**Indoor PM2.5 in East Asian countries: A review of sources, health effects, and mitigation techniques**

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# Abstract

PM2.5, or fine particulate matter, is an airborne particle with an aerodynamic size of 2.5 microns or less which poses a more significant threat to humans. People spend the majority of their time at home, thus it is crucial to understand indoor air quality. Health issues are raised from exposure to PM2.5. It depends on the infrastructure, air circulation, and insulation which are ultimately related to the country profile. This review selected East Asia countries that highlight the sources of PM2.5 and its associated health risk. As per our knowledge, data from North Korea is absent. The primary sources of indoor PM2.5 include outdoor air pollution, indoor combustion, and building materials. Exposure to indoor PM2.5 has been associated with various health effects, including respiratory and cardiovascular diseases, cancer, and cognitive impairment. The article continues by addressing mitigating techniques to lower indoor PM2.5 concentrations in east Asian countries, such as better ventilation, the use of cleaner fuels and stoves, and regulatory reforms. However, the effectiveness of these techniques depends on various factors, such as building design, occupancy patterns, and cultural practices. The documented literature provides a valuable resource for policymakers, researchers, and stakeholders who are working to improve indoor air quality in developing countries facing similar challenges.

**Outline**

# Introduction

# In many nations, notably in East Asia, indoor air pollution has become a primary environmental and public health concern. The impact of indoor environment quality on our health and well-being is becoming more well recognized. Particularly, indoor air quality (IAQ) has an effect on a variety of health consequences. People are spending 90% of their time in their indoor environment, therefore it is crucial to understand indoor air quality (Lai H. K., 2004). Fine particulate matter (PM2.5) has been identified as among the most damaging and prevalent air contaminants in indoor environments. The rapid industrialization, urbanization, and rise in energy use in recent years have led to severe air pollution issues, particularly in East Asian countries. As a result, indoor PM2.5 pollution has grown to be a significant health risk for the people in the region. Several studies have found a range of indoor PM2.5 sources, including indoor sources like combustion products from heating and cooking, smoking, and building materials and furnishings. Depending on the location, climate, and level of urbanization of the area, there might be a wide variety of outdoor sources of PM2.5 including traffic emissions, industrial emissions, agricultural activities, and climate and weather conditions.

# Sources of indoor PM2.5

# Status of indoor PM2.5 in East Asia

# China

# Hong Kong

# Japan

# Mongolia

The use of unprocessed coal as a primary source of fuel for heating and cooking in traditional Mongolian houses known as gers, has resulted in a significant negative impact on indoor air quality in the capital city of Mongolia, Ulaanbaatar. A study measured the daytime indoor PM2.5 concentrations in 28 gers using a real-time PM monitor and observed the behavior of the residents. The results indicated that the average PM2.5 concentrations in 61% of the gers exceeded 100 μg/m3, and the daytime temporal profile suggested a high PM2.5 concentrations at night-time. The use of other solid fuels such as wood, plastic, rubber, and garbage was also reported. Moreover, households living in a ger in UB are costly to keep warm, with an average temperature of over 21℃ in 70% of the gers.

The high indoor PM2.5 concentrations observed in the gers have resulted in significant health impacts on the residents of Ulaanbaatar. Annual average population-weighted PM2.5 exposures at baseline were estimated at 59 μg/m3 in 2014, and under current control policies, exposures increased slightly to 60 μg/m3 by 2024. The moderate improvement pathway decreased per capita annual disability-adjusted life year (DALY) and death burdens by approximately 40%. The burden attributable to PM2.5 exposures was calculated for lung cancer, ischemic heart disease (IHD), stroke, and chronic obstructive pulmonary disorder (COPD) in all UB residents, as well as acute lower respiratory tract infection (ALRI) in children for 2014-2024 using a version of the Household Air Pollution Intervention Tool (HAPIT). The health impacts of exposure to PM2.5 in UB in 2014 were responsible for 33% of all ALRI deaths in children, 19% of all COPD deaths, 27% of all IHD deaths, 24% of all lung cancer deaths, and 42% of all stroke deaths, for a total of 1,400 attributable deaths and 40,000 attributable DALYs. Deaths and DALYs attributable to PM2.5 at baseline were dominated by cardiovascular disease. These findings highlight the urgent need for effective interventions to reduce indoor PM2.5 concentrations in gers and improve air quality and public health in Ulaanbaatur

# Macao

# South Korea

The presence of PM2.5 particles indoors is a concern in South Korea due to its severe implications for human health. A plethora of sources, including but not limited to outdoor air pollution, indoor smoking, solid fuel combustion during cooking, household cleaning products, and construction work, contribute to the accumulation of these particles. During the winter months, the high levels of outdoor air pollution in the country exacerbate the issue, as fine dust particles easily penetrate indoor spaces, leading to increased PM2.5 levels. Using traditional stoves that rely on solid fuels for cooking further escalates indoor PM2.5 concentrations.

Studies have revealed that PM2.5 concentrations indoors vary from 37.1 μg/m3 to 45.2 μg/m3 in residential areas and up to 51.1 μg/m3 in areas close to construction sites. Furthermore, other sources of indoor PM2.5 pollution include subway trains, computer game rooms, and outdoor sources such as traffic, construction sites, and industrial emissions. The findings highlight the criticality of monitoring outdoor air quality and implementing appropriate measures to reduce the impact of outdoor sources on indoor air quality.

To mitigate indoor PM2.5 concentrations and promote respiratory health, several effective indoor air quality management methods, such as natural and mechanical ventilation, range hoods, and air purifiers, can be employed. Reducing exposure to indoor PM2.5 is crucial in South Korea as high indoor PM2.5 levels can pose significant risks to human respiratory health and increase the transmission of viruses such as SARS-CoV-2. Smoke-free legislation has been introduced in public areas, including indoor spaces of bars and restaurants, to reduce the impact of cigarette smoke on indoor air quality. However, managing indoor air quality is a complex issue that requires a multi-faceted approach. It is imperative to increase awareness about the sources and health implications of indoor PM2.5 pollution and promote the adoption of effective mitigation strategies. These could include advocating using clean energy sources for cooking and heating, implementing building codes prioritizing indoor air quality, and improving ventilation systems in public areas.

Addressing the fundamental causes of outdoor air pollution, such as reducing emissions from transportation and industrial activities, is also essential for improving indoor air quality. This necessitates coordinated efforts from the government, industry, and individuals to reduce overall air pollution levels.

# Taiwan

# Health Impacts

# Mitigation Techniques

# Policy and regulatory frameworks

# Conclusion and recommendations

# References