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The Effects of PM10 on the Hospital Admission of Patients with Respiratory Disease in Seoul, Korea

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서울지역 미세먼지가 호흡기계 질환으로 입원한 환자에 미치는 영향

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Abstract This cohort study aimed to identify the effects of daily PM10 exposure on the hospital admission of patients with respiratory diseases, during the nine-year period (2002-2010), in Seoul, Korea. The research subjects were 13,974 patients who had been hospitalized with respiratory diseases, including chronic obstructive pulmonary disease (COPD), asthma, and pneumonia. During the follow-up period, an increase of 10 ug/m3 in PM10 under the threshold of 50 ug/m3 of PM10 led to hospital admission in 1.38% of the age group younger than 15 years, 1.62% in those 65 years or older, 2.87% in patients 75 years or older and in 1.50% of pneumonia patients, 1.51% of COPD patients, and 1.55% of pneumonia and asthma patients. Under the threshold of 80 ug/m3 of PM10, there was a 3.71% increase in new patients admitted in the age group 65 years or older and 4.25% in those at least 75 years old. Our study found that high PM10 was associated with increased risk of admission of respiratory patients, especially in the elderly. People who already have a respiratory disease should refrain from exposure to particulate matter when there is a high concentration of PM10, especially older patients.

Key Words : Particulate Matter (PM10), Threshold, Respiratory disease, Episode, Sample cohort database

요 약 서울지역의 호흡기질환으로 입원한 환자를 대상으로 미세먼지 노출에 대한 건강영향을 평가하였다. 건강보험공단의 2002-2010년 동안 표본코호트의 만성폐쇄성 폐 질환(COPD), 천식 및 폐렴과 같은 호흡기 질환으로 입원한 13,974명의 환자를 대상자로 하였다. 추적관찰 기간동안 미세먼지 농도가 50ug/m3 이상에서 10ug/m3 증가할 때 15세 미만의 연령층에서는 1.38%, 65세 이상의 연령층에서는 1.62%, 75세 이상 연령층에서는 2.87% 호흡기질환으로 입원이 증가하였고, 폐렴환자는 1.50%, COPD 환자는 1.51%, 폐렴 및 천식환자는 1.55% 입원이 증가하였다. 또한 미세먼지가 80ug/m3 이상에서는 65세 이상 연령층에서 3.71%, 75세 이상 연령층에서 4.25% 입원환자가 증가하였다. 높은 미세먼지농도와 호흡기 질환으로 입원한 환자들과, 특히 노인에서 관련성이 높게 나타났다. 이미 호흡기 질환이 있었던 사람들, 특히 나이가 많은 환자는 고농도의 미세먼지에 노출되지 않도록 주의해야 한다.

주제어 : 미세먼지, 임계값, 호흡기질환, 에피소드, 표본 코호트 연구

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1. Instruction

Health impacts of air pollution have been reported since the early 20th century. According to the World Health Organization than in 2012 around 7 million people die each year from pollution-related causes1. The mortality rate when the quality of the air is between 20-70 ug/m3 PM10 for a number of days has been reported to be about 15%[1]. Korean residents are exposed to yellow sand in the spring and particulate matter (PM10) in the winter, and these pollutants have gradually decreased the number of clear days. Exposure to this form of air pollution has produced increases in respiratory diseases. The importance of air pollution was first recognized during the latter half of the 1990s in Korea, when epidemiological studies of the health impacts of air pollution began to be actively promoted[2-5]. In particular, Korea has a high relative concentration of PM10 compared to other countries due to the nation's geographic location, and the incidence of disease caused by exposure to this fine dust is considered very high.

The average daily reference values of PM10 and PM2.5 in the air quality standards are 100 ug/m3 and 50 ug/m3 or less, respectively, while the average annual reference values are defined as 50 ug/m3 and 25 ug/m3 or less. Of the three objectives defined by the World Health Organization, the average daily reference value in Korea corresponds to the intermediate stage. Compared to the general population, patients with respiratory diseases, including asthma, chronic obstructive pulmonary disease (COPD), and pneumonia, may experience serious health effects when exposed to this fine dust. One important risk factor is the age of respiratory patients upon exposure to the fine dust.

The purpose of this study was to understand the effects of PM10 on patients who had been hospitalized with respiratory diseases; these patients were quantitatively analyzed to determine the impact of an increase in dust concentration on health. The study also attempted to determine the health effects among existing and new patients with respiratory diseases.

2. Materials and Methods

2.1. Study scope

We examined respiratory episodes that occurred in all ages, in those aged 15 years or older (65+, 75+). The time-series of daily data available for analysis in Seoul covered a duration of nine years(2002-2010). A sample cohort database was derived from National Health information data. This sample cohort database contained 10-year cohort data, including socioeconomic variables (residence, year and month of death, cause of death, income level) and details of medical treatment and health examinations of approximately 1 million people from 2002-2010, which represent 2% of the total Korean population.

2.2. Variables

Meteorological data on 24-hour mean temperature, relative humidity, and sea-level air pressure were obtained from the database of the Korea Meteorological Administration. These data from individual meteorological stations were grouped by city or province. No important changes in station locations occurred during the study period, and each station recorded complete data series for the period of 2002-2010.

Air pollution data were obtained as the hourly PM10 concentration recorded by the Ministry of the Environment in Korea. Exposure measurements during the study period were based on 25 monitoring stations in Seoul and were averaged to calculate the daily mean PM10 level in Seoul. To reduce the impact of outliers in the pollution variables, the days when PM10 level was lower than 150 ug/m3 (which represented the 99th percentile) were excluded from the analysis.

Morbidity data from 2002-2010 were obtained, and a sample cohort database was derived from National Health Information data. The cohort participants were patients hospitalized with respiratory diseases, who totaled 13,974 people of one million.

2.3. Data analysis

To examine the distributed lag effects, we fitted a constrained distributed lag model that included lagged exposure variables as covariates and applied a function of days of lag according to the B-spline bases. We used generalized additive Poisson regression models, which include nonparametric smoothing functions, to control the potential nonlinear dependence of daily time-trends and weather variables on the logarithm of morbidity.

We used the following basic model:

$$\log[E(Y)] = \beta_0 X + S_1(Z_1) + \cdots + S_j(Z_j)$$

where Y is the daily number of patients hospitalized with respiratory diseases, X is the PM10 level, Zj is time and meteorological variables, and Sj is the Loess smooth function. The Zj values include temperature, relative humidity, and sea-level pressure on the day of hospitalizations due to respiratory disease, as well as the previous day's temperature, time trends, and the day of number. The threshold of PM was confirmed through a comparison of Akailke's Information Criterion (AIC). AIC values were interactively calculated for Poisson regression models using 10 ug/m3 increments in daily mean PM10 concentration that were selected based on a visual inspection of the plots[6]. A similar model has been adopted in many previous studies[7].

In our study, morbidity data were episodic based on patients that were obtained by applying the episode of care in a sample cohort database from National Insurance claim data. We examined respiratory diseases in four age categories: all ages, those younger than 15 year, those older than 65, and those older than 75. Asthma, COPD, and pneumonia were investigated in all participants.

All analyses were performed using R software version 2.11.1 (The R Foundation for Statistical Computing, version 2.11.1, http://cran.r-project.org).

3. Results

Table 1 shows the seasonal variation in the severity and age of patients with respiratory diseases by episode during the follow-up period. The dust concentration in Seoul is the highest in spring (76.1 ug/m3), followed by winter (65.9 ug/m3). The daily average number of patients hospitalized with respiratory diseases in all patients was 6.8 cases: 7.0 in spring, 7.4 in winter, 6.0 in summer, and 6.9 in autumn. The seasonal aspects of respiratory disease show similar patterns to those for increased fine dust concentration.

The upper part of Fig. 1 shows the trend of daily fine dust concentration during the study period, while the lower part displays the number of daily episodes of respiratory diseases that required hospital admissions. Based upon the number of patients hospitalized with respiratory disease and the PM10 trend during the study period, as the concentration of PM10 increased, the number of hospitalization episodes for respiratory disease also increased.

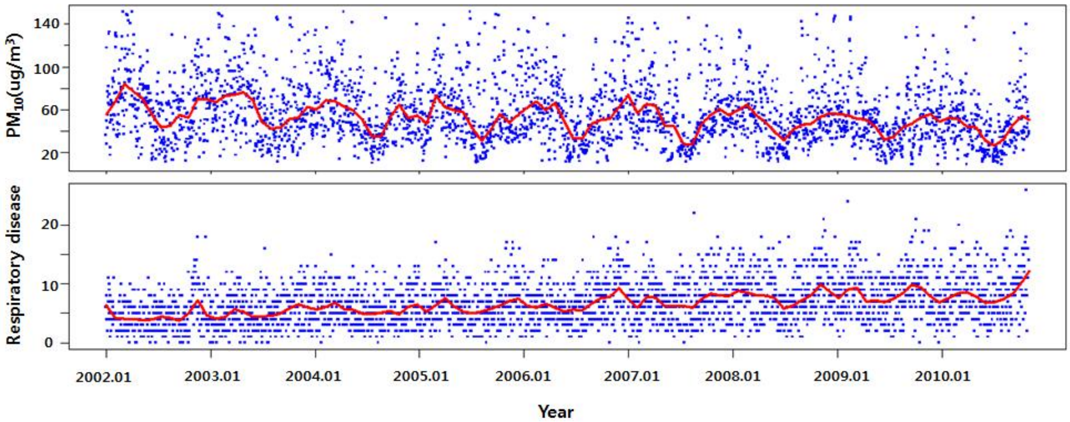

Fig. 1. Trends of PM10 and daily hospitalization due to respiratory disease episodes

Table 1. Summary of hospital admissions, weather, and air pollution in Seoul

Variable	Mean					Minimum	Maximum
	Yearly	Spring	Summer	Autumn	Winter		
Weather							
Temperature (°C)	12.8	12.2	24.2	14.7	0.0	−14.0	30.4
Humidity (%)	61.7	56.2	71.8	62.7	56.2	19.4	96.3
Pressure (hpa)	1005.7	1004.5	997.6	1008.1	1012.9	981.0	1026.4
Hospital admissions (admissions/day)							
Respiratory							
Total	6.8	7.0	6.0	6.9	7.4	1.0	26.0
Male	3.9	3.9	3.5	3.9	4.2	0.0	15.0
Female	2.9	3.1	2.5	2.9	3.2	0.0	16.0
Age <15	2.6	2.8	2.2	2.8	2.8	0.0	13.0
15≤ age <65	2.9	2.9	2.7	2.8	3.2	0.0	14.0
Age ≥65	1.3	1.3	1.1	1.3	1.4	0.0	10.0
Age ≥75	0.6	0.6	0.6	0.6	0.7	0.0	7.0
COPD	1.4	1.5	1.1	1.5	1.4	0.0	9.0
Asthma	0.8	0.9	0.6	1.0	0.8	0.0	7.0
Pneumonia	2.1	2.4	1.6	2.4	2.3	0.0	13.0
COPD + Asthma	2.2	2.3	1.8	2.5	2.3	0.0	14.0
COPD + Pneumonia	3.6	3.8	2.7	3.9	3.8	0.0	18.0
Asthma + Pneumonia	3.0	3.3	2.2	3.4	3.1	0.0	18.0
Air pollutant levels							
PM_{10}(ug/m^3)	60.3	76.1	47.9	51.4	65.9	9.0	988.7
Moving 8 hours	60.1	76.3	47.0	50.4	66.5	8.3	925.8

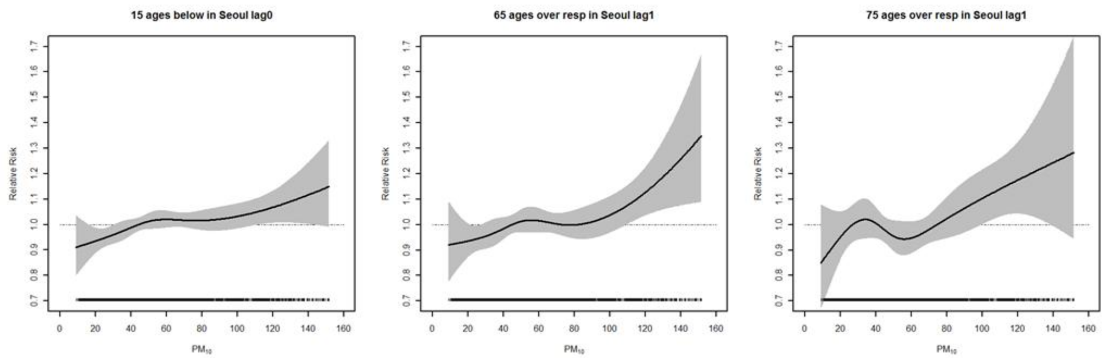

Fig. 2. Relative risk functions of PM10 in respiratory patients for the three age groups on the lag effect in 2002-2010

Table 2. Percent increase (95% confidence interval) in daily outpatient count per each 10 ug/m3 increment above the age group- and disease-specific threshold

Variable	Threshold (ug/m3)	Day 1		Lag 1 day	
		Percent change (95% CI)		Percent change (95% CI)	
		Total	New	Total	New
Total		0.63 (−0.07-1.34)	0.54 (−0.21-1.29)	0.85 (0.15-1.55)	0.77 (0.03-1.52)
Age ≤14		0.85 (−0.27-1.98)	0.84 (−0.36-2.05)	1.38 (0.27-2.50)	1.32 (0.13-2.53)
15-64		0.50 (−0.57-1.58)	0.40 (−0.75-1.56)	0.06 (−1.01-1.14)	−0.04 (−1.18-1.11)
≥65		0.57 (−1.05-2.22)	0.33 (−1.38-2.08)	1.62 (0.01-3.26)	1.54 (−0.16-3.27)
≥75		0.81 (−1.49-3.16)	0.65 (−1.76-3.11)	2.87 (0.60-5.20)	2.55 (0.18-4.98)
Male		0.41 (−0.52-1.34)	0.20 (−0.79-1.20)	1.03 (0.11-1.97)	1.02 (0.03-2.02)
Female	50	0.93 (−0.13-2.00)	0.98 (−0.15-2.13)	0.61 (−0.45-1.68)	0.45 (−0.68-1.58)
COPD		0.49 (−1.04-2.04)	0.41 (−1.25-2.11)	1.40 (−0.11-2.94)	1.34 (−0.32-3.02)
Asthma		0.47 (−1.49-2.48)	0.23 (−1.93-2.43)	1.67 (−0.27-3.65)	1.64 (−0.49-3.82)
Pneumonia		0.16 (−1.06-1.40)	−0.03 (−1.34-1.28)	1.50 (0.28-2.73)	1.20 (−0.10-2.51)
COPD + Asthma		0.48 (−0.73-1.71)	0.31 (−1.01-1.65)	1.51 (0.31-2.72)	1.50 (0.19-2.83)
COPD+ Pneumonia		0.29 (−0.67-1.26)	0.11 (−0.92-1.15)	1.46 (0.51-2.42)	1.31 (0.28-2.34)
Asthma+ Pneumonia		0.25 (−0.79-1.31)	0.01 (−1.11-1.13)	1.55 (0.52-2.60)	1.37 (0.26-2.50)
Total		−0.14 (−1.35-1.09)	−0.04 (−1.86-1.81)	0.13 (−1.09-1.37)	0.37 (−0.95-1.71)
Age ≤14		0.89 (−1.03-2.85)	−1.66 (−5.02-1.82)	0.70 (−1.24-2.68)	0.94 (−1.17-3.10)
15-64		−1.01 (−2.86-0.88)	−0.05 (−3.27-3.28)	−1.58 (−3.47-0.34)	−1.65 (−3.68-0.43)
≥65		−0.27 (−3.09-2.63)	1.12 (−1.74-4.07)	2.86 (0.03-5.78)	3.71 (0.70-6.81)
≥75		1.27 (−2.75-5.45)	−0.62 (−4.57-3.49)	4.25 (0.25-8.41)	4.59 (0.39-8.97)
Male		−0.87 (−2.47-0.77)	0.61 (−1.82-3.09)	0.86 (−0.77-2.51)	1.20 (−0.56-2.99)
Female	80	0.81 (−1.03-2.68)	−0.86 (−3.58-1.94)	−0.81 (−2.66-1.07)	−0.70 (−2.69-1.33)
COPD		0.60 (−2.05-3.31)	1.30 (−1.63-4.32)	1.03 (−1.62-3.75)	2.07 (−0.85-5.08)
Asthma		0.96 (−2.42-4.45)	2.01 (−1.76-5.94)	1.23 (−2.13-4.70)	2.18 (−1.56-6.06)
Pneumonia		−0.96 (−3.07-1.21)	−1.23 (−3.51-1.10)	1.30 (−0.84-3.48)	1.31 (−0.99-3.65)
COPD + Asthma		0.73 (−1.36-2.87)	1.58 (−0.75-3.96)	1.11 (−0.98-3.24)	2.24 (−0.07-4.61)
COPD + Pneumonia		−0.36 (−2.01-1.33)	−0.25 (−2.06-1.58)	1.19 (−0.48-2.88)	1.73 (−0.08-3.58)
Asthma + Pneumonia		−0.42 (−2.22-1.41)	−0.35 (−2.31-1.65)	1.28 (−0.52-3.13)	1.68 (−0.28-3.68)

Table 2 shows the estimated percentage increase in daily hospitalization episodes associated with a 10-ug/m3 increase in PM10 for various kinds of respiratory diseases by day 1 or lag 1 day. The day before, the probability of exposure to a respiratory disease that would require hospitalization was increased. The thresholds of PM10 analysis were 50 ug/m3 and 80 ug/m3, respectively. When the PM10 was high (above the threshold), the percentage increase per 10-ug/m3 increase in PM10 increased by 1.38% (95% Confidence Interval [CI]: 0.27-2.50%), 1.62% (95% CI: 0.01-3.26%), and 2.87% (95% CI: 0.60-5.20%) of daily hospitalization episodes in existing patients younger than 15 years, older than 65 years, and older than 75 years old, respectively. There was no significant difference in the impact on health between existing patients with respiratory diseases and new patients. When the PM10 was high (above the threshold), percentage increase per 10-ug/m3 increase in PM10 increased by 1.32% (95% CI: 0.13-2.53%) and 2.55% (95% CI: 0.18-4.98%) of daily hospitalization episodes in new patients <15 and <75 years of age, respectively. Compared to all patients, people suffering from asthma, COPD, or pneumonia experienced twice as many health effects when exposed to PM10. The percentage increase of daily hospitalization episodes per a 10-ug/m3 increase in PM10 increased by 1.50% (95% CI: 0.28-2.73%), 1.51% (95% CI: 0.31-2.72%), 1.46% (95% CI: 0.51-2.42%), and 1.55% (95% CI: 0.52-2.60%) in patients with pneumonia, COPD and asthma, COPD and pneumonia, and asthma and pneumonia, respectively.

Fig. 2 shows the effect on health above a certain threshold. The figure on the left depicts the day of PM10 exposure in a group younger than 15 years. The other two figures show the health effects of PM10 on the next day. As confirmed in the figure, exposure to a PM10 concentration above a certain threshold produced health effects. In particular, the graph is J-shaped in patients older than 65 years, as well as in those older than 75 years.

4. Disccusion

This study focused on daily PM10 concentrations to assess the health impacts and risk of negative effects in patients with severe respiratory disease by age. Those who already have a respiratory disease should refrain from exposure to particulate matter when a high concentration of PM10 is forecast, especially vulnerable groups. Studies of the health effects of air pollutants and PM10 and ozone and health effects study, and have a lot of research is mostly a mortality data to health outcome[7-12]. The PM10 concentration is higher in spring and winter in Seoul, which may be due to increases in neighboring countries like China, where diesel vehicles are heavily used. There were trends in hospitalized patients with respiratory diseases and PM10 concentration during the study period; however, in Korea, a high heavy metal content of PM10 is reported in both the spring and winter each year[13-15]. Also it was significantly associated in a 10$\mu g/m^3$ increase in PM10 in cardiovascular disease mortality of 0.96% in fall[16]. In a study conducted in the United States on atmospheric pollutants, fine dust level in 112 cities increased the incidence of total mortality, cardiovascular disease, stroke, and death from respiratory diseases, especially in spring[12].

PM10 and health impact assessments have revealed a lag effect. In this study, exposure to PM10 was closely related to the health effects of exposure on the day before hospital admission. When patients were divided into new and existing groups, respiratory diseases that have had a greater health impact were not significant. However, a threshold of 50 ug/m3 was analyzed based on the health effects of exposure to PM10 in patients <15 years (1.38%), ≥65 years (1.62%), and ≥75 years (2.87%); health effects were shown to increase. A threshold of 80 ug/m3 of fine dust exposure in those ≥65 years and in ≥75 years of age was confirmed to increase susceptibility to health effects in such patients (2.86% and 4.25%, respectively).

While fine dust has local and temporal effects on human health due to its size and concentration, it also has a wide range of compositions, which poses a number of uncertainties in the reported levels each year[17]. In cities like Seoul, exhaust and other substances produced from the combustion of gasoline by vehicles are increasingly creating a harmful atmosphere; the death rates due to respiratory disorders and cardiovascular disorders are associated with each other[18]. Air quality issues also have a negative effect on fetal health[10].

This study has some limitations. First, PM10 is seasonal and has a large variation in each region. This study is not the only interpretation or overall result for Seoul, Korea. Second, there was a waiting period to obtain data and weather materials in this study because these data require a mean of the day's measurement data from 25 stations in Seoul; therefore, the specific conditions do not always accurately reflect the exposure level of individuals. Nevertheless, since air pollutants have had the finding that there is no reasonable even reflect only the temporal characteristics then viewed[18-20].

If a high concentration of PM10 is present, it is recommended that vulnerable children/elderly/those with respiratory diseases remain indoors; the Food Safety Bureau of the Korean Food and Drug Administration has suggested that the next best thing for people who must go out is to wear a mask. However, since the use of personal protective equipment is not a fundamental solution that can reduce PM10 exposure, Korea, China, and Japan must work to develop a policy that can improve the national air quality and also complement the existing geographical weak points.

REFERENCES

[1] WHO(2006). Air quality guidelines: Global update 2005. particulate matter, ozone, nitrogen dioxide and sulfur dioxide. *World Health Organization.*

[2] J. N. B. Bell, L. Davies, S Honour, A. Klumpp, W. Ansel & G. Klumpp. (2004). Air pollution research in london. *Urban air pollution bioindication and environmental awareness,* 3-16.

[3] M. L. Bell et al. (2007). Climate change, ambient ozone, and health in 50 US cities. *Climate Change. 82(1-2),* 61-76.

[4] Y. K. Lin, C. F. Chen, H. C. Yeh & Y. C. Wang. (2016). Emergency room visits associated with particulate concentration and Asian dust storms in metropolitan Taipei. *Journal of Exposure Science and Environmental Epidemiology, 26(6),* 104-111.

[5] W. J. Requia, C. D. Higgins, M. D. Adams, M. Mohamed & P. Koutrakis. (2018). The health impacts of weekday traffic: Ahealth risk assessment of PM2.5 emissions during congested periods. *Environment International, 111,* 14-176.

[6] H. Akaike. (1998). Information theory and an extension of the maximum likelihood principle. *Selected Papers of Hirotugu Akaike,* 199-213.

[7] Y. Chung et al. (2015). Mortality Related to Extreme Temperature for 15 cities in Northeast Asia. *Epidemiology, 26(20),* 255-262.

[8] Y. Choi, H. Kim & J. T. Lee. (2018). Temporal variability of short term effects of PM10 on mortality in Seooul, Korea. *Science of The Total Environment, 644(10),* 122-128.

[9] W. Ji & B Zhao. (2015). Estimation Mortality Derived from Indoor Exposre to Particles of Outdoor Origin. *PLoS One, 10(4), e0124238.*

[10] E. H. Ha et al. (2009). Infant susceptibility of mortality to air pollution in Seoul, South Korea. *Pediatrics, 111(2),* 284-290.

[11] S. Hales, C. Salmond, G. I, Town, T. Kjellstrom & A. Woodward. (2000). Daily mortality in relation to weather and air pollution in Christchurch, New Zealand. *Australian and New Zealand Journal of Public Health, 20(1),* 89-91.

[12] A. Zanobetti & J. Schwartz. (2009). The effect of fine and coarse particulate air pollution on mortality: A national analysis. *Environmental Health Perspectives, 117(6),* 898-903.

[13] S. S. Hwang, S. H. Cho & H. J. Kwon. (2005). Effects

of the severe asian dust events on daily mortality during the spring of 2002, in Seoul, Korea. *Journal of Preventive Medicine and Public Health, 38(2),* 197–202.

[14] J. C. Choi, M. Lee, Y. Chun, J. Kim & S. Oh. (2001). Chemical composition and source signature of spring aerosol in Seoul, Korea. *Journal of geophysical research, 106(D16),* 18067–18074.

[15] H. Lee, S. S. Park, K. W. Kim & Y. J. Kim. (2008). Source identification of PM 2.5 particles measured in Gwangju, Korea. *Atmospheric Research, 88(3),* 199–211.

[16] S. E. Kim et al. (2017). Seasonal analysis of the short-term effects of air pollution on daily mortality on Northeast Asia. *Science of The Total Environment, 576(17),* 850–857.

[17] A. Faustini et el. (2011). The relationship between ambient particulate matter and respiratory mortality: a multi-city study in Italy. *European Respiratory Jouranl, 38(3),* 538–547.

[18] P. Salvador et al. (2011). Spatial and temporal variations in PM10 and PM2. 5 across madrid metropolitan area in 1999-2008. *Procedia Environmental Sciences, 4,* 198–208.

[19] E. Soleimanian et al. (2019). Spatial trends and sources of PM2.5 organic carbon volatility fractions(OCx) across the Los Angeles Basin. *Atmospheric Environment, 209,* 201–211.

[20] C. Rpper, L. G. Chubb, L. Cambal, B. Tunno, J. E. Clougherty & S E, Mischler. (2015). Characterization of ambient and extracted PM2.5 collected on filters for toxicology applications. *Inhalation Toxicology, 27(13),* 673–681.

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