The Relationship between Particulate Matter (PM2.5) and Outpatient Visits for Urticaria and Atopic Dermatitis at the Institute of Dermatology, Thailand

Pattaraporn Permpol[1], and Poohglin Tresukosol[*2]

[1]College of Medicine, Rangsit University, Pathum Thani 12000, Thailand
[2]Institute of Dermatology, Thung Phayathai, Ratchathewi, Bangkok 10400, Thailand
[*]Corresponding author, E-mail: baybamster@gmail.com

Abstract

Air pollution, particularly particulate matter (PM2.5), is a major public health concern and has been increasingly associated with inflammatory skin diseases. However, epidemiological evidence examining the combined effects of PM2.5 exposure and meteorological factors on dermatological morbidity in Thailand remains limited. This study aimed to examine the association between PM2.5 concentrations, meteorological factors, and outpatient visits for urticaria and atopic dermatitis at the Institute of Dermatology, Bangkok, Thailand. A retrospective time-series study was conducted using 6,570 outpatient records from the Institute of Dermatology between January 2020 and December 2024. Daily PM2.5 concentrations and meteorological data were analyzed using descriptive statistics, correlation analysis, and lag models to assess both immediate and delayed effects of PM2.5 exposure on outpatient visits. Atopic dermatitis was more prevalent among younger individuals (45.6%), whereas urticaria predominated in older adults (54.7%). Outpatient visits occurred most frequently during periods of moderate to high temperatures and low rainfall. Outpatient visits for atopic dermatitis were inversely associated with temperature ($r = -0.264$, $p < 0.05$). Lag analysis suggested a cumulative increase in atopic dermatitis visits associated with PM2.5 exposure, with an estimated increase of up to 16.76% (0.33 to 33.19) at lag 0–7. These findings suggest potential delayed effects of PM2.5 exposure on atopic dermatitis, particularly at lag 0–5 and lag 0–7, although the associations were not consistently statistically significant. These findings highlight the need for timely air quality monitoring and targeted preventive strategies to reduce delayed dermatological impacts, particularly among vulnerable populations.

Keywords: *Particulate Matter 2.5, Atopic Dermatitis, Urticaria, Meteorological factors*, *Air pollution, Time-series study*

1. Introduction

The health impacts of air pollution are diverse, affecting individuals in both the short and long term. Numerous studies have demonstrated associations between air pollution exposure and a wide range of adverse health outcomes, including acute respiratory infections in children, lung cancer, cardiovascular diseases, and premature mortality, ultimately leading to reduced life expectancy (Kampa & Castanas, 2008). In addition to systemic effects, air pollution has also been implicated in several dermatological conditions, such as acne, psoriasis, and atopic dermatitis (Roberts, 2020).

Air pollution remains a major global public health concern, particularly in rapidly urbanizing regions (Shi & Zhao, 2026). Recent evidence indicates a growing burden of ambient air pollutants, especially fine particulate matter with an aerodynamic diameter ≤2.5 µm (PM2.5), which poses substantial health risks even at low concentrations (World Health Organization, 2021). In Thailand, PM2.5 levels have consistently exceeded national and international air quality standards, with a notable upward trend since 2018 (Pollution Control Department, 2021). According to the IQAir World Air Quality Report, Thailand ranked 28th among 98 countries in 2019, with an annual mean PM2.5 concentration of 24.3 µg/m³—approximately twice the WHO-recommended limit. Bangkok reported a similarly elevated annual average concentration of 22.8 µg/m³, reflecting persistent exposure to potentially harmful air pollution levels (IQAir, 2019).

Exposure to PM2.5 may exacerbate atopic dermatitis (AD) through oxidative stress , which damages skin cells and impairs the epidermal barrier. This disruption, characterized by reduced filaggrin function and increased transepidermal water loss, enhances skin permeability to environmental allergens (Hu et al., 2017; Kim et al., 2021). Consequently, allergen penetration triggers Th2 - mediated immune responses and inflammatory pathways, contributing to the exacerbation of AD symptoms (Pan et al., 2023).

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Several studies in Thailand have demonstrated associations between air pollution, including PM2.5, and respiratory health outcomes such as hospital admissions (e.g., Chankaew et al., 2022; Phosri et al., 2019). However, evidence regarding dermatological outcomes remains limited, and no prior study has specifically evaluated the lagged effects of PM2.5 on dermatology outpatient visits. Given the high prevalence of these inflammatory skin diseases and the increasing burden of air pollution, investigating the association between PM2.5 concentrations and outpatient visits for urticaria and atopic dermatitis is essential. Such evidence may contribute to improved public awareness and inform health policy regarding the dermatological consequences of PM2.5 exposure in urban Thai populations.

2. Objectives

1) To examine the association of PM2.5 concentrations and meteorological factors with outpatient visits for urticaria and atopic dermatitis.

3. Materials and Methods

3.1 Study Design and Population

Individuals who attended the outpatient department of the Institute of Dermatology and were diagnosed with urticaria (ICD-10 code L50) or atopic dermatitis (ICD-10 code L20) between January 1, 2020, and December 31, 2024, were included in the study. Demographic information, including age, sex, and residential region, was extracted, and daily counts of outpatient visits were aggregated for time-series analysis.

Inclusion criteria included patients with a recorded home address or workplace in Bangkok who were diagnosed with atopic dermatitis (ICD-10 code L20) or urticaria (ICD-10 code L50). Exclusion criteria included patients attending follow-up visits and those with incomplete medical records (e.g., missing age, sex, or home address/workplace). Patients diagnosed with urticaria associated with anaphylaxis, autoinflammatory syndromes, hereditary angioedema (bradykinin-mediated angioedema), drug-induced causes (including penicillin, sulfonamides, aspirin, nonsteroidal anti-inflammatory drugs, morphine, or codeine), or viral infection.

Ethical approval was obtained from the Ethics Committee of the Institute of Dermatology, Thailand (COA NO.003/2025).

3.2 Particulate matter 2.5 and Meteorological Data

Daily mean PM2.5 concentrations were obtained from the Thailand Pollution Control Department's air quality monitoring network (air4thai.pcd.go.th, accessed on 20 May 2025). Data from fixed monitoring stations located in Bangkok were used to calculate regional daily mean PM2.5 concentrations corresponding to patients' residential areas. Daily meteorological data, including mean temperature (°C) and total rainfall (mm), were retrieved from the Thailand Meteorological Department's network (data-service.tmd.go.th, accessed on 20 May 2025) and temporally aligned with daily outpatient visit counts and PM2.5 measurements.

3.3 Data analysis

A time-series analysis was conducted to investigate the short-term associations between daily ambient PM2.5 concentrations and outpatient visits for atopic dermatitis and urticaria. Daily outpatient visit counts were analyzed using a generalized additive model (GAM) framework with a log link function.

Due to evidence of overdispersion in the count data, quasi-Poisson models were applied. The model was specified as follows:

$$\log(E(Y_t)) = \beta 0 + \beta 1\ PM2.5(t-lag) + s(Temp_t) + s(Rain_t) + \gamma\ DOW_t + \delta\ Holiday_t + s(Time_t, df)$$

where Y_t represents the number of outpatient visits on day t, and PM2.5(t−lag) denotes the daily PM2.5 concentration at a specific lag day. Time t represents a continuous variable indicating the long-term temporal trend (i.e., the sequence of days).

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Lag effects of PM2.5 exposure were evaluated for the same day (lag 0) and up to seven previous days (lag 1–7). Cumulative lag effects were assessed using moving average PM2.5 concentrations over multiple lag periods (lag 0–1 to lag 0–7).

A smooth function of time with 7 degrees of freedom per year (total df = 35) was included to control for long-term trends and seasonality. Meteorological variables, including daily mean temperature and rainfall, were incorporated as smooth functions to account for potential nonlinear relationships.

Indicator variables for day of the week (DOW) and public holidays were included to control for temporal variations in healthcare-seeking behavior.

Model residuals were examined for autocorrelation using partial autocorrelation function (PACF) plots.

Effect estimates were expressed as percentage changes with corresponding 95% confidence intervals (95% CIs) per 10 μg/m³ increase in daily mean PM2.5 concentration. A p-value of < 0.05 was considered statistically significant.

Sensitivity analyses were conducted by varying the degrees of freedom for the time trend (6 to 8 df per year).

The study period overlapped with the COVID-19 pandemic (2020–2022), which may have influenced healthcare-seeking behavior and outpatient visit patterns. However, no specific indicator variable for the pandemic period was included in the model.

4. Results and Discussion

4.1 Descriptive Results

Ambient PM2.5 concentrations during the study period had a mean of 24.20 μg/m³ (SD = 14.02), with values ranging from 12.57 to 50.51 μg/m³.

During the study period (2020–2024), a total of 6,570 outpatient visits were recorded, corresponding to a mean of 3.60 visits per day. The average daily number of visits was 1.83 for atopic dermatitis and 1.77 for urticaria.

Table 1 Demographic and Meteorological Characteristics of Outpatient Visits for Atopic Dermatitis (L20) and Urticaria (L50)

Variable	Total (N = 6,570)		Atopic dermatitis (L20) (N = 3,343)		Urticaria (L50) (N = 3,227)	
	N	%	N	%	N	%
Sex						
Male	2,333	35.5	1,431	42.8	902	28.0
Female	4,237	64.5	1,912	57.2	2,325	72.0
Age (years)						
< 18	1,707	26.0	1,526	45.6	181	5.6
19 - 39	2,594	39.5	1,314	39.3	1,280	39.7
> 39	2,269	34.5	503	15.0	1,766	54.7
Residential region						
Central Bangkok	1,250	19.0	604	18.1	646	20.0
East Bangkok	1,347	20.5	753	22.5	594	18.4
South Bangkok	882	13.5	463	13.8	419	13.0
North Bangkok	1,711	26.0	819	24.5	892	27.6
Thonburi North	670	10.2	334	10.0	336	10.4
Thonburi South	710	10.8	370	11.1	340	10.5

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Table 1 Cont.

Variable	Total (N = 6,570)		Atopic dermatitis (L20) (N = 3,343)		Urticaria (L50) (N = 3,227)	
	N	%	N	%	N	%
Temperature (°C)						
≤ 27.00	268	4.1	147	4.4	121	3.7
27.01 - 29.00	955	14.5	475	14.2	480	14.9
29.01 - 31.00	3,258	49.6	1,667	49.9	1,591	49.3
≥ 31.00	2,089	31.8	1,054	31.5	1,035	32.1
Rainfall (mm)						
≤ 10.00	5,729	87.2	2,910	87.0	2,819	87.4
10.01 - 30.00	528	8.0	285	8.5	243	7.5
30.01 - 50.00	158	2.4	82	2.5	76	2.4
≥ 50.01	155	2.4	66	1.9	89	2.8

N represents the number of outpatient visits

Table 1 presents the demographic characteristics of 6,570 outpatient visits for atopic dermatitis (L20) and urticaria (L50) during the five-year study period from 2020 to 2024. Characteristics were summarized by sex, age group, and residential region, with percentages calculated within each disease category and for the overall study population.

Sex distribution analysis indicated that females accounted for a higher proportion of outpatient visits than males in the overall study population (64.5% vs. 35.5%). Among patients with atopic dermatitis, females comprised 57.2% of visits, while males accounted for 42.8%. A more pronounced female predominance was observed among patients with urticaria, with females representing 72.0% of visits compared with 28.0% among males.

Age-specific patterns indicated that the largest proportion of outpatient visits occurred among individuals aged 19–39 years (39.5%). For atopic dermatitis, visits were most frequently observed among individuals younger than 18 years (45.6%), followed by those aged 19–39 years (39.3%). In contrast, urticaria visits predominantly occurred among individuals older than 39 years, accounting for 54.7% of cases, whereas only 5.6% were observed among individuals younger than 18 years.

In terms of residential region, North Bangkok accounted for the highest proportion of outpatient visits (26.0%), followed by East Bangkok (20.5%) and Central Bangkok (19.0%). Similar regional patterns were observed across both disease groups.

Analysis of ambient temperature on the day of visit revealed that the most frequent temperature range was 29.01–31.00°C, accounting for 49.6% of all outpatient visits. Comparable distributions were observed for both disease groups, with approximately half of the visits occurring within this temperature range. Additionally, approximately 31.0% of visits occurred on days with temperatures exceeding 31.00°C.

Regarding precipitation levels, the majority of outpatient visits (87.2%) occurred on days with rainfall below 10.00 mm. Only a small proportion of visits (2.4%) were recorded on days with rainfall greater than 50.01 mm. Similar rainfall distributions were observed for both atopic dermatitis and urticaria.

4.2 Inferential Results

As shown in Table 2, PM2.5 concentrations were significantly negatively correlated with ambient temperature ($r = -0.317$, $p < 0.05$) and rainfall ($r = -0.563$, $p < 0.01$). Ambient temperature also demonstrated a significant negative correlation with outpatient visits for atopic dermatitis ($r = -0.264$, $p < 0.05$).

In contrast, no statistically significant same-day correlations were observed between PM2.5 concentrations or rainfall and outpatient visits for atopic dermatitis.

For urticaria, PM2.5 concentrations were likewise significantly negatively correlated with ambient temperature ($r = -0.291$, $p < 0.05$) and rainfall ($r = -0.476$, $p < 0.01$). However, no statistically significant correlations were observed between meteorological factors and outpatient visits for urticaria. Although a

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positive correlation was observed between PM2.5 concentrations and outpatient visits (r = 0.165), this association did not reach statistical significance.

Table 2 Correlation Analysis of PM2.5, Meteorological Factors, and Outpatient Visits for Atopic Dermatitis (L20) and Urticaria (L50)

Variable	PM2.5	Temperature	Rainfall	Outpatient visits
Atopic dermatitis (L20)				
PM2.5	1.000			
Temperature	-0.317*	1.000		
Rainfall	-0.563**	-0.089	1.000	
Outpatient visits	0.187	-0.264*	-0.050	1.000
Urticaria (L50)				
PM2.5	1.000			
Temperature	-0.291*	1.000		
Rainfall	-0.476**	-0.155	1.000	
Outpatient visits	0.165	-0.223	-0.045	1.000

*p<0.05 (two-tailed)
**p< 0.01 (two-tailed)

Table 3 Lag Pattern Analysis of PM2.5 and Outpatient Visits for Atopic Dermatitis (L20) and Urticaria (L50)

Lag Pattern	Total		Atopic Dermatitis (L20)		Urticaria (L50)	
	Percent change	95% CI	Percent change	95% CI	Percent change	95% CI
0-1	2.89	(-3.69, 9.47)	5.04	(-3.08, 13.17)	3.01	(-4.34, 10.36)
0-2	4.99	(-4.09, 14.06)	8.46	(-2.94, 19.87)	4.15	(-4.79, 13.09)
0-3	5.67	(-3.56, 14.90)	9.67	(-2.27, 21.62)	4.29	(-4.19, 12.77)
0-4	8.90	(-2.58, 20.37)	14.24	(-0.79, 29.27)	7.24	(-3.74, 18.23)
0-5	9.88	(-1.14, 20.90)	15.94	(0.61, 31.26)	7.96	(-2.82, 18.73)
0-6	9.90	(-1.72, 21.51)	15.22	(-0.17, 30.60)	7.99	(-2.44, 18.43)
0-7	11.47	(-2.05, 24.99)	16.76	(0.33, 33.19)	10.06	(-3.02, 23.14)

Table 3 presents the percentage changes and their corresponding 95% confidence intervals (95% CI) across different lag periods.

For total outpatient visits, the estimated percentage change ranged from +2.89% (−3.69, 9.47) at lag 0–1 to +11.47% (−2.05, 24.99) at lag 0–7.

For atopic dermatitis (L20), the estimated percentage changes ranged from +5.04% (−3.08, 13.17) at lag 0–1 to +16.76% (0.33, 33.19) at lag 0–7. Statistically significant associations were observed at lag 0–5 and lag 0–7; however, the confidence intervals were relatively wide, and the lower bounds were close to the null value, indicating limited precision and borderline statistical significance. These findings should therefore be interpreted with caution.

For urticaria (L50), the estimated percentage changes ranged from +3.01% (−4.34, 10.36) at lag 0–1 to +10.06% (−3.02, 23.14) at lag 0–7. No statistically significant associations were observed across any lag periods.

4.3 Discussion

This study investigated the short-term associations between ambient PM2.5 concentrations, meteorological factors, and outpatient visits for atopic dermatitis and urticaria in Bangkok, Thailand, using a time-series analytical approach. Overall, the findings indicate that same-day PM2.5 exposure was not significantly associated with outpatient visits for either condition. However, analyses incorporating lagged exposure windows suggested delayed effects of PM2.5, particularly for atopic dermatitis at lag 0–5 and lag 0–7, whereas associations with urticaria were modest and not consistently observed. In addition, ambient temperature demonstrated a modest inverse association with outpatient visits for atopic dermatitis.

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The association between PM2.5 exposure and outpatient visits appeared more pronounced for atopic dermatitis than for urticaria, which is consistent with existing epidemiological evidence. Several studies conducted in East Asia have reported similar patterns. For instance, Park et al. (2022) reported that short-term increases in PM2.5 concentrations were associated with increased hospital visits for atopic dermatitis in South Korea, particularly during periods of elevated pollution. Likewise, Zhang et al. (2023) reported increased outpatient visits for eczema in relation to rising PM2.5 levels in Guangzhou. These findings support the notion that inflammatory skin diseases such as atopic dermatitis may be particularly sensitive to short-term air pollution exposure.

Previous time-series studies conducted in highly polluted urban settings have reported immediate associations between PM2.5 exposure and eczema-related outpatient visits. For example, Wang et al. (2019) examined outpatient visits for eczema in Beijing and found that a 10 μg/m³ increase in daily PM2.5 concentration was significantly associated with an approximately 0.3% increase in outpatient visits on the same day of exposure. This finding suggests that acute fluctuations in PM2.5 levels may trigger immediate exacerbations of eczema symptoms in settings with high background pollution levels.

Unlike these studies, the present analysis did not identify statistically significant same-day associations between PM2.5 exposure and outpatient visits for atopic dermatitis. Instead, suggestive evidence emerged in lagged and cumulative exposure models, indicating potential delayed effects. Differences in background PM2.5 concentrations, climatic conditions, population characteristics, and healthcare-seeking behavior between Bangkok and more heavily polluted cities such as Beijing may partly explain the observed discrepancies. Collectively, these findings suggest that the temporal pattern of PM2.5-related dermatological effects may vary across regions, with both immediate and delayed responses depending on local environmental and population contexts.

The delayed effects observed in this study, rather than same-day associations, may be explained by a combination of biological, behavioral, and environmental factors. From a biological perspective, several mechanisms may explain the observed associations. PM2.5 exposure can induce oxidative stress, leading to the generation of reactive oxygen species that damage keratinocytes and impair skin barrier function (Hu et al., 2017). In addition, particulate matter may activate the aryl hydrocarbon receptor (AhR), which plays a critical role in regulating skin homeostasis and immune responses (Kim et al., 2021; Pan et al., 2023). Furthermore, PM2.5 exposure may alter the skin microbiome, disrupting microbial balance and enhancing susceptibility to inflammation (Krutmann et al., 2017).

Behavioral factors may also contribute to the observed lag structure. Patients with chronic dermatological conditions, such as atopic dermatitis, may delay seeking medical care until symptoms worsen or become persistent. This delay in healthcare-seeking behavior could result in increased outpatient visits several days after exposure, thereby contributing to lagged associations observed in this study.

Environmental conditions may further influence these patterns. PM2.5 exposure often occurs alongside variations in meteorological factors such as temperature and humidity, which can independently affect skin barrier function and allergen exposure (World Health Organization, 2021). The combined and potentially cumulative effects of air pollution and environmental conditions may therefore contribute to delayed clinical outcomes rather than immediate effects. These processes likely operate over time, contributing to the delayed clinical responses observed in this study.

Importantly, the progressive increase in effect estimates across longer lag periods observed in this study supports a cumulative or delayed response to PM2.5 exposure. This pattern is particularly evident for atopic dermatitis, in which statistically significant associations emerged only in extended lag windows (e.g., lag 0–5 and lag 0–7), suggesting that repeated or sustained exposure may be necessary to trigger clinically meaningful exacerbations.

In this study, ambient temperature demonstrated a significant negative correlation with outpatient visits for atopic dermatitis. This finding is consistent with the study by Chen et al. (2023), Chen et al. (2023), who reported that both high and low ambient temperatures were significantly associated with an increased risk of atopic dermatitis, with stronger effects observed at lower temperatures.

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For urticaria (L50), associations with PM2.5 exposure and meteorological factors were weaker and less consistent, with wide confidence intervals and largely non-significant estimates. This observation aligns with existing literature, which reports heterogeneous findings regarding environmental influences on urticaria. The multifactorial nature of urticaria, as it may be triggered by infections, psychological stress, medications, or dietary factors, could attenuate the relative contribution of environmental exposures such as air pollution (Grattan, 2012).

The findings of this study have several important public health implications. First, the observed delayed associations suggest that air pollution warning systems should consider not only same-day exposure levels but also potential lagged health effects, allowing for more effective risk communication and preventive measures (World Health Organization, 2021). Second, dermatology clinics and healthcare systems may need to anticipate increased patient visits following periods of elevated PM2.5 concentrations and adjust resource allocation accordingly. Finally, certain populations, particularly children who represented a substantial proportion of atopic dermatitis cases in this study may be more vulnerable due to their developing skin barrier and immune system (Kim et al., 2021; Pan et al., 2023). Targeted public health interventions and protective strategies should therefore be prioritized for these high-risk groups.

This study has several strengths. First, it utilized a relatively large dataset over a five-year period, enhancing statistical power and robustness. Second, the use of lag models enabled the assessment of delayed effects, providing a more comprehensive understanding of temporal relationships. Third, the integration of meteorological variables allowed for improved control of environmental confounding factors.

This study has several limitations that should be acknowledged. First, the study period (2020–2024) overlapped with the COVID-19 pandemic, particularly during 2020–2022, which may have influenced healthcare-seeking behavior, outpatient service utilization, and access to dermatological care. These changes could have affected the observed number of outpatient visits independently of environmental exposures. In addition, atopic dermatitis and urticaria are complex, multifactorial diseases influenced by a wide range of environmental, behavioral, genetic, and immunological factors. Multiple potential triggers—including allergens, infections, psychological stress, climate variability, and individual susceptibility—may contribute to disease exacerbation, making it difficult to attribute observed outcomes solely to PM2.5 exposure or to draw definitive conclusions regarding causality. Furthermore, the retrospective time-series design limited the ability to control for individual-level confounding factors, such as personal exposure patterns, lifestyle behaviors, medication use, and comorbidities, which were not available in the dataset. Future prospective studies with improved individual-level exposure assessment are warranted to strengthen causal inference regarding the relationship between PM2.5 exposure and inflammatory skin diseases.

A further limitation of this study is the absence of multi-pollutant models. Other air pollutants, such as NO2 and O3, were not included due to data limitations. As these pollutants may coexist and have potential confounding or synergistic effects, the observed associations may partly reflect combined exposures. Future studies using multi-pollutant models are needed to better isolate the independent effects of PM2.5.

5. Conclusion

This study found no statistically significant same-day association between ambient PM2.5 exposure and outpatient visits for atopic dermatitis or urticaria. However, lagged analyses showed positive trends suggesting cumulative delayed effects of PM2.5, particularly for atopic dermatitis. In addition, lower ambient temperature was modestly associated with increased outpatient visits for atopic dermatitis in same-day analyses. Overall, the findings indicate that short-term PM2.5 exposure was associated with delayed dermatological morbidity, highlighting the importance of considering lag effects and meteorological conditions in environmental health assessments.

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