 Chinese Medical Journal®

Health effects of air pollution: a Southern European perspective

Giovanni Viegi[1,2], Sandra Baldacci[2], Sara Maio[2], Salvatore Fasola[1], Isabella Annesi-Maesano[3], Francesco Pistelli[4], Laura Carrozzi[5], Stefania La Grutta[1], Francesco Forastiere[1]

[1]National Research Council (NCR) Institute for Biomedical Research and Innovation (IRIB), 90146 Palermo, Italy;

[2]National Research Council (NCR) Institute of Clinical Physiology (IFC), 56126 Pisa, Italy;

[3]Department of Epidemiology of Allergic and Respiratory Diseases, Sorbonne Université and INSERM, Institut Pierre Louis d'Épidémiologie et de Santé Publique, F75012 Paris, France;

[4]Department of Cardiothoracic and Vascular, University Hospital of Pisa, 56124 Pisa, Tuscany, Italy;

[5]Department of Surgical, Medical, Molecular Pathology and Critical Area, University of Pisa, 56126 Pisa, Tuscany, Italy.

Abstract

Objective: To summarize the main updated evidence about the health effects of air pollution, with a special focus on Southern Europe.

Data sources: Literature was obtained through PubMed Central and the official websites of European Agencies and Scientific Societies.

Study selection: Recent shreds of evidence about the health effects of air pollution coming from international reports and original research were collected and described in this review.

Results: Air pollution is an avoidable risk factor that causes a huge burden for society, in terms of death, health disorders, and huge socio-economic costs. The southern European countries face a more threatening problem because they experience the effects of both anthropogenic pollutants and natural dusts (particulate matter [PM]). The European Environment Agency reported the number of premature deaths in the 28 countries of the European Union attributable to air pollutant exposure in the year 2016: 374,000 for $PM_{2.5}$, 68,000 for nitrogen dioxide, and 14,000 for ozone. In Italy, time series and analytical epidemiological studies showed increased cardio-respiratory hospital admissions and mortality, as well as increased risk of respiratory diseases in people living in urban areas.

Conclusions: Based on abundant evidence, the World Health Organization, which hosts the Global Alliance against Chronic Respiratory Diseases (GARD), the scientific respiratory societies, and the patients' associations, as well as others in the health sector, must increase their engagement in advocacy for clean air policies.

Keywords: Environment; Respiratory disorders; Epidemiology

Introduction

In October 2019, the European Environment Agency (EEA) released its 2019 annual report on "Air quality in Europe."[1] The report confirmed that the percent of the urban population in the European Union (EU)-28 countries which was exposed to air pollution above EU standards was generally much lower than the proportion estimated to be exposed to air pollution above the World Health Organization (WHO) Air Quality Guidelines (AQG) [Figure 1].[1] For particulate matter (PM) with an aerodynamic diameter smaller than 2.5 μm ($PM_{2.5}$), 6% to 8% of people lived in areas exceeding the EU standards whereas 74% to 81% of people lived in areas exceeding the WHO-AQG. For ozone (O_3), 2% to 29% of people lived in areas exceeding the EU standards whereas 95% to 98% of people lived in areas exceeding the WHO-AQG. The nitrogen dioxide (NO_2) values are identical (7%–8%) because the EU and the WHO-AQG reference values are the same.[1] The reason of the difference between WHO AQG and EU standards, and thus between the percentages of the exposed population, is likely due to the fact that WHO essentially takes into consideration the health effects of air pollution, whilst the EU also takes into account the economic sustainability of the actions needed to reduce the air pollution concentrations.

Among the health effect indicators published by the EEA, the yearly numbers of premature deaths attributable to $PM_{2.5}$, NO_2, and O_3 in 2016 are striking: 374,000 for $PM_{2.5}$, 68,000 for NO_2 and 14,000 for O_3, in the EU-28, as well as 412,000 for $PM_{2.5}$, 71,000 for NO_2 and 15,100 for O_3 in the 41 European countries.[1]

Access this article online

Quick Response Code:

Website: www.cmj.org

DOI: 10.1097/CM9.0000000000000869

Correspondence to: Dr. Giovanni Viegi, National Research Council (NCR) Institute for Biomedical Research and Innovation (IRIB), Via U. La Malfa, 153, 90146 Palermo, Italy

E-Mail: giovanni.viegi@irib.cnr.it

Chinese Medical Journal 2020;133(13)

Received: 22-01-2020 **Edited by:** Peng Lyu

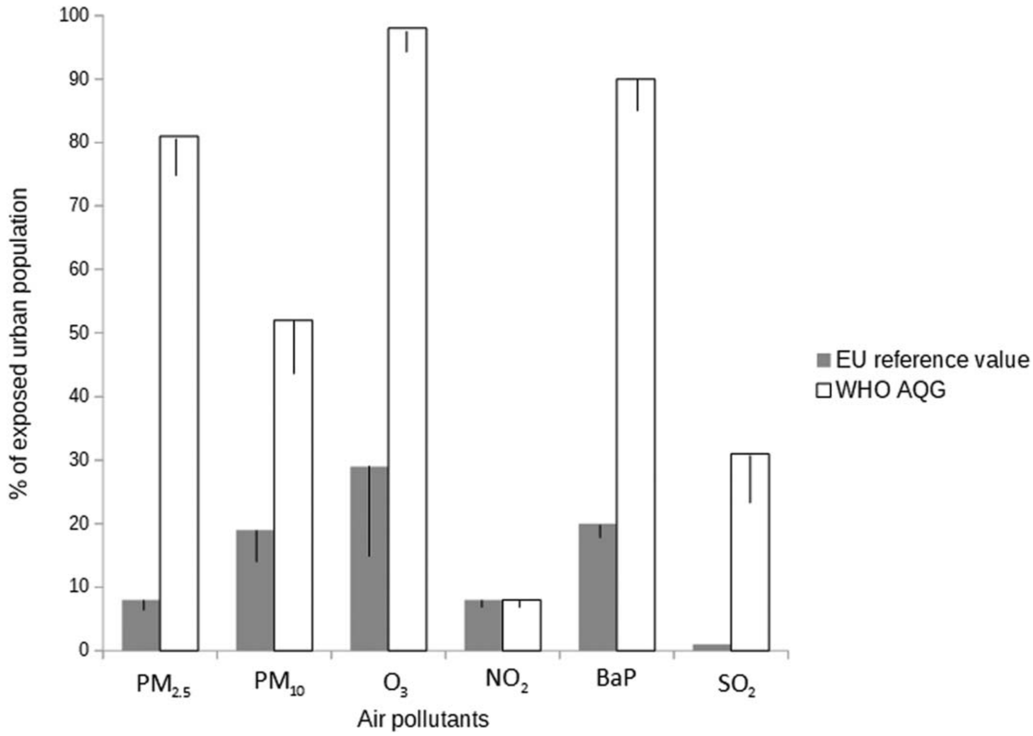

Figure 1: Percentage of urban population exposed to air pollution concentration above the standards in the European Union (EU)-28 during period 2015 to 2017. In the grey bar, the percentage of urban population exposed to air pollution concentration above the EU reference values is reported; in the white bar, the percentage of urban population exposed to air pollution concentration above the WHO air quality guidelines is reported. The black line inside the bar represents the percentage range of urban population exposed. BaP: Benzo(a)pyrene; EU: European Union; NO_2: Nitrogen dioxide; O_3: Ozone; $PM_{2.5}$: Particulate matter with an aerodynamic diameter smaller than 2.5 μm; PM_{10}: Particulate matter with an aerodynamic diameter smaller than 10 μm; SO_2: Sulfur dioxide; WHO AQG: World Health Organization Air Quality Guidelines. The figure was modified from reference 1.

Another relevant indicator is represented by the years of life lost (YLL) attributable to $PM_{2.5}$, NO_2, and O_3: in the EU-28, YLL were 3,848,000 for $PM_{2.5}$, 682,000 for NO_2 and 149,000 for O_3. Concerning the 41 European countries, YLL were 4,223,000 for $PM_{2.5}$, 707,000 for NO_2 and 160,000 for O_3.[1]

A recent comprehensive review on what constitutes an adverse health effect of air pollution was jointly published by the American Thoracic Society (ATS) and the European Respiratory Society (ERS).[2] It updated and expanded previous important documents published by ATS in 1985 and 2000.[3,4] The ATS/ERS report integrated the latest scientific evidence into a general framework for interpreting the adverse effects of air pollution on human health. It gave an overview of diseases, conditions, and biomarkers affected by outdoor air pollution showing that air pollution affects almost all systems of the human body, including the respiratory, cardiovascular, central nervous, and endocrine systems. Besides, air pollution causes adverse effects on the fetus.[2]

The adverse respiratory effects of air pollution span the life cycle and affect an array of illnesses, from symptoms to premature mortality. Symptoms, such as cough, sputum, wheeze, and dyspnea are increased. Morbidity, as measured by hospital admissions, and prevalence, as measured by the diagnoses of asthma and chronic obstructive pulmonary disease (COPD), are all related to air pollution. The ATS/ERS document points out clinical and biological biomarkers that can be used to assess the detrimental pollution effects in analytical epidemiological studies on the general population, such as lung function tests, bronchial responsiveness, and the fractional concentration of exhaled nitric oxide.[2]

This review article is based on the presentation, entitled "Health impact of air pollution," delivered by Dr. Giovanni Viegi within the Pre-conference Workshop of the 13th Global Alliance against Chronic Respiratory Diseases (GARD) General Meeting, in Beijing, on October 25, 2019. It reports recent references about the health effects of air pollution, with a special focus on Southern Europe.

Methods

Literature was obtained through PubMed Central (archive of biomedical and life sciences journal literature at the U.S. National Institutes of Health's National Library of Medicine) and the official websites of European Agencies and Scientific Societies.

We chose relevant epidemiological studies, meta-analyses, and systematic reviews and summarized them based on the following keywords: "outdoor air pollution," "cardio-respiratory morbidity and mortality," "respiratory symptoms," "respiratory diseases," "asthma," "Chronic obstructive pulmonary disease (COPD)," "lung function," "Southern Europe" and "Italy." In addition, we paid special attention to the Italian Po Delta and Pisa epidemiological studies carried out by the Italian National Research Council (CNR) [Tables 1 and 2].

The Current Global Perspective

A recent study on ambient particulate air pollution and mortality in a large number of cities ($n = 652$) published concentration-response curves demonstrating a mortality effect below the "safe" threshold levels proposed by the US National Ambient Air Quality Standards (NAAQS), the China Air Quality Standards (AQS), and the WHO. The effects occurred at 24-h average concentrations below 50 $\mu g/m^3$ for PM_{10} and below 25 $\mu g/m^3$ for $PM_{2.5}$.[5]

More studies are needed to assess the health effects of air pollution in areas of low particulate pollution. The Health Effect Institute prepared a report using three studies in areas characterized by low average $PM_{2.5}$ levels, such as 15 $\mu g/m^3$ (Europe), 11 $\mu g/m^3$ (US), and 7 $\mu g/m^3$ (Canada).[6] A 10 $\mu g/m^3$ increase in $PM_{2.5}$ was associated with a 7.3% increase in mortality, reaching a value of 13.6% at concentrations below 12 $\mu g/m^3$ ($PM_{2.5}$ US NAAQS). Moreover, the health benefit per unit decrease in $PM_{2.5}$ levels was larger for concentrations below the annual NAAQS than for those above that level.[6]

Epidemiological Studies Including Southern European Areas

Long-term exposure to fine particulate air pollution was associated with natural-cause mortality, even at PM concentrations well below the current European annual mean limit, in a study on 22 European cohorts,[7] as well as exposure to NO_2 was significantly associated with premature mortality in a Spanish cohort.[8] Higher exposure to traffic-related air pollutants was associated with respiratory morbidity in European cohorts: increased asthma incidence in adults,[9] increased lifetime asthma prevalence[10,11] and decreased lung function during adulthood, that is, an outcome strictly related to the development and progression of COPD.[12]

Moreover, a meta-analysis of data from nine European countries showed a statistically significant association between lung cancer development and PM exposure.[13]

Fewer data are available on the relationship between air pollution and respiratory allergic diseases, even if increasing air pollution, improved hygiene practices, and climatic changes are identified as possible determinants of the allergy upward trend.[14] The first study about the effect of long-term PM exposure and rhinitis incidence in adults was published in 2018: data from two European cohort studies did not show any association between annual exposure to air pollutants at the participants' home addresses and rhinitis incidence reported by the subjects.[15] Differently, the same authors, later on, observed that increased air pollution exposure was linked to an increased severity score of rhinitis.[16]

The Peculiarity of Southern Europe

According to the EEA report, Southern Europe is affected by higher concentrations of outdoor air pollutants.[1] In the Po River Valley of Italy, the orographic and climatic conditions hinder pollutant dispersion, making it one of the most polluted areas in Europe. This is clearly shown by the satellite images of the European Space Agency, highlighting a big stain, made of NO_2 and fine particles, situated above the Po Valley.[17]

The MED-PARTICLES project funded by the EU showed that the Mediterranean countries had a higher percentage increase in mortality associated with a 10 $\mu g/m^3$ increase in PM compared to other European areas. In particular, an increase of 1.91% (95% confidence interval [CI] 0.71%–3.12%) in respiratory mortality was associated with a 10 $\mu g/m^3$ increase in $PM_{2.5}$ after a lag period of up to 5 days.[18] In the same study, $PM_{2.5}$ and PM_{10} were positively associated with respiratory admissions in eight cities of Southern Europe.[19]

The type of climate can influence the respiratory health; the Italian phase of the European Community Respiratory Health Survey on young-adults suggested that climate plays a role in determining the between-center heterogeneity in the prevalence of asthma in Italy, with higher prevalence in dry-hot Mediterranean climates, and lower prevalence in rainy-cold northern climates.[20] As regards rhinitis, it was suggested an interaction between climate and NO_2 outdoor exposure, increasing the risk of allergic rhinitis in subjects exposed to a high and stable temperature in Italy.[21]

A peculiar adverse situation for the Mediterranean countries is the presence of desert sand dust, which can be high for many days in the year. For example, in Italy, the number of days with high African dust (up to 100 $\mu g/m^3$) ranges from 17% in the Po River Valley to 37% in Palermo, Sicily.[22]

For many years, there has been the false belief that desert sand dust was inert and did not cause harm to the health of exposed citizens. However, recent studies have shown that this is not the case. Stafoggia and colleagues demonstrated that, similarly to anthropogenic dust, each 10 $\mu g/m^3$ increase in desert sand PM_{10} is associated with increased all-cause and cardiovascular mortality, as well as respiratory hospital admissions for children and adolescents. For the latter, the percent increase was 2.38 (95% CI 0.09–4.71).[23]

More recently, a Greek study showed that, during the desert dust storm with daily-average PM_{10} above 500 $\mu g/m^3$, there was an increase in emergency department visits for dyspnea and COPD exacerbations and an increase in COPD hospital admissions.[24]

Air Pollution Effects in Italy

The impact of air pollution on human health in Italy was estimated in the "Integrated assessment of the environment and health impact of air pollution in Italy" (VIIAS) project in 2015. The project used the methodological approach of the health impact assessment that combines dispersion models and monitoring network data. Sub-municipal census data of the population were projected on the dispersion model grid. Health outcomes on the baseline years (2005 and 2010) and on three scenarios for 2020 were used to evaluate the trends and effects of different policies.[25] A total of 34,552 premature deaths attributable to $PM_{2.5}$ were estimated for 2005, while 28,595 were estimated for 2020 under the current legislation.[25] This decrease was due to reduced emissions from several sources (eg, vehicles, industry), leading to a reduction in air pollution concentrations. The study showed that considerable improvement could be achieved if Italy were to comply with the WHO recommendations [Table 2].

Moreover, in Italy, two major analytical longitudinal surveys on general population samples from 1980 to 2011 were conducted by the Italian CNR. One was in Po River Delta, a rural area near Venice, before and after the construction of a large oil-burning central power plant. The other was in Pisa and its surrounding area, before and after the construction of a new highway far from the residential zones.[26,27] This epidemiological investigation used subjective (eg, standardized questionnaire on respiratory symptoms, diseases, and risk factors) and objective tools (eg, lung function tests, bronchial responsiveness, skin prick tests, inflammation, and mutagenetic biomarkers).

In the early nineties, it became clear that living in the city was associated with more respiratory symptoms and diseases than living in a rural area [Table 1].[28,29] Those living in cities had higher bronchial responsiveness as measured by a methacholine dose-response challenge.[30] Also, city residents had a 41% increased risk of developing airway hyper-responsiveness compared to rural residents. The 41% increase of city-dwellers was similar to the 39% increased risk shown by smokers compared to never smokers [Table 2].[30]

A cross-sectional spatial analysis of the effects of traffic-related air pollution was carried out in the urban and suburban areas of Pisa, Italy.[31] The house of each

Table 1: Respiratory health effects of air pollution in Italy (study period 1991–1999).

Study	Study area	Exposure	Health outcome	Health outcome results in the respective study area
Viegi *et al*, 1991[28]	Rural area	Traffic, industry	Chronic cough prevalence (%)	9
	Suburban-traffic area			10
	Urban-traffic area			11
	Urban-traffic-industry area			17
	Rural area	Traffic, industry	Chronic phlegm prevalence (%)	9
	Suburban-traffic area			9
	Urban-traffic area			7
	Urban-traffic-industry area			14
	Rural area	Traffic, industry	Wheeze prevalence (%)	8
	Suburban-traffic area			15
	Urban-traffic area			17
	Urban-traffic-industry area			23
	Rural area	Traffic, industry	Dyspnea prevalence (%)	14
	Suburban-traffic area			22
	Urban-traffic area			26
	Urban-traffic-industry area			28
	Rural area	Traffic, industry	Rhinitis prevalence (%)	5
	Suburban-traffic area			17
	Urban-traffic area			13
	Urban-traffic-industry area			25
	Rural area	Traffic, industry	Chronic bronchitis or emphysema prevalence (%)	2
	Suburban-traffic area			5
	Urban-traffic area			7
	Urban-traffic-industry area			8
	Rural area	Traffic, industry	Asthma prevalence (%)	5
	Suburban-traffic area			7
	Urban-traffic area			12
	Urban-traffic-industry area			5
Petruzzelli *et al*, 1998[32]	Urban area *vs*. suburban area	Traffic	Serum antibodies to Benzo(a)pyrene Diol Epoxide-DNA adducts (OR, 95% CI)	1.49 (1.16–1.92)

OR: Odds ratio; 95% CI: 95% Confidence interval.

Table 2: Respiratory health effects of air pollution in Italy (study period 2000–2019).

Study	Study area	Exposure	Health outcome	Health outcome results in the respective study area
Viegi *et al*, 2004[29]	Rural area	Traffic, industry	Obstructive lung diseases prevalence (%)	6.9
Maio *et al*, 2009[30]	Urban-suburban area			10.9
	Urban-suburban area *vs*. rural area	Traffic, industry	Bronchial hyper-responsiveness (OR, 95% CI)	1.41 (1.13–1.76)
VIIAS[25]	Italy	$PM_{2.5}$	Number of attributable deaths due to non-accidental causes in 2005 (*n*)	34,552
	North Italy			22,485
	Central Italy			5513
	South Islands			6554
	Urban areas			19,358
	Non-urban areas			15,194
	Italy	$PM_{2.5}$	Attributable mortality (rate/100,000) due to non-accidental causes in 2005(*n*)	86
	North Italy			119
	Center Italy			62
	South Islands			53
	Urban areas			136
	Non-urban areas			59
Maio *et al*, 2016[33]	Urban area *vs*. suburban area	Traffic	Allergic rhinitis (OR, 95% CI)	1.19 (1.05–1.35)
	Urban area *vs*. suburban area	Traffic	Usual phlegm (OR, 95% CI)	1.30 (1.12–1.49)
	Urban area *vs*. suburban area	Traffic	COPD (OR, 95% CI)	1.54 (1.25–1.90)
Maio *et al*, 2019[34]	Urban-suburban area	Incident vehicular traffic exposure	Asthma attacks incidence (OR, 95% CI)	2.20 (1.00–4.50)
	Urban-suburban area	Incident vehicular traffic exposure	Allergic rhinitis incidence (OR, 95% CI)	1.80 (1.20–2.80)
	Urban-suburban area	Incident vehicular traffic exposure	COPD incidence (OR, 95% CI)	2.40 (1.10–5.20)

VIIAS: Integrated assessment of the environment and health impact of air pollution in Italy; $PM_{2.5}$: Particulate matter with an aerodynamic diameter smaller than 2.5 μm; OR: Odds ratio; 95% CI: 95% Confidence interval; COPD: Chronic obstructive pulmonary disease.

participating subject was geo-referenced and people were stratified in three groups according to the distance from the main road: less than 100 m, 100 to 250 m, more than 250 m. People who lived closest to the traffic had significantly increased risks of respiratory symptoms and diseases and airflow obstruction, as measured by the forced expiratory volume in the first second /forced vital capacity ratio [Table 2].[31]

Urban residents were also more likely to have increased serum antibodies to benzo(*a*)pyrene diol epoxide-DNA adducts (odds ratio [OR] 1.49, 95% CI 1.16–1.92), compared to sub-urban residents [Table 1].[32]

Three cross-sectional surveys conducted in Pisa and suburbs from 1985 to 2011 have shown increased prevalence rates of respiratory symptoms and diseases, especially allergic rhinitis. Living in the urban area was associated with increased risks for allergic rhinitis (OR 1.19, 95% CI 1.05–1.35), cough (OR 1.14, 95% CI 0.99–1.31), phlegm (OR 1.30, 95% CI 1.12–1.49), and COPD (OR 1.54, 95% CI 1.25–1.90), compared to those living in the sub-urban area [Table 2].[33]

The 18-year cumulative incidence of respiratory and allergic symptoms, diseases and risk factors from the Pisa epidemiological study was published in 2019.[34] The cumulative incidence values ranged from 3.2% for asthma to 31.7% for allergic rhinitis. The incidence of vehicular traffic exposure was significantly associated with the incidence of asthma attacks (OR 2.20, 95% CI 1.00–4.50), allergic rhinitis (OR 1.80, 95% CI 1.20–2.80), and COPD (OR 2.40, 95% CI 1.10–5.20) [Table 2].[34]

Advocacy for Clean Air in Europe

The GARD was launched in Beijing on March 28, 2006, as a partnership among the WHO, governmental institutions, scientific societies, and patients' associations. The GARD motto is "a world where all people breathe freely." Air pollution is one of the most important risk factors for health and reducing it is a priority for the prevention and control of chronic respiratory diseases.[35]

The ERS has been active in advocating for more stringent EU air quality limits to align them with the WHO AQG, by issuing ten principles for clean air.[36] Unfortunately, that campaign was not successful in changing the EU standards, which remain much higher than the WHO guidelines. However, the ERS has issued other ten principles for climate, environment, and respiratory health with similar goals.[37]

A workshop on a global approach to the fight against air pollution and climate change, organized by the Vatican in 2017, produced a Declaration of the Health of the People, Health of Planet and Our Responsibility and issued twelve recommendations.[38]

In the last decade, the WHO has taken the leadership of the fight against air pollution.[39] The Global Conference on Air Quality and Health, organized by the WHO and held at its headquarters in Geneva on October 30 to November 1, 2018, was a historical step in inducing many commitments from governments and non-governmental organizations.

The awareness of environmental exposures is increasing in the general population and assisted by the use of the risk charts, such as those for COPD elaborated in collaboration with the Italian National Institute of Health.[40] The charts let people calculate their risk of getting COPD in the next 10 years based on gender, age, smoking habits, and environmental exposures.

Conclusion and Call to Action

Air pollution is an avoidable health risk that causes a great burden to society in terms of death and health disorders, at a huge social and economic cost. Within Europe, the Southern countries face a difficult situation because they experience the effects of anthropogenic and natural air pollution. The EU AQS are laxer than those of the WHO and recent studies have shown significant health effects even below the most stringent current standards. The WHO, GARD, scientific societies, and other members of the health community must increase their engagement in advocacy for clean air.

Conflicts of interest

None.

References

1. European Environment Agency. Air Quality in Europe - 2019 Report. EEA Report No. 10/2019. Luxembourg: Publications Office of the European Union, 2019.
2. Thurston GD, Kipen H, Annesi-Maesano I, Balmes J, Brook RD, Cromar K, *et al.* A joint ERS/ATS policy statement: what constitutes an adverse health effect of air pollution? An analytical framework. Eur Respir J 2017;49:1600419. doi: 10.1183/13993003.00419-2016.
3. American Thoracic Society. Guidelines as to what constitutes an adverse respiratory health effect, with special reference to epidemiologic studies of air pollution. Am Rev Respir Dis 1985;131:666–668. doi: 10.1164/arrd.1985.131.4.666.
4. American Thoracic Society. What constitutes an adverse health effect of air pollution? Official statement of the American Thoracic Society. Am J Respir Crit Care Med 2000;161:665–673. doi: 10.1164/ajrccm.161.2.ats4-00.
5. Liu C, Chen R, Sera F, Vicedo-Cabrera AM, Guo Y, Tong S, *et al.* Ambient particulate air pollution and daily mortality in 652 cities. N Engl J Med 2019;381:705–715. doi: 10.1056/NEJMoa1817364.
6. Dominici F, Schwartz J, Di Q, Braun D, Choirat C, Zanobetti A. Assessing adverse health effects of long-term exposure to low levels of ambient air pollution: phase 1. Res Rep Health Eff Inst 2019;200:1–51.
7. Beelen R, Raaschou-Nielsen O, Stafoggia M, Andersen ZJ, Weinmayr G, Hoffmann B, *et al.* Effects of long-term exposure to air pollution on natural-cause mortality: an analysis of 22 European cohorts within the multicentre ESCAPE project. Lancet 2014;383:785–795. doi: 10.1016/S0140-6736(13)62158-3.
8. Nieuwenhuijsen MJ, Gascon M, Martinez D, Ponjoan A, Blanch J, Garcia-Gil MDM, *et al.* Air pollution, noise, blue space, and green space and premature mortality in Barcelona: a mega cohort. Int J Environ Res Public Health 2018;15:E2405. doi: 10.3390/ijerph15112405.
9. Jacquemin B, Siroux V, Sanchez M, Carsin AE, Schikowski T, Adam M, *et al.* Ambient air pollution and adult asthma incidence in six European cohorts (ESCAPE). Environ Health Perspect 2015;123:613–621. doi: 10.1289/ehp.1408206.
10. Cibella F, Cuttitta G, La Grutta S, Melis MR, Lospalluti ML, Uasuf CG, *et al.* Proportional Venn diagram and determinants of allergic respiratory diseases in Italian adolescents. Pediatr Allergy Immunol 2011;22:60–68. doi: 10.1111/j.1399-3038.2010.01097.x.
11. Khreis H, Cirach M, Mueller N, de Hoogh K, Hoek G, Nieuwenhuijsen MJ, *et al.* Outdoor air pollution and the burden of childhood asthma across Europe. Eur Respir J 2019;54:1802194. doi: 10.1183/13993003.02194-2018.
12. Adam M, Schikowski T, Carsin AE, Cai Y, Jacquemin B, Sanchez M, *et al.* Adult lung function and long-term air pollution exposure. ESCAPE: a multicentre cohort study and meta-analysis. Eur Respir J 2015;45:38–50. doi: 10.1183/09031936.00130014.
13. Raaschou-Nielsen O, Andersen ZJ, Beelen R, Samoli E, Stafoggia M, Weinmayr G, *et al.* Air pollution and lung cancer incidence in 17 European cohorts: prospective analyses from the European Study of Cohorts for Air Pollution Effects (ESCAPE). Lancet Oncol 2013;14:813–822. doi: 10.1016/S1470-2045(13)70279-1.
14. Baldacci S, Maio S, Cerrai S, Sarno G, Baïz N, Simoni M, *et al.* HEALS Study. Allergy and asthma: effects of the exposure to particulate matter and biological allergens. Respir Med 2015;109:1089–1104. doi: 10.1016/j.rmed.2015.05.017.
15. Burte E, Leynaert B, Bono R, Brunekreef B, Bousquet J, Carsin AE, *et al.* Association between air pollution and rhinitis incidence in two European cohorts. Environ Int 2018;115:257–266. doi: 10.1016/j.envint.2018.03.021.
16. Burte E, Leynaert B, Marcon A, Bousquet J, Benmerad M, Bono R, *et al.* Long-term air pollution exposure is associated with increased severity of rhinitis in 2 European cohorts. J Allergy Clin Immunol 2020;145:834–842.e6. doi: 10.1016/j.jaci.2019.11.040.
17. European Space Agency. Available from: http://www.esa.int/Applications/Observing_the_Earth/Envisat/Global_air_pollution_map_produced_by_Envisat_s_SCIAMACHY. [Accessed April 2, 2020]
18. Samoli E, Stafoggia M, Rodopoulou S, Ostro B, Declercq C, Alessandrini E, *et al.* Associations between fine and coarse particles and mortality in Mediterranean cities: results from the MED-PARTICLES project. Environ Health Perspect 2013;121:932–938. doi: 10.1289/ehp.1206124.
19. Stafoggia M, Samoli E, Alessandrini E, Cadum E, Ostro B, Berti G, *et al.* MED-PARTICLES Study Group. Short-term associations between fine and coarse particulate matter and hospitalizations in Southern Europe: results from the MED-PARTICLES project. Environ Health Perspect 2013;121:1026–1033. doi: 10.1289/ehp.1206151.
20. Pesce G, Bugiani M, Marcon A, Marchetti P, Carosso A, Accordini S, *et al.* Geo-climatic heterogeneity in self-reported asthma, allergic rhinitis and chronic bronchitis in Italy. Sci Total Environ 2016;544:645–652. doi: 10.1016/j.scitotenv.2015.12.015.
21. de Marco R, Poli A, Ferrari M, Accordini S, Giammanco G, Bugiani M, *et al.* ISAYA study group. Italian study on asthma in young adults. The

impact of climate and traffic-related NO2 on the prevalence of asthma and allergic rhinitis in Italy. Clin Exp Allergy 2002;32:1405–1412.
22. Pey J, Querol X, Alastuey A, Forastiere F, Stafoggia M. African dust outbreaks over the Mediterranean Basin during 2001–2011: PM10 concentrations, phenomenology and trends, and its relation with synoptic and mesoscale meteorology. Atmos Chem Phys 2013;13:1395–1410. doi: 10.5194/acp-13-1395-2013.
23. Stafoggia M, Zauli-Sajani S, Pey J, Samoli E, Alessandrini E, Basagaña X, *et al*. Desert dust outbreaks in Southern Europe: contribution to daily PM_{10} concentrations and short-term associations with mortality and hospital admissions. Environ Health Perspect 2016;124:413–419. doi: 10.1289/ehp.1409164.
24. Lorentzou C, Kouvarakis G, Kozyrakis GV, Kampanis NA, Trahanatzi I, Fraidakis O, *et al*. Extreme desert dust storms and COPD morbidity on the island of Crete. Int J Chron Obstruct Pulmon Dis 2019;14:1763–1768. doi: 10.2147/COPD.S208108.
25. Metodi per la Valutazione Integrata dell'Impatto Ambientale e Sanitario dell'inquinamento atmosferico (VIIAS). Available from: https://www.viias.it/. [Accessed December 30, 2019]
26. Carrozzi L, Giuliano G, Viegi G, Paoletti P, Di Pede F, Mammini U, *et al*. The Po River Delta epidemiological study of obstructive lung disease: sampling methods, environmental and population characteristics. Eur J Epidemiol 1990;6:191–200. doi: 10.1007/bf00145793.
27. Baldacci S, Carrozzi L, Viegi G, Giuntini C. Assessment of respiratory effect of air pollution: study design on general population samples. JEPTO 1997;16:77–83.
28. Viegi G, Paoletti P, Carrozzi L, Vellutini M, Diviggiano E, Di Pede C, *et al*. Prevalence rates of respiratory symptoms in Italian general population samples, exposed to different levels of air pollution. Environ Health Perspect 1991;94:95–99. doi: 10.1289/ehp.94-1567935.
29. Viegi G, Matteelli G, Angino A, Scognamiglio A, Baldacci S, Soriano JB, *et al*. The proportional Venn diagram of obstructive lung disease in the Italian general population. Chest 2004;126:1093–1101. doi: 10.1378/chest.126.4.1093.
30. Maio S, Baldacci S, Carrozzi L, Polverino E, Angino A, Pistelli F, *et al*. Urban residence is associated with bronchial hyper-responsiveness in Italian general population samples. Chest 2009;135:434–441. doi: 10.1378/chest.08-0252.
31. Nuvolone D, Della Maggiore R, Maio S, Fresco R, Baldacci S, Carrozzi L, *et al*. Geographical information systems and environmental epidemiology: a cross-sectional spatial analysis of the effects of traffic-related air pollution on population respiratory health. Environ Health 2011;10:1–12. doi: 10.1186/1476-069X-10-12.
32. Petruzzelli S, Celi A, Pulerà N, Baliva F, Viegi G, Carrozzi L, *et al*. Serum antibodies to benzo(a)pyrene diol epoxide-DNA adducts in the general population: effects of air pollution, tobacco smoking, and family history of lung diseases. Cancer Res 1998;58: 4122–4126.
33. Maio S, Baldacci S, Carrozzi L, Pistelli F, Angino A, Simoni M, *et al*. Respiratory symptoms/diseases prevalence is still increasing: a 25yr population study. Respir Med 2016;110:58–65. doi: 10.1016/j.rmed.2015.11.006.
34. Maio S, Baldacci S, Carrozzi L, Pistelli F, Simoni M, Angino A, *et al*. 18-yr cumulative incidence of respiratory/allergic symptoms/diseases and risk factors in the Pisa epidemiological study. Respir Med 2019;158:33–41. doi: 10.1016/j.rmed.2019.09.013.
35. Bousquet J, Kiley J, Bateman ED, Viegi G, Khaltaev N, Cruz AA. Prioritized research agenda for prevention and control of chronic respiratory diseases. Eur Respir J 2010;36:995–1001. doi: 10.1183/09031936.00012610.
36. Brunekreef B, Annesi-Maesano I, Ayres JG, Forastiere F, Forsberg B, Künzli N, *et al*. Ten principles for clean air. Eur Respir J 2012;39:525–528. doi: 10.1183/09031936.00001112.
37. Barry M, Annesi-Maesano I. Ten principles for climate, environment and respiratory health. Eur Respir J 2017;50:1701912. doi: 10.1183/13993003.01912-2017.
38. Ramanathan V, Samet J, Neira M, Sorondo MS. Air pollution, climate change, and health: a declaration from the Vatican. Ann Am Thorac Soc 2018;15:1027–1029. doi: 10.1513/AnnalsATS.201805-319ED.
39. First WHO Global Conference on Air Quality and Health. Available from: https://www.who.int/airpollution/events/conference/en/. [Accessed December 16, 2019]
40. Zuccaro P, Pichini S, Mortali C, Pacifici R, Viegi G, Baldacci S, *et al*. Fumo e patologie respiratorie. Le carte del rischio per broncopneumopatia cronica ostruttiva e tumore al polmone. Roma: Centro Stampa De Vittoria S.r.l., 2004

How to cite this article: Viegi G, Baldacci S, Maio S, Fasola S, Annesi-Maesano I, Pistelli F, Carrozzi L, La Grutta S, Forastiere F. Health effects of air pollution: a Southern European perspective. Chin Med J 2020;133:1568–1574. doi: 10.1097/CM9.0000000000000869