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Indoor Air Pollution by Particulate Matter from Wood Fuel: An Unresolved Problem

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Introduction

Air pollution, an environmental and public health problem

The deleterious effect of air pollution on health has been recognized since many years, especially after episodes that occurred in Meuse, Belgium in 1930 [1], Donora, Pennsylvania in 1948 [2] and London in 1952 [3]. In the case of London the smog remained for four days causing approximately four thousand deaths over those expected for the period, as a result of inhalation of smoke particles and acid from reactions of SO_2. Events like these led to the concern of the population and the media on the subject to encourage the generation of policies and laws related to the prevention and control of air pollution, seeking to prevent episodes such as these. Since then, it was logical to assess the immediate effect of excessive levels of pollution, however, from these facts; scientific interest has focused in both the short and long term exposure levels. So then, it has been observed that adverse health effects can occur even with low levels of pollution, considering that there is no safe threshold of exposure to air pollutants [4].

The particulate matter (PM) refers to a generic class of contaminant rather than a particular individual contaminant with a specific chemical structure; it applies to solid or liquid particles suspended in the air independently of composition [5]. The PM consists of a heterogeneous group of components where the particles are derived from various sources including traffic, biomass burning small- and large-scale waste incineration and industrial processes, among others [6]. Consequently, these airborne particles are a complex mixture of organic and inorganic, solid and liquid substances, which vary in size and composition including gaseous pollutants, sulfate and nitrate ions, condensed acid, soil dust, soot, ash, mold and pollen [7]. The classification of particles according to their aerodynamic properties is critical since these properties determine how the particle is transported and removed from the air, their deposition in the respiratory system and its chemical composition and source [8]. Since the composition of the particles vary widely, it is postulated that some are more toxic than others, and therefore, the evaluation of interventions in public health requires assess them differentially [9]. Some studies suggest different health outcomes with different particle size. The information so far available indicates that $PM_{2.5}$ (particles in air with 2.5 micrometers in diameter or smaller) is a better predictor of health effects that the PM10 (particles up to 10 micrometers in diameter).

Air pollution derives from a variety of sources from which the combustion of fossil fuels can be considered a primary source [10]. Wood smoke can be an important contributor PM and gas in the ambient air, reaching up to 80% of airborne particles during the winter.

Today there are studies on air pollution and its effects on health that have established a relatively consistent link between the two. However, investigations have focused with more emphasis on outdoor air pollution more than in the indoor [11].

Indoor air pollution, particulate matter and health

Annually, 4.3 million people die prematurely from diseases attributable to indoor air pollution caused by inefficient use of solid fuels, including pneumonia, stroke, ischaemic heart disease, chronic obstructive pulmonary disease and, lung cancer [12].

The main sources of emission of pollutants of interior spaces include the use of fuels, cigarette smoke and outdoor air infiltration. Studies have shown that between 60 and 75% of $PM_{2.5}$ from outside penetrates into indoor environment [13]. Thus it has been determined that construction activities and vehicular traffic are important sources of atmospheric PM but they also affect indoor PM concentrations [14]. The study of McCormack et al. [15], carried out at Baltimore, Maryland, found a statistically significant relationship between environmental and indoor $PM_{2.5}$ concentration, calculating that for every 1 $\mu g/m^3$ increase in environmental $PM_{2.5}$ indoor levels increase 0.58 $\mu g/m^3$ ($p=0.02$). However, it could be expected that in smaller cities, where vehicular traffic and construction activity are significantly lower, PM concentrations depend mainly of indoor emission sources. Thus, from a global point of view, many factors affect indoor particle concentration, including environmental particles, activities within the home (cooking, cleaning, moving), particle deposition and air exchange rate [13].

The use of solid fuels for cooking and heating is probably the main source of indoor pollution. Solid fuels are cheaper than gas and electricity and are used more frequently in urban and rural areas of extreme poverty. The preference for this type of fuel is due to the favorable ratio of price and heat quality and is used for cooking and to heat homes. In this context, pollutants emitted by the combustion of solid fuel (CO, NOx and PM) reach significantly higher levels indoor than the outdoor air, mainly due to poor ventilation and inappropriate technology, for example, using incomplete combustion stoves or open fires, which is still common in many developing countries [16]. Many harmful components are products of burning solid fuels, so the problem is particularly relevant in areas where home heating and food preparation are made at the expense of these fuels. Approximately 3 billion people are still cooking and heating their homes with solid fuel (i.e., wood) in open fires and leaky stoves, mostly poor people living in low-and middle-income countries [12]. Specifically, the use of solid fuels has been associated with acute respiratory infections in children under 5 in developing countries, such as Nepal, Argentina, Nigeria, Tanzania, Gambia and Brazil [17]. However, although PM concentrations in developed countries are much lower than in developing countries given

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the differences in the advancement of technology for routine household activities and the use of cleaner fuels (i.e., liquefied petroleum gas, electricity and natural gas) for cooking and heating, there are still health risks in people from developed countries.

In developing countries, such as Nepal and China, where traditional methods such as open cooking fire and other open devices are used, the total suspended MP from wood smoke range from 2.7 up to 25 mg/m^3 [12]. Meanwhile, it has been shown that particles emitted by the combustion of pine, oak and eucalyptus, ranging from 0.1 to 0.3 microns in aerodynamic diameter [18].

Indoor air pollution derived from solid fuels has been considered the eleventh overall risk factor for mortality and the seventh risk factor for burden of disease, estimated to be responsible for 2.6% of the global burden of disease [19]. Compared to households that use cleaner fuels (i.e., electricity, kerosene, natural gas) mortality rates of children under five from households that use more polluting fuel (biomass) are substantially higher. Consequently it has been estimated higher risk of death in rural areas (RR=2,0; CI 95% 1,4-2,8) as well as urban (RR=1,22; CI 95% 1,004-1,5) [20].

There are several factors that increase the risk of exposure to indoor air pollution such as large amount of exposed population, frequent use of stoves, time spent by people at home and, in particular, the proximity of women and children to stoves while biomass is burned [21]. The adverse effects of indoor air pollution on health are often exacerbated by the lack of ventilation in homes using biomass fuel and poorly designed stoves that do not have fireplaces or hoods to bring the smoke outside the inhabited area. Moreover, the combustion efficiency of biomass is also very low, resulting in relatively high levels of incomplete combustion products, which are harmful to health [22].

Policy interventions to indoor air pollution

Under a common sense approach, it is clear that indoor exposure to PM can be reduced by using air conditioning and particle filters, reducing indoor combustion for heating and cooking, and smoking cessation. However, the problem is more complex than it appears, especially if we think that the problem is more common in people with lower incomes and higher socioeconomic vulnerability. To ensure that the air of the house and its environment is healthy actions should be implemented to change the types of fuels and technologies currently used to promote efficient domestic energy technologies.

Some strategies consider subsidizing cleaner fuel technologies as kerosene, gas or electricity. However, this strategy is often not entirely feasible and can be very expensive. For example, electric stoves are not practical in areas with low electricity levels, and the access of the poor to electricity varies greatly across countries. In addition, kerosene and gas are too expensive for poor households. Furthermore, these subsidy programs tend to be quite expensive, related to the overstretched budgets [23].

In Chile, where domestic $PM_{2.5}$ levels in several households using wood fuel exceed Chilean and WHO Air Quality Standards [11], the efficiency of wood combustion equipment used in the residential sector varies between 15 to 65% and the average efficiency in the use of firewood by the urban residential sector nationwide is 42% [24]. This is critical, because many wood stoves have obsolete technology, resulting in incomplete combustion and thus higher emissions of PM to the indoor environment as well as to the atmosphere. In this regard, other strategies have been the development, promotion and subsidization of improved cooking stoves. Improving the systems of wood burning, related to their condition and maintenance functionality, improves the indoor air quality, reducing the $PM_{2.5}$ concentration 73% [25]. Similarly, the replacement of old systems and heating devices for new ones, manages to reduce concentrations of $PM_{2.5}$ average between 36% and 71% [26,27].

Usually in places where firewood is used, the equipment is old and of low efficiency compared with equipment using gas, paraffin or electricity. However, the lower cost of wood makes it a very competitive fuel. Moreover, there is poor regulation for the heating equipment market, independent of the type of technology and fuel.

While there is a progress to incorporate the problem into the public agenda in different countries, there is a significant gap to achieve sustainability of the sector and enough environmental protection to reduce air pollution caused by the bad use of wood energy. In addition, there is scarce legislation and plans coordinated between public and private institutions that provide transversal support to the market. In this regard, the State must assume a new role to set clear rules and implement public policies involving institutional structure and relationships between the State, the market and the citizenry.

Conclusion

Despite the thorough knowledge about the extent to exposure to indoor air pollution by PM, and its potential effects on health, it has not yet been possible to implement effective control measures at the population level. The understanding of the elements involved in indoor pollution by PM that are harmful to human health is a critical policy issue for the public health.

Thus, strategies can be implemented coordination with civil society and public-private partnerships, through spaces of institutional coordination, strengthening and participation. The challenge is to address this point from the perspective of coordination between the various actors in the sector, both public and private, promotion and research, among others.

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