

미세먼지, 건강영향과 대응

경 선 영

2021년 9월 4일

가천대 길병원 호흡기알레르기내과

내 용

1. 미세먼지 정의, 발생원, 구성성분
2. 미세먼지 관리기준, 현황
3. 미세먼지 건강영향
4. 미세먼지 행동요령
5. 미세먼지 건강수칙

미세먼지 정의¹⁾

- 먼지: 대기 중에 떠다니거나 흩날려 내려오는 입자상 물질
석탄·석유 등의 화석연료를 태울 때나 공장·자동차 등의 배출가스에서 많이 발생

크기에 따른 분류

- 총먼지(TSP, Total Suspended Particles)
- 미세먼지(PM, Particulate Matter)

미세먼지 (PM10): 지름이 10 μm 보다 작은 미세먼지

초미세먼지 (PM2.5): 지름이 2.5 μm 보다 작은 미세먼지



1) 미세먼지, 도대체 뭘까? 환경부 소책자, 2016

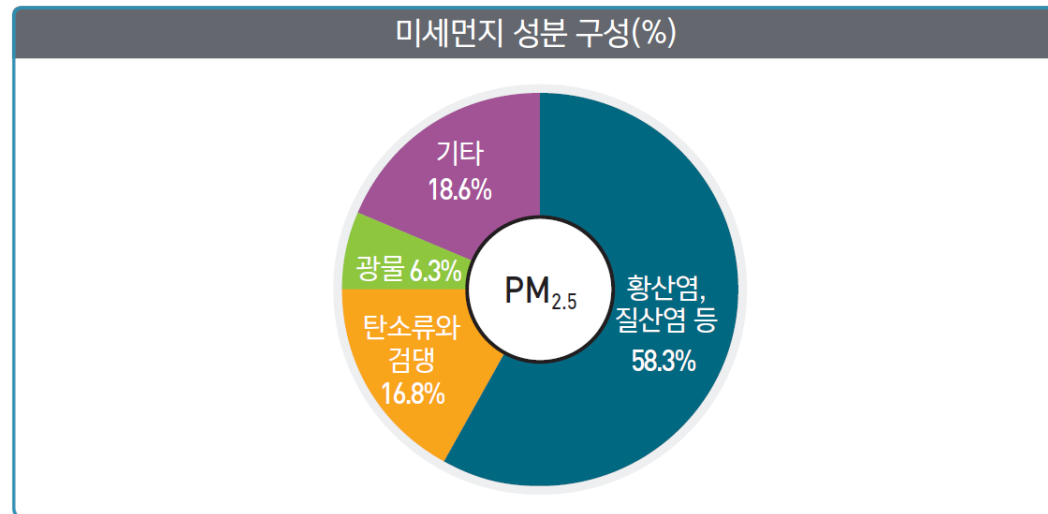
2) 미국 환경보호청(US EPA)

미세먼지 성분¹⁾

- 미세먼지 성분은 다양: 발생한 지역이나 계절, 기상조건 등에 따라 다름

미세먼지 구성 성분

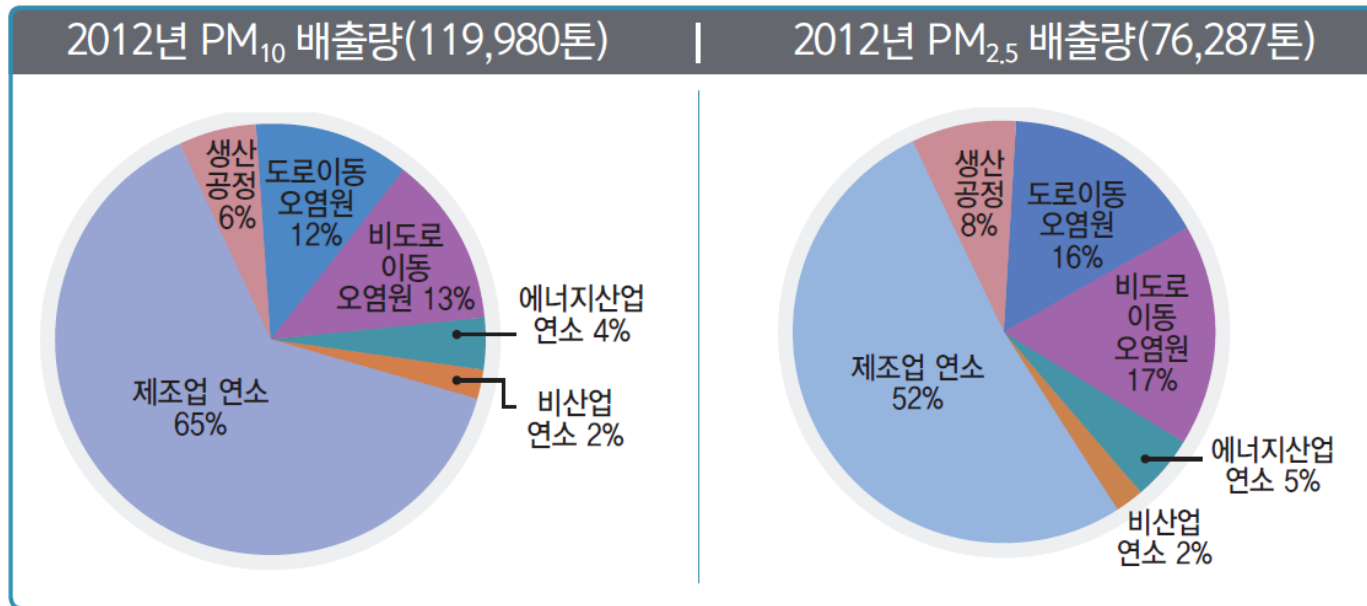
- 대기오염물질이 공기 중에서 반응하여 형성된 덩어리 (황산염, 질산염 등)
- 석탄·석유 등 화석연료를 태우는 과정에서 발생하는 탄소류와 검댕
- 지표면 흙먼지 등에서 생기는 광물



1) 미세먼지, 도대체 뭘까? 환경부 소책자, 2016

미세먼지 발생원¹⁾

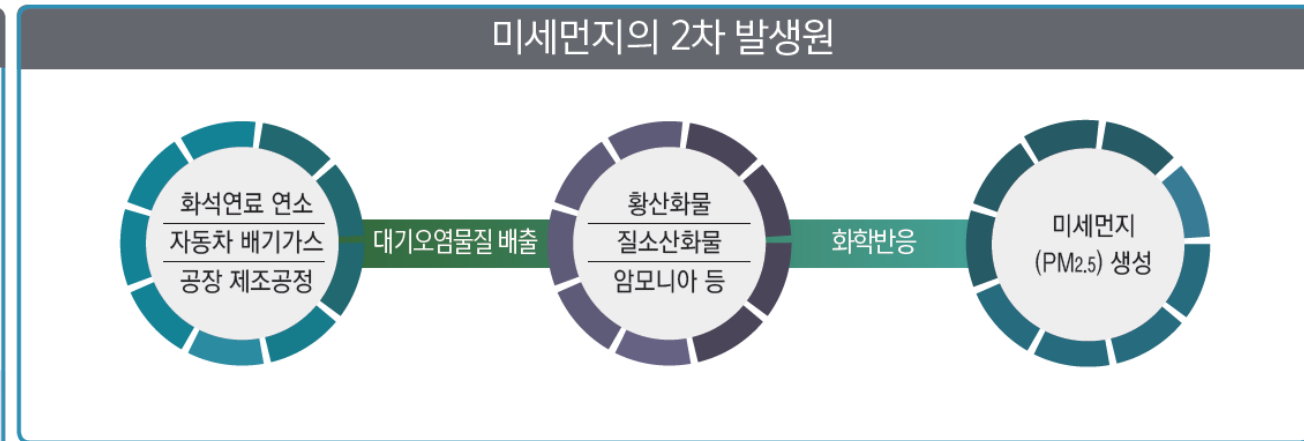
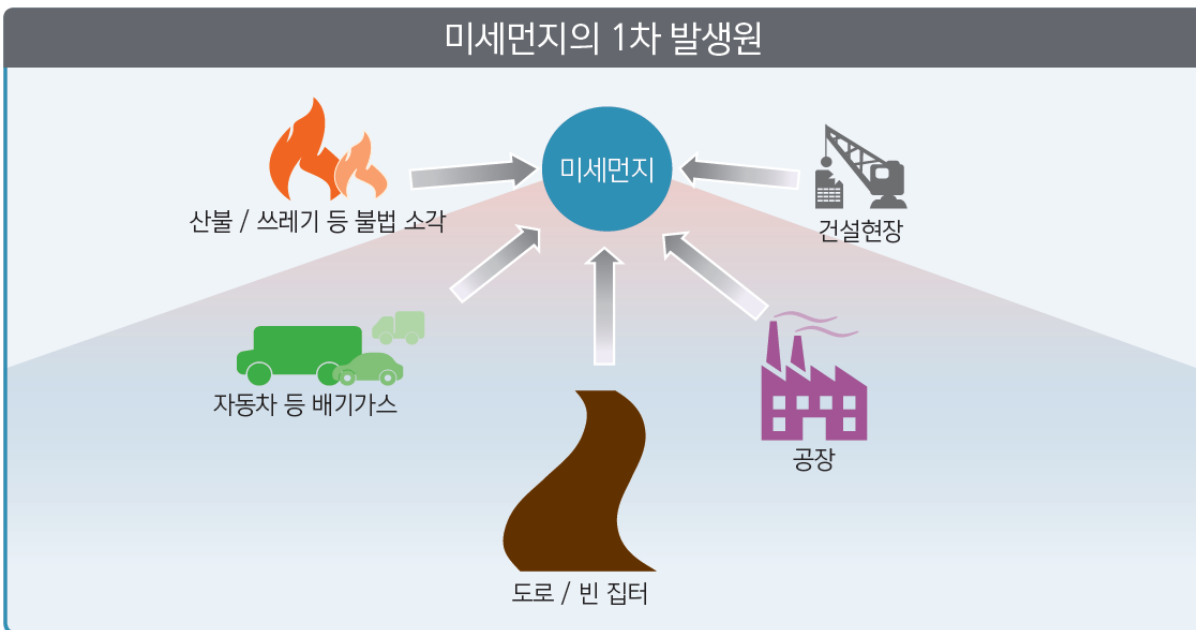
- 자연적 발생원: 흙먼지, 바닷물에서 생기는 소금, 식물의 꽃가루 등
- 인위적 발생원: 보일러나 발전시설 등에서 석탄·석유 등 화석연료를 태울 때 생기는 매연, 자동차 배기가스, 건설현장 등에서 발생하는 날림먼지, 공장 내 분말형태의 원자재, 부자재 취급공정에서의 가루성분, 소각장 연기 등



1) 미세먼지, 도대체 뭘까? 환경부 소책자, 2016

미세먼지 발생원¹⁾

- 1차적 발생: 굴뚝 등 발생원에서부터 고체 상태의 미세먼지로 나오는 경우
- 2차적 발생: 발생원에서는 가스 상태로 나온 물질이 공기 중의 다른 물질과 화학반응을 일으켜 미세먼지가 되는 경우



1) 미세먼지, 도대체 뭘까? 환경부 소책자, 2016

미세먼지와 황사¹⁾

황사

- 주로 중국 북부나 몽골의 사막지대와 황토고원에서 강력한 회오리 바람이 발생하는 경우 휩쓸려 올라간 미세한 흙먼지가 장거리를 이동하여 우리나라의 지상으로 내려옴으로써 발생
- 3-5월 경 많이 발생하며 강한 서풍을 타고 일본, 태평양, 북아메리카까지 날아가기도 함
- 구성 성분: 자연적으로 발생한 흙먼지로 자연 토양성분이 주임

1) 미세먼지, 도대체 뭘까? 환경부 소책자, 2016

국내 미세먼지 기준³⁾

미세먼지 (PM ₁₀)	연간 평균치	50 $\mu\text{g}/\text{m}^3$ 이하
	24시간 평균치	100 $\mu\text{g}/\text{m}^3$ 이하
초미세먼지 (PM _{2.5})	연간평균치	15 $\mu\text{g}/\text{m}^3$ 이하
	24시간평균치	35 $\mu\text{g}/\text{m}^3$ 이하

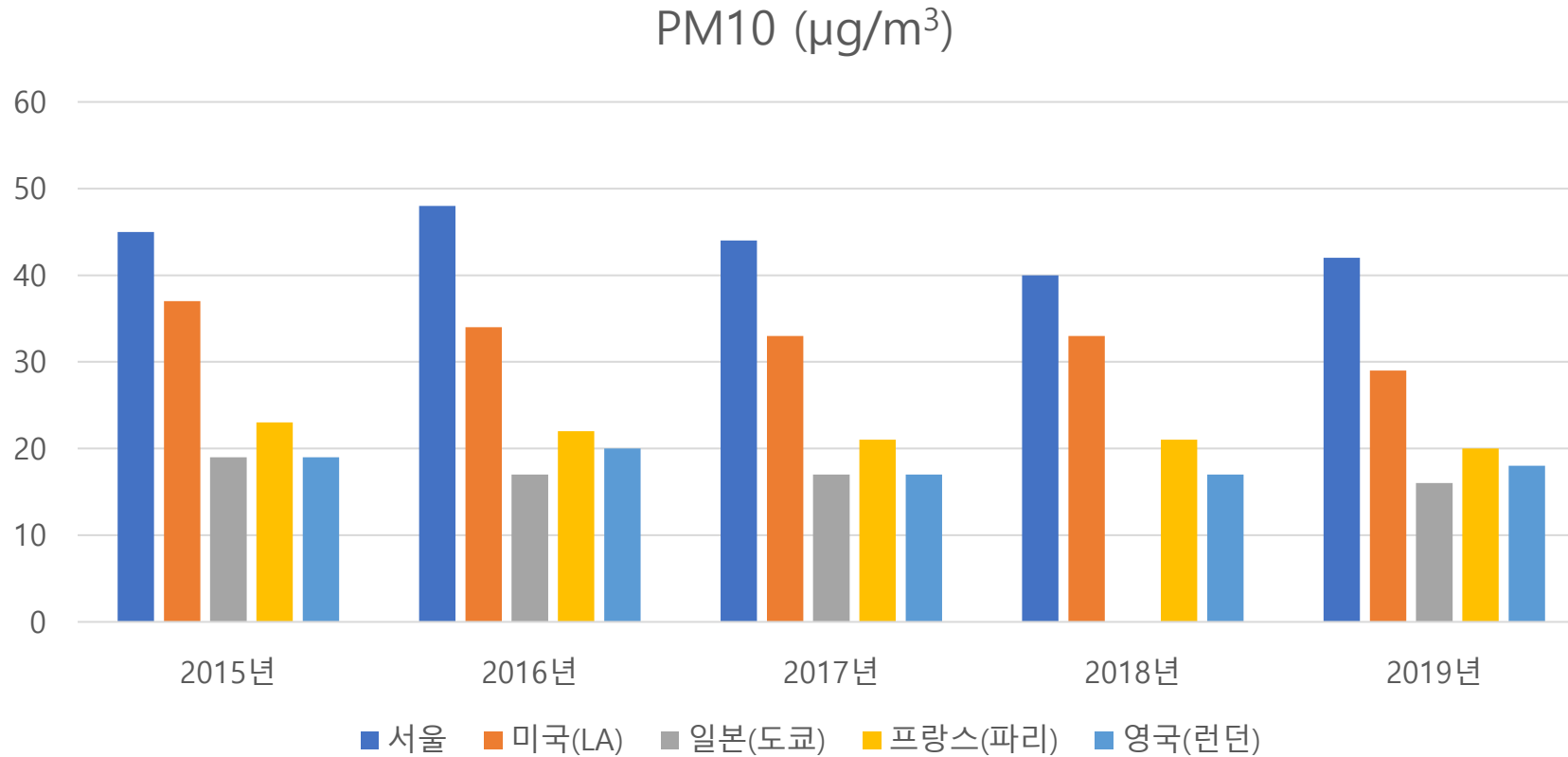
국외 미세먼지 기준⁴⁾

항목	기준시간	한국	미국 ¹⁾	일본	캐나다 ¹⁾	호주	홍콩	중국 ¹⁾	영국 ¹⁾	EU	WHO
PM ₁₀	1시간			200 $\mu\text{g}/\text{m}^3$							
	24시간	100 $\mu\text{g}/\text{m}^3$	150 ^{P,S} ⁶⁾ $\mu\text{g}/\text{m}^3$	100 $\mu\text{g}/\text{m}^3$		50 ²⁾ $\mu\text{g}/\text{m}^3$	100 ²⁾ $\mu\text{g}/\text{m}^3$	150 $\mu\text{g}/\text{m}^3$	50 ⁷⁾ $\mu\text{g}/\text{m}^3$	50 ⁵⁾ $\mu\text{g}/\text{m}^3$	50 $\mu\text{g}/\text{m}^3$
	1년	50 $\mu\text{g}/\text{m}^3$					50 $\mu\text{g}/\text{m}^3$	70 $\mu\text{g}/\text{m}^3$	40 $\mu\text{g}/\text{m}^3$	40 $\mu\text{g}/\text{m}^3$	20 $\mu\text{g}/\text{m}^3$
PM _{2.5}	24시간	35 ¹⁾ $\mu\text{g}/\text{m}^3$	35 ^{P,S} ⁴⁾ $\mu\text{g}/\text{m}^3$	35 ²⁾ $\mu\text{g}/\text{m}^3$	27 $\mu\text{g}/\text{m}^3$	25 $\mu\text{g}/\text{m}^3$	75 ²⁾ $\mu\text{g}/\text{m}^3$	75 $\mu\text{g}/\text{m}^3$			25 $\mu\text{g}/\text{m}^3$
	1년	15 ^{1),2)} $\mu\text{g}/\text{m}^3$	12 ^P ⁷⁾ $\mu\text{g}/\text{m}^3$ 15 ^S ⁷⁾ $\mu\text{g}/\text{m}^3$	15 $\mu\text{g}/\text{m}^3$	8.8 $\mu\text{g}/\text{m}^3$	8 $\mu\text{g}/\text{m}^3$	35 $\mu\text{g}/\text{m}^3$	35 $\mu\text{g}/\text{m}^3$	25 $\mu\text{g}/\text{m}^3$	25 $\mu\text{g}/\text{m}^3$	10 $\mu\text{g}/\text{m}^3$

3) 환경정책기본법시행령[시행일:2015.5.][별표]환경기준(제2조관련)

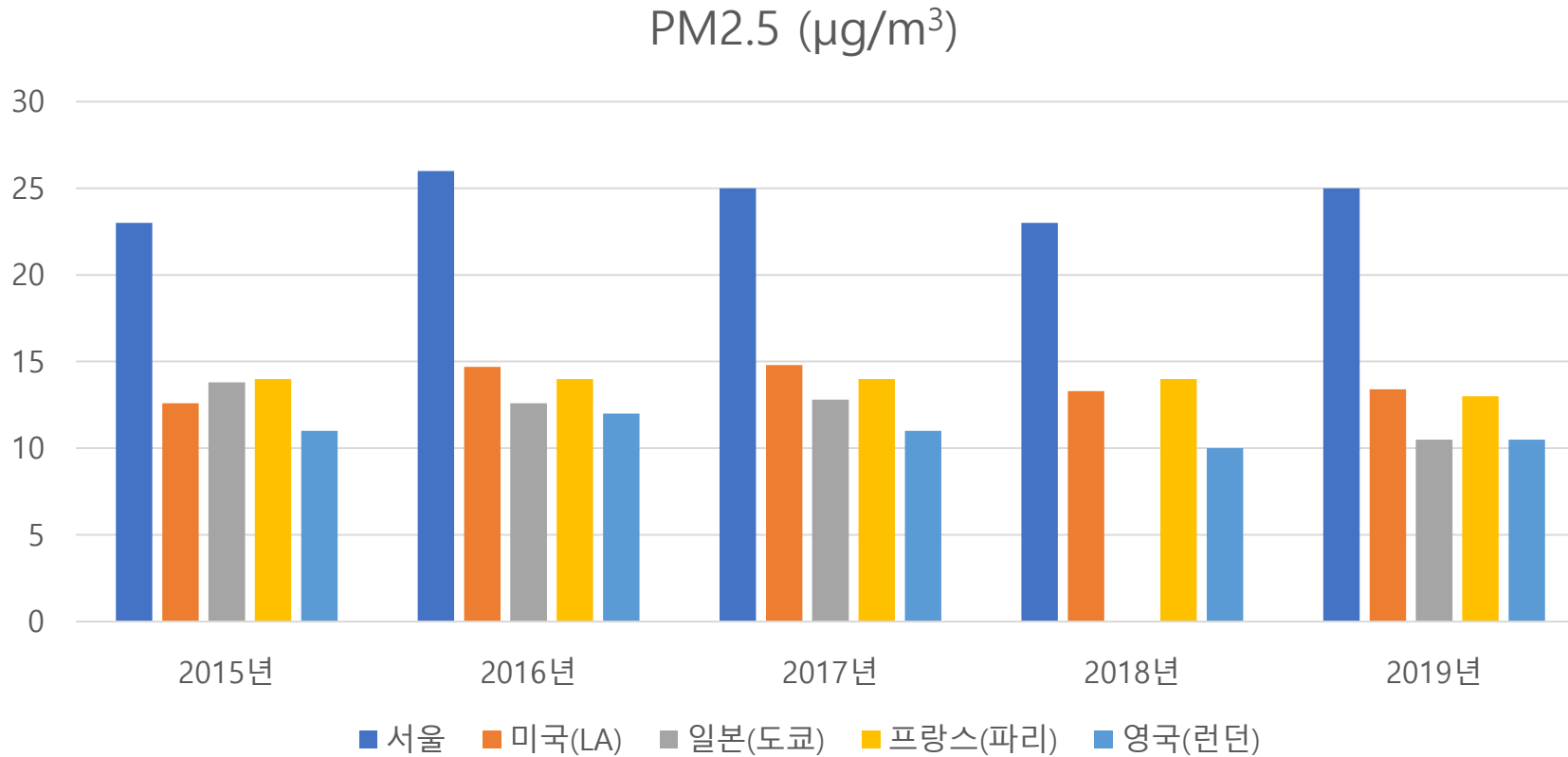
4) 대기환경연보, 2017

최근 5년 간 국내·외 미세먼지(PM10) 현황⁵⁾



5) 에어코리아 <http://www.airkorea.or.kr>

최근 5년 간 국내·외 미세먼지(PM2.5) 현황⁵⁾



5) 에어코리아 <http://www.airkorea.or.kr>

국내 미세먼지 요인¹⁾

- 국내·외 요인이 모두 작용하여 미세먼지 농도가 높음
- 높은 인구밀도, 고도로 진행된 도시화·산업화로 단위 면적 당 미세먼지 배출량이 많음
- 지리적으로 편서풍 지대에 위치하여 주변국 영향을 받음
- 기상학적으로 미세먼지를 씻어내는 강수가 여름철에 편중되어 있고, 겨울철, 봄철에는 강수가 극히 적음
주변에 형성되는 대륙성 고기압으로 인한 대기정체가 잦음

미세먼지 건강영향 연구

단기 영향: 미세먼지 노출 수 일 이내: 시계열분석, 환자-교차 연구, 패널 연구

- 국외: PM10 5일 이동 평균농도가 $100 \mu\text{g}/\text{m}^3$ 증가할 때 일별 사망 16% 증가⁶⁾⁷⁾
- 국내: PM10 농도 $10 \mu\text{g}/\text{m}^3$ 높아질 때 일별 사망 약 0.5% 내외 증가⁸⁾⁹⁾

장기 영향: 미세먼지 노출 수 년 동안: 코호트 연구, 개별 질환에 대한 환자-대조군 연구

- 하버드 6개 도시 연구(Harvard Six Cities Study): 연평균 PM2.5 농도가 $10 \mu\text{g}/\text{m}^3$ 높아질 때 전체 사망 13.9% 증가, 심장호흡기계 질환 사망 19.8% 증가¹⁰⁾
- 미국 메디케어 자료 코호트: 연평균 PM2.5 농도 $10 \mu\text{g}/\text{m}^3$ 증가할 때 사망 7.3% 증가¹¹⁾
- ESCAPE cohort: 유럽 다국가 다기관 코호트

6) Pope CA 3rd, Schwartz J, Ransom MR. Daily mortality and PM10 pollution in Utah Valley. Arch Environ Health 1992

7) Dockery DW, Schwartz J, Spengler JD. Air pollution and daily mortality: associations with particles and acid aerosols. Environ Res 1992

8) Kim SE, Honda Y, Hashizume M et al. Seasonal analysis of the short-term effects of air pollution on daily mortality in Northeast Asia. Aci Total Environ 2017

9) Park HY, Bae S, Hong YC. PM(10) exposure and non-accidental mortality in Asian populations: a meta-analysis of time series and case-crossover studies, J Prev Med Public Health 2013

10) Dockery DW, Pope CA 3rd, Xu X et al. An association between air pollution and mortality in six U.S. cities. N Engl J Med 1993

11) Di Q, Wang Y, Zanobetti A et al. Air pollution and mortality in the medicare population. N Engl J Med 2017

미세먼지 건강영향

미세먼지에 의한 조기사망

- 세계보건기구(WHO): 미세먼지로 인한 연간 조기 사망 700만명 (2014년)¹²⁾
- 국내: PM2.5 노출에 의한 추가 사망 연간 11,924명 (2015년)¹³⁾
PM2.5 노출에 의한 추가 사망 연간 17,203명 (1990-2013년)¹⁴⁾

12) World Health Organization (WHO), 2014

13) Han C, Kim S, Lim YH et al. Spatial and temporal trends of number of deaths attributable to ambient PM(2.5) in the Korea. J Korean Med Sci 2018

14) Kim JH, Oh IH, Park JH et al. Premature deaths attributable to long-term exposure to ambient fine particulate matter in the Republic of Korea. J Korean Med Sci 2018.

Air Pollution Data Portal

Burden of disease

7 million

deaths each year from exposure to ambient and household air pollution

Household exposure

2.6 billion

people primarily rely on polluting fuels and technologies for cooking

Ambient exposure

91%

of the world's population live in places where air pollution levels exceed WHO guideline limits

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GHO Home | Indicators | Countries | Data API | Map Gallery | Publications | Data Search

Visualisations | Data | Metadata | Related Indicators

Concentrations of fine particulate matter (PM2.5)

FILTERS | Year: Latest | Residence Area Type: Total

Legend: <10, [10-15], [15-25], [25-35], [35-100], Data not available, Not applicable

The boundaries and names shown and the designations used on this map do not imply the expression of any opinion whatsoever on the part of the World Health Organization concerning the legal status of any country, territory, city or area or of its authorities, or concerning the delimitation of its frontiers or boundaries. Dotted and

World Health Organization

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Ambient air pollution attributable deaths

Appears in: Ambient air pollution: burden of disease - deaths

Visualisations | Data | Metadata | Related Indicators

Ambient air pollution attributable deaths

FILTERS | Year: Latest | Sex: Both sexes | Cause: Total

Legend: 1150296.00, 22.39, Data not available, Not applicable

The boundaries and names shown and the designations used on this map do not imply the expression of any opinion whatsoever on the part of the World Health Organization concerning the legal status of any country, territory, city or area or of its authorities, or concerning the delimitation of its frontiers or boundaries. Dotted and

World Health Organization

미세먼지 건강영향: 개별 질환

Table 1. Influence on the major organs and diseases of human by particulate matter¹⁵⁾

Organ	Disease	Organ	Disease
Eyes	Inflammation Pruritus	Nose	Rhinitis
Lung	Pneumonia Lung cancer COPD Asthma	Brain	Cerebral stroke Neurodegenerative diseases Dementia Depressive disorder
Cardiovascular	Arrhythmia Myocardial infarction Heart failure Hypertensive disease Deep vein thrombosis	Pancreas	Type 2 diabetes Type 1 diabetes
Skin	Atopy Aging	Uterus	Premature birth Decreased birthweight Decreased fetal growth

COPD, chronic obstructive pulmonary disease.

15) 경선영, 정성환. 미세먼지의 건강영향. J Korean Med Assoc 2017

미세먼지 건강영향: 호흡기계

16)

TABLE 3 Examples of respiratory clinical effects associated with air pollution

Increased respiratory mortality

Increased incidence of malignancies of the respiratory tract

Increased incidence, prevalence or frequency of exacerbations in chronic pulmonary disease: asthma, COPD and cystic fibrosis

Increased incidence or severity of upper and lower respiratory tract infections

Increased respiratory symptoms that affect quality of life: cough, phlegm, wheezing, dyspnoea and nasal drainage

Increased incidence of preterm birth, low birthweight or growth restriction leading to adverse respiratory outcomes

Reduced growth of lung function in children

Transient (hours) reductions in lung function associated with symptoms in healthy individuals

Transient (hours) reductions in lung function without symptoms in especially susceptible individuals (e.g. children with severe asthma)

Persistent or chronic (weeks, months or years) reductions in lung function

COPD: chronic obstructive pulmonary disease.

미세먼지와 폐암

- 세계보건기구 산하 국제암연구소(International Agency for Research on Cancer, IARC) 미세먼지를 1군 발암물질로 지정 (2013.10)¹⁷⁾
- 국내: 10년간의 평균 PM10농도가 $10 \mu\text{g}/\text{m}^3$ 증가할 때 폐암의 위험 1.16배 높아짐¹⁸⁾
- 미세먼지 장기 노출 시 폐암 사망 위험 1.1-1.2배 증가¹⁹⁾²⁰⁾

17) International Agency for Research on Cancer; World Health Organization. Outdoor air pollution, 2013

18) Lamichhane DK, Kim HC, Choi CM et al. Lung cancer risk and residential exposure to air pollution: a Korean population-based case-control study. Yonsei Med 2017

19) Hamra GB, Guha N, Cohen A et al. Outdoor particulate matter exposure and lung cancer: a systematic review and meta-analysis. Environ Health Perspect 2014

20) Raaschou-Nielsen O, Andersen ZJ, Beelen R et al. Air pollution and lung cancer incidence in 17 European cohorts: prospective analyses from the European Study of Cohorts: prospective analyses from the ESCAPE. Lancet Oncol 2013

Air pollution and lung cancer incidence in 17 European cohorts: prospective analyses from the European Study of Cohorts for Air Pollution Effects (ESCAPE)

Ole Raaschou-Nielsen, Zorana J Andersen, Rob Beelen, Evangelia Samoli, Massimo Stafoggia, Gudrun Weinmayr, Barbara Hoffmann, Paul Fischer, Mark J Nieuwenhuijsen, Bert Brunekreef, Wei W Xun, Klea Katsouyanni, Konstantina Dimakopoulou, Johan Sommar, Bertil Forsberg, Lars Modig, Anna Oudin, Bente Oftedal, Per E Schwarze, Per Nafstad, Ulf De Faire, Nancy L Pedersen, Claes-Göran Östenson, Laura Fratiglioni, Johanna Penell, Michal Korek, Göran Pershagen, Kirsten T Eriksen, Mette Sørensen, Anne Tjønneland, Thomas Ellermann, Marloes Eeftens, Petra H Peeters, Kees Meliefste, Meng Wang, Bas Bueno-de-Mesquita, Timothy J Key, Kees de Hoogh, Hans Concin, Gabriele Nagel, Alice Vilier, Sara Griani, Vittorio Krogh, Ming-Yi Tsai, Fulvio Ricceri, Carlotta Sacerdote, Claudia Galassi, Enrica Migliore, Andrea Ranzi, Giulia Cesaroni, Chiara Badaloni, Francesco Forastiere, Ibon Tamayo, Pilar Amiano, Miren Dorronsoro, Antonia Trichopoulou, Christina Bamia, Paolo Vineis*, Gerard Hoek*

Summary

Background Ambient air pollution is suspected to cause lung cancer. We aimed to assess the association between long-term exposure to ambient air pollution and lung cancer incidence in European populations.

Methods This prospective analysis of data obtained by the European Study of Cohorts for Air Pollution Effects used data from 17 cohort studies based in nine European countries. Baseline addresses were geocoded and we assessed air pollution by land-use regression models for particulate matter (PM) with diameter of less than 10 µm (PM₁₀), less than 2.5 µm (PM_{2.5}), and between 2.5 and 10 µm (PM_{coarse}), soot (PM_{2.5absorbance}), nitrogen oxides, and two traffic indicators. We used Cox regression models with adjustment for potential confounders for cohort-specific analyses and random effects models for meta-analyses.

Findings The 312944 cohort members contributed 4013131 person-years at risk. During follow-up (mean 12.8 years), 2095 incident lung cancer cases were diagnosed. The meta-analyses showed a statistically significant association between risk for lung cancer and PM₁₀ (hazard ratio [HR] 1.22 [95% CI 1.03–1.45] per 10 µg/m³). For PM_{2.5} the HR was 1.18 (0.96–1.46) per 5 µg/m³. The same increments of PM₁₀ and PM_{2.5} were associated with HRs for adenocarcinomas of the lung of 1.51 (1.10–2.08) and 1.55 (1.05–2.29), respectively. An increase in road traffic of 4000 vehicle-km per day within 100 m of the residence was associated with an HR for lung cancer of 1.09 (0.99–1.21). The results showed no association between lung cancer and nitrogen oxides concentration (HR 1.01 [0.95–1.07] per 20 µg/m³) or traffic intensity on the nearest street (HR 1.00 [0.97–1.04] per 5000 vehicles per day).

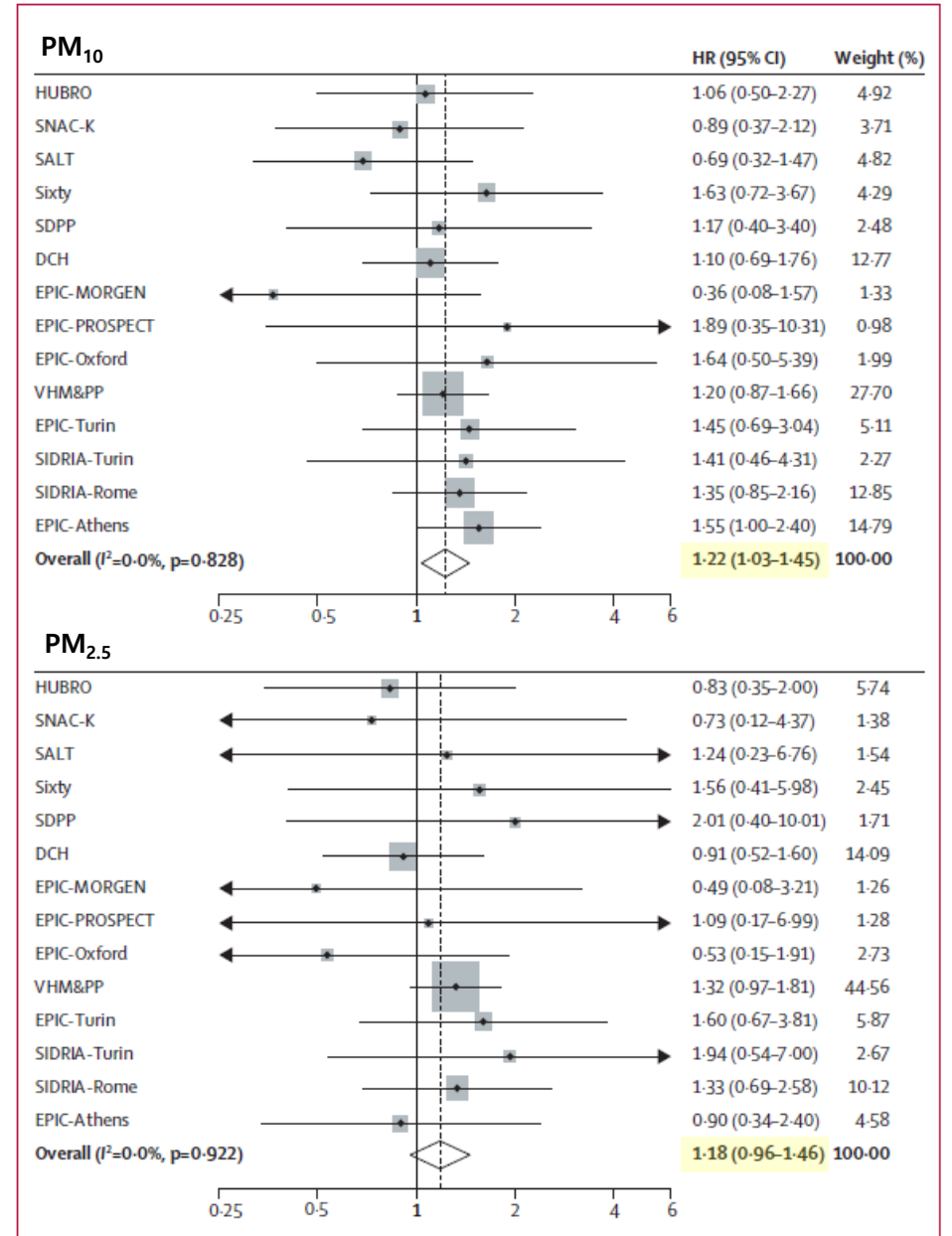


Figure 3: Risk for lung cancer according to concentration of particulate matter in each cohort study

미세먼지와 폐기능

- 미세먼지 농도가 높은 지역에 사는 소아들은 FEV₁, FVC가 유의하게 낮음²¹⁾²²⁾
- 성인의 폐기능은 PM10 연간 평균농도가 10 µg/m³ 증가 시 폐기능이 감소함 (FVC 3.4%, FEV₁ 1.6%)²³⁾²⁴⁾
- PM10 노출이 감소하면 폐기능 감소 속도가 줄어듦 (약 10년 동안 PM10 10 µg/m³ 감소 시 연간 감소속도 FEV₁ 9%, FEF₂₅₋₇₅ 16% 줄어듦)²⁴⁾

21) Gauderman WJ, McConnell R, Gilliland F et al. Association between air pollution and lung function growth in southern California children. Am J Respir Crit Care Med 2000

22) Gehring U, Gruzieva O, Aglus RM et al. Air pollution exposure and lung function in children: the ESCAPE project. Environ Health Perspect 2013

23) Ackermann-Liebrich U, Leuenberger P, Schwartz J, et al. Lung function and long term exposure to air pollutants in Switzerland. Am J Respir Crit Care Med 1997

24) Downs SH, Schindle C, Liu LJ et al. SAPALDIA Team. Reduced exposure to PM10 and attenuated age-related decline in lung function. N Engl J Med 2007

Reduced Exposure to PM₁₀ and Attenuated Age-Related Decline in Lung Function

Sara H. Downs, Ph.D., Christian Schindler, Ph.D., L.-J. Sally Liu, Sc.D., Dirk Keidel, M.A., Lucy Bayer-Oglesby, Ph.D., Martin H. Brutsche, M.D., Ph.D., Margaret W. Gerbase, M.D., Ph.D., Roland Keller, M.D., Nino Künzli, M.D., Ph.D., Philippe Leuenberger, M.D., Nicole M. Probst-Hensch, Ph.D., Jean-Marie Tschopp, M.D., Jean-Pierre Zellweger, M.D., Thierry Rochat, M.D., Joel Schwartz, Ph.D., Ursula Ackermann-Lieblich, M.D., M.Sc., and the SAPALDIA Team*

METHODS

We conducted a prospective study of 9651 adults (18 to 60 years of age) randomly selected from population registries in 1990 and assessed in 1991, with 8047 participants reassessed in 2002. There was complete information on lung volumes and flows (e.g., forced vital capacity [FVC], forced expiratory volume in 1 second [FEV₁], FEV₁ as a percentage of FVC, and forced expiratory flow between 25 and 75% of the FVC [FEF₂₅₋₇₅]), smoking habits, and spatially resolved concentrations of particulate matter that was less than 10 μm in aerodynamic diameter (PM₁₀) from a validated dispersion model assigned to residential addresses for 4742 participants at both the 1991 and the 2002 assessments and in the intervening years.

RESULTS

Overall exposure to individual home outdoor PM₁₀ declined over the 11-year follow-up period (median, -5.3 μg per cubic meter; interquartile range, -7.5 to -4.2). In mixed-model regression analyses, with adjustment for confounders, PM₁₀ concentrations at baseline, and clustering within areas, there were significant negative associations between the decrease in PM₁₀ and the rate of decline in FEV₁ (P=0.045), FEV₁ as a percentage of FVC (P=0.02), and FEF₂₅₋₇₅ (P=0.001). The net effect of a decline of 10 μg of PM₁₀ per cubic meter over an 11-year period was to reduce the annual rate of decline in FEV₁ by 9% and of FEF₂₅₋₇₅ by 16%. Cumulative exposure in the interval between the two examinations showed similar associations.

CONCLUSIONS

Decreasing exposure to airborne particulates appears to attenuate the decline in lung function related to exposure to PM₁₀. The effects are greater in tests reflecting small-airway function.

Table 2. Estimated Effect of Change in PM₁₀ and of Interval Exposure to PM₁₀ on Annual Change in Lung Function.*

Variable	No. of Participants	Decrease in PM ₁₀ of 10 μg/m ³ between 1991 and 2002		Decrease in Interval Exposure of 109 μg/m ³ -yr	
		Effect (95% CI)	P Value	Effect (95% CI)	P Value
All participants	4742				
FVC (ml)		-0.2 (-4.3 to 3.9)	0.91	5.3 (-1.1 to 11.7)	0.10
FEV ₁ (ml)		3.1 (0.03 to 6.2)	0.045	6.9 (2.1 to 11.7)	0.005
FEV ₁ as a percentage of FVC		0.06 (0.01 to 0.12)	0.02	0.05 (-0.04 to 0.13)	0.27
FEF ₂₅₋₇₅ (ml/sec)		11.3 (4.3 to 18.2)	0.001	14.0 (3.1 to 24.8)	0.01
All participants who never smoked	2213				
FVC (ml)		2.2 (-3.4 to 7.9)	0.43	9.9 (1.3 to 18.4)	0.02
FEV ₁ (ml)		4.2 (-0.3 to 8.5)	0.06	9.3 (2.6 to 16.0)	0.006
FEV ₁ as a percentage of FVC		0.05 (-0.03 to 0.13)	0.18	0.03 (-0.08 to 0.15)	0.59
FEF ₂₅₋₇₅ (ml/sec)		11.3 (1.4 to 21.2)	0.03	15.4 (0.2 to 30.6)	0.047

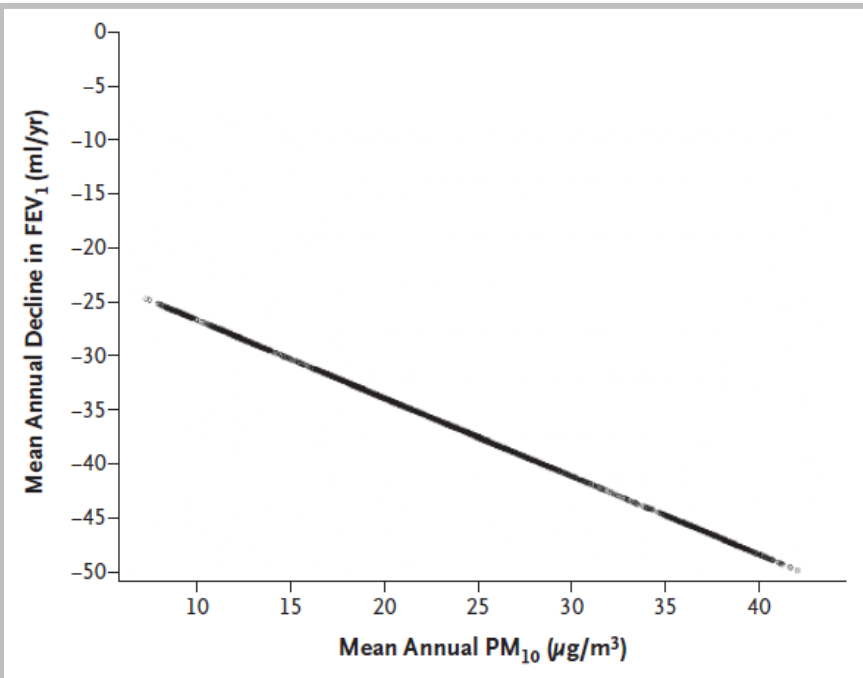


Figure 3. Estimated Effect of Interval Exposure between 1991 and 2002 (Expressed as Mean Annual PM₁₀) on Mean Annual Decline in FEV₁.

미세먼지와 COPD

- 미세먼지 노출 시 COPD 증상 악화, 응급실 방문, 입원 및 사망 증가함²⁵⁾²⁶⁾
- 미세먼지(PM2.5)에 의한 COPD 발생 증가²⁷⁾²⁸⁾

25) Gan WQ, FitzGerald JM, Carlsten C et al. Associations of ambient air pollution with chronic obstructive pulmonary disease hospitalization and mortality. Am J Respir Crit Care Med 2013

26) Kyung SY, Kim SY, Kim WJ et al. Guideline for the prevention and management of particulate matter/Asian dust particle-induced adverse health effect on the patients with pulmonary diseases. J Korean Med Assoc 2015

27) Zhang Y, Want L, Mutlu GM et al. More to Explore: further definition of risk factors for COPD-Differential gender difference, modest elevation in PM2.5, and e-cigarette use. Frontiers in Physiology 2021

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Association Between Long-term Exposure to Ambient Air Pollution and Change in Quantitatively Assessed Emphysema and Lung Function

DESIGN, SETTING, AND PARTICIPANTS This cohort study included participants from the Multi-Ethnic Study of Atherosclerosis (MESA) Air and Lung Studies conducted in 6 metropolitan regions of the United States, which included 6814 adults aged 45 to 84 years recruited between July 2000 and August 2002, and an additional 257 participants recruited from February 2005 to May 2007, with follow-up through November 2018.

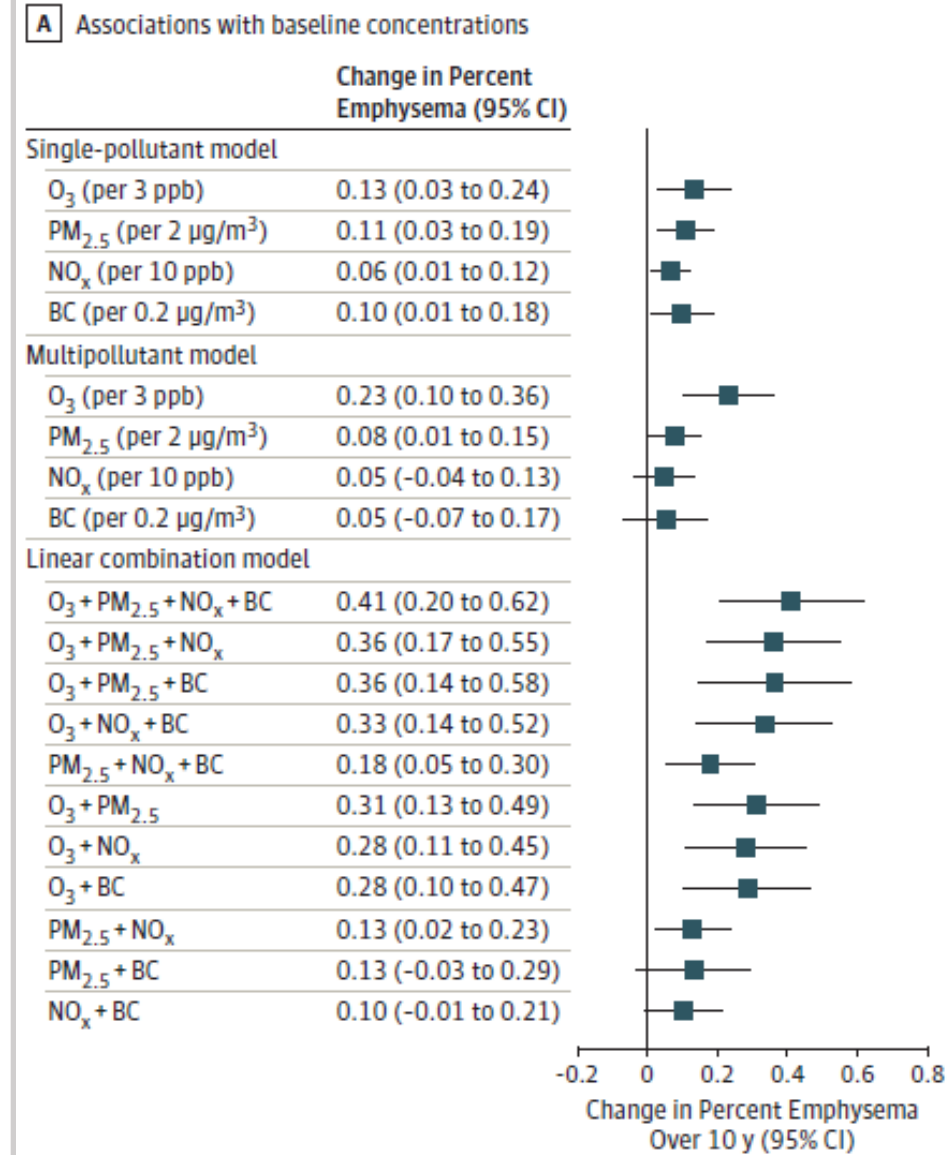
EXPOSURES Residence-specific air pollutant concentrations (O_3 , $PM_{2.5}$, NO_x , and black carbon) were estimated by validated spatiotemporal models incorporating cohort-specific monitoring, determined from 1999 through the end of follow-up.

MAIN OUTCOMES AND MEASURES Percent emphysema, defined as the percent of lung pixels less than -950 Hounsfield units, was assessed up to 5 times per participant via cardiac CT scan (2000-2007) and equivalent regions on lung CT scans (2010-2018). Spirometry was performed up to 3 times per participant (2004-2018).

RESULTS Among 7071 study participants (mean [range] age at recruitment, 60 [45-84] years; 3330 [47.1%] were men), 5780 were assigned outdoor residential air pollution concentrations in the year of their baseline examination and during the follow-up period and had at least 1 follow-up CT scan, and 2772 had at least 1 follow-up spirometric assessment, over a median of 10 years. Median percent emphysema was 3% at baseline and increased a mean of 0.58 percentage points per 10 years. Mean ambient concentrations of $PM_{2.5}$ and NO_x , but not O_3 , decreased substantially during follow-up. Ambient concentrations of O_3 , $PM_{2.5}$, NO_x , and black carbon at study baseline were significantly associated with greater increases in percent emphysema per 10 years (O_3 : 0.13 per 3 parts per billion [95% CI, 0.03-0.24]; $PM_{2.5}$: 0.11 per $2 \mu\text{g}/\text{m}^3$ [95% CI, 0.03-0.19]; NO_x : 0.06 per 10 parts per billion [95% CI, 0.01-0.12]; black carbon: 0.10 per $0.2 \mu\text{g}/\text{m}^3$ [95% CI, 0.01-0.18]). Ambient O_3 and NO_x concentrations, but not $PM_{2.5}$ concentrations, during follow-up were also significantly associated with greater increases in percent emphysema. Ambient O_3 concentrations, but not other pollutants, at baseline and during follow-up were significantly associated with a greater decline in forced expiratory volume in 1 second per 10 years (baseline: 13.41 mL per 3 parts per billion [95% CI, 0.7-26.1]; follow-up: 18.15 mL per 3 parts per billion [95% CI, 1.59-34.71]).

CONCLUSIONS AND RELEVANCE In this cohort study conducted between 2000 and 2018 in 6 US metropolitan regions, long-term exposure to ambient air pollutants was significantly associated with increasing emphysema assessed quantitatively using CT imaging and lung function.

Figure 4. Effect Estimates for the Associations Between Air Pollutants and Progression of Percent Emphysema



미세먼지와 기관지천식

- 알레르기 물질의 감작: 천식의 발생률과 유병률을 높임²⁹⁾
- 천식의 증상 악화: 기침, 천명, 호흡곤란 증상의 악화, 폐기능 감소, 병원 이용 및 입원 증가²⁹⁾³⁰⁾

29) Guarnieri M, Balmes JR. Outdoor air pollution and asthma. Lancet 2014

20) Yang HJ, Kim SH, Jang AS et al. Guideline for the prevention and management of particulate matter/yellow dust-induced adverse health effects on the patients with bronchial asthma. J Korean Med Assoc 2015.

미세먼지와 호흡기 감염성 질환

- 급성 기관지염, 만성 기관지염, 폐렴 발생률 증가²⁹⁾³⁰⁾
- 폐렴 사망률 증가³¹⁾

29) MacIntyre EA, Gehring U, Molter A et al. Air pollution and respiratory infections during early childhood: an analysis of 10 European birth cohorts within the ESCAPE project. Environ Health Perspect 2014

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Short-Term Air Pollution and Incident Pneumonia

A Case–Crossover Study

Cheryl S. Pirozzi¹, Barbara E. Jones^{1,2}, James A. VanDerslice³, Yue Zhang^{3,4}, Robert Paine III^{1,2}, and Nathan C. Dean^{1,5}

Methods: We applied time-stratified case–crossover analyses with distributed lag to patients presenting to seven emergency departments with pneumonia over a 2-year period. We compared levels of particulate matter less than or equal to 2.5 μm in aerodynamic diameter, nitrogen dioxide, and ozone at patient residences with emergency department cases, hospitalizations, objectively defined severe pneumonia, and mortality. We calculated direct cost impacts of particulate matter less than or equal to 2.5 μm in aerodynamic diameter reduction.

Results: We evaluated 4,336 pneumonia cases in seven hospitals. Among adults aged 65 years and older, we found consistently positive associations between particulate matter less than or equal to 2.5 μm in aerodynamic diameter within 6 days of presentation and instances of pneumonia (Lag Day 1 adjusted odds ratio, 1.35 per 10 $\mu\text{g}/\text{m}^3$ over 12 $\mu\text{g}/\text{m}^3$; 95% confidence interval, 1.16–1.57), severe pneumonia (Lag Day 1 adjusted odds ratio, 1.38; 95% confidence interval, 1.06–1.80), and inpatient mortality (Lag Day 5 adjusted odds ratio, 1.50; 95% confidence interval, 1.03–2.16). Smaller associations were found between nitrogen dioxide exposure and pneumonia occurrence, severity, and inpatient and 30-day mortality. Ozone exposure was modestly associated with increased instance and severity of pneumonia in younger adults. Particulate matter less than or equal to 2.5 μm in aerodynamic diameter and nitrogen dioxide effects were greatest in colder months, and ozone effects were greatest in warmer months. Reduction of particulate matter less than or equal to 2.5 μm in aerodynamic diameter levels to less than 12.0 mg/m^3 could prevent 76–112 cases of pneumonia per year in these hospitals serving approximately half of the Wasatch Front’s population, reducing direct medical facility costs by \$807,000 annually.

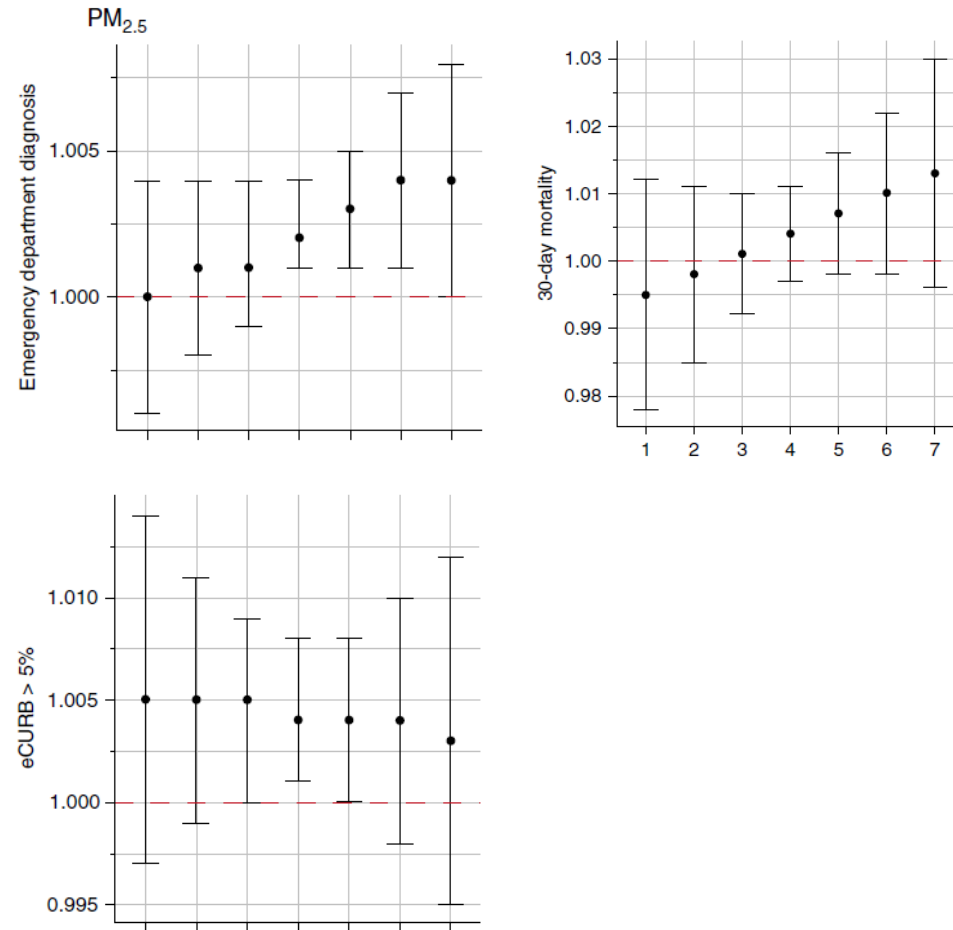


Figure 3. Odds ratios (ORs) for pneumonia outcomes

미세먼지의 기도 내 침착 기전

- 크기에 따라 침착 또는 흡수 부위와 건강영향이 다름²⁹⁾

기도내 침착 기전³¹⁾

- 충돌
- 중력침강
- 확산, 정전기적 흡착

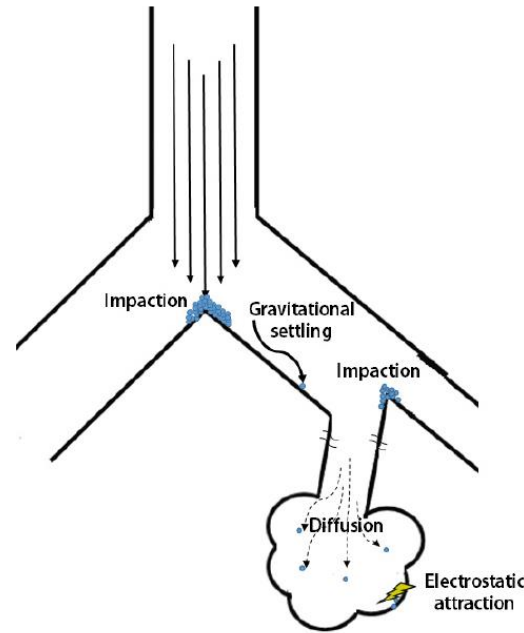


Figure 3. Possible mechanisms of particulate matter deposition.

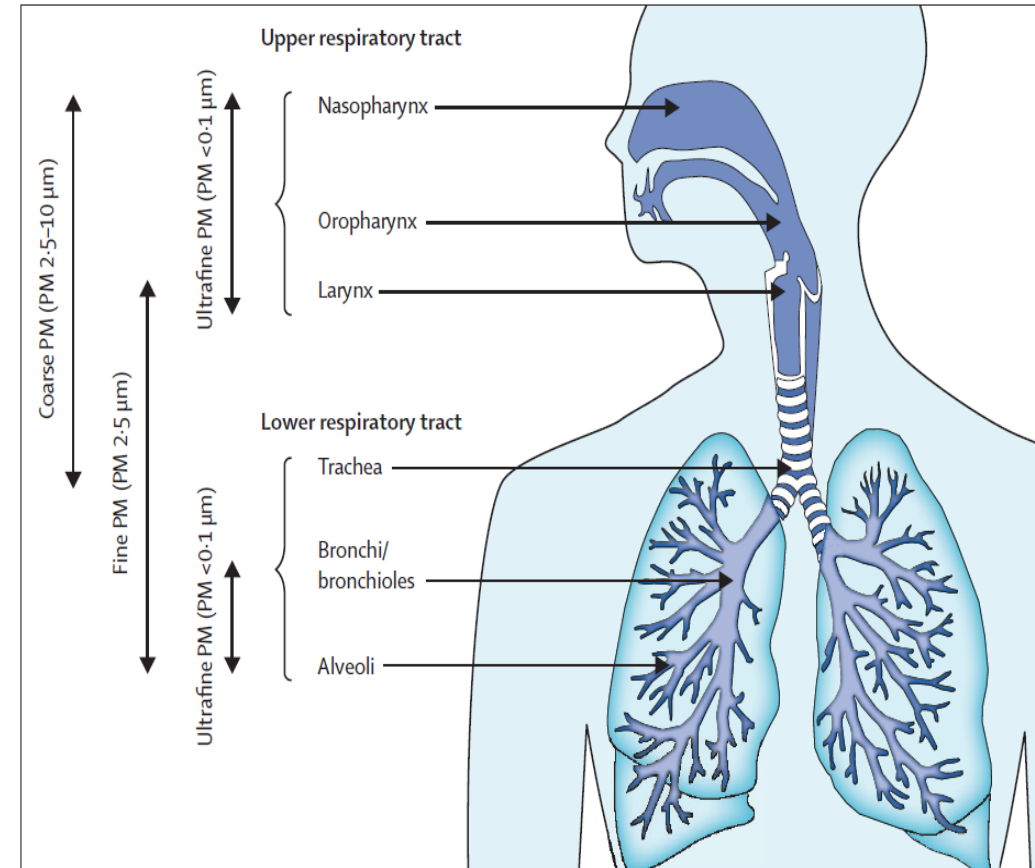


Figure 4: Compartmental deposition of particulate matter

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미세먼지 인체 영향 기전

- 선천면역, 후천면역, 산화스트레스
 - 대식세포 탐식작용, 염증 매개 인자 증가, T세포 매개 염증 증가
 - 급성·만성 염증 반응, 기도개형, 기도과민반응, 기도청소, 감염에 대한 면역기능에 영향
 - 호흡기질환 발병, 악화, 사망률 증가 초래³²⁾

- 미세먼지 구성성분 중 유기화합물, 황화물 이온, 질산염 이온, 암노늄 이온 등
 - DNA 결합 분리, DNA 산화손상, 염색체 단절
 - 폐암 유발³¹⁾

31) 명준표. 미세먼지와 건강 장애. 대한내과학회지 2016

32) 장안수. 미세먼지가 건강에 미치는 영향. J Korean Med Assoc 2014

미세먼지에 의한 기도질환 발생·악화 기전

29)

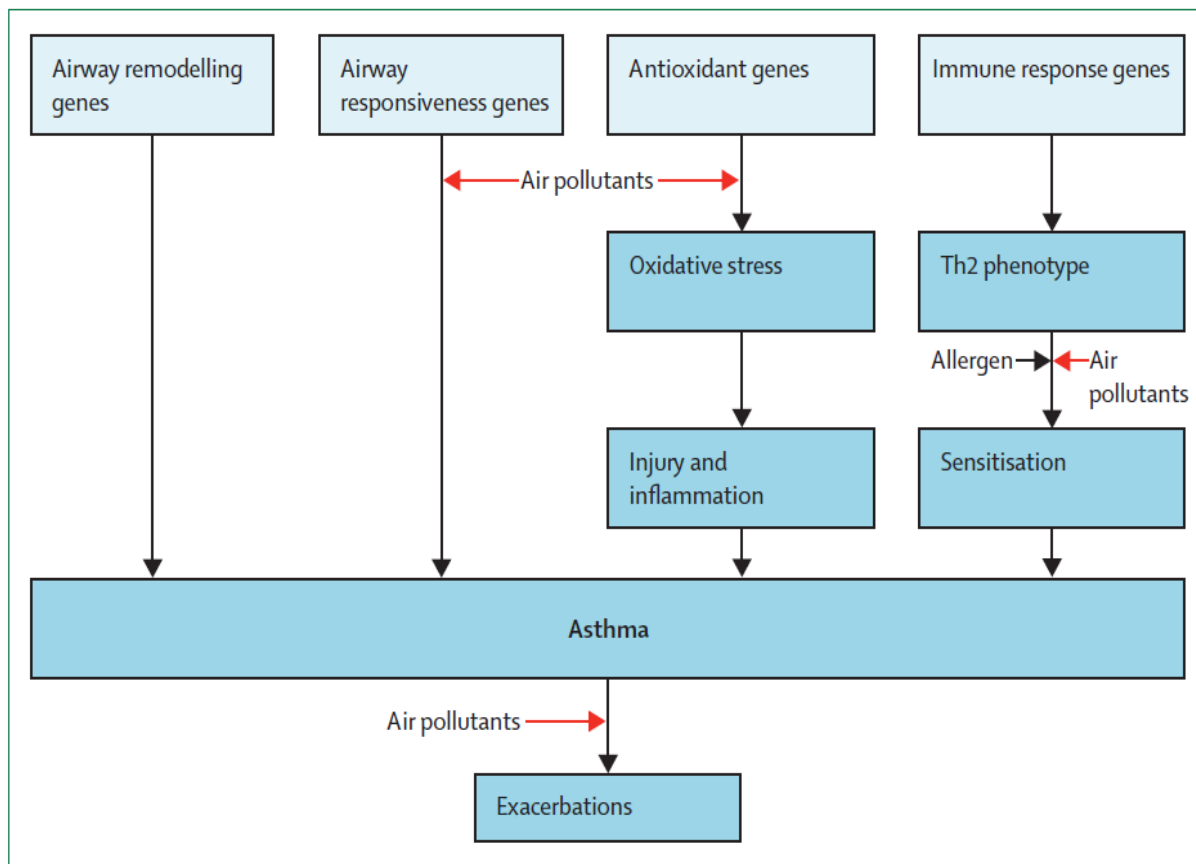


Figure 2: Mechanistic framework for air pollution effects in asthma

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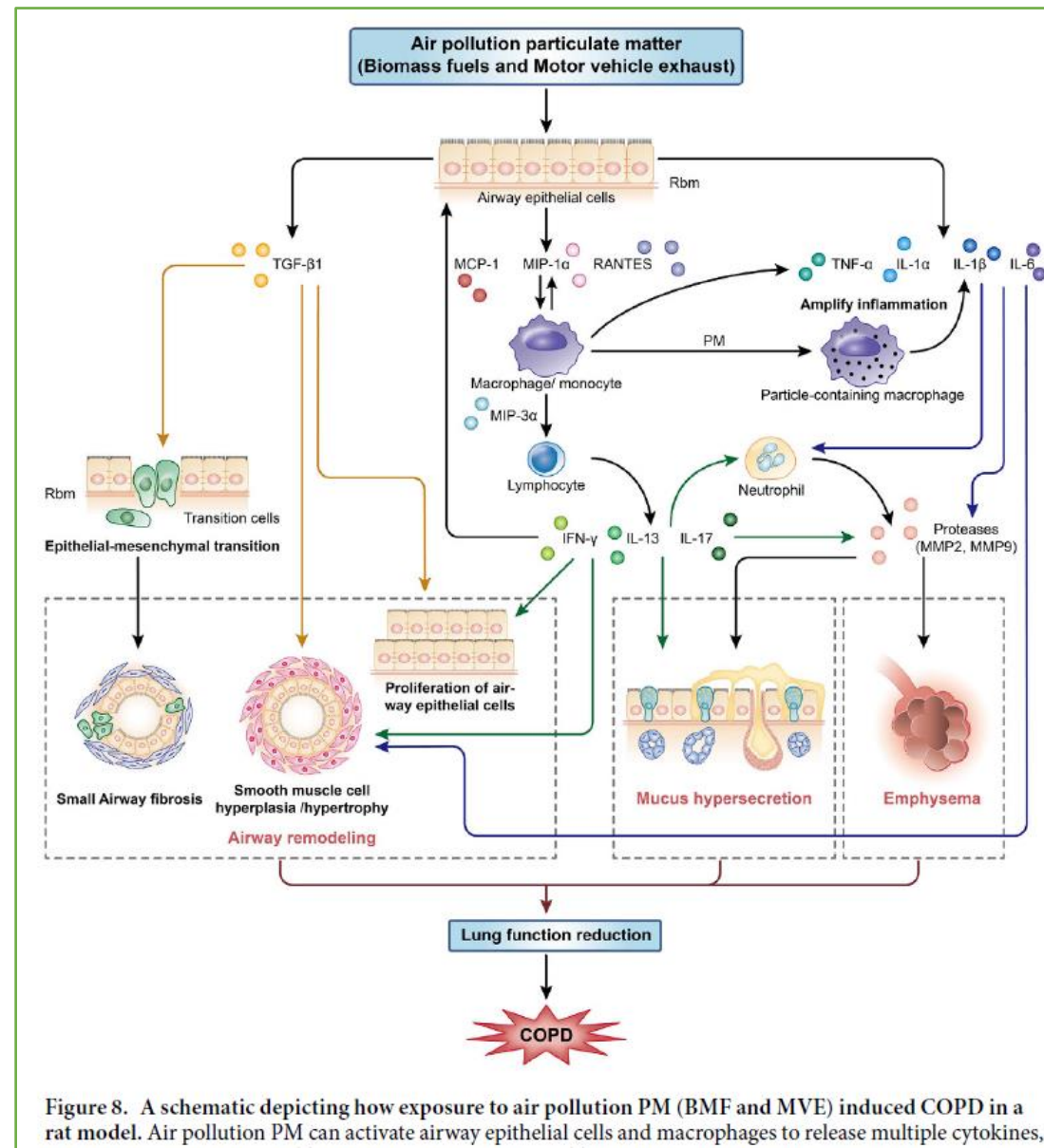


Figure 8. A schematic depicting how exposure to air pollution PM (BMF and MVE) induced COPD in a rat model. Air pollution PM can activate airway epithelial cells and macrophages to release multiple cytokines,

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미세먼지 기본 건강수칙³⁴⁾

권고 등급	근거 수준	참고 문헌	미세먼지 기본 건강수칙	미세먼지 예보등급	
				보통	나쁨
	높음	1-3	평소 미세먼지 예보 확인하기	★★	★★
	높음	4-7	나는 미세먼지 민감군*인지 확인하기 * 임산부·영유아, 어린이, 노인, 심뇌혈관질환자, 호흡기·알레르기질환자 등	★★	★★
	높음	8-11	미세먼지 노출 후 나타나는 증상* 확인하기 * 호흡 곤란, 가슴 답답함, 눈이나 피부 자극증상, 기침 등	★★	★★
	높음	12-13	보건용 마스크 준비하기		★★
	보통	14	손씻기와 위생관리 철저히 하기	★	★★
	높음	3,15	미세먼지가 나쁠 때는 야외활동 줄이기		★★
	높음	16	물을 충분히 섭취하기	★	★★
	보통	17-19	비타민과 항산화제가 풍부한 과일과 채소 먹기	★	★★

권고 등급 표기 | 근거와 편익이 명백한 경우 근거와 편익이 신뢰할만한 경우 근거가 불충분, 전문가 위원회 합의

근거 수준 표기 | 높음 : 수칙 도출의 근거가 명백한 경우 (1개 이상의 무작위임상연구 (RCT) 혹은 체계적 문헌고찰 (SR or Meta-analysis))

보통 : 수칙 도출의 근거가 명백한 경우 (1개 이상의 비 무작위임상연구 (non-RCT), 코호트 or 환자-대조군 연구 (Cohort or Case-control))

낮음 : 수칙 도출의 근거가 있으나 신뢰할 수 없는 경우, 근거가 불충분한 경우 관찰연구, 증례보고, 전문가 의견 (Expert opinion)








34) 미세먼지 건강수칙, 대한의학회·질병관리청 2020




미세먼지 기본 건강수칙

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미세먼지 실외 건강수칙

권고 등급	근거 수준	참고 문헌	미세먼지 기본 건강수칙	미세먼지 예보등급	
				보통	나쁨
▶ 외출 동안					
	높음	34-35	외출 전 미세먼지 예보를 확인하여 활동 계획 세우기	★★	★★
	높음	13,36	미세먼지가 나쁠 때는 외출 시 보건용 마스크 쓰기 : 숨이 차거나 머리가 아프면 바로 벗기		★★
	높음	3,15	미세먼지가 나쁠 때는 실외 활동량 줄이기		★★
	높음	38-39	외출 시 대로변, 공사장 주변 등 대기오염 심한 곳 피하기	★	★★
▶ 운동을 할 경우					
	높음	40-43	공원, 학교 운동장 등 미세먼지 배출원이 없는 장소에서 운동하기	★★	
	높음	44-47	차량 대기오염이 심한 대로변에서 운동 자제하기	★★	
	높음	48	미세먼지가 나쁠 때는 실외 운동을 자제하고 실내에서 강도를 낮추어 운동하기		★★

권고 등급 표기 |  근거와 편익이 명백한 경우  근거와 편익이 신뢰할만한 경우  근거가 불충분, 전문가 위원회 합의

근거 수준 표기 | 높음 : 수칙 도출의 근거가 명백한 경우 (1개 이상의 무작위임상연구 (RCT) 혹은 체계적 문헌고찰 (SR or Meta-analysis))

보통 : 수칙 도출의 근거가 명백한 경우 (1개 이상의 비 무작위임상연구 (non-RCT), 코호트 or 환자-대조군 연구 (Cohort or Case-control))

낮음 : 수칙 도출의 근거가 있으나 신뢰할 수 없는 경우, 근거가 불충분한 경우 관찰연구, 증례보고, 전문가 의견 (Expert opinion)

미세먼지 실외 건강수칙

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권고 등급	근거 수준	참고 문헌	미세먼지 민감군별 건강수칙	미세먼지 예보등급	
				보통	나쁨
보통	1-2	1-2	1. 평소 건강관리에 힘쓰고 질환 치료하기 1. Chen L, et al. Air particulate pollution and hospital admission for chronic obstructive pulmonary disease in Reno, Nevada. <i>Inhal Toxicol</i> 2000;12:281-298. 2. Norback D, et al. Asthma and rhinitis among Chinese children - Indoor and outdoor air pollution and indicators of socioeconomic status (SES). <i>Environ Int</i> 2018;115:1-8	★★	★★
보통	3-5	3-5	2. 천식, 만성폐쇄성폐질환이 있는 분은 외출 시 증상 완화제 휴대하기 3. Chen L, et al. Air particulate pollution and hospital admissions for chronic obstructive pulmonary disease in Reno, Nevada. <i>Inhal Toxicol</i> 2000;12:281-298. 4. Annesi-Maesano I, et al. Poor air quality in classrooms related to asthma and rhinitis in primary schoolchildren of the French 6 Cities Study. <i>Thorax</i> 2012;67(8):682-8. 5. US Environmental Protection Agency. Managing asthma in the school environment. Washington, DC: US EPA 2010.		★★
보통	6-7	6-7	3. 아토피피부염이 있는 분은 외출 시 보습제 휴대하기 6. Kim HO, et al. Improvement of atopic dermatitis severity after reducing indoor air pollutants. <i>Am Dermatol</i> 2013;25:292-297. 7. Norback D, et al. Sources of indoor particulate matter (PM) and outdoor air pollution in China in relation to asthma, wheeze, rhinitis and eczema among pre-school children: Synergistic effects between antibiotics use and PM10 and second hand smoke. <i>Environ Int</i> 2019;125:252-26K		★★
높음	8-13	8-13	4. 인플루엔자 예방접종 받기 8. 대한결핵 및 호흡기학회. COPD 진료지침. 2018. 9. Fiore AE, Shay DK, Broder K, et al. Prevention and control of seasonal influenza with vaccines: recommendations of the Advisory Committee on Immunization Practices (ACIP), 2009. <i>MMWR Recommendations and reports : Morbidity and mortality weekly report Recommendations and reports</i> 2009;58:1-52. 10. Feng C. Impact of ambient fine particulate matter (PM2.5) exposure on the risk of influenza-like-illness: a time-series analysis in Beijing, China. <i>Environ Health</i> 2016;15:17. 11. Nichol KL. The additive benefits of influenza and pneumococcal vaccinations during influenza seasons among elderly persons with chronic lung disease. <i>Vaccine</i> 1999;17Suppl 1:S91-3. 12. Poole PJ, Chacko E, Wood-Baker RW, et al. Influenza vaccine for patients with chronic obstructive pulmonary disease. <i>Cochrane Database Syst Rev</i> , 2006(1): p.CD002733. 13. Wongsurakiat P, Maranetra KN, Wasi C, et al. Acute respiratory illness in patients with COPD and the effectiveness of influenza vaccination: a randomized controlled study. <i>Chest</i> 2004;125(6):2011-20.	★★	★★

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미세먼지 건강수칙: 호흡기·알레르기질환자

권고 등급	근거 수준	참고 문헌	미세먼지 민감군별 건강수칙	미세먼지 예보등급		
				보통	나쁨	
높음 14-20	높음 14-20	<p>5. 의사와 상의하여 미세먼지가 나쁠 때는 보건용 마스크 올바르게 착용하기: 숨이 차거나 머리가 아프면 바로 벗기</p> <p>14. 경선영 등. 미세먼지/황사 건강피해 예방 및 권고지침: 호흡기질환. J Korean Med Assoc 2015;58(11):1060-1069.</p> <p>15. 양현종 등. 미세먼지/황사 건강피해 예방 및 권고지침: 천식. J Korean Med Assoc 2015;58(11):1034-1043.</p> <p>16. 합승현 등. 식품안전처에서 허가된 보건용 마스크의 특성 분석. 한국환경보건학회지 2015;41(3):203-215.</p> <p>17. Langrish JP, et al. Reducing personal exposure to particulate air pollution improves cardiovascular health in atients with coronary heart disease. Environ Health Perspect. 2012;120:367-372.</p> <p>18. Langrish JP. Beneficial cardiovascular effects of reducing exposure to particulate air pollution with a simple facemask. Particle and Fibre Toxicology 2009;6:8.</p> <p>19. Shi J, et al. Cardiovascular benefits of wearing particulate-Fltering respirators: a randomized crossover trial. Environ Health Perspect. 2017;125(2):175-180.</p> <p>20. Sinkule EJ, et al. Evaluation of N95 respirator use with a surgical mask cover: effects on breathing resistance and inhaled carbon dioxide. Ann Occup Hyg 2013;57:384-398.</p>		★★		
			낮음 21-22	<p>6. 미세먼지가 나쁠 때는 실외 운동을 자제하고 실내에서 강도를 낮추어 운동하기</p> <p>21. Qin F, et al. Exercise and air pollutants exposure: a systematic review and meta-analysis. Life Sci. 2019;218:153-164.</p> <p>22. Tainio M, et al. Can air pollution negate the health benefits of cycling and walking? Prev Med. 2016;87:233-236.</p>		★★
					보통 23-24	<p>7. 외출 시 대로변, 공사장 주변 등 대기오염이 심한 곳 피하기</p> <p>23. Bowatte G, et al. Traffic related air pollution and development and persistence of asthma and low lung function. Environ Int 2018;113:170-176.</p> <p>24. Gonzalez-Barcala FJ. Truck traffic related air pollution associated with asthma symptoms in young boys: a cross-sectional study. Public Health 2013;127(3):275-81.</p>

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경청 해주셔서 감사합니다.