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Asia Pacific Association of Allergy Asthma and Clinical Immunology White Paper 2020 on climate change, air pollution, and biodiversity in Asia-Pacific and impact on allergic diseases

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ABSTRACT

Air pollution, climate change, and reduced biodiversity are major threats to human health with detrimental effects on a variety of chronic noncommunicable diseases in particular respiratory and cardiovascular diseases. The extent of air pollution both outdoor and indoor air pollution and climate change including global warming is increasing-to alarming proportions particularly in the developing world especially rapidly industrializing countries worldwide. In recent years, Asia has experienced rapid economic growth and a deteriorating environment and increase in allergic diseases to epidemic proportions. Air pollutant levels in many Asian countries especially in China and India are substantially higher than are those in developed countries. Moreover, industrial, traffic-related, and household biomass combustion, indoor pollutants from chemicals and tobacco are major sources of air pollutants, with increasing burden on respiratory allergies. Here we highlight the major components of outdoor and indoor air pollutants and their impacts on respiratory allergies associated with asthma and allergic rhinitis in the Asia-Pacific region. With Asia-Pacific comprising more than half of the world's population there is an urgent need to increase public awareness, highlight targets for interventions, public advocacy and a call to action to policy makers to implement policy changes towards reducing air pollution with interventions at a population-based level.

Keywords: Climate change; Air pollution; Allergic disease; Asia-Pacific

KEY POINTS

1. Epidemiological studies show that indoor and outdoor pollutions affect respiratory health, including an increased prevalence of asthma and allergic diseases. Global warming will increase the effects of outdoor air pollution on health.
2. The Asia-Pacific is the most populated region in the world, with a huge burden of both outdoor and indoor pollutants, including $PM_{2.5}$, PM_{10}, SPM, CO, O_3, NO_2, SO_2, NO and household pollutants including biomass and tobacco.
3. The risk factors for the epidemic rise of allergic diseases in the Asia-Pacific are due to the increasing urbanization, environmental factors of air pollution and climate changes in recent decades than in the other parts of the world.
4. In light of the different environmental exposures in different countries of the Asia-Pacific region, strategies to combat allergic disease in this region should be focused on active government policies to fight air pollution based on the local conditions.
5. Substantial efforts need to be implemented with a concerted strategy at legislative, administrative, and community levels to improve air quality.
6. Abatement of the main risk factors for respiratory diseases, in particular, environmental tobacco smoke, indoor biomass fuels, and outdoor air pollution, as well as better control of asthma and rhinitis will achieve huge health benefits.

INTRODUCTION

Changes in our living environments especially altered urbanized living environments results in reduced biodiversity of plants and animals [1]. This, in turn, induces changes in the interactions between humans and microbes that could be causally related to the increasing prevalence of respiratory diseases like asthma and allergic rhinitis [1, 2]. Constant exposure to outdoor pollutants like carbon dioxide (CO_2), sulfur dioxide (SO_2), ozone (O_3), and indoor pollutants like tobacco smoke and chemicals leading to limited plant, animal and microbial life lead to immune dysfunction and impaired tolerance in humans [3, 4]. Epidemiological and experimental studies have shed light on the relationship between these environmental factors and allergic respiratory diseases [5-12] such as rhinitis and asthma. The Asia Pacific Association of Allergy, Asthma and Clinical Immunology (APAAACI) white paper highlights the current status of air pollution in the Asia-Pacific region, and the impact of air pollution (both outdoor and indoor), climate change and reduced biodiversity on respiratory allergies. The APAAACI plans to build a consortium and calls to action for the health and environmental global bodies and national authorities to address this major threat to human health.

OVERVIEW OF CLIMATE CHANGE AND AIR POLLUTION IN ASIA-PACIFIC ON RESPIRATORY ALLERGY DISEASE

Climate change on respiratory allergy in the Asia-Pacific

Climate change correlates with [8, 9, 13, 14] the increasing concentration of CO_2 in the atmosphere, can accelerate plant growth; increase pollen production, allergen potency, release and dispersion of pollen, accelerate the onset of the pollen season as well as lengthen the duration of the pollen season and allow the emergence of new pollen species which are not endemic to the area. Westernized diets and lifestyle, urbanization coupled with increased vehicular emissions correlate with an increase in the incidence of respiratory allergies in people living in urban versus rural areas [8, 9, 15]. In South-East Asia, air pollution is one consequence of a massive exodus from farm to city that has occurred in recent decades. The change has contributed to rising emissions from both vehicles and factories, especially coal-fired power plants, and an emerging middle class that increasingly desires a range of consumer goods that are common in Europe and the United States. According to the World Health Organization (WHO), nearly one million of the 3.7 million people who died from ambient air pollution in 2012 lived in South-East Asia [9].

Air pollution and respiratory allergies in the Asia-Pacific

Air pollution has become a growing concern, especially in urban cities with rapidly developing economies, increasing infrastructure, numbers of vehicles, and reduced green spaces. Fossil fuel and transportation are the main sources of air pollution (e.g., sulfur oxide and nitrous) released into the atmosphere leading to health problems, poor air quality, and acid rain. A global study that 9–23 million and 5–10 million annual asthma emergency room visits globally in 2015 could be attributable to O_3 and particulate matter (PM) with a diameter of 2.5 μm or less ($PM_{2.5}$), respectively, representing 8%–20% and 4%–9% of the annual number of global visits, respectively [15]. Anthropogenic emissions were responsible for ~37% and 73% of O_3 and $PM_{2.5}$ impacts, respectively. Remaining impacts were attributable to naturally occurring O_3 precursor emissions (e.g., from vegetation, lightning) and $PM_{2.5}$ (e.g., dust, sea salt), though several of these sources are also influenced by humans. The largest impacts were estimated in China and India.

The top 3 countries for both asthma incidence and prevalence in Asia were India, China, and Indonesia, driven largely by population size nearly half (48%) of estimated O_3-attributable and over half (56%) of $PM_{2.5}$-attributable asthma emergency room visits were estimated in Southeast Asia (includes India), and western Pacific regions (includes China). O_3 and

$PM_{2.5}$ were estimated to be responsible for 6%–23% and 1%–12%, respectively, of all asthma emergency room visits [15]. Of all countries globally, India and China had the most estimated asthma emergency room visits attributable to total air pollution concentrations, respectively contributing 23% and 10% of global asthma emergency room visits estimated to be associated with O_3, 30% and 12% for $PM_{2.5}$, and 15% and 17% for nitrogen dioxide (NO_2). In this global study,16 million new pediatric asthma cases could occur globally each year due to anthropogenic $PM_{2.5}$ concentrations, translating to 33% of global pediatric asthma incidence. The percentage of national pediatric asthma incidence that may be attributable to anthropogenic $PM_{2.5}$ was estimated to be 57% in India, 51% in China, and over 70% in Bangladesh. Approximately half of estimated NO_2- and $PM_{2.5}$-attributable new asthma cases were in the Southeast Asia and western Pacific regions. Estimated asthma incidence attributable to NO_2 and $PM_{2.5}$ translates to ~1:7 million disability-adjusted life years (DALYs) among children (~97% of these attributable to $PM_{2.5}$), adding ~8% to the most recently estimated DALY burden from ambient air pollution among all ages. Results are 1.2 and 1.6 times higher when using total concentrations for NO_2 and $PM_{2.5}$, respectively.

CO_2

CO_2 is the most important anthropogenic greenhouse gas, and its atmospheric concentration has increased from 280 ppm to 379 ppm in 2005 [1, 2]. Over the last 50 years, global earth's temperature has markedly risen [5]. About 75% of the anthropogenic CO_2 emissions to the atmosphere during the past 50 years resulted from fossil fuel burning [16]. The key determinants of greenhouse gas emissions are energy production, transportation, agriculture, food production, and waste management [6]. Moreover, rising temperatures contribute to the elevation of the concentrations of O_3 and PM at ground level [9, 10]. Various measures to reduce greenhouse gas emissions may have positive benefits for health and the need for a political multigovernmental agreement on the reduction of CO_2 in atmosphere is essential.

Urbanization, high levels of vehicle emissions and westernized lifestyle have been shown to increase the frequency of seasonal respiratory allergy in people living in urban areas in comparison with those living in rural areas [17]. Wayne et al. [18] observed that a doubling of the atmospheric CO_2 concentration stimulated ragweed-pollen production by 61% more per plant. Furthermore, ragweed pollen collected along high-traffic roads showed a higher allergen city due to traffic-related pollution. In Southeast Asia, wherein only 2 seasons (wet and dry) are present, perennial allergen exposure is common. A study in Taiwan revealed that most patients with allergic rhinitis were sensitized with perennial allergens such as dust mite, cockroaches, and pollen in the context of a highly polluted environment. Thus, increased and persistent allergen load may lead to worsening disease manifestations year-round [19].

O_3

O_3 has been reported to cause respiratory symptoms by inducing increase in airway responsiveness, airway injury and inflammation and systemic oxidative stress [20]. O_3 and fine $PM_{2.5}$ are associated with respiratory symptoms and increased use of rescue medication among asthmatic children using maintenance medication. A 50 parts per billion (ppb) increase in 1-hour O_3 was associated with increased likelihood of wheeze (35%) and chest tightness (47%). The highest levels of O_3 (1-hour or 8-hour averages) were associated with increased shortness of breath and rescue medication use [20]. Particular PM and diesel exhaust particle, O_3, NO_2, and SO_2—can exacerbate airway inflammation in susceptible subjects, causing increased permeability, easier penetration of allergens into the mucus membranes, and easier interaction with immune cells [20]. There is also evidence that

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predisposed subjects have increased airway reactivity induced by air pollution and increased bronchial responsiveness to inhaled allergens [20].

Regional weather (changes of wind patterns, precipitation timing and intensity, increase of temperature) also can affect the severity and frequency of air pollution episodes. Tropospheric O_3 is formed in the presence of bright sunshine and high temperatures by the reaction between volatile organic compounds (VOCs) and nitrogen oxides (NOx), both emitted from natural and anthropogenic sources. An association between tropospheric O_3 concentrations and temperature has been demonstrated from measurements in outdoor smog chambers and from measurements in ambient air, even if it does not occur when the ratio of VOCs to NOx is low. Tropospheric O_3 concentrations are increasing in most regions, and this trend is expected to continue over the next 50 years. Understanding the complexity and uncertainty of current and future weather patterns in the subtropical and tropical climate zones of the Asia-Pacific are of particular importance.

Risk factors and the impact of changing environment on the pollinosis in the Asia-Pacific

Pollen from birch trees exposed to higher O_3-levels induces larger wheals and flares in skin prick test compared to lower O_3-exposed pollen suggesting an allergenicity increasing effect of O_3 [10, 18, 21]. Changes in temperature and precipitation patterns may also increase the frequency and severity of forest fires, sometimes with dire public health consequences. Changes in wind patterns may increase episodes of long-distance transport of pollutants as well as of pollen grains, making large-scale circulation patterns as important as regional ones [20].

Climate change appears to induce an increased concentration of all health-related air pollutants. Climate change influences not only the levels and the type of air pollution but also of allergenic pollen. Global warming affects the onset, duration, and intensity of the pollen season, as well as the pollen allergen potency. Over the last decades, many studies have shown changes in the production, dispersion, and allergen content of pollen and spores and that nature of the changes may vary in different regions and species. Climate change is also impacting on the biogeographical distribution of plants with consequences for the composition of airborne pollen diversity as well as the magnitude and duration of pollen seasons [22]. Current knowledge on the worldwide effects of climate change on respiratory allergic diseases is provided by several studies on the relationship between asthma and environmental factors, like meteorological variables, airborne allergens, and air pollution. Published data suggest an increasing effect of aeroallergens on allergic patients, leading to a greater likelihood of development of an allergic respiratory disease in sensitized patients and an aggravation in patients already symptomatic [20, 21].

Thunderstorm asthma

One of the effects of climate change and global warming is an increasing frequency and intensity of floods and cyclones [9, 10]. An example of how this effect can threaten respiratory health is "Thunderstorm related asthma" [20-23]. Actually, thunderstorms occurring during the pollen season have been observed to induce severe asthma attacks and also deaths in pollen-allergic patients [20, 21]. Thunderstorm asthma refers to an observed increase in acute bronchospasm cases following the occurrence of thunderstorms in the local vicinity. Evidence suggests these thunderstorm asthma epidemics occurred only during the pollen season, with pollen-allergic patients at highest risk. Events have been reported from Europe, North America, the Middle East, and Australia [21]. Previously the largest documented outbreak occurred in June 1994, when 640 patients attended London Emergency Departments within a 30-hour period. This has been greatly surpassed by a recent thunderstorm event in Melbourne, Australia on November 21–22, 2016 as more than 9,900 patients presented to hospitals with asthma attacks. In excess of 2,300 emergency calls were received, and despite valiant efforts of emergency services, 10 deaths have been attributed to this tragic crisis [23]. A pilot questionnaire study of 344 patients who presented to the Emergency Departments in eastern Melbourne received 262 responses (overall response rate 76%). They found that (1) the majority (57%) did not have previous diagnosis of asthma, although most (51%) of these had symptoms suggestive of latent asthma; (2) rhinitis was highly prevalent in 88% of subjects with 71% of these being moderate to severe; (3) 46% of cases were born outside Australia with a mean duration of 16.0±11.9 years living in Australia; (4) there was overrepresentation of non-Caucasian population, with 27% identifying ethnically as Asian (Chinese, Vietnamese, East, or South-East Asian), and 16% as Indian (including subcontinental Sri Lankan, Pakistani, or Bangladeshi) [24]. This overrepresentation of those born outside Australia (46%), and being of Asian or Indian ethnicity (43%), is far in excess of that expected in the resident population, and has not been previously described. This has been confirmed in a subsequent analysis across the Melbourne population [23].

Indoor pollutants

A third of the world's population uses solid fuel derived from plant material (biomass) or coal for cooking, heating, or lighting. These fuels are smoky, often used in an open fire or simple stove with incomplete combustion, and result in a large amount of household air pollution when smoke is poorly vented. Air pollution is the biggest environmental cause of death worldwide, with household air pollution accounting for about 3·5–4 million deaths every year. In Southeast Asia, many rural and even urban households use coal-based heating systems for cooking due to financial reasons. Women and children living in severe poverty have the greatest exposures to household air pollution. Exposure to particulate emissions poses a variety of public health concerns worldwide, specifically in developing countries. One review summarized the documented studies on indoor PM emissions and their major health concerns in South Asia [24]. Reviewed literature illustrated the alarming levels of indoor air pollution in India, Pakistan, Nepal, and Bangladesh, while Sri Lanka and Bhutan are confronted with relatively lower levels, albeit not safe. Authors found that the reported levels of PM with a diameter of 10 μm or less (PM_{10}) and $PM_{2.5}$ in Nepal, Pakistan, Bangladesh, and India were 2-65, 3-30, 4-22, 2-28, and 1-139, 2-180, 3-77, 1-40 fold higher than WHO standards for indoor PM_{10} (50 μg/m^3) and $PM_{2.5}$ (25 μg/m^3), respectively. Regarding indoor air pollution-mediated health concerns, mortality rates and incidences of respiratory and nonrespiratory diseases were increasing with alarming rates, specifically in India, Pakistan, Nepal, and Bangladesh. The major cause might be the reliance of approximately 80% population on conventional biomass burning in the region. Current review also highlighted the prospects of indoor air pollution reduction strategies, which in future can help to improve the status of indoor air quality and public health in South Asia.

VOCs are a group of carbon-based chemicals that easily evaporate at room temperature. Many common household materials and products, such as paints and cleaning products, give off VOCs. Common VOCs include acetone, benzene, ethylene glycol, formaldehyde, methylene chloride, perchloroethylene, toluene, and xylene. Several studies suggest that exposure to VOCs may make symptoms worse in people who have asthma or are particularly sensitive to chemicals. VOCs particularly affect indoor air quality—concentrations of many VOCs are consistently higher indoors (up to 10 times higher) than outdoors (US Environmental

Protection Agency 2016). Some VOCs are known to be air toxics. Government regulations on using low-VOC products have not been strictly enforced or developed in Asia mainly because of unavailability of these products or their restrictive costs.

COUNTRY WISE INFORMATION ON AIR POLLUTION AND IMPACT ON RESPIRATORY ALLERGIC DISEASES IN THE ASIA-PACIFIC (Summarized in Table 1 With References [23-48])

Australia

Australia's metropolitan cities all experience episodes of poor air quality (measured in terms of particulate pollution, or pollution by O_3 and its precursors NOx and VOCs). The frequency, duration, and severity of these episodes are strongly influenced by short-term meteorological conditions (principally temperature and wind conditions), in combination with local topography, as well as atypical events such as dust storms, bushfire smoke or accidental releases, such as from factory fires or chemical spills. Air quality is usually restored to acceptable levels once the immediate conditions change, either through a change in the wind, cessation of the emissions or dispersion of the pollutant. According to the recent report from Australian government, air quality is usually restored to acceptable levels in urban center, whereas air pollution is most prevalent. All levels of government play a role in preventing or minimizing air pollutant emissions, through such measures as national air quality standards, and emissions standards for vehicles and industry. Levels of lead and NO_2 have declined markedly in all centers in recent decades. O_3 levels have remained stable since the 2011 state of the environment report. Levels of PM_{10} now rarely exceed the national standard. However, the advisory limit for $PM_{2.5}$ is frequently exceeded because of extreme events such as bushfires, smog and dust storms.

Climate change may influence the frequency of respiratory allergies and epidemic level asthma events like the one that occurred during the pandemic thunderstorm-induced asthma of Melbourne in 2016, with the involvement of more than 9,000 persons and 10 deaths. The thunderstorm arising in a rural area swept across Melbourne with a sudden change in temperature, wind speed and direction occurred on a day with extreme concentration of grass pollen in the air. It is proposed that this led to a major rise in concentration of pollen grains, hydration and rupture of pollens by osmotic shock with release of allergen-carrying paucimicronic particles of respirable size such as starch granules and other cytoplasmic components into the atmosphere. This resulted in the inhalation of these particles by those who had seasonal allergic rhinitis to the pollen with or without prediagnosed asthma and the onset of asthma epidemics. Therefore, patients with pollen allergy should be aware of the danger of being outdoors during a thunderstorm in the pollen season.

China

From the study of the burden of air pollution and weather condition on daily respiratory deaths among older adults in China, Jinan from 2011 to 2017, outdoor air pollution was significantly related to mortality from all respiratory diseases especially from chronic airway disease in Jinan, China. An increase of 10 mg/m^3 or 10 ppb of $PM_{2.5}$, PM_{10}, SO_2, NO_2, and O_3 corresponds to increments in mortality caused by chronic airway disease of 0.243% at lag 1 day, 0.127% at lag 1

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day, 0.603% at lag 3 day, 0.649% at lag 0 day, and 0.944% at lag 1 day, respectively. The effects of air pollutants were usually greater in females and varied by respiratory subgroups. Sex, age, temperature, humidity, pressure, and wind speed may modify the short-term effects of outdoor air pollution on mortality in Jinan. Spearman correlation analysis suggested that there was a significant association between meteorological indexes and air pollutants. Compared with the other pollutants, O_3 had a stronger effect on respiratory deaths among the elderly. Moreover, chronic airway diseases were more susceptible to air pollution.

Hong Kong

From a cohort study in Hong Kong regarding the household incense burning and children's respiratory health, incense burning was associated with 48.6 mL/min lower maximum midexpiratory flow in boys. In follow-up, incense burning was associated with reduced peak expiratory flow growth in all participants. The authors also found that incense burning was associated with increased prevalence of bronchitis and bronchiolitis. Incense burning was also associated with higher prevalence of pneumonia (odds ratio [OR], 2.79) and wheezing (OR, 1.49) in boys, but not in girls. The respiratory effects of secondhand smoke have been widely studied, supporting a causal relation between parental smoking and respiratory symptoms, including cough, phlegm, breathlessness, and wheeze, in children aged 5–16 years. Ventilation systems may reduce but not eliminate secondhand smoke exposure. From of cross-section study in Hong Kong on the relationship of exposure to secondhand smoke from neighbors and respiratory symptoms in never-smoking adolescents, they found in all study subjects, 33.2% were exposed to secondhand smoke at home, including 16.2% from inside the home only, 10.0% from neighbors only and 7.0% from both. The prevalence of secondhand smoke exposure from neighbors was 17.1%, including 13.5% for 1–4 days/wk and 3.6% for 5–7 days/wk. In never-smokers, respiratory symptoms were significantly associated with secondhand smoke exposure from neighbors with adjusted odds ratio (95% confidence interval [CI]) of 1.29 for any exposure, 1.21 for 1–4 days/wk and 1.63 for 5–7 days/wk. They concluded that second-hand smoking exposure at home from neighbors was prevalent in adolescents due to Hong Kong's crowded living condition, and was associated with respiratory symptoms in never-smokers.

India

Global burden of disease data analysis revealed more than one million premature deaths attributable to ambient air pollution in 2015 in India. More than one million additional deaths can be attributed to household air pollution. $PM_{2.5}$ has been causatively linked with the most premature deaths. Acute respiratory tract infections, asthma, chronic obstructive pulmonary disease (COPD), exacerbations of preexisting obstructive airway disease and lung cancer are proven adverse respiratory effects of air pollution. Targeting air quality standards laid by the WHO can significantly reduce morbidity and mortality because of air pollution in India. India is currently exposed to high levels of ambient and household air pollutants. Respiratory adverse effects of air pollution are significant contributors to morbidity and premature mortality in India. Substantial efforts are being made at legislative, administrative, and community levels to improve air quality. However, much more needs to be done to change the 'status quo' and attain the target air quality standards. According to the report published by the India State-Level Disease Burden Initiative. India has a disproportionately high burden of chronic respiratory diseases. A third of the total global health loss from chronic respiratory diseases occurs in India. There is marked heterogeneity between the states of India in this burden and the associated risks, highlighting the need for individual states to adopt different policy approaches according to the trajectory of the disease burden they are facing. The increasing contribution of these diseases to the overall disease burden across India and the high rate of health loss from them, especially in the less developed low epidemiological transition level states, highlights the need for focused policy interventions to address this significant cause of disease burden in India.

Indonesia

According to the WHO, nearly one million of the 3.7 million people who died from ambient air pollution in 2012 lived in South-East Asia. Indonesia, as a part of the South-East Asia area, has encountered similar problems as its economies and populations have boomed. On top of that, Indonesia also faces an added burden, smoke haze produced in several areas such as Sumatra and Borneo islands resulted in spikes of increased pollution and health hazard. Landscape fires that occurred sporadically in several areas of Indonesia, was caused by the opening of palm plantation by burning. Several studies have linked the smoke and haze produced by the fires to chronic respiratory problems. It was estimated that about 339,000 deaths between 1997 and 2006 were associated with landscape fires, and 110,000 deaths occurred in South-East Asia. The rate of mortality especially spiked during the El Nino weather phenomenon, which typically correlates with drier conditions in South-East Asia. Elevated exposure during El Nino years caused 15,000 cardiovascular-linked adult deaths per year, and roughly two-thirds were linked to fine-grained $PM_{2.5}$ particles.

$PM_{2.5}$ levels across Indonesia, including urban and rural areas, are more than twice the recommended level, and nearly 28% of the population is exposed to household pollution from solid fuels. Many of Indonesian poorest citizens are regularly exposed to air pollution levels as much as 20 times higher than the WHO guidelines. Unfortunately, there was no wide spread real-time data about air quality in Indonesia, the only source is located in the US Embassy in Jakarta and it provided grim results. According to the air quality monitor there have been only 14 days of "good" and safe air to breathe in Jakarta around the year. The lowest and highest level $PM_{2.5}$ in the past 48 hours are between 10 to 164, with levels of more than 55.5 considered to be unhealthy and levels above 150.5 considered very unhealthy. There are several health-related effects of air pollution, whether it is indoor or outdoor, such as asthma, allergic rhinitis, and COPD. Unfortunately, there were only limited data available on the subject matter in Indonesia. Data released from the Health Ministry through National Health Survey in 2013 showed that there is an increase in asthma prevalence from 3.5% to 4.5%. The survey data also showed the highest prevalence is in the more than 75 years old age group, although due to the self-reported nature of the survey this data should be interpreted cautiously [5]. Data from the Greenpeace Research Laboratory also sends an alarming result, as there is plan for 4 new coal powered plant, they predicted that there will be an increase in complications caused by $PM_{2.5}$ and NO_2, such as lower respiratory infections and COPD. Unfortunately, there was no reliable national data about allergic rhinitis found for the source of this report.

Seasonal investigations on rainwater chemistry and PM pollution suspended particulate matter (SPM), PM_{10}, and $PM_{2.5}$ were conducted to understand the recent state of the ambient air quality in Jakarta, Indonesia. The characteristics of $PM_{2.5}$ were also analyzed during Eid Al Fitr in 2016 and 2017. Based on the observational data, the ambient air quality in Jakarta improved during the period of our study (2000–2016). The chemical constituents, i.e., the anion and cation concentrations, in precipitation show decreasing trends starting from 2006. Moreover, the PM_{10} and SPM concentrations also decreased slightly. The causes of these favorable trends are climatic conditions—namely, an increasing trend of rainfall—and policy intervention. Additionally, an assessment during the feast of Ied Al Fitr in 2016 and 2017 indicated a further decrease in $PM_{2.5}$ due to highly reduced inner-city traffic. These events exhibited an extreme reduction of the $PM_{2.5}$ concentration in Jakarta.

Japan

During the 1960s, the concentrations of air pollutants particularly that of SO_2, were extremely high in many industrial cities in Japan and the prevalence of bronchial asthma and chronic bronchitis increased among residents living in the cities. Many epidemiological studies were conducted, and the findings played an important role in the regulatory control of air pollution. After 1970, the concentration of SO_2 has decreased markedly, and its adverse health effects have been minimized. On the other hand, the increasing automobile traffic in Japan has caused considerable increases in concentrations of air pollutants, such as NOx and PM. The large-scale epidemiological studies conducted in Japan showed that traffic-related air pollution was associated with the development of asthma in school children and the persistence of asthmatic symptoms in preschool children. In recent years, however, the concentrations of NOx and PM have gradually decreased, since control measures based on the Automobile NOx/PM law were enforced in 2001. At present, the adverse health effects of airborne $PM_{2.5}$ and photochemical oxidants have become a major concern. These air pollutants consist of not only emissions from primary sources but also secondary formations in air, and have spread worldwide. Both short- and long-term exposures to these air pollutants are reported to increase the risk of respiratory diseases in the population. In the study of acute effects of ambient $PM_{2.5}$ on all-cause and cause-specific emergency ambulance dispatches (EAD) in Japan, showed that, in all-cause EAD, significant increases were observed in both shorter lag (lag 0: 1.24%) and average lag 0–1 (0.64%). Increases of 1.88% and 1.48% in respiratory and neuropsychological EAD outcomes, respectively, were observed at shorter lag per 10-$\mu g/m^3$ increase in $PM_{2.5}$. While respiratory outcomes demonstrated significant average effects, no significant effect was observed for cardiovascular outcomes. Meanwhile, an inverse association was observed in cerebrovascular outcomes. In summary, effects of $PM_{2.5}$ on all-cause, respiratory and neuropsychological EAD were acute, with average effects not exceeding 3 days prior to EAD onset.

Korea

It has been reported that the total Korean environmental burden of disease (DALY) was 17.98 per 1,000 persons in 2007. The most serious risk factor was outdoor air pollution (6.89 per 1,000 persons) followed by occupation (3.29 per 1,000 persons), and indoor air pollution (2.91 per 1,000 persons). The DALY of air pollution (indoor and outdoor) was 9.80 per 1,000 persons, accounting for more than half of the total environmental burden of disease. The burden of COPD, lung cancer, and asthma were 4.07, 3.16, and 1.96 per 1,000 persons, respectively.

In Korea, several studies have reported the relationships between air pollution and asthma outcomes. The majority were based on a single metropolitan city like Seoul or Busan, and measured asthma-related emergency room visits or hospitalization only, which is a marker for severe asthma exacerbations. A recent study in Seoul has suggested the possibility that hourly increase in air pollution may increase the risk of asthma exacerbation. From a population-based case-crossover study using the National Health Insurance and air pollution data between January 1, 2014 and December 31, 2016, the authors found that when compared with the control days, the average number of asthma-related hospital visits on the 24-hour and 2-hour event days for PM_{10} and $PM_{2.5}$ were increased by 4.10%, 3.45%, 5.66%, and 3.74%, respectively. The ratio of an average number of asthma-related hospital visits increased from the 24-hour event day for PM_{10} to 4 days after the event day, peaking on the third day after the event day. Hospitalizations also increased on the third day after the event. Although there was a difference in magnitude, $PM_{2.5}$ exposure showed similar trends when compared with PM_{10} exposure. They concluded that a significant association between short-term PM exposure exceeding the current daily average environmental standard and asthma-related hospital visits. These results are expected to aid in establishing appropriate environmental standards and relevant policies for PM.

People spend most of time indoors at their homes, schools, buildings, and even underground. Naturally concerns regarding indoor air pollutants have been increased with modern life style. Major indoor air pollutants include VOCs, PM and combustion pollutants such as SO_2, CO, and NO_2. Indoor air pollutants come from various sources: Environmental tobacco smoke, furniture, combustion products such as stoves and gas ranges, building materials, and biological agents from mold and animals. Although there are some debates, sick building syndrome (SBS) may stand for the possible clinical manifestations associated with indoor pollutants. Possible symptoms related with SBS are a runny nose, stuffy nose, sneezing, headache, eye dryness, eye irritation, tiredness, skin dryness, chest discomfort, breathing difficulties, sputum, cough, hypersensitivity to pollutions or irritants, wheezing, and any sleeping difficulties. In Korea, a study showed changes in inflammatory markers before and after a move into a new building that had higher levels of ambient VOCs and formaldehyde. Decreased fractional exhaled nitric oxide and an increase in urinary leukotriene E4 after the move suggested changes in the inflammatory environment of the airway, possibly increased non-Th2 inflammation. In another study done in Korea, the researchers showed that urinary levels of VOC metabolites are related with oxidative stress and decreased lung function in the elderly. It has been reported that about half of 314 store workers in underground shopping centers had experienced SBS symptom groups. It has been also reported that children who had moved to a newly built home were 2.92 times (95% CI, 1.76–4.84) and 3.09 times (95% CI, 1.71–5.57) more likely to have overlapped rhinitis (rhinitis with asthma or eczema) or overlapped allergic rhinitis (overlapped rhinitis and exhibiting sensitization to more than one inhaled allergen in the skin prick test) from the phase III International Study of Asthma and Allergies in Childhood study from Korea.

Malaysia

In a study of the air quality on Langkawi Island, a famous tourist destination in Malaysia, using 13 years of data (1999–2011) recorded by the Malaysian Department of Environment. Variations of 7 air pollutants (O_3, CO, NO, NO_2, NOx, SO_2, and PM_{10}) and 3 meteorological factors (temperature, humidity, and wind speed) were analyzed. The results showed PM_{10} was the dominant air pollutant in Langkawi and values ranged between 5.0 mg/m^3 and 183.2 mg/m^3. The patterns of monthly values showed that the concentrations of measured air pollutants on Langkawi were higher during the south-west monsoon (June–September) due to seasonal biomass burning activities. High CO/NOx ratio values (between 28.3 and 43.6), low SO_2/NOx ratio values (between 0.04 and 0.12) and NO/NO_2 ratio values exceeding 2.2 indicate the source of air pollutants in this area was motor vehicles. The status of air quality on the island could be improved through control on motor vehicle emissions as well as collaborative efforts to reduce regional air pollution, especially from biomass burning.

Mongolia

A central Asian country bordered by China and Russia, Mongolia is known for its vast tracts of largely empty grassland, freezing winters, and nomadic culture. In recent years

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it has become known as one of the world's worst air in the winter months, particularly in Ulaanbaatar, where 46% of the country's population resides. The Mongolian National Agency for Meteorology and Environment Monitoring reports that in 2017, in the winter months that extend from November to March, the mean concentration of PM for the country as a whole was between 80–140 μg per cubic meter. In the districts of Ulaanbaatar, the concentration of fine PM can reach well above 1,000 $\mu g/m^3$. According to the World Health Organization Regional Office for the Western Pacific policy brief published in 2018, the brief states that 80% of Ulaanbaatar's air pollution in the winter months is caused by households and low-pressure boilers burning raw coal in the districts. The 2017 Mongolia national program on reduction of air and environmental pollution aims by 2025 to decrease air pollutants by 80% and calls for prohibiting the use of unprocessed coal everywhere except in thermal power plants in Ulaanbaatar. The State Great Khural of Mongolia on measures to reduce air pollution based on the Air Law. The Government of Mongolia prohibited use raw coal in Ulaanbaatar since May 15, 2019. In 2020 winter, the environmental pollution decreased air pollutants by 30% in Ulaanbaatar.

Philippines

In the Philippines, the researchers studied the effect of air pollution on the pulmonary function of high school students studying in a secondary public school in Quezon City. This is a cross-sectional study. 153 students (80 males, 73 females) were included with a mean age of 14.5 years. They found that air pollution may have an effect on the subjects' lung function based on spirometry readings. Only 54.74% had normal lung function test results while 23.36% had reduced $FEF_{25\%\text{-}75\%}$ (forced expiratory flow 25%–75%). Smoking exposure resulted in low lung function values, while no causal association can be made between total suspended particulate levels and lung function in this cross-sectional study.

Singapore

Atmospheric fine particles in Singapore are generated not only from emissions of common combustion sources such as power plants and motor vehicle traffic, but also from wildfires in the region. Forest and peat fire emissions from Indonesia elevated the $PM_{2.5}$ concentrations in Singapore several times over the last decade, leading to reduced atmospheric visibility (haze) and respiratory ailments. In late 1994, the air of Singapore was affected by a haze of pollutants originating from forest fires and agricultural burning in south Sumatra, and carried by southwest monsoon winds more than 500 km to Singapore. In a study in Singapore, researchers examined the effect of the haze on asthma in children less than 12 years old. Between September and October, 1994, atmospheric concentration of PM_{10} was 20% higher than the year's average moving trend. An increase in emergency room attendances for acute childhood asthma was observed in 2 large general hospitals in Singapore. In the following study, positive correlation between levels of air pollutants, i.e., SO_2, NO_2, and total suspended particles, maximum 1 hour daily average for O_3 and daily Emergency Department visits for asthma was observed in children aged 3–12 years, but not among adolescents and young adults (13–21 years old).

Taiwan

A case-crossover study in northern Taiwan to assess the associations between 5 major air pollutants and asthma, which demonstrated that a stronger association between PM_{10} and asthma hospitalization was found in cool temperature (temperature < 25°C) than in warm temperature (temperature > 25°C). In addition, the number of outpatients visit due to asthma were higher in the cold season than in the warm season, which may also contribute to the season-specific association. A nationwide asthma survey on the effects of air pollution in Taiwan using National health research insurance database and evaluated the association between different air pollutants and outpatient and inpatient visits. This study found that CO, NO_2, and PM_{10} had significant estimated associations on outpatient visits due to asthma and children are more susceptible than other age groups. A study in 2017 characterized the $PM_{2.5}$ components in a suburban site of central Taiwan and conducted a time-stratified case-crossover study to elaborate the effects of daily concentration of each $PM_{2.5}$ component on asthma outpatient visits. Multiple linear regression models were used to back extrapolate the historic concentration of individual components of $PM_{2.5}$ from 2000 through to 2010, including black carbon and 8 ions, namely, sulfate, nitrate (NO_3), ammonium, chloride, potassium, magnesium, calcium, sodium. The results suggest that exposure to NO_3, black carbon, and potassium derived from industry-related combustion or motor vehicles emission sources may increase the risk of asthma outpatient visits, particularly during the cold season.

Thailand

Thailand has faced increasing levels of air pollution in the past few years. According to the Pollution Control Department, ground-level O_3 and airborne particles are the 2 pollutants that pose the greatest threat to human health in Thailand. PM is the most important air pollutant in both urban and rural areas. The sources are from traffic, agricultural burning and forest fires. The study published in 2014 by Guo et al. [34] about the association between air pollution and mortality in Thailand examined the effects of air pollutants including PM < 10 mm in aerodynamic diameter (PM_{10}), SO_2, and O_3 on mortality. They found that all air pollutants had significant short-term impacts on nonaccidental mortality. An increase of 10 μg/m^3 in PM_{10}, 10 ppb in O_3, 1 ppb in SO_2 were associated with a 0.40% (95% posterior interval [PI], 0.22%–0.59%), 0.78% (95% PI: 0.20%–1.35%) and 0.34% (95% PI, 0.17%–0.50%) increase of nonaccidental mortality, respectively. O_3 air pollution is significantly associated with cardiovascular mortality, while PM_{10} is significantly related to respiratory mortality. Phosri et al. [35] have investigated the effects of ambient air pollution on hospital admissions for cardiovascular and respiratory diseases in Bangkok, Thailand. From January 2006 to December 2014, they found an increase of 10 μg/m^3 in O_3, NO_2, SO_2, PM_{10}, and 1 mg/m^3 in CO at lag 0–1 day was associated with a 0.14%, 1.28%, 8.42%, 1.04%, and 6.69% increase in cardiovascular admission, respectively; and 0.69%, 1.42%, 4.49%, 1.18%, and 7.69% increase in respiratory admission, respectively. The elderly (≥65 years) seemed to be the most susceptible group to the effect of air pollution, whereas the effect estimate for male and female was not significantly different.

Vietnam

In Ho Chi Minh City, Vietnam, average daily concentrations for PM_{10}, O_3, NO_2, and SO_2 were 73, 75, 22, and 22 μg/m^3, respectively, with higher pollutant concentrations observed in the dry season (November through April) compared with the rainy season. To estimate the effect of exposure to air pollution on hospital admissions of young children for acute lower respiratory infection and to explore whether such effects differed between poor children and other children. In the dry season, risks for acute lower respiratory infections (ALRI) hospital admissions with average pollutant lag (1–6 days) were highest for NO_2 and SO_2 in the single-pollutant case-crossover analyses, with excess risks of 8.50% and 5.85% observed, respectively. NO_2 and SO_2 effects remained higher than PM_{10} effects in both the single-pollutant and two-pollutant models. The 2-pollutant model indicated that NO_2 confounded the PM_{10} and SO_2 effects. In the rainy season, negative associations between PM_{10} and ALRI admissions were observed. No association with O_3 was observed in the single-pollutant

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model, but O_3 exposure was negatively associated with ALRI admissions in the 2-pollutant model. There was little evidence of an association between NO_2 and ALRI admissions. As the time between onset of illness and hospital admission was thought to range from 1 to 6 days, ALRI admissions were generally positively associated with ambient levels of PM_{10}, NO_2, and SO_2 during the dry season (November–April), but not the rainy season (May–October). Positive associations between O_3 and ALRI admissions were not observed in either season.

Table 1. The effect of air pollution on allergic diseases in the different countries of Asia-Pacific

Country	Pollutants	Key findings	References
Australia	O_3, NOx, and VOC: principally temperature and wind conditions	Those with higher mean annual residential NO_2 exposure had greater odds of urgent healthcare use in the previous year (OR, 3.45 per one interquartile range increase; 95% CI, 1.31–9.10; $p = 0.01$).	22,23
China	$PM_{2.5}$, PM_{10}, SO_2, NO_2, and O_3	An increase of 10 mg/m^3 or 10 ppb of $PM_{2.5}$, PM_{10}, SO_2, NO_2, and O_3 corresponds to increments in mortality caused by chronic airway disease of 0.243% (95% CI, 0.172–0.659) at lag 1 day, 0.127% (95% CI, 0.161–0.415) at lag 1 day, 0.603% (95% CI, 0.069–1.139) at lag 3 day, 0.649% (95% CI, 0.808–2.128) at lag 0 day and 0.944% (95% CI, 0.156–0.1598) at lag 1 day. O_3 had a stronger effect on respiratory deaths among the elderly.	26
Mongolia	Households smoking, severe air pollution	The asthma prevalence 20.9% in Mongolian children was higher than that in Asia-Pacific countries. It was attributable to households' (especially mothers) smoking in draft-free houses designed for the cold area and severe air pollution due to rapid industrialization and urbanization. Prevalence of current wheezer and diagnosed asthma were 15.7% (95% CI, 14.7–16.8) and 4.7% (95% CI, 4.3–5.6) among adults in all age respectively. Prevalence of current allergic rhinitis was 23.6% (95% CI, 22.4–24.9) in all age group. Pollutants are SO_2, CO, NO_2, diesel exhaust particle, and $PM_{2.5}$.	27,28
Japan	SO_2, NOx, and $PM_{2.5}$	During the 1960s, air pollutants are particularly SO_2. After 1970, the increasing automobile traffic has caused increases in concentrations of s NOx and PM. At present, $PM_{2.5}$ and photo chemical oxidants have become a major concern.	29,30
Korea	1. PM_{10}, CO, NO_2, and VOC	1. Using adults as the referent, the RR of asthma admissions with 10-μg/m^3 increase of PM_{10} is 1.5% (95% CI, 0.1%–2.8%) lower for children, and 1.3% (95% CI, 0.7%–1.9%) higher for the elderly; RR with 1-ppm increase of CO is 1.9% (95% CI, 0.3%–3.8%) lower for children; RR with 1-ppb increase of NO_2 (1 ppb) is 0.5% (95% CI, 0.3%–0.7%) higher for the elderly. PM, and combustion pollutants such as SO_2, CO, and NO_2. Indoor air pollutants come from various sources: Environmental tobacco smoke, furniture, combustion products such as stoves and gas ranges, building materials, and biological agents from mold and animals. VOCs are important indoor air pollutants produced by evaporation at room temperature from diverse sources, such as building materials, paints, cleaning agents, furnishings, adhesives, combustion materials, floor, and wall coverings. Formaldehyde, xylene, toluene, benzene, ethyl-benzene, and phthalate are commonly found VOCs at home or in buildings. Children who had moved to a newly built home were 2.92 times (95% CI, 1.76–4.84) and 3.09 times (95% CI, 1.71–5.57) more likely to have overlapped rhinitis (rhinitis with asthma or eczema) or overlapped allergic rhinitis (overlapped rhinitis and exhibiting sensitization to more than one inhaled allergen in the skin prick test) from the phase III ISAAC study from Korea.	31,48
	2. CO, NO_2, SO_2, and O_3	2. The frequency of asthma treatment during the past 12 months showed a significant increase with exposure to NO_2 (1.67; 95% CI, 1.03–2.71) in the complex source zones. The frequency of allergic rhinitis treatment during the past 12 months increased significantly with exposure to black carbon (1.60; 95% CI, 1.36–1.90) ($p < 0.001$), SO_2 (1.09; 95% CI, 1.01–1.17) ($p < 0.05$), NO_2 (1.18; 95% CI, 1.07–1.30) ($p < 0.01$) for all subjects.	32
Malaysia	O_3, CO, NO, NO_2, NOx, SO_2, and PM_{10}	Annual average concentrations of all air pollutants (PM_{10}, O_3, CO, NO, NO_2, and NOx) on Langkawi Island were below the suggested limits by RMAQG and the WHO. The diurnal patterns showed an increase in all air pollutant concentrations except O_3 during peak hours which are from 07:00 to 08:00 and from 17:00 to 18:00.	33
Thailand	O_3, NO_2, SO_2, PM_{10}, and CO	An increase of 10 μg/m^3 in O_3, NO_2, SO_2, PM_{10}, and 1 mg/m^3 in CO at lag 0–1 day was associated with a 0.69% (95% CI, 0.18–1.21), 1.42% (0.98–1.85), 4.49% (2.22–6.80), 1.18% (0.79–1.57), and 7.69% (5.20–10.23) increase in respiratory admission. PM_{10}, SO_2, and O_3 on mortality. They found that all air pollutants had significant short-term impacts on nonaccidental mortality. An increase of 10 μg/m^3 in PM_{10}, 10 ppb in O_3, 1 ppb in SO_2 were associated with a 0.40% (95% posterior interval [PI], 0.22%–0.59%), 0.78% (95% PI, 0.20%–1.35%) and 0.34% (95% PI, 0.17%–0.50%) increase of nonaccidental mortality, respectively. O_3 air pollution is significantly associated with cardiovascular mortality, while PM_{10} is significantly related to respiratory mortality.	34,35
Vietnam	PM_{10}, O_3, NO_2, and SO_2 were 73, 75, 22, and 22 μg/m^3	PM_{10}, O_3, NO_2, and SO_2 were 73, 75, 22, and 22 μg/m^3, with higher pollutant concentrations observed in the dry season compared with the rainy season. The major cause might be the reliance of approximately 80% population conventional biomass burning in the region.	35-37

(continued to the next page)

Table 1. (Continued) The effect of air pollution on allergic diseases in the different countries of Asia-Pacific

Country	Pollutants	Key findings	References
Taiwan	PM_{10}, $PM_{2.5}$, CO, and O_3	1. Exposure to PM_{10}, $PM_{2.5}$, CO, and O_3 was associated with asthma (OR [95% CI]: 1.39 [1.03–1.87], 1.45 [1.07–1.97], 1.36 [1.01–1.83], and 0.68 [0.51–0.92]). $PM_{2.5}$ may have increased the risk of AR (1.54 [1.03–2.32]). 2. Exposure to $PM_{2.5}$ and mite allergens had a synergistic effect on the development of asthma. $PM_{2.5}$, PM_{10}, O_3, SO_2, and NO_2 were positively associated with childhood asthma hospitalization, while O_3 was negatively associated with childhood asthma hospitalization. SO_2 was identified as the most significant risk factor.	37,38
Hong Kong	High- or low-pollution district	Compared to those in the low-pollution district, girls in the high-pollution district (HPD) were at significantly higher risk for cough at night (OR adjusted, 1.81; 95% CI, 1.71–2.78) and phlegm without colds (OR adjusted, 3.84; 95% CI, 1.74–8.47). Marginal significance was reached for elevated risks for asthma, wheezing symptoms, and phlegm without colds among boys in HPD (adjusted OR, 1.71–2.82), and chronic cough among girls in HPD (OR adjusted, 2.03; 95% CI, 0.88–4.70).	39,40
India	$PM_{2.5}$ and PM_{10}	Short-term exposures to ambient pollutants have strong associations between COPD, respiratory illnesses and higher rates of hospital admission or visit. The long-term effects of ambient air pollution, was associated with deficit lung function, asthma. $PM_{2.5}$ and PM_{10} are primarily responsible for respiratory health problems.	41-44
	$PM_{2.5}$ and PM_{10}	The ORs for the risk of asthma in children with exposure to mild, moderate and heavy traffic pollution compared with minimal traffic pollution were 1.63 (95% CI, 1.43–1.85), 1.71 (95% CI, 1.49–1.96). and 1.53 (95% CI, 1.31–1.78) in the younger group. In the older group, they were 1.19 (95% CI, 1.04–1.36), 1.51 (95% CI, 1.31–1.75), and 1.51 (95% CI, 1.29–1.76).	45
Indonesia	SPM, PM_{10}, and $PM_{2.5}$	An assessment during the feast of Ied Al Fitr in 2016 and 2017 indicated a further decrease in $PM_{2.5}$ due to highly reduced inner-city traffic. These events exhibited an extreme reduction of the $PM_{2.5}$ concentration in Jakarta. Impact only on asthma.	Indonesian Government data
Philippines		An assessment of 153 highs school students noted that exposure to air pollution affected lung function which only 54.7% having normal lung functions. Exposure to indirect smoking had a large effect on lower lung function values compared to total suspended particulate matter levels.	46

O_3, ozone; NO_2, nitrogen dioxide; PM, particulate matter; $PM_{2.5}$, PM with a diameter of 2.5 µm or less; PM_{10}, PM with a diameter of 10 µm or less; SO_2, sulfur dioxide; NOx, nitrogen oxides; VOC, volatile organic compound; OR, odds ratio; CI, confidence interval; RR, relative rate; ISSAC, International Study of Asthma and Allergies in Childhood; RMAQG, Recommended Malaysian Air Quality Guidelines; WHO, World Health Organization; AR, allergic rhinitis; COPD, chronic obstructive pulmonary disease; SPM, suspended particulate matter.

SUMMARY

The Asia-Pacific which is regarded as the most populated continent in the world, has a huge burden of both outdoor and indoor pollutants, including $PM_{2.5}$, PM_{10}, SPM, CO, O_3, NO_2, SO_2, NO, and household pollutants including biomass and tobacco. The risk factors for the epidemic rise of allergic diseases in the Asia-Pacific are due to the increasing urbanization, environmental factors of air pollution, lack of environmental awareness programs or pollution control regulations in many countries lack of environmental awareness programs or pollution control regulations in many countries and climate changes in recent decades than the other part of the world. Because of the different environmental exposure in different countries of the Asia-Pacific, strategies to combat allergic disease in the Asia-Pacific region should be focused on active government policies to fight air pollution based on the local data. Substantial efforts need to be implemented with a concerted strategy at legislative, administrative, and community levels to improve air quality. Recent studies have shown that adequate control of allergic airways disease like rhinitis could reduce the impact of air pollution [47].

UNMET RESEARCH NEEDS AND ACTIONS NEEDED

Collaborative multicity studies in Asia-especially when designed, conducted, and analyzed using a common protocol-will provide more robust air pollution effect estimates for the region as well as relevant, supportable estimates of local adverse health effects needed by environmental and public-health policymakers.

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