Health effects of air pollution: a Southern European perspective

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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 to PM2.5, 68,000 to nitrogen dioxide, and 14,000 to 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 (PM2.5), 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 (O3), 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 (NO2) 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 PM2.5, NO2, and O3 in 2016 are striking: 374,000 for PM2.5, 68,000 for NO2 and 14,000 for O3, in the EU-28, as well as 412,000 for PM2.5, 71,000 for NO2 and 15,100 for O3 in the 41 European countries.[1]
Another relevant indicator is represented by the years of life lost (YLL) attributable to PM2.5, NO2, and O3: in the EU-28, YLL were 3,848,000 for PM2.5, 682,000 for NO2 and 149,000 for O3. Concerning the 41 European countries, YLL were 4,223,000 for PM2.5, 707,000 for NO2 and 160,000 for O3.[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].

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; NO2: Nitrogen dioxide; O3: Ozone; PM2.5: Particulate matter with an aerodynamic diameter smaller than 2.5 \( \mu \text{m} \); PM10: Particulate matter with an aerodynamic diameter smaller than 10 \( \mu \text{m} \); SO2: Sulfur dioxide; WHO AQG: World Health Organization Air Quality Guidelines. The figure was modified from [1].
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 μg/m^3 for PM_{10} and below 25 μg/m^3 for PM_{2.5}.

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 μg/m^3 (Europe), 11 μg/m^3 (US), and 7 μg/m^3 (Canada). A 10 μg/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 μg/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.

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, as well as exposure to NO\textsubscript{2} was significantly associated with premature mortality in a Spanish cohort. Higher exposure to traffic-related air pollutants was associated with respiratory morbidity in European cohorts: increased asthma incidence in adults, increased lifetime asthma prevalence and decreased lung function during adulthood, that is, an outcome strictly related to the development and progression of COPD.

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

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. 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. Differently, the same authors, later on, observed that increased air pollution exposure was linked to an increased severity score of rhinitis.

The Peculiarity of Southern Europe
According to the EEA report, Southern Europe is affected by higher concentrations of outdoor air pollutants. 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\textsubscript{2} and fine particles, situated above the Po Valley.

The MED-PARTICLES project funded by the EU showed that the Mediterranean countries had a higher percentage increase in mortality associated with a 10 μg/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 μg/m^3 increase in PM\textsubscript{10} after a lag period of up to 5 days. In the same study, PM\textsubscript{2.5} and PM\textsubscript{10} were positively associated with respiratory admissions in eight cities of Southern Europe.

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. As regards rhinitis, it was suggested an interaction between climate and NO\textsubscript{2} outdoor exposure, increasing the risk of allergic rhinitis in subjects exposed to a high and stable temperature in Italy.

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 μg/m^3) ranges from 17% in the Po River Valley to 37% in Palermo, Sicily.

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 μg/m^3 increase in desert sand PM\textsubscript{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 10.09–4.71).

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

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” (VIHAS) 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. A total of 34,552 premature death 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 $^{[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 $^{[28,29]}$ 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 $^{[28]}.$

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).

<table>
<thead>
<tr>
<th>Study</th>
<th>Study area</th>
<th>Exposure</th>
<th>Health outcome</th>
<th>Health outcome results in the respective study area</th>
</tr>
</thead>
<tbody>
<tr>
<td>Viegi et al, 1991$^{[28]}$</td>
<td>Rural area</td>
<td>Traffic, industry</td>
<td>Chronic cough prevalence (%)</td>
<td>9</td>
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<td>Suburban-traffic area</td>
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<td>Suburban-traffic area</td>
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<td>Wheeze prevalence (%)</td>
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<td>Suburban-traffic area</td>
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<td>Dyspnea prevalence (%)</td>
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<td>Suburban-traffic area</td>
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<td>Chronic bronchitis or emphysema prevalence (%)</td>
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<td>Urban-traffic area</td>
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<td>Petruzelli et al, 1998$^{[32]}$</td>
<td>Urban area vs. suburban area</td>
<td>Traffic</td>
<td>Serum antibodies to Benzo(a)pyrene Diol Epoxide-DNA adducts (OR, 95% CI)</td>
<td>1.49 (1.16–1.92)</td>
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</table>

OR: Odds ratio; 95% CI: 95% Confidence interval.
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 1.22–1.49), 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 2.2, 95% CI 1.0–4.5), allergic rhinitis (OR 1.8, 95% CI 1.2–2.8), and COPD (OR 2.4, 95% CI 1.1–5.2) [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.

Conflict of interest

None.

References

impact of climate and traffic-related NO2 on the prevalence of asthma and allergic rhinitis in Italy. Clin Exp Allergy 2002;32:1405–1412.


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