception and preventive behaviors for PM2.5 in people in the Bangkok Metropolitan Region found that 42.6 percent of people had preventive behaviors for PM2.5 at a moderate level. Moreover, based on the literature review, most studies were conducted on the general public and focused on individual factors, such as gender, educational background (Health Impact Assessment Bureau, Department of Health, 2020), age, income, school environment (Malaicharoen et al., 2022), residential area (Radisic et al., 2016) and knowledge (Xiong et al., 2018). Researchers conducted the studies to examine the relationship between independent variables and preventive behaviors for PM2.5; however, they found a weak relationship, and other contributing factors remain unexplored and require further investigation. The PM2.5 problem is a major environmental problem caused by many factors, including economics, society, politics, and culture. Therefore, solving the problem requires cooperation from all sectors of society. Therefore, the Social Ecological Model (Mcleroy et al., 1988) is appropriate for this study since it studies factors at all levels that can influence an individual's health behavior, and this model has the concept that an individual's behavior is influenced or determined. Personal factors and environmental factors consist of factors at 5 levels: individual factors, interpersonal factors, institutional factors, community factors, and public policy factors (Mcleroy et al., 1988). In addition, the Social Ecological Model of McLeroy et al. (1988) is well-suited for examining PM2.5 exposure preventive behaviors among high school students in Bangkok Metropolitan. It captures the multilevel determinants of health behaviors, including individual, interpersonal, institutional, community, and public policy factors. These levels are especially relevant within Thailand's complex sociocultural and urban environmental context, where collectivist values and social structures significantly shape youth health behavior. Utilizing this model allows for a comprehensive understanding that extends beyond personal knowledge and attitudes to encompass broader social influences. Moreover, the target group of this study is upper-secondary school students. In Thailand, researchers have not widely explored studies on this target group. This target group is an age group with various outdoor activities, such as traveling to school, exercising, and meeting friends. Notably, this age group experiences changes in every aspect, including development as they grow into adults (Jonathan, 2023). If well-educated, they will become a key social driving force to solve the pollution and PM2.5 problems in the future. Despite increasing global concern over PM2.5 and its associated health risks, empirical research examining preventive behaviors among adolescents-particularly high school students, through the lens of the Social Ecological Model remains markedly limited within the Thai context. This gap appears especially significant in major urban centers like the Bangkok Metropolitan area, where researchers have yet to thoroughly examine the complex, multilevel determinants of adolescent students' preventive behavior. Bridging this gap is essential for the development of context-specific interventions and for informing public policies aimed at mitigating long-term exposure risks among urban upper-secondary school students. Based on the above statement, the researchers are interested in studying the socio-ecological factors predicting preventive behaviors for PM2.5 exposure among upper secondary school students in Bangkok to apply the study results to relevant agencies and to use them as a guideline for planning appropriately and correctly solve the health problem of PM2.5 exposure for upper secondary school students.

Research questions

1. What is the level of preventive behaviors for PM2.5 exposure of upper secondary school students in Bangkok?

2. Are individual interpersonal, institutional, community, and public policy factors related to preventive behaviors for PM2.5 exposure? How can they predict preventive behaviors for PM2.5 exposure ~~of~~ in upper secondary school students in Bangkok?

Research objectives

1. To assess the level of preventive behaviors for PM2.5 exposure of upper secondary school students in Bangkok.

2. To study the relationship and predictive factors of preventive behaviors for PM2.5 exposure from individual interpersonal, institutional, community, and public policy factors with preventive behaviors for PM2.5 exposure of upper secondary school students in Bangkok.

Research hypothesis

Individual factors, interpersonal factors, institutional factors, community factors, and public policy factors are related to preventive behaviors for PM2.5 exposure. They can predict preventive behaviors for PM2.5 exposure among upper secondary school students in Bangkok.

Research conceptual framework

In this study, the Social Ecological Model of McLeroy et al. (1988), which consists of 5 levels of factors: Individual, interpersonal, institutional, community, and Public Policy Factors, was employed as a conceptual framework to study the social-ecological factors predicting preventive behaviors for PM2.5 exposure among upper secondary school students in Bangkok as shown in Figure 1.

Methods

This descriptive research investigated socio-ecological factors predicting PM2.5 exposure preventive behaviors among upper secondary school students in Bangkok.

Population and sample

The population is students studying in upper secondary school (grades 10-12) in schools under the jurisdiction of the Secondary Educational Service Area Office Bangkok, Area 1, and Area 2, totaling 119 schools and 111,734 students (Office of the Basic Education Commission, Ministry of Education, 2023).

The sample consists of 450 students studying in upper secondary school (grades 10-12) in schools under the Secondary Educational Service Area Office Bangkok, Area 1 and Area 2.

For calculating the sample size, the method of Daniel finding the proportion estimation formula with a known population size was employed (Daniel, 1995).

$$n = \frac{NZ^2_{\frac{\alpha}{2}}P(1-P)}{d^2(N-1)+Z^2_{\frac{\alpha}{2}}P(1-P)}$$

When n = Sample size; N = Population of students studying in upper secondary level in schools under the Secondary Educational Service Area Office Bangkok Area 1 and Area 2, totaling 119 schools and 111,734 upper secondary school students; $Z_{\frac{\alpha}{2}}$ = Standard value under the normal curve at the 95% confidence interval (2-tailed) = 1.96; P = Proportion of preventive behaviors for PM2.5 = 0.426

(Health Impact Assessment Division, Department of Health, 2020); d = Acceptable error 5% = 0.05.

Based on the sample size calculation, the sample was 375 people. However, to obtain a sample representative of the population and prevent incomplete questionnaire responses, the researcher increased the sample by another 20 percent (Bujang, 2021), resulting in a research sample size of 450 students.

Multi-stage random sampling consisted of five steps: Step 1: Researchers divided the population into two strata based on the Secondary Educational Service Area Office Bangkok Area 1 and Area 2. In Step 2, they randomly selected schools from both areas randomly selected from both areas. One school from each area was selected using simple random sampling by drawing lots without replacement. The inclusion criteria required schools to be medium-sized or larger. Step 3: The number of students was determined by selecting the sampling unit by probability proportional to size (PPS), resulting in 214 students from School A and 236 students from School B, to obtain a total sample size of 450 students. Step 4: The number of students was stratified according to grade level, which included 3 levels: Grades 10, 11, and 12 of School A and School B, by selecting the sampling unit by probability proportional to size (PPS) to maintain the total research sample size of 450 students. In Step 5, researchers used simple random sampling to select classrooms in each grade level.

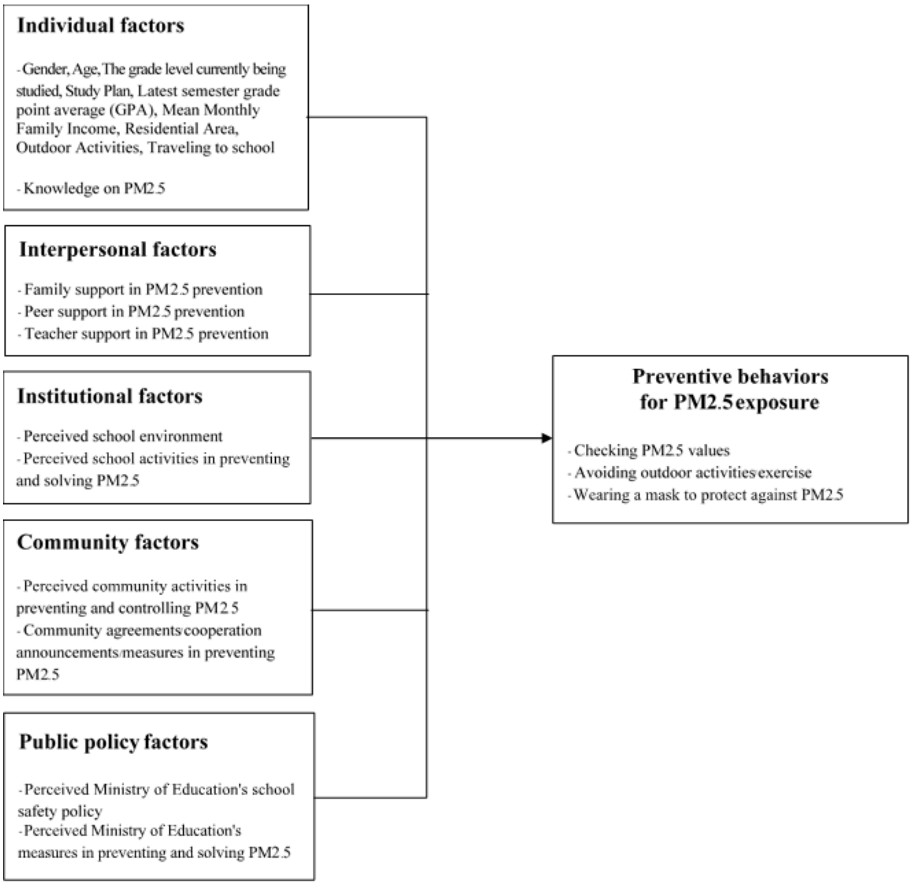

Figure 1 Research conceptual framework

Data collection

After getting research ethics approval from the Human Research Ethics Committee of Mahidol University in writing, we contacted the Faculty of Graduate Studies, Mahidol University, to request a letter asking for assistance and permission to collect data from the directors of both schools. We also met with the samples' directors and homeroom teachers or teachers for introduction and to explain the objectives and research details. After getting permission from the school director, the researcher organized training for 2 research assistants to ensure their understanding of the questionnaire and the correct method of selecting research samples. The research assistants must be qualified to read, write, and understand Thai. After that, the researchers met and introduced themselves to the sample to explain the purpose of the research and details of the data collection process. They asked the research sample for their cooperation in answering the questionnaire. The researchers first provided the sample with a copy of the copyright protection document to read and allowed them to ask questions before deciding to participate in the study. The researchers asked the participants to bring a signed consent letter from their parents and schedule an appointment to return it on the data collection day. The data of the sample who agreed to participate in the research and passed the inclusion criteria were collected, namely, students who were currently studying in upper secondary school and had been studying in school for at least 1 semester. Researchers distributed the questionnaire to collect data during the semester opening from August to September 2024. When the data collection was complete, the researcher checked the accuracy and completeness of the data for research result analysis.

Research instruments

The researchers developed the instrument for this study, which consisted of one set with five sections and 57 items. Three experts reviewed the instrument for content validity: one in health education and behavioral sciences, one in health promotion, and one with experience in PM2.5 prevention. The instrument details are as follows: Part 1: Personal Factors Information: The questions are multiple-choice with 9 questions. Part 2: Knowledge on PM2.5: The questions are multiple-choice with 9 items and 2 options: yes or no. The index of item objective congruence (IOC) was 0.66 - 1.00 and the Cronbach's alpha coefficient from the tryout was 0.82. The results are interpreted at 3 levels: low (0-3 points), moderate (4-6 points), and high (7-9 points) (Best, 1977). Part 3: Interpersonal Factors with 9 questions, consisting of family support, peer support, and teacher support in preventing PM2.5, with 5 options: always, often, sometimes, rarely, and never, with an IOC value of 0.66 -1.00 and a Cronbach's alpha coefficient from trying out of 0.89, interpreted into 3 levels: low (less than 60 percent), moderate (60-79 percent), and high (more than or equal to 80 percent) (Bloom et al., 1988). Part 4: Institutional factors, community factors, and public policy factors with 18 questions: (1) institutional factors: perceived school environment and perceived school activities in solving PM2.5 problem; (2) community factors: perceived community activities on PM2.5 prevention and control, and perceived community agreements in preventing PM2.5; and (3) public policy factors: perceived school safety policy and perceived measures in preventing and solving PM2.5 problem. The questions have 5 options: strongly agree, agree, uncertain, disagree, and strongly disagree. The IOC value was 0.66-1.00, and the Cronbach's alpha coefficient from the try-out was 0.91. Researchers interpreted the results using three levels: low (less than 60%), moderate (60-79%), and high (80% or above), based on the criteria by Bloom et al. (1988). Part 5: Preventive behaviors for PM2.5, consisting of 12 items, including checking PM2.5 values, avoiding outdoor activities/exercise, and wearing a mask to prevent PM2.5 with 5 options: always, often, sometimes, rarely, and never, with an IOC value of 0.66-1.00 and a Cronbach's alpha coefficient from the try-out of 0.92, interpreted into 3 levels: low (0-16 points), moderate (17-33 points), and high (34-48 points) (Best, 1977).

Data analysis

The researchers employed statistics including frequency, percentage, mean, standard deviation, Chi-square test, and Pearson's correlation to examine the relationship between individual, interpersonal, institutional, community, and public policy factors with preventive behaviors related to PM2.5 exposure among upper secondary school students in Bangkok. The researchers also conducted a multiple regression analysis to identify the predictive factors of preventive behaviors for PM2.5 exposure based on these five categories of factors.

Ethical consideration

This study obtained a Human Research Ethics Certificate from the Faculty of Public Health, Mahidol University, COA. No. MUPH 2024-079 on July 24,

2024. The researchers met the sample group for introduction. They explained the purpose of the research, the steps, the data collection method, the data collection period, and the rights of the sample group to participate or refuse to participate in this study without affecting the treatment. If the sample group agrees to participate in the research, they have the right to leave it at any time without giving any reason. The data are kept confidential. The researchers present the data in general form and deletes the data within two years after publishing the research.

Results

1. The level of preventive behaviors for PM2.5 exposure among upper secondary school students in Bangkok

The study on preventive behaviors for PM2.5 exposure among upper secondary school students in Bangkok revealed that most samples had preventive behaviors for PM2.5 exposure at a moderate level with a mean score of 27.34 points (M = 27.34, S.D. = 9.08). The details were classified according to the 5 factors as follows:

1.1) Individual factors consisted of personal information and knowledge on PM2.5 exposure, including (1) personal information: the sample consisted of 450 people, most of whom were female (54.0%), followed by male (39.6%) and LGBTQ (6.4%). The sample had a mean age of 16.55±0.98 years old. Most of them were studying in Grade 11 (34.7%), followed by Grade 10 (34.2%) and Grade 12 (31.1%), respectively. Most samples lived in Bangkok (80.2%). The outdoor activities that most samples regularly did at school were daily school activities, such as lining up to pay respect to the national flag, and outdoor recreational and sports activities. For commuting between school and residence, they usually used personal vehicles with air conditioning, such as personal cars and personal vans. (2) Knowledge of PM2.5 exposure: Most samples knew PM2.5 exposure at a high level with a mean knowledge score on PM2.5 of 7.28 points (M = 7.28, S.D. = 1.26, Min = 4, Max = 9) as shown in Table 1.

Table 1 Number and percentage of the samples classified by personal information (n = 450)

Personal Information	Person(s)	Percentage
Gender		
Male	178	39.6
Female	243	54.0
LGBTQ	29	6.4
Age		
14 – 15 Years	76	16.9
16 – 17 Years	294	65.3
18 – 19 Years	80	17.8
(M = 16.55, S.D. = 0.989, Min = 14, Max = 19)		
The grade level currently being studied		
Grade 10	154	34.2
Grade 11	156	34.7
Grade 12	140	31.1
Study plan / course		
Science-Mathematics Program	347	77.1
Liberal Arts-Language Program	103	22.9
Latest semester grade point average (GPA)		
2.00 - 2.50	11	2.4
2.51 - 3.00	53	11.8
3.01 - 3.50	130	28.9
3.51 - 4.00	256	56.9

Personal Information	Person(s)	Percentage
(M = 3.49, S.D. = 0.185, Min = 2, Max = 4)		
Residential area		
Bangkok	361	80.2
Outside Bangkok or surrounding areas	89	19.8
Mean monthly family income (including regular income and part-time work of father, mother, guardian, and family members)		
Less than 15,000 Thai Baht	31	6.9
15,000 – 20,000 Thai Baht	103	22.9
20,001 – 25,000 Thai Baht	63	14.0
More than 25,000 Thai Baht	253	56.2
Outdoor activities performed more than 3 days per week at school *(can answer more than 1)*		
Extracurricular learning activities	163	36.2
Outdoor recreation and sports activities	307	68.2
Daily school activities, such as national flag activity	308	68.4
Commuting between school and residence more than 3 days per week *(can answer more than 1)*		
Air-conditioned public transportation, such as vans, air-conditioned buses, and e-taxis	153	34.0
Air-conditioned private vehicles, such as private cars and vans	234	52.0
Non-air-conditioned public transportation, such as truck taxis, fan buses, and motorcycle taxis	115	25.6
Non-air-conditioned private vehicles, such as motorcycles, bicycles, and electric scooters	113	25.1
On foot	44	9.8

1.2) Interpersonal factors: The sample had a low level of overall interpersonal support, with a mean of 20.01 (M = 20.01, S.D. = 7.02). The sample had low family support in preventing PM2.5 with a mean of 8.08 (M = 8.08, S.D. = 2.50), low peer support in preventing PM2.5, with a mean of 4.72 (M = 4.72, S.D. = 3.16), and low teacher support in preventing PM2.5, with a mean of 7.20 (M = 7.20, S.D. = 2.93).

1.3) Institutional factors: The sample had a moderate level of perceived institutional factors with a mean of 21.17 (M = 21.17, S.D. = 3.52), a low level of perceived school environment with a mean of 7.44 (M = 7.44, S.D. = 1.28), and a low level of perceived school activities in solving the PM2.5 problem with a mean of 6.88 (M = 6.88, S.D. = 1.73).

1.4) Community factors: The sample had a low level of perceived community factors, with a mean of 6.54 (M = 6.54, S.D. = 1.82), a low level of perceived community activities in preventing and controlling PM 2.5, with a mean of 6.48 (M = 6.48, S.D. = 1.86), and a low level of perceived community agreements/cooperation announcements/measures in preventing PM2.5, with a mean of 6.52 (M = 6.52, S.D. = 1.87).

1.5) Public policy factors: The sample had low perceived public policy factors with a mean of 6.94 (M = 6.94, S.D. = 1.71), low perceived Ministry of Education's school safety policy with a mean of 7.20 (M = 7.20, S.D. = 1.57), low perceived Ministry of Education's measures in preventing and solving PM2.5 with a mean of 6.66 (M = 6.66, S.D. = 1.90) as shown in Table 2.

2. The relationship between individual factors, interpersonal factors, institutional factors, and public policy factors with preventive behaviors for PM2.5 exposure among upper secondary school students in Bangkok

The analysis results of the relationship between individual factors, institutional factors, and public policy factors with preventive behaviors for PM2.5 exposure among upper secondary school students in Bangkok revealed that individual factors, including gender, age, current grade, study plan/course, academic achievement (GPA), latest semester, average monthly family income, residential area, outdoor activities at school, commuting between school and residence, and knowledge on PM2.5 were not related to preventive behaviors for PM2.5 (Chi-square = 0.024-5.896, p-value = 0.224-0.988). Interpersonal factors including family support in preventing PM2.5, friends support in preventing PM2.5, and teacher support in preventing PM2.5 were significantly positively related to preventive behaviors for PM2.5 at 0.05 (r = 0.505, p = 0.000), (r = 0.578, p = 0.000), (r = 0.459, p = 0.000)), respectively. The analysis revealed that institutional factors, including the perceived school environment and perceived school activities in preventing and solving PM2.5, were significantly and positively related to preventive behaviors for PM2.5 at a statistical level of 0.05 ((r = 0.214, p = 0.000), (r = 0.415, p = 0.000)) respectively. Community factors, including perceived community activities in preventing and controlling PM2.5 and perceived community agreements/cooperation announcements/measures in preventing PM2.5, were significantly positively related to preventive behaviors for PM2.5 at a statistical level of 0.05 (r = 0.391, p = 0.000), (r = 0.394, p = 0.000)) respectively. Public policy factors, including the perceived Ministry of Education's school safety policy and perceived Ministry of Education's measures in preventing and solving PM2.5, were significantly positively related to preventive behaviors for PM2.5 at a statistical level of 0.05 (r = 0.436, p = 0.000), (r = 0.412, p = 0.000)) respectively as shown in Table 2.

Table 2 Relationship between factors and preventive behaviors for PM2.5 exposure (n = 450)

Factors	M	S.D.	Min	Max	1	2	3	4	5	6	7	8	9	10
1.Family support in PM2.5 prevention (I)	8.08	2.50	0	12	1.000	0.471*	0.439*	0.131*	0.261*	0.251*	0.296*	0.252*	0.238*	0.505*
2. Peer support in PM2.5 prevention (I)	4.72	3.16	0	12		1.000	0.573*	0.156*	0.416*	0.442*	0.401*	0.309*	0.345*	0.578*
3. Teacher support in PM2.5 prevention (I)	7.20	2.93	0	12			1.000	0.138*	0.438*	0.430*	0.411*	0.410*	0.429*	0.459*
4. Perceived school environment (O)	7.44	1.28	3	10				1.000	0.210*	0.176*	0.186*	0.175*	0.140*	0.214*
5. Perceived school activities in preventing and solving PM2.5 (O)	6.88	1.73	2	10					1.000	0.466*	0.494*	0.562*	0.536*	0.415*
6. Perceived community activities in preventing and controlling PM2.5 (C)	6.48	1.86	2	10						1.000	0.658*	0.487*	0.480*	0.391*
7. Community agreements/cooperation announcements/measures in preventing PM2.5 (C)	6.52	1.87	2	10							1.000	0.466*	0.482*	0.394*
8. Perceived Ministry of Education's school safety policy (P)	7.20	1.57	2	10								1.000	0.589*	0.436*
9. Perceived Ministry of Education's measures in preventing and solving PM2.5 (P)	6.66	1.90	2	10									1.000	0.412*
10. Preventive behaviors for PM2.5 exposure (B)	27.34	9.08	0	48										1.000

Note: * $p < 0.05$; (I) = interpersonal factors, (O) = institutional factors, (C) = community factors, (P) = public policy factors, (B) = preventive behaviors for PM2.5 exposure

3. Predictive power of individual factors, interpersonal factors, institutional factors, community factors, and public policy factors on preventive behaviors for PM2.5 exposure among upper secondary school students in Bangkok

Prior to analysis, all assumptions of multiple regression were thoroughly assessed: (1) the dependent variable, PM2-5 exposure preventive behaviors, was measured at an interval or ratio level; (2) the data followed a normal distribution, as shown by the histogram and supported by the Kolmogorov-Smirnov ($p = 0.060$) and Shapiro-Wilk ($p = 0.065$) tests; (3) the independent variables included both dummy and continuous variables measured on a ratio scale; (4) there was no evidence of multicollinearity, with Tolerance values between 0.623 and 0.955 and VIFs ranging from 1.047 to 1.605; (5) residuals were independent (Durbin-Watson = 1.898); (6) linearity was confirmed by the normal P-P plot; and (7) the variance of residuals was homoscedastic, falling within a reasonable range (-3 to 3). With all assumptions satisfied, the data were well-suited for multiple regression analysis.

The stepwise multiple regression analysis results revealed that 5 independent variables could significantly predict preventive behaviors for PM2.5 among upper secondary school students in Bangkok at 0.05, arranged by effect size as follows: peer support in preventing PM2.5 (X1) ($\beta = 0.349$, $t = 8.553$, $p = 0.000$), family support in preventing PM2.5 (X2) ($\beta = 0.258$, $t = 6.547$, $p = 0.000$), perceived Ministry of Education's school safety policy (X3) ($\beta = 0.184$, $t = 4.251$, $p = 0.000$), perceived Ministry of Education's measures in preventing and solving PM2.5 (X4) ($\beta = 0.111$, $t = 2.542$, $p = 0.011$), and perceived school environment (X5) ($\beta = 0.079$, $t = 2.231$, $p = 0.026$). All 5 factors could predict preventive behaviors for PM2.5 exposure among upper secondary school students in Bangkok at 47.5 percent ($R^2 = 0.475$), with a statistical significance of 0.05. When considering the direction and weight of the relationship of the predictive variables, most were positively correlated, and the predictive equation in the form of a standard score was "$Z = 0.349Z_{X1} + 0.184Z_{X2} + 0.258Z_{X3} + 0.111Z_{X4} + 0.079Z_{X5}$" (as shown in Table 3 and Figure 2).

Table 3 Results of Multiple Regression Analysis of Factors Influencing Preventive Behaviors for PM2.5 Exposure (n = 450)

Factors	b	SE	β	t	p - value
1. Peer support in PM2.5 prevention (I)	1.001	0.117	0.349	8.553*	0.000
2. Perceived Ministry of Education's school safety policy (P)	1.065	0.251	0.184	4.251*	0.000
3. Family support in PM2.5 prevention (I)	0.936	0.143	0.258	6.547*	0.000
4. Perceived Ministry of Education's measures in preventing and solving PM2.5 (P)	0.529	0.208	0.111	2.542*	0.011
5. Perceived school environment (O)	0.556	0.249	0.079	2.231*	0.026
$R = 0.689$, $R^2 = 0.475$, Adj.$R^2 = 0.469$, S.D. = 6.623, df = 5, F = 80.243, Durbin-Watson = 1.898, Constant = (- 0.290), *$p < 0.05$					

Note: (I) = interpersonal factors, (O) = institutional factors, (P) = public policy factors, b = regression coefficient, β = standardized regression coefficients.

Discussion

In this study, preventive behaviors for PM2.5 exposure consisted of 3 main components: checking PM2.5 values, avoiding outdoor activities/exercises, and wearing masks to prevent PM2.5. The results showed that overall, the sample had preventive behaviors for PM2.5 exposure at a moderate level (M = 27.34, S.D. = 9.08). When examining behavior on an item-by-item basis, several noteworthy patterns were observed. Specifically, 29.3 percent of participants reported occasionally checking PM2.5 levels before leaving home or engaging in outdoor activities. Similarly, 29.8 percent occasionally avoided outdoor activities or exercise upon learning that PM2.5 levels exceeded the standard threshold. In addition, 31.1 percent occasionally wore PM2.5 protective masks before going outdoors or participating in physical activities. Notably, a majority of participants, 61.1 percent, consistently replaced their PM2.5 masks with new ones whenever they were damaged or dirty. Several factors may affect the level of preventive behaviors for PM2.5 exposure, possibly due to the study area in Bangkok with PM2.5 values exceeding the standard of 50 micrograms per cubic meter, ranked number 1 in the country (Department of Disease Control, 2023). Therefore, the research sample was careful in safeguarding themselves from PM2.5, resulting a moderate preventive behavior for PM2.5. This aligns with the study of the perception and health preventive behaviors for PM2.5 among people in the Bangkok Metropolitan Region, which found that health preventive behaviors for PM2.5 were at a moderate level or 42.6 percent (Health Impact Assessment Bureau, Department of Health, 2020). The researchers compared the study results of preventive behaviors for PM2.5 among upper secondary school students in Bangkok were compared with the study of preventive behaviors for PM2.5 among people aged 18-60 years in Bangkok, upper secondary school students in Bangkok with those of individuals aged 18-60 years in the same area. The comparison revealed that upper secondary school students demonstrated lower levels of preventive behaviors than the 18-60 age group, who exhibited a good level of preventive behaviors, averaging 71.24% (Wiwattanapaisarn, 2024). When compared with the study results on knowledge, attitudes, and approaches in dealing with inhaled particulate matter of the residents of Dhaka, Bangladesh, upper secondary school students in Bangkok had higher preventive behaviors for PM2.5 than people aged 18-60 years in Dhaka, Bangladesh (Majumder et al., 2019). The study revealed that preventive behaviors were at a low level. However, the differences may be due to the classification of different behavior levels, tools to measure preventive behaviors for PM2.5, research samples, and the number of questions. The study of Malaicharoen et al. employed preventive behaviors for PM2.5 questionnaire with 14 questions to measure self-preventive behaviors for PM2.5 only and divided the scale into 3 levels considered from the score criteria of self-preventive behaviors for PM2.5 (Malaicharoen et al., 2022). The study of Sittiyos et al. found that the level of self-preventive behaviors for PM2.5 was lower. The researchers used only 12 questions to measure preventive behaviors for PM2.5, covering just two aspects: behaviors of monitoring personal and community health and prevention of exposure to PM2.5. They divided the scale into 3 levels, considering the mean criteria of behaviors to prevent health impacts from PM2.5 (Sittiyos et al., 2023). Moreover, Majumder' study used a questionnaire on particulate matter preventive behaviors with only 5 questions and divided the scale into 3 levels to measure preventive behaviors when exposed to particulate matter (Majumder et al., 2019).

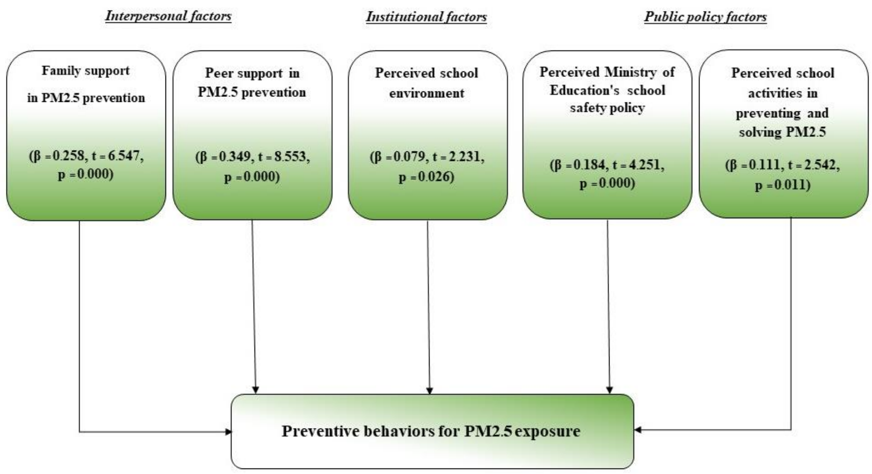

Figure 2 Visualization of multiple regression analysis outcomes

The findings of the present study align with the principles of the Social Ecological Model (McLeroy et al., 1988), which posits that individual health behaviors are shaped not only by intrapersonal factors but also by a complex interplay of environmental influences across multiple levels of individual, interpersonal, institutional, community, and public policy factors. Notably, our results indicate that factors at entire levels of this model influence PM2.5 exposure preventive behaviors among high school students in Bangkok. These include individual-level determinants such as knowledge and personal habits, as well as influences from parental and peer support, school-based health promotion efforts, media messaging, and relevant public policies. Thus, interpreting students' behaviors through the lens of the Social Ecological Model provides a comprehensive framework that reflects Thailand's multifaceted social and environmental contexts, particularly in major urban areas such as the Bangkok Metropolitan.

The researchers discuss the five significant factors that predict preventive behaviors for PM2.5 among upper secondary school students in Bangkok below;

1) Peer support in preventing PM2.5, which is one of the interpersonal factors of the social-ecological model of McLeroy et al. (1988), could predict the preventive behaviors for PM2.5 among upper secondary school students in Bangkok at a statistical significance of 0.05 ($\beta = 0.349$, $p = 0.000$). This may be because adolescence is a developmental stage during which individuals perceive friends as important sources of encouragement, emotional support, and problem understanding. Peers also help strengthen adolescents' ability to negotiate with parents and teachers. Adolescents value friends. They want to be accepted by their friends and want to communicate with friends the most. In particular, the sample spent most of their time at school with friends. Therefore, friends play a significant role in adolescents' decision-making and behavioral expressions (Royal College of Pediatricians of Thailand & Pediatric Society of Thailand, 2017). Moreover, studies on peer support in preventive behaviors for PM2.5 are limited. However, other studies were related to peer support influencing health behaviors, such as the study of factors influencing health management to prevent obesity in adolescents in Lampang, which found that social support from friends influenced health management to prevent obesity in adolescents in Lampang ($\beta = 0.233$, $p = 0.000$) (Wannalai, 2021) and the study of the influence of gender, adaptation, social support from friends, and family bonding on life strength in disadvantaged adolescents, which found that social support from friends influenced life strength ($\beta = 0.356$, $p = 0.000$) (Pramnoi et al., 2024) Therefore, peer support in preventing PM2.5 could predict preventive behaviors for PM2.5, which is one of the health behaviors.

2) Family support in preventing PM2.5, which is one of the interpersonal factors of the social-ecological model of McLeroy et al. (1988), could significantly predict preventive behaviors for PM2.5 among upper secondary school students in Bangkok at a statistical level of 0.05 ($\beta = 0.258$, $p < 0.05$). This is consistent with a study on the knowledge, attitudes, and practices of urban residents in Dhaka, Bangladesh, in dealing with inhaled particulate matter, which found that social support influenced particulate matter preventive behaviors. With the less support a respondent received, their preventive behaviors worsened (Majumder et al., 2019. Nowadays, studies on family support in preventing PM2.5 are still limited, but other studies were related to family support influencing health behaviors, such as the study of the situation of health determinants and health behaviors affecting families and communities, which found that the health and lifestyles of family members affected families and communities (Banpoun et al., 2024). Accordingly, it was found that family support in preventing PM2.5 affected preventive behaviors for PM2.5 among upper secondary school students in Bangkok. This may be explained by the fact that adolescence is a developmental stage during which individuals still depend on their families. In addition, adolescents' mental development is still basic and similar to adults' needs Adolescents still need love, care, and concern from their families. Therefore, family influences their behaviors (Royal College of Pediatricians of Thailand & Pediatric Society of Thailand, 2017). Moreover, the family is the most important and influential in society. It can determine human potential as the foundation of society (Banpoun et al., 2024). Family is very important to individuals regarding physical, biological, social, and cultural aspects due to its first institution of human beings and an institution with a close relationship with individuals from birth until death (Banpoun et al., 2024). Therefore, family support in preventing PM2.5 influenced preventive behaviors for PM2.5 among upper secondary school students in Bangkok.

3) Perceived Ministry of Education's safety policy, which is one of the public policy factors of the socio-ecological model of McLeroy et al. (1988)., could significantly predict preventive behaviors for PM2.5 among upper secondary school students in Bangkok at a statistical significance of 0.05 ($\beta = 0.184$, $p = 0.000$). The Ministry of Education has implemented operations

on school safety within the scope of school safety, which consists of four groups of threats: "Violence, Accident, Right, and Unhealthiness". The PM2.5 problem is classified as "Unhealthiness" under the topic of toxic pollution (Ministry of Education, 2021). This explains that all schools under the Ministry of Education have implemented various operations and activities to prevent and solve PM2.5 problems according to the Ministry of Education's School Safety Policy (Ministry of Education, 2023). Therefore, the sample perceived the Ministry of Education's School Safety Policy, which could predict preventive behaviors for PM2.5 among upper secondary school students in Bangkok.

4) Perceived Ministry of Education's measures to prevent and solve PM2.5, which is one of the public policy factors of the social-ecological model of McLeroy et al. (1988)., could significantly predict preventive behaviors for PM2.5 among upper secondary school students in Bangkok at a statistical level of 0.05 (β = 0.111, p = 0.011). The Ministry of Education has implemented measures in preventing and solving the PM2.5 problem. The Ministry of Education announced on measures to prevent and solve the PM2.5 problem for agencies and educational institutions to use as a guideline for implementation, consisting of urgent and long-term measures. Additionally, an announcement was made to establish a coordination center to monitor and follow up on the PM2.5 problem, which consists of operations in the central and regional areas (Ministry of Education, 2023). So, every school under the Ministry of Education operates according to the measures to prevent and solve the PM2.5 problem. Accordingly, the sample had perceived the Ministry of Education's measures in preventing and solving PM2.5, which could jointly predict preventive behaviors for PM2.5 dust among upper secondary school students in Bangkok.

Lastly, (5) perceived school environment, which is one of the institutional factors of the social-ecological model of McLeroy et al (Ministry of Education, 2023)., could significantly predict preventive behaviors for PM2.5 among upper secondary school students in Bangkok with a statistical significance of 0.05 (β = 0.079, p = 0.026). This may be because most samples had a mean perceived school environment level of 49.60, and the higher the perceived school environment, the higher the preventive behaviors for PM2.5. Currently, studies on perceived school environment are limited. However, there is a study of factors related to preventive behaviors for PM2.5 of the people of Na Phra Lan Subdistrict, Chaloem Phra Kiat District, Saraburi Province, which discovered that the arrangement of the preventive environment against PM2.5 had a moderate positive relationship with preventive behaviors for PM2.5 with statistical significance at 0.05. The researchers found that a high level of preventive environmental arrangements for PM2.5 led to higher preventive behaviors (Malaicharoen et al., 2022). However, there has been no in-depth study of the factors that can predict preventive behaviors for PM2.5 of the people of Na Phra Lan Subdistrict, Chaloem Phra Kiat District, Saraburi Province (Malaicharoen et al., 2022)., so it is not possible to compare the predictive factors. In addition, a handbook for safe environments in schools highlights the surrounding environment as important, and affecting health, and a good environment in schools would foster students' safety (Environmental Health Bureau, Department of Health, 2010). Therefore, a good environment is a crucial foundation for good health behavior. Therefore, the perceived school environment could predict preventive behaviors for PM2.5 among upper secondary school students in Bangkok.

Conclusions and recommendation

This study found that the level of preventive behaviors for PM2.5 exposure among upper secondary school students was moderate reflecting the need to improve health promotion policies that could increase self-care in preventing PM2.5 threat. The related factors included interpersonal, institutional, community, and public policy factors. The researchers found no significant relationship between individual factors and preventive behaviors for PM2.5 exposure. The key factors that could predict preventive behaviors for PM2.5 exposure among upper secondary school students consisted of 5 factors, classified by effect size: interpersonal factors: peer support in preventing PM2.5, family support in preventing PM2.5; Public policy factors: perceived Ministry of Education's school safety policy, perceived Ministry of Education's measures in preventing and solving PM2.5; and institutional factors: perceived school environment.

For the recommendation and application, this study found that most upper secondary school students had a high level of knowledge on PM2.5 exposure but a moderate level of preventive behaviors for PM2.5 exposure. Therefore, health personnel should promote and support upper secondary school students to learn more about it along with awareness to prevent PM2.5. The researchers also found that interpersonal factors such as peer support and family support in preventing PM2.5 were the strongest predictors of preventive behaviors for PM2.5. Relevant agencies should organize activities and projects and integrate them among the target group of upper secondary school students, friends, and families to foster more awareness and support among individuals in preventing PM2.5. Furthermore, since institutional factors, community factors, and public policy factors were related to preventive behaviors for PM2.5 among upper secondary school students, relevant agencies determining policies or measures related to solving PM2.5 problems should construct strong policy frameworks and laws and should work together with all sectors to improve health care for upper secondary school students to prevent health impacts from PM2.5.

To translate these findings into practice, educational institutions should integrate PM2.5 prevention into the formal curriculum, focusing on skill-based learning and sustained behavioral reinforcement. Creating supportive environments through peer- led programs and active family involvement is also essential. At the policy level, strengthening the Ministry of Education's safety framework is imperative. This includes the development of standardized air quality protocols, implementing effective filtration systems, and establishing clear, timely communication mechanisms for PM2.5 alerts. Collectively, these strategies form a comprehensive top-down approach to mitigating air pollution exposure among students. For further research on PM2.5 exposure, preventive behaviors among upper secondary school students should adopt a multifaceted approach. This should include in-depth qualitative data collection to explore students' motivations and levels of awareness, and perspectives from key stakeholders such as family members, teachers, and policymakers to identify influencing factors. The ultimate objective is to support the development of comprehensive PM2.5 prevention programs that address determinants at the individual, interpersonal, institutional, community, and public policy levels.

However, a limitation of this study is that the researchers conducted it among upper secondary school students in an urban community in Bangkok. It may not apply to the entire upper secondary school student population in Thailand due to differences in social context, environment, and living conditions.

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