Editorial of Air Pollution Section

Health effects of air pollution: what we need to know and to do in the next decade

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Submitted Mar 14, 2019. Accepted for publication Mar 17, 2019.
doi: 10.21037/jtd.2019.03.65
View this article at: http://dx.doi.org/10.21037/jtd.2019.03.65

On January 12, 2019, we gathered for a mini-symposium hosted by the Center for Environment and Health of Peking University to discuss the knowledge gaps concerning efforts to reduce the health impact of air pollution. As epidemiologists, toxicologists, exposure scientists, environmental health scientists, and clinician scientists, we were motivated to share our perspectives on what data and actions are required over the next decade. We consider such discussions as timely given that there have been numerous studies of air pollution and health effects in recent years. Our goal was to identify priority areas that will help guide future studies to address the most important issues pertinent to mitigating these health risks.

Following decades of studies documenting a large range of adverse health effects of air pollution, one central question continues—why do we still need more studies? The argument commonly used is that there is enough persuasive evidence that air pollution has many negative health effects and therefore there is no need to keep demonstrating that air pollution is toxic. Perhaps, all efforts should be focused now on how to mitigate the effects of this pollution. However, we counter argue that it is still imperative to conduct meaningful air pollution health effects studies for the following reasons:

First, research is needed to provide information and results that support effective governmental regulations. In the US, UK, and other countries where air pollution levels are relatively low, emerging evidence suggests that adverse health effects continue to persist even at levels below current regulatory standards (1-3). In these settings, research is essential to provide the scientific basis for revisions of air quality standards (1,3). One apparent question is how low is low enough; and answering this question requires new methods to accurately assess exposures at these low levels and to separate true health effects from "background noise".

On the other hand, in China, India and other countries with high-levels of air pollution, research is needed to identify the sources of pollution most responsible for the adverse health impact. We notice that the focus of pollution control has been on primary emission sources of particulate matter especially fine particulate matter ($PM_{2.5}$). While this is important and necessary, ignoring secondary particle formation and the composition of these particles would limit the effectiveness of measures for further reductions of $PM_{2.5}$ generated from atmospheric reactions and would also not address the need to reduce ground-level ozone concentrations. For example, air quality policies successfully reduced air pollutant concentrations from 2005 to 2016 in New York State in the US and the population as a whole experienced a health benefit (4). However, changes in particulate matter may have made the same dose of air pollution more toxic (4). Thus, we recommend that future studies, performed in both low and high air pollution locations, focus on the examination of health effects of the air pollution mixtures including primary and secondary pollutants. Determining which components of the air pollution mixture are more toxic is useful in targeting the priority emission sources that require more cost-effective controls.

Second, research is required to assess health benefits of air pollution reduction policies. In the US, assessments of health and economic benefits, relative to the cost, associated with a particular regulation or policy, have been instrumental to justify the needs for this and similar polices. It is important to do this type of research in other countries. For example, China is now counting the number of blue-sky days each year as a measure of success for air pollution controls. However, whether this measure accurately reflects the true health benefit remains unanswered. The US Environmental Protection Agency (EPA) has developed methods to evaluate the health economics and cost/benefit ratio of a pollutant emission reduction/standard setting (5,6). These methods can be adopted and modified to assess health benefits of pollutant reductions for other countries. Methods that are currently used to assess health benefits have focused mostly on mortality and more recently on certain morbidity outcomes such as incidence of heart attacks for cardiovascular disease or exacerbations for asthma or chronic obstructive pulmonary disease (COPD). However, it is important to develop other short-term or long-term health outcome measures that could predict sensitivity or risk of disease development in particular individuals and at-risk populations, e.g., children and pregnant women, rather than in the general population. In this regard, currently we do not have exposure-effect relationships specifically developed for short- versus long-term, indoor versus outdoor, single-pollutant versus multi-pollutant exposure scenarios. Recent advancements in spatiotemporal modeling of air pollution exposure with refined scales can help improve exposure-effect estimates (7). More accurate exposure-effect relationships will help with the assessment of health benefits associated with various control measures. Future research in this area should look at lessons learned from previous "accountability" studies and different methods by which regulatory actions were evaluated (8).

Third, research is needed to develop and/or evaluate exposure reduction strategies, rather than just focusing on reducing ambient levels. Given that urban residents spend a very large fraction (>80%) of time indoors, reducing indoor levels of air pollutants can lead to substantial reductions in exposure. Countries like China can leverage their indoor air quality standards as a policy instrument to reduce indoor air pollutants emitted from indoor sources and those infiltrating from outdoors. A recent study demonstrated a significant mortality reduction in urban China if current indoor air standard for $PM_{2.5}$ is met (9). We recommend that future studies be conducted to evaluate health benefits associated with achieving the current and more stringent (hypothetical) indoor air quality standards. We regard this line of research particularly important in countries with high outdoor air pollution, because it is not practical to anticipate ambient pollutant concentrations to fall rapidly to the levels of the US EPA standards or the WHO guidelines. In contrast, indoor air filtration and other technologies are readily available to reduce indoor concentrations to meet the air quality standards or guidelines.

In rural households using solid fuels, indoor air pollution is from cooking and heating sources. Based on the current knowledge, this line of research needs to find an exposure reduction "threshold" that is sufficient to result in measurable health improvements, as many improved stoves capable to reduce indoor $PM_{2.5}$ and CO levels have failed to show improvements in health outcomes (10). It is also important to develop new study designs, exposure and/or health outcome assessment methods, more suitable for rural indoor air pollution settings.

Fourth, research is essential to study health effects of air pollutants other than those defined as criteria air pollutants by US EPA (particulate matter, carbon monoxide, ozone, nitrogen dioxide, sulfur dioxide, and lead). Synthetic chemicals have been widely used in the industry, commercial, and consumer sectors. Some of these chemicals fall into the category of volatile organic compounds (VOCs). Reactive VOCs have received attention due to their ozone-forming potentials. However, many of these chemicals (e.g., benzene, formaldehyde) are toxic and/or carcinogenic. Some of these chemicals have higher concentrations indoors because they are off-gassed from building materials and consumer products. Few studies have examined the health effects of these air pollutants, especially within the context of real-world exposure to mixtures.

Fifth, research is critical to understand individual susceptibility to air pollutants. It has been increasingly recognized that not everyone will be equally affected by the same amount of air pollution exposure. Identifying individuals who are most vulnerable is helpful to develop more personalized preventive strategies for maximal public health impact. Susceptible factors may include age, existing health/disease status, smoking status, gender and vulnerable populations (children and pregnant women). Whether and how each of these factors modifies a person's response to air pollution exposure may depend on health outcomes (e.g., lower birth weight, preterm birth, neurodevelopmental disorder, cardiometabolic dysfunction, and inflammatory airway diseases) and pollutants (e.g., $PM_{2.5}$, ozone, constituents of $PM_{2.5}$, VOC, and NO_2). Therefore, studies are essential to identify factors of susceptibility specific to health outcomes. Of particular note is the global aging population, which calls for research into the interactions between these two health risk factors (aging × air pollution). The introduction of personal monitors should make an important impact on this issue of individual susceptibility because we can relate personal exposure to personal health outcome measures.

Sixth, research is needed to further understand biological mechanisms by which air pollution affects human health. This line of research should be maximized for clinical relevance by examining clinical outcomes (e.g., disease, organ function), pathophysiology (e.g., tissue inflammation, immune dysfunction), and molecular responses (e.g., damage to DNA, lipids and proteins reflecting metabolic dysfunction). Such mechanistic investigations, by measuring individual-level responses, should naturally consider susceptibility factors discussed above. Findings from these studies are expected to guide individual-level interventions such as dietary recommendations or supplementations (e.g., antioxidants to alleviate oxidative stress particularly mitochondrial sources, supplements containing reactive oxygen species scavengers such as melatonin and sulfide salts). Although a handful of studies have evaluated the effectiveness of using these dietary interventions, future studies are needed to help understand why an intervention seems to work for certain individuals/populations and not for others.

Finally, research is important to comprehensively assess the efficacy of individual-level or population-level preventive measures. This requires accurate exposure assessment, social behavioral assessment, health outcome assessment, and sociodemographic attributes (for targeted population-level interventions), as each of these aspects can affect the outcome of the intervention. For example, if the intervention is to wear a face mask, the effectiveness depends largely on whether the face mask is worn properly during periods of heavy pollution and appropriate for the pollutants involved. Increasing availability of low-cost sensors enables personal air pollution monitoring to determine actual exposures. Furthermore, pollution forecasting, coupled with personal monitoring, can help individuals, especially those susceptible to air pollution, avoid spending time in highly polluted places for exercising or other activities. From a social behavior standpoint, it is necessary to understand what characteristics of people make them more likely to have an intervention effective in reducing air pollution health effects.

Air pollution is a lasting global health hazard, as 9 out of 10 people in the world today live in places whether air quality does not meet the WHO guidelines, and climate change is projected to exacerbate air pollution problems (11-14). Meaningful state of the art research is required to gain knowledge that can be used to effectively reduce the disease burden attributable to this hazard. Those of us working in the research field of air pollution health effects will continue to be busy in the next decade. We need innovative ideas and methodologies to move the field forward and to provide step-change contributions to mitigate the health effects of air pollution!

Acknowledgements

None.

Footnote

Conflicts of Interest: KF Chung is on a Scientific Board of the Clean Breathing Institute set up by GlaxoSmithKline and has been remunerated for attending their Advisory Board meetings. He is also a co-investigator on the UK-

India-funded project investigating the effects of pollution in Indian megacities. The other authors have no conflicts of interest to declare.

References

1. Di Q, Dai L, Wang Y, et al. Association of Short-term Exposure to Air Pollution With Mortality in Older Adults. JAMA 2017;318:2446-56.
2. Di Q, Wang Y, Zanobetti A, et al. Air Pollution and Mortality in the Medicare Population. N Engl J Med 2017;376:2513-22.
3. Zhang J. Low-Level Air Pollution Associated With Death: Policy and Clinical Implications. JAMA 2017;318:2431-2.
4. Rich DQ, Zhang W, Lin S, et al. Triggering of cardiovascular hospital admissions by source specific fine particle concentrations in urban centers of New York State. Environ Int 2019;126:387-94.
5. Chen L, Shi M, Gao S, et al. Assessment of population exposure to $PM_{2.5}$ for mortality in China and its public health benefit based on BenMAP. Environ Pollut 2017;221:311-7.
6. Sacks JD, Lloyd JM, Zhu Y, et al. The Environmental Benefits Mapping and Analysis Program - Community Edition (BenMAP-CE): A tool to estimate the health and economic benefits of reducing air pollution. Environ Model Softw. 2018;104:118-29.
7. Zhang Y, Wang J, Chen L, et al. Ambient $PM_{2.5}$ and clinically recognized early pregnancy loss: A case-control study with spatiotemporal exposure predictions. Environ Int 2019;126:422-9.
8. Rich DQ. Accountability studies of air pollution and health effects: lessons learned and recommendations for future natural experiment opportunities. Environ Int 2017;100:62-78.
9. Xiang J, Weschler CJ, Wang Q, et al. Reducing Indoor Levels of "Outdoor $PM_{2.5}$" in Urban China: Impact on Mortalities. Environ Sci Technol 2019;53:3119-27.
10. Miele CH, Checkley W. Clean Fuels to Reduce Household Air Pollution and Improve Health. Still Hoping to Answer Why and How. Am J Respir Crit Care Med 2017;195:1552-4.
11. Brauer M, Freedman G, Frostad J, et al. Ambient Air Pollution Exposure Estimation for the Global Burden of Disease 2013. Environ Sci Technol 2016;50:79-88.
12. GBD 2017 Risk Factor Collaborators. Global, regional, and national comparative risk assessment of 84 behavioural, environmental and occupational, and metabolic risks or clusters of risks for 195 countries and territories, 1990-2017: a systematic analysis for the Global Burden of Disease Study 2017. Lancet 2018;392:1923-94.
13. Stowell JD, Kim YM, Gao Y, et al. The impact of climate change and emissions control on future ozone levels: Implications for human health. Environ Int 2017;108:41-50.
14. Silva RA, West JJ, Lamarque JF, et al. Future Global Mortality from Changes in Air Pollution Attributable to Climate Change. Nat Clim Chang 2017;7:647-51.

Cite this article as: Zhang JJ, Adcock IM, Bai Z, Chung KF, Duan X, Fang Z, Gong J, Li F, Miller RK, Qiu X, Rich DQ, Wang B, Wei Y, Xu D, Xue T, Zhang Y, Zheng M, Zhu T. Health effects of air pollution: what we need to know and to do in the next decade. J Thorac Dis 2019;11(4):1727-1730. doi: 10.21037/jtd.2019.03.65

