

Clean air actions and health plans in China

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China has been experiencing some of the world's most serious air pollution, especially severe smog events swept China in January of 2013, leading to extensive international attention. Efforts to understand and mitigate the impacts of ambient air pollution on public health have been taken to tackle this pollution in China. Clean air actions developed nationwide have aggressively lowered fine particulate matter (PM_{2.5}) pollution in recent years.^[1] National health plans and research projects on air pollution have been motivated and funded by the government. Rapidly growing epidemiological evidence has emerged to preliminarily uncover the effects of elevated levels of ambient air pollution on human health. However, China's pollution levels still exceed that of the World Health Organization (WHO) least-stringent target.^[1] Ambient air pollution still poses a serious threat to human health and welfare. It is critical to elucidate targets and efforts on the improvement of air quality and the reduction of related health effects. Therefore, this paper has organized the development of clean air actions, health plans, relevant research projects, and reviewed key milestones of health evidence in China to propose suggestions to air pollution mitigation in its next stage.

China Clean Air Actions

Since 2013, the China National Environmental Monitoring Centre has expanded the air pollution monitoring network, with now more than 2000 stations across the country, recording concentrations of pollutants including inhalable particulate matter (PM₁₀), PM_{2.5}, ozone (O₃), sulfur dioxide (SO₂), nitrogen dioxide (NO₂), and carbon monoxide (CO).^[2,3] This monitoring network provides a key data source for air pollution control.

In the same year, the China Air Pollution Prevention and Control Action Plan (APPCAP) was established, stipulating targets for PM control across the country and in several

key areas by 2017. Specifically, concentrations of PM_{2.5} in major cities nationwide will drop by more than 10% relative to 2012 levels. For some of the most heavily polluted areas of concern, APPCAP also pointed out that the concentration of PM_{2.5} in the Beijing-Tianjin-Hebei region (BTH), Yangtze River Delta (YRD), and Pearl River Delta (PRD) will drop by about 25%, 20%, and 15% by 2017, respectively.^[4,5] In order to achieve the above goals, APPCAP proposes ten tasks that need to be completed, including optimizing the industrial structure, accelerating technological advancement, establishing early warning and emergency monitoring systems, and so on.^[5] In line with the policies related to air quality control, relevant laws were formulated to put forward the prevention and control of air pollution requirements. The newly revised environmental protection law in 2014 clearly stated the requirements to establish and improve environmental and health monitoring, investigation and risk assessment systems, as well as encourage research on environmental health.^[6,7]

Up until 2017, air quality has been significantly improved across the whole country as well as in key regions, with the percentage of days with good air quality reaching 72.7%. The annual average PM_{2.5} concentration in 74 major cities was 47 µg/m³, decreasing by 33.3% compared with PM_{2.5} concentrations in 2013, while the reduction of annual average PM_{2.5} concentration in BTH, YRD, and PRD was 37.3%, 35.2%, and 26.1%, respectively.^[5] In addition, levels of SO₂, NO₂, and CO across the country also showed a slight or significant decrease compared to that of 2013, decreasing by 57.5%, 9.1%, and 32.0%, respectively.^[3] In 2018, the State Council released a three-year action plan to "win the defense of the blue sky," reducing total emissions of major air pollutants and greenhouse gases by 2020, increasing the proportion of days with blue sky to 80%, and reducing heavy pollution days by 25% compared to that of 2015.^[8] However, challenges remain.

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Air pollution in China is still much worse than that experienced on average across the globe. O₃ pollution, with a significant increasing trend recently, has not been included in the clean actions taken to date.

National Health Plans and Research Projects in China

With the promoting and deepening of clean air actions, a series of health plans and scientific research projects, which bring benefits to air quality improvement, have been issued by the government in recent years. The National Health Commission has adopted environmental pollution control as a critical step to reduce health hazards and listed it into national health plans. Health China 2030, released in 2016, calls for better management of health risks caused by pollution, in which the emphasis is on integrating health policies with all other major policies, such as reducing environmental pollution, to promote the level of people's health. Healthy China initiative 2019 to 2030, from vision to action for health care, targeted largely towards the promotion of a healthy environment and improvement of air quality.^[9] One of the main tasks is that, by 2022 and 2030, residents' environmental and health literacy levels will reach 15% and 25% or above, respectively.

The Ministry of Science and Technology of the People's Republic of China issued guidelines of the National Key Research and Development Plan "Research on the Causes and Control Techniques of Air Pollution" and granted four projects to explore the health effects of air pollution in 2016 and 2017. These projects focus on acute and chronic health effects of air pollution and the development of high-precision exposure assessment and risk source identification techniques, as well as early identification techniques for the adverse human health effects caused by air pollutants. The National Natural Science Foundation of China issued a joint research program titled "Causes, health effects and coping mechanisms of combined air pollution in China" to reveal the key chemical and physical processes of the atmosphere and explore key control technologies and principles to cope with combined pollution. As the most critical air pollution area in China, the BTH region and surrounding areas (named "2 + 26" cities) have received great attention. In 2017, 28 projects were supported by the Ministry of Ecology and Environment of the People's Republic of China to investigate the sources of heavy air pollution, advance techniques for emissions reduction, and evaluate the health impacts of air pollution in the "2 + 26" cities.

Epidemiological Evidence on Air Pollution and Human Health in China

Efforts to understand the effects of China's air pollution on human health have skyrocketed since 2013, especially focusing on PM_{2.5} as the primary pollutant of interest. Early studies took smog events as a starting point and compared death counts or hospital visits for a short period before, during, and after extreme air pollution episodes.^[10,11] Research then began to better estimate short-term pollution-mortality associations in China and found a link between heavy PM_{2.5} pollution and adverse health impacts in China.^[12,13] Chen *et al*^[12] found that a per 10 µg/m³ increase in the 2-day moving average of

PM_{2.5} concentrations at the city-level was significantly associated with increases in mortality of 0.29% in respiratory diseases and 0.27% for cardiovascular mortality. A study of 130 Chinese counties performed from 2013 to 2018 added additional causes of death at the county-level, including acute myocardial infarction (0.21%, 95% confidence interval [CI]: 0.05–0.37) and acute ischemic heart disease (0.19%, 95% CI: 0.04–0.35).^[13] A new study of 104 Chinese counties found a J-shaped association of the mortality burden attributable to short-term PM_{2.5} exposure and an estimated 169,862 additional deaths from PM_{2.5} pollution in 2015.^[14]

In terms of long-term effects of ambient PM_{2.5} pollution, Li *et al*^[15] estimated an hazard ratio (HR) of 1.08 (95% CI 1.06–1.09) of all-cause mortality for a 10 µg/m³ increase in PM_{2.5} based on the Chinese Longitudinal Healthy Longevity Survey. An HR of 1.11 (95% CI 1.05–1.17) of incident hypertension for a 10 µg/m³ increase in PM_{2.5} was estimated in the China-PAR (Prediction for Atherosclerotic Cardiovascular Disease Risk in China) cohort study.^[16] Xie *et al*^[17] reported that pre-mature deaths attributed to ambient PM_{2.5} pollution have resulted in 1,255,400 pre-mature deaths in 2010, 42% greater than that of in 2000.

In addition, comparable findings suggested that clean air actions not only improved air quality but also reduced the burden of air pollution-related diseases. Huang *et al*^[5] evaluated the effects of the China APPCAP on long-term air quality management and found that after substantial improvements in air quality, 47,240 fewer deaths and 710,020 fewer years of life lost in 2017 than in 2013. Wang *et al*^[18] estimated health benefits associated with PM_{2.5} nationwide under the air quality scenarios proposed by the 13th Five-Year Plan for Eco-Environmental Protection and reported that these scenarios could reduce the PM_{2.5}-related pre-mature deaths by 129,278 by 2020 and 217,988 by 2030.

The health pieces of evidence listed above have given some preliminary answers regarding how air pollution affects health in China. They consistently show that air pollution still has a large impact on public health during the implementation of clean air actions. Nevertheless, most research focused on PM_{2.5} and ignored the impact of combined pollution nationwide, as well as potential new challenges, such as O₃ pollution.

Suggestions for Clean Air and Health Protection

Air quality intervention is a protracted and arduous task. To better improve air quality and health impacts, we propose some suggestions below to plan strategies against air pollution in the next stage.

To learn from our experience and lessons to date for the development of future interventions, involving a clear understanding of the effectiveness and benefits of air quality interventions, and currently unresolved pollution problems and existing barriers. We can use pollution exposure and health risk assessments to assess short- and long-term benefits of air quality improvement as well as identify where health risks still exist. These can provide

massive and important information for policy-makers to implement the next steps in clean air actions.

To continue to take efforts to substantially improve our air quality. On one hand, more steps should be taken to reduce ambient PM_{2.5} pollution. We should notice that PM_{2.5} pollution in China still far exceeds the levels of most countries worldwide. Furthermore, we observed robust and consistent evidence of China pointing out life-threatening of PM_{2.5} at this pollution level. One of the effective steps is to identify the primary targeted fractions and components of PM_{2.5} for local clean-air initiatives, and then take further control against these toxic components as well as their major emission sources. On the other hand, it is important to pay more attention to ambient O₃ pollution. With respect to O₃ pollution posing new health risks with the continual increase in ground-level O₃, which does not get enough attention in clean air actions, emission reduction actions should target relevant emission sources that largely contribute to O₃ pollution.

To improve China's current air quality standards to achieve broad population health co-benefits. Standards or guidelines have been a powerful tool in air quality management during the history of air quality improvement in the United States and Europe. However, our air quality standards implemented in 2012 lacked evidence from China-specific epidemiologic studies. They are not strict enough to protect public health effects, especially compared with developed countries' standards and the WHO's guidelines. We need to strengthen the standards and plan appropriate goals supported by current evidence of pollutant-related health effects in China to gradually close in on a sustainable target at pollution reduction to a relatively safe level.

To motivate and initiate innovative research projects to support air pollution control development. Current research projects have concentrated on PM_{2.5} pollution. However, the health effects of PM_{2.5} extends far beyond mass alone, and its inhaled fractions and chemical components are suggested to be toxicologically more important. Besides, combined pollution of multi-pollutants, including O₃ and other gas pollutants, can be more harmful to public health. Therefore, priority areas for research to guide policy include a better understanding of the injury mechanism involved in PM_{2.5}-related fractions and components and additional studies on adverse health outcomes from air pollution mixtures, especially characterizing the health risks from O₃.

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Conflicts of interest

None.

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