Pollution and respiratory consequences – Have we done enough?

Poluarea şi consecinţele respiratorii – oare am făcut suficient?

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Abstract

Pollution is the second major cause for many respiratory diseases, after smoking. For every country it is a challenging problem to diminish the exposure of their citizens. The authors are discussing the history of progressing of pollution in different countries, the interactions with some respiratory diseases, the influence on mortality and morbidity and the strategies in developing and developed countries for diminishing the level of the polluted particles.
Keywords: *pollution, mortality, morbidity, respiratory diseases*

Rezumat

Poluarea rămâne a doua cauză de inducere a unor boli respiratorii, după fumat. Pentru fiecare ţară este o provocare diminuarea expunerii cetăţenilor săi. Autorii discută istoria progresiei expunerii la poluare în diferite ţări, interacţiunea cu unele boli respiratorii, influenţa asupra mortalităţii şi morbidităţii şi strategiile în ţările în curs de dezvoltare sau dezvoltate de diminuare a nivelului particulelor poluante.
Cuvinte-cheie: *poluare, mortalitate, morbiditate, boli respiratorii*

Introduction

Air pollution is a major contributor to cardiopulmonary illnesses. Most countries are confronted with these problems. A third of the world's population uses solid fuel derived from plant material (biomass) or coal for cooking, heating or lighting. According to the results of the Global Burden of Disease Study, outdoor particulate matter air pollution contributed to more than 3.2 million premature deaths and 76 million disability-adjusted life-years in 2010, ranking among the most important health risks worldwide[1]. Respiratory infections (comprising both upper and lower respiratory tract infections with viruses, bacteria and mycobacteria) have all been associated with exposure to household air pollution. Respiratory tract cancers, including both nasopharyngeal cancer and lung cancer, are strongly associated with pollution from coal burning and further data are needed about other solid fuels. Chronic lung diseases, including chronic obstructive pulmonary disease and bronchiectasis in women, are associated with solid fuel use for cooking, and the damaging effects of exposure to household air pollution in early life on lung development are yet to be fully described. Ambient air contains many pollutants including gases such as ozone, oxides of nitrogen, and sulphur dioxide along with particulates of different sizes. There are two different primary air pollution factors: second hand smoking, car and industrial pollution. We are trying to review in this article the health problems induced by the latter type of pollution.

Short history

Particulate air pollution has been a great concern for health, since the increased mortality reported by the "London Fog" study in 1952[2]. Other similar events were noted in Belgium in 1930 (the Meuse fog)[3] and in Pennsylvania in 1948 (the Donora fog)[4]. All this events showed that air pollution can be deadly. These remarks led to the "Air Pollution Control Act" and then the "Clean Air Act"[4]. Another step after 1950 was the implementation of measurement of air pollution levels.

There are many sources of pollution. One of them is the biomass smoke produced by the combustion of organic matter and includes emissions from domestic solid fuel use and landscape fires, with both indoor and outdoor sources contributing to the global burden of mortality. The complex smoke mixture contains numerous toxic co-pollutants, including volatile organic compounds and gases[5]. The information about the levels and the types of particles are available on different web sites: American Lung Association for the United States (State of the Air app), Cite Air II for many European cities (http://www.airqualitynow.eu/) and the Embassy of the United States or the Chinese government for Beijing. For measurements of particulate matter (PM), the levels are fractionated according to size, which determines their ability to be retained in the lungs: 5-8 PM_{10} (particles up to 10 μm in aerodynamic diameter) deposit in the nasal passages or larger airways, $PM_{2.5}$ (particles smaller than 2.5 μm in aerodynamic diameter) can reach the alveoli[6,7].

Status of air pollution in some UE countries

Air quality data reported to the European Environment Agency (EEA) indicate that four of the five cities with the highest concentrations of air pollution in the EU were in Bulgaria. In January 2014 heavy polluted fog blanketed 14 major cities across the country for days - the capital Sofia had pollution concentrations four to eight times higher than normal during the fog. EEA reports that whereas the EU (excluding Croatia) has recorded a 32% decline in particulate matter (PM_{10}) emissions since 1990, emissions in Bulgaria have increased by 44% in the same period[8]. Only 1.5% of Bulgarian households have direct access to natural gas in their homes, compared with 55% for Europe as a whole, leaving the average Bulgarian exposed to the fluctuations of the energy market. Incidental to this larger dispute, the cutoff of natural gas supplies to the Ukraine left millions of Bulgarians without an affordable source of heat, and many turned back to older and dirtier fuel sources, such as wood and coal. In 2009, 82% of passenger cars were over ten years old, compared with 33% in Europe as a whole. This almost certainly why the incidence of COPD was 15% of the general population in the area[9,16]. By contrast, the incidence of COPD in the rest of Europe ranges from 5–10%. COPD accounts for 3.45% of disability adjusted life years in Bulgaria versus 2.95% in the EU as a whole[9]. A similar situation with the same causes of pollution can also be found in Romania.

Air pollution in London and South-East UK reached level 9 on the 10 point daily air quality index in April 2014. Increases of NO_2 levels in city center are largely the result of vehicle engines. In particular, the oxidizing catalysts used in modern Diesel engines to burn particulate matter and reduce CO_2 emissions produce high concentrations of NO[10].

Influence of the pollution on the population in different countries

In the last years more and more published articles are describing these consequences. It is a long list. We are describing only some of them.

Influence on mortality

Exposure to ambient biomass smoke has been clearly associated with adverse respiratory outcomes and mortality, and there is evidence emerging for the association to cardiovascular outcomes[11,12]. Little evidence is available on the strength of the association between ambient air pollution exposure and health effects in developing countries such as South Africa. In the warm period, PM10 was significantly associated with respiratory daily and cardiovascular daily mortality. NO2 had significant associations with cerebrovascular, respiratory and cardiovascular mortality, whilst SO2 was associated with cardiovascular mortality. None of the pollutants were associated with any of the three outcomes in the cold period[13]. Pollution also contributes to chronic lung diseases, especially in industrial and mining regions, with lead, sulphur dioxide and carbon dioxide as the main causes. According to an Eurasian Development Bank report, in Russia air pollution causes more than 80,000 deaths yearly and 17% of deaths in children[14]. Results from a study recently released by Greenpeace and Peking University's School of Public Health showed that in 2010 an estimated 7,770 premature deaths in four Chinese cities (Beijing, Shanghai, Guangzhou, and Xi'an) could be linked to $PM_{2.5}$ air pollution, with a total economic loss of 982 million US dollars[15]. India generates two thirds of its electricity from burning coal. Urban Emissions estimates that emissions from the 111 power plants devoted to this task are responsible for 80,000 to 115,000 premature deaths every year, along with 170,000 cases of chronic bronchitis and 20.9 million cases of asthma. India's environment already bears the scars of this booming development: outdoor air pollution is the country's fifth biggest killer, causing an estimated 627,000 premature deaths every year[16]. In Africa, childhood pneumonia caused by indoor air pollution kills 500,000 children under 5 years annually[17].

Influence on morbidity

Asthma. The peri-urban environment of Lima was associated in a study with a 2.6 fold greater odds (95% CI 1.3 to 5.3) of asthma in multivariable regression. Higher NO values in Lima (p <0.001) were attributable to higher rates of asthma and atopy[18]. Urbanization leads to increased asthma due to higher levels of air pollution including particulate matter[19]. There is a significant association between traffic-related pollution and the development of asthma exacerbations and respiratory infections in children born from atopic parents and in those suffering from recurrent wheezing or asthma. These findings suggest that environmental control may be crucial for respiratory health in children with underlying respiratory disease[20]. An increase of 10 $\mu g/m^3$ of particulates less than 10 microns in diameter (PM_{10}) and nitrogen dioxide (NO_2) increased the onset of pneumonia only in wheezing/asthmatic children (continuous rate ratio [RR] = 1.08, 95% CI: 1.00-1.17 for PM_{10}; continuous RR = 1.08, 95% CI: 1.01-1.17 for NO_2)[20]. The ISAAC phase 3 study group assessed the relationship between open-fire cooking and asthma symptoms, and showed that open-fire cooking was associated with asthma symptoms and asthma diagnosis in two age groups: 6–7 years and 13–14 years. In the group of participants aged 6–7 years, exclusive use of an open fire for household cooking was associated with an odds ratio of 2.17 (95% CI 1,64–2,87) for wheezing in the past year. This positive association was only identified in non-affluent countries[21].

On children, chronic exposure to toxins (in prenatal and early postnatal life) may have potential lifelong health consequences, especially exposure to air pollution[22,23,24]. Air pollution has been consistently shown to exacerbate existing asthma among school children[25]. However it is unclear whether outdoor air pollutants hasten asthma onset[26]. The role of exposure to air pollution in the development of childhood asthma and the timing of first occurrence of respiratory symptoms has been controversial[27,28]. Research has shown that both maternal and early-life nutrition, as well as exposure to environmental factors such as pollution, smoking, biomass fuels, and allergens, can affect lung function in later life. Exposure to traffic-related air pollution is only weakly associated with respiratory symptoms in young children in the first 7 years of life in a prospective study. No clear association was found and only marginally increased ORs emerged between time-weighted exposure to NO_2 and respiratory symptoms during the first 7 years of life. The strength of association seemed to increase with age[29]. Two recent prospective cohort studies[30,31] have indicated that a possible relationship might exist but the effect sizes are small and difficult to detect. A recent meta-analysis of 10 European birth cohorts within the ESCAPE project found a clear association between air pollution[32] and children's health. A study in Zimbabwe[33] showed that babies born by mothers cooking with wood, dung, or straw were 175 g lighter (95% CI 50–300) than were those born by mothers using cleaner fuels. Therefore, maternal exposure to biomass smoke could be a major driver of infant respiratory morbidity and potentially mortality. Increased ozone smog, and increased air pollution overall, poses a specific threat to pediatric health. Children are more susceptible than adults to pollutants that injure airways, and chronic exposure to irritants decreases lung growth and function from birth to young adulthood. Exposure to particulate matter, nitric oxide, atmospheric acidity, elemental carbon, and traffic pollution are associated with decreased lung function. Haze from land-clearing fires in Indonesia caused air quality emergencies in Singapore, Malaysia (where hundreds of schools were closed) and southern Thailand. The haze has cost Singapore about 4 million US$ per day in this time due to lost tourism, other consumer spending, and increased health costs related to respiratory symptoms, about 28 million US$ in total[34.]

"Beijing cough" is an ideal example of one of the consequences of exceedingly high levels of air pollution. The American Embassy in Beijing, which has been independently running an air monitoring system and releasing its readings since 2008, reported that the 24 h average level of particles with a diameter smaller than 2.5 μm ($PM_{2.5}$) had reached 630 μg /m^3 in the capital of China[35]. $PM_{2.5}$ are among the most harmful pollutants because they can enter deeply into the lungs and bloodstream.

The combined data from 14 population based birth cohorts (74,178 mother–child pairs) across Europe, noted an association between exposure to ambient air pollution and traffic during pregnancy and low birth weight at term (weight <2500 g at birth after 37 weeks of gestation)[36]. A 5 μg /m^3 increase in exposure to particulate matter with an aerodynamic diameter of less than 2.5 μm was associated with an increased risk of low birth weight at term (adjusted odds ratio 1.18, 95% CI 1.06–1.33).

Pollution has been definitively linked to **pneumonia, lung cancer, and COPD** as it is mentioned by Global Burden of Disease Study[37]. Smoking of cigarettes and inhaling combusted biomass fuels, the mix of pollutants are recognized as possible causes of this diseases. A recent study from the European Study of Cohorts for Air Pollution Effects[38] which covered 17 cohorts from nine European countries including Norway, Sweden, Denmark, the UK, the Netherlands, Austria, Spain, Italy, and Greece, showed that exposure to $PM_{2.5}$ and PM_{10} was associated with increased risk of **adenocarcinoma of the lung**. The metaanalyses[38] showed that the hazard ratio for lung cancer and for $PM_{2.5}$ was 1.18 per 5 μg/m^3 and PM_{10} was 1.22 per 10 μg/m^3.

What has been done, or started?

The precarious situation of the European Union (EU) clean air policy package is extremely worrying[1]. The package was announced at the end of 2013, the EU's so-called ***Year of Air***, by the previous European Commission, headed by Jose Manuel Barroso. It includes a proposed new directive aiming to reduce pollution from medium-sized combustion installations and a revised national emission ceilings directive, which would reduce national emissions limits for particulate matter, sulphur dioxide, nitrogen oxides, volatile organic compounds, ammonia and methane[1]. Public health experts and campaigners have consistently pointed to the discrepancy between EU air pollution standards and WHO recommendations as an area in need of urgent action. The average annual limit or particulate matter with a diameter less than 2.5 μm set by the EU in 2008 was 25 μg/m^3, despite WHO recommending a limit of 10 μg/m^3 in 2005, based on the evidence of detrimental health effects available at that time. Evidence generated since then, summarized in a more recent WHO report, lends support to these guideline measures[1]. In 2012[1], the USA reduced its annual average limit for $PM_{2.5}$ from 15 to 12 μg/m^3. Members of the European Parliament campaigners and public health advocates must now work to ensure that the clean air policy is not delayed or watered down under pressure from lobby groups as political negotiations proceed[1].

Strategies in developing countries

In low-income countries, the major source of air pollution is the burning of biomass for cooking and heating. In different countries the interventions brought some changes, like in Central America where the replacing of open cooking fires in dwellings with vented stoves reduced indoor pollution from biomass smoke. Reported health improvements in the intervention groups include fewer respiratory symptoms, lower blood pressure, and babies with higher birth weights[39,40,41]. The Global Alliance for Clean Cookstoves, a public-private partnership launched by the UN Foundation planned the worldwide take-up of clean cook stoves in 100 million households by 2020 (this would cover 20% of the affected population)[42]. Entrepreneurs are working on creating inexpensive and efficient cook stoves, and policy makers craft innovative financing mechanisms, epidemiologists strive to fill the gaps in what is a largely under-researched field[17]. It still remains an important need for more tools for monitoring and evaluating the health impact of cleaner household energy interventions.

Strategies in developed countries

In Canada, an intervention using air filters to reduce indoor particulate matter from wood heaters found that biological markers of inflammation and endothelial dysfunction were reduced[42] while in the US a 5 μg/m^3 reduction in outdoor fine particulate matter from biomass smoke was associated with reduced wheeze and respiratory infections in children[43]. Government funded interventions to reduce ambient air pollution from indoor wood stoves in the Tasmanian city of Launceston diminished the daily annual and wintertime all cause, cardiovascular, and respiratory mortality rates during a 6.5 year period of documented poor air quality in Launceston, with a 6.5 year period of improved air quality[44]. In males, the reduction in annual mortality in winter observed was larger and significant for all causes (–11.4%, 95% confidence interval–19.2% to –2.9%; P=0.01),

cardiovascular (–17.9%, –30.6% to –2.8%; P=0.02) and respiratory (–22.8%, –40.6% to 0.3%; P=0.05) mortality. In wintertime reductions in cardiovascular (–19.6%, –36.3% to 1.5%; P=0.06) and respiratory (–27.9%, –49.5% to 3.1%; P=0.07) mortality were of borderline significance (males and females combined)[45]. In a comparable intervention in the community of Libby, Montana, older wood heaters were exchanged with new, less polluting models during in the winter of 2006-2007. Concentrations of fine particulate matter ($PM_{2.5}$) fell from a mean of 27.2 μg/m^3 in the two winters before the intervention to 19.7 μg/m^3 for two winters after. The respiratory heath of children was assessed by repeated annual surveys of their parents. A reduction of 5 μg/m^3 in $PM_{2.5}$ was associated with a 27% (95% confidence interval 3% to 45%) reduction in wheeze and even larger reductions in respiratory infections, including flu (52%, 43% to 61%) and throat infections (45%, 29% to 58%)[43].

Interventions like reducing the sulphur content of petrol in Hong Kong, and banning coal sales for domestic heating in Dublin, brought a 45% decline in mean ambient concentration of sulphur dioxide over five years, with no significant change in the ambient concentration of particulate matter after the intervention[46,47]. The reported outcomes were a 2.1% (0.9% to 3.3%) decrease in all-cause mortality, a 3.9% (6.2% to 1.6%) decrease in respiratory mortality, and a 2.0% (3.7% to 0.3%) decrease in cardiovascular mortality[46].

To address air pollution and minimize its health risks, the Beijing Government took emergency response measures over the weekends, including taking some Government vehicles off the road and halting outdoor activities for school children[48]. Since the beginning of 2013, equipped with 496 monitoring stations, 74 cities around China began monitoring and releasing real time readings on pollutants such as $PM_{2.5}$ and ozone[48]. UK policy makers have shied away from radical solutions to the issue, such as changing Diesel-powered black cabs (which contribute 20% of London's locally generated particulate matter) to cleaner petrol-powered alternatives[49].

The increased risk of low birth weight at term recorded at air pollution concentrations lower than the present recommended European Union annual $PM_{2.5}$ limit of 25 μg/m^3 provides worrying data; the European Environment Agency noted that 11 member states had failed to adhere to the recommended limit in 2011[8]. The target for $PM_{2.5}$ concentrations in 2015 has been set at 20 μg/m^3. Concentrations in cities that rely on public transport (like in London) will probably necessitate a shift to electric vehicles[10].

Conclusions

As the Forum of International Respiratory Societies noted "breathing unhealthy air is a cause or contributor to most respiratory conditions"[50]. The higher effects during the warmer months may be due to more time spent outdoors or because of a closer similarity between indoor and outdoor air pollution. Lower background mortality in the warmer months, thus resulting in a larger pool of susceptible people, may also explain the higher relative effects observed in these months[37]. It is a heterogeneity in air pollutant effects estimates in different studies based on variations in exposure measurement error, toxicity of the pollution, different ages and vulnerability of the population, differences in the way the exposure and outcome series, statistical approaches selected, specification of meteorological variables, approaches to control time-varying confounders and publication bias, etc[51]. The relative contributions of these factors were (and still are) poorly understood[52]. Fighting pollution still has a long journey ahead, and the future ought to bring important political and medical decisions. ■

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