Brief Communication

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# Pollution and Global Health – An Agenda for Prevention

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**Summary:** Pollution is a major, overlooked, global health threat that was responsible in 2015 for an estimated 9 million deaths and great economic losses. To end neglect of pollution and advance prevention of pollution-related disease, we formed the *Lancet* Commission on Pollution and Health. Despite recent gains in understanding of pollution and its health effects, this Commission noted that large gaps in knowledge remain. To close these gaps and guide prevention, the Commission made research recommendations and proposed creation of a Global Pollution Observatory. We posit that successful pollution research will be translational and based on transdisciplinary collaborations among exposure science, epidemiology, data science, engineering, health policy, and economics. We envision that the Global Pollution Observatory will be a multinational consortium based at Boston College and the Harvard T.H. Chan School of Public Health that will aggregate, geocode, and archive data on pollution and pollution-related disease; analyze these data to discern trends, geographic patterns, and opportunities for intervention; and make its findings available to policymakers, the media, and the global public to catalyze research, inform policy, and assist cities and countries to target pollution, track progress, and save lives. https://doi.org/10.1289/EHP3141



## Background

Pollution is a grave threat to planetary health. Like climate change (McMichael 2017), biodiversity loss, ocean acidification, desertification, and depletion of the world's fresh water supply, pollution destabilizes the earth's support systems and endangers the continuing survival of human societies (McMichael 2017; Rockström et al. 2009; Steffen et al. 2015; Whitmee et al. 2015). Pollution, especially pollution caused by industrial emissions, vehicular exhausts, and toxic chemicals, has increased in the past 100 y, with greatest increases reported in rapidly developing low- and middle-income countries (Lelieveld et al. 2015). Children are exquisitely vulnerable to pollution (Suk et al. 2006).

Pollution has been neglected in the international development and global health agendas as well as in the planning strategies of many countries. The foreign aid budgets of the European Commission, the U.S. Agency for International Development, and bilateral development agencies direct only meager resources to control of pollution from industrial, automotive, and chemical sources and to prevention of the diseases caused by these forms of pollution (Greenberg et al. 2016; Nugent 2016). No major foundation has made pollution prevention its priority.

In 2015, several of the authors formed the Commission on Pollution and Health under the sponsorship of *The Lancet* (Landrigan et al. 2017). The Commission conducted its work over a 2-y period and published its findings in October 2017 (Landrigan et al. 2017). The Commission's goals were to raise awareness of pollution's magnitude, end neglect of pollution-related disease, and mobilize the resources, the political leadership, and the civic will needed to control pollution and prevent pollution-related disease.

The Commission was highly interdisciplinary and included physicians, epidemiologists, exposure scientists, lawyers, policy analysts, political scientists, a former head of state, a princess, engineers, and economists. The decision to include economics and political science was modeled on the pathbreaking Stern Review on Climate Change (Stern 2007), which examined the economic costs of climate change and projected that, without intervention, these losses will consume 5% or more of global economic output. By reframing climate change as an economic challenge, the Stern Review moved the issue to center stage of international policy development and was a powerful catalyst to action.

To achieve its goals, the Commission adopted a four-part strategy:

1. Gather, combine, and analyze data on the global burden of disease, disability, and premature death attributable to all forms of pollution from the Institute for Health Metrics and Evaluation (Forouzanfar 2016a, 2016b), the World Health Organization (WHO) (WHO 2016a, 2016b, 2016c, 2017a, 2017b), and Pure Earth (Pure Earth 2016).
2. Develop robust new estimates of the economic costs of pollution-related disease and death.
3. Elucidate the interconnections between pollution, poverty, and injustice and advance the argument that pollution is a violation of human rights.
4. Examine prospects and pathways for control of pollution and prevention of pollution-related disease.

## Discussion

The Commission found that all forms of pollution were responsible in 2015 for an estimated 9 million premature deaths—16% of all deaths worldwide—as well as for 268 million disability-adjusted life-years (DALYs). Pollution is thus the world's largest environmental cause of disease and premature death (Landrigan et al. 2017).

The majority—71%—of the deaths attributed to pollution are caused by noncommunicable diseases (NCD). The impact of pollution on NCD mortality varies by national income (Figure 1) (Fuller et al. (In press) 2018). In high-income countries, where many of the unhealthiest forms of pollution have been controlled, behavioral and metabolic risk factors are the major causes of NCD mortality and overshadow the impacts of pollution. However, in upper-middle-income countries, pollution and behavioral risk factors are of approximately equal importance in NCD causation, and in lower-middle- and low-income countries, pollution is the predominant risk factor for NCD mortality.

The Commission considered chemical pollution to be a great and growing global threat. The threat of chemical pollution is especially high in low- and middle-income countries, where 70% of chemical manufacture now occurs and public health protections are often scant. An estimated 140,000 new chemicals and pesticides have been invented since 1950, and many have become widely disseminated in the environment (Landrigan and Goldman

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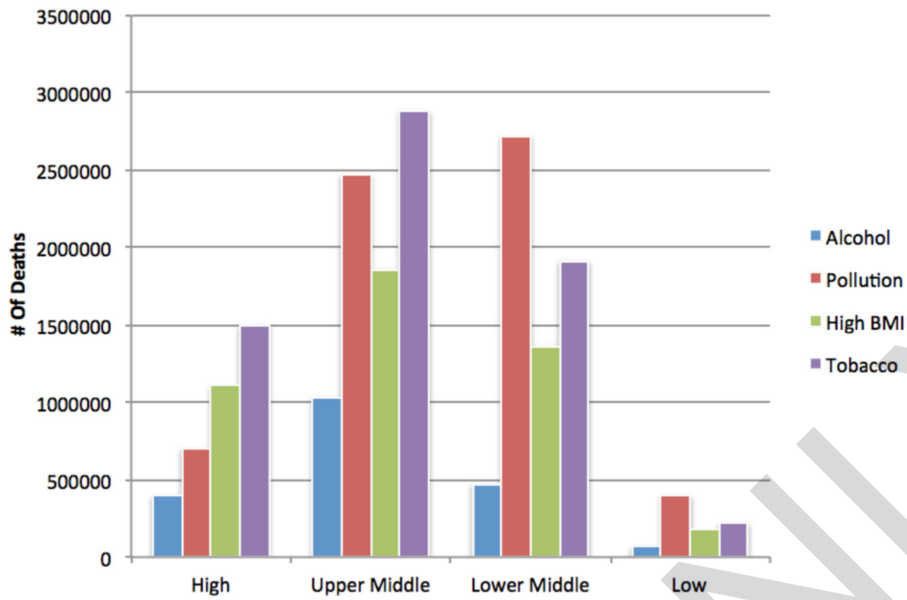


**Figure 1.** Global NonCommunicable Disease (NCD) Deaths by Risk Factor and Income Group, 2015. Note: Adapted from Fuller R et al. (In press) 2018. Permission for reproduction granted by *Lancet Planetary Health*.

2011; Prüss-Ustün et al. 2015). Human exposure is nearly universal (CDC 2018).

A key message of the *Lancet* Commission on Pollution and Health is that pollution is preventable. The Commission noted that many countries, especially high-income and some upper-middle-income countries have developed robust, cost-effective, and politically viable pollution-control strategies based on law, policy, science, and technology (U.S. EPA 2011; Samet et al., 2017; Suk et al. 2018). The Commission expressed the view that pollution- control strategies that have proven successful in high-income and middle-income countries are ready to be taken off-the- shelf, brought to global scale, and applied in cities and countries at every level of income (Landrigan et al. 2017).

The Commission identified substantial gaps in knowledge about pollution and noted that these gaps result in underestimation of pollution's contribution to the global burden of disease while also impeding prevention (Landrigan et al. 2017). To create a framework for organizing knowledge about pollution and prioritizing research and intervention, the Commission developed the concept of the pollutome. Because scientific knowledge about pollution's effects on health and contributions to the global burden of disease varies by pollutant and by health



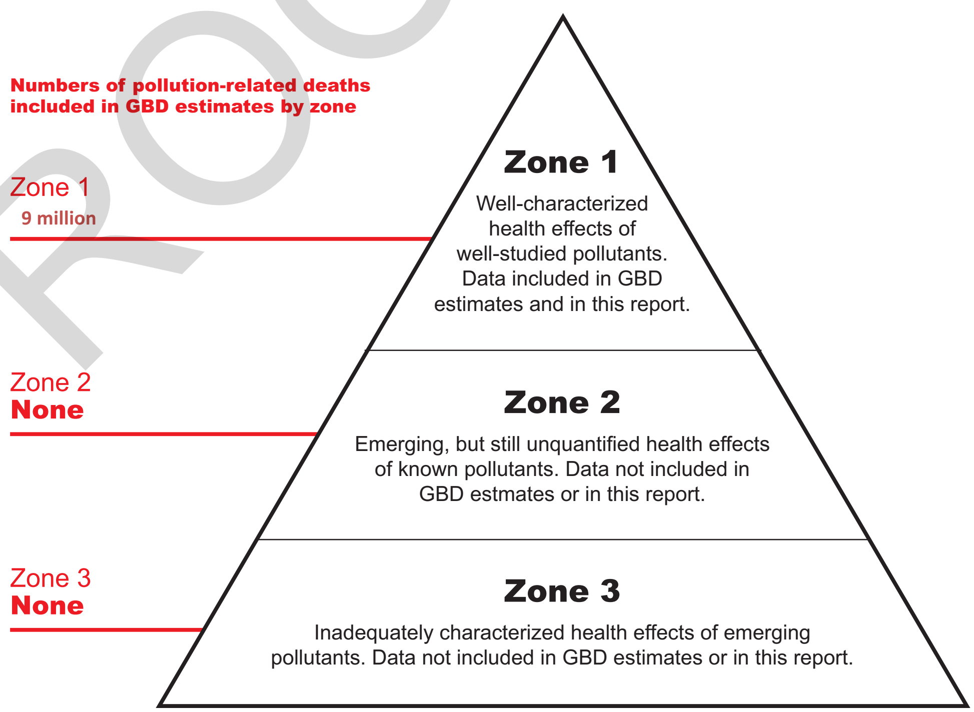


**Figure 2.** The Pollutome. Note: Based on 2015 data. Adapted from Landrigan PJ et al. 2017. Permission for reproduction granted by *The Lancet*.

**Table 1.** A Research agenda for pollution control and disease prevention.

| Agenda items | References |
|---|---|
| **Health-Related Research** | |
| Define and quantify the burden of neurodegenerative disease in adults that may be attributable to PM2.5 air pollution | Kioumourtzoglou et al. 2015; Heusinkveld et al. 2016; Cacciottolo et al. 2017 |
| Define and quantify the burden of neurodevelopmental disabilities in children such as cognitive impairment ADHD and autism that may be attributable to PM2.5 pollution or to traffic-related air pollution | Perera et al. 2014; Volk et al. 2013; Casanova et al. 2016 |
| Define and quantify the burden of diabetes that may be attributable to PM2.5 air pollution | Meo et al. 2015 |
| Define and quantify the burden of chronic kidney disease that may be attributable to PM2.5 air pollution | Bowe et al. 2018 |
| Define and quantify the burden of preterm birth and low birth weight attributable to PM2.5 air pollution | Ha et al. 2014; Cacciottolo et al. 2017; Malley et al. 2017 |
| Better quantify the burden of disease and premature death caused by lead at lower blood lead levels in light of recent data linking low levels of lead in blood with increases in all-cause mortality and cardiovascular disease mortality | Lanphear et al. 2018 |
| Better quantify the burden of disease caused by mercury | Ha et al. 2017 |
| Better quantify the burden of disease caused by arsenic | Wasserman et al. 2016 |
| Discover and quantify health effects associated with new and emerging chemical pollutants, such as developmental neurotoxicants, (Grandjean and Landrigan 2014) endocrine disruptors, (Bergman et al., 2013; Gore et al., 2015) chemical herbicides, newer classes of insecticides such as the neonicotinoids, (Cimino et al. 2016) and pharmaceutical wastes. (Petrie et al. 2015) | Grandjean and Landrigan 2014 (developmental neurotoxicants); Bergman et al. 2013; Gore et al. 2015 (endocrine disruptors); Cimino et al. 2016 (chemical herbicides); Cimino et al. 2016 (neonicotinoids); Petrie et al. 2015 (pharmaceutical wastes) |
| Develop new methodologies to improve quantification of the burden of disease and the loss of human capital that results from early-life exposures to neurodevelopmental toxicants | Bellinger 2012 |
| Advocate for the inclusion of measures of pollution and its effects on health in the large cohort, precision medicine and other "Big Data" health projects currently in development | Hu et al. 2017 |
| **Research in exposure science** | |
| Improve mapping of pollution exposures particularly in low-income and middle-income countries, using a combination of ground-based monitoring and satellite imaging. | Rice et al. 2018 |
| Increase research into transboundary pollution | Lin et al. 2015 |
| Undertake systematic surveys in multiple countries of levels of lead and other toxic chemicals in blood and urine. (CDC) Data from such surveys will provide a benchmark to measurer future progress toward pollution control | |
| Establish umbilical cord blood banks in multiple countries to examine prenatal and perinatal exposures to lead and other developmental neurotoxicants | Arbuckle 2010 |
| Support the development, application and networking of new technologies such as lab-on-a-chip apps for smart phones for personal and/or area sampling of pollutant exposures in low-resource settings | Dragone et al. 2017 |
| Undertake source apportionment studies to identify and prioritize pollution sources | National Academy of Sciences 2012 |
| Better define pathways of pollutant exposure in different countries and in different age groups | National Academy of Sciences 2012 |
| **Economic research** | |
| Improve estimates of the morbidity costs of pollution | Landrigan et al. 2017 |
| Improve estimates of the non-health benefits of reducing pollution | Landrigan et al. 2017 |
| Quantify the health and economic benefits of interventions against pollution in relation to the costs of those interventions | Landrigan et al. 2017 |
| **Policy research** | |
| Link pollution sources within countries with relevant government ministries and policies and to efforts supporting each country's commitment to the U.N.'s Sustainable Development Goals (SDGs) | United Nations 2017 |
| Identify health as well as non-health sectoral targets for education on the costs to health and economies of pollution and the benefits of prevention-oriented policies and interventions | Galvão et al. 2016 |
| Track progress on policy changes and resulting impacts on pollution | Watts et al. 2015 |
| **Research on pollution and vulnerable populations** | |
| Document and map the disproportionate effects of pollution upon the poor, women, and girls | Sommer et al. 2017 |
| Quantify the disproportionate exposure of indigenous peoples and their communities to pollution and use the information gained from this research to guide protection of indigenous peoples | Thomas-Muller 2008 |
| Improve assessment of workers' exposure to known occupational carcinogens such as asbestos | |
| **Research within cities and countries** | |
| Identify and prioritize the pollution sources in cities that have the largest impacts on human health | Pure Earth 2018 |
| Develop city- and country-wide exposure data for toxic chemical pollutants such as lead, cadmium, mercury, asbestos and industrial pollutants | National Academy of Sciences 2012 |
| Evaluate economic costs and benefits of locally based interventions against pollution | Landrigan et al. 2017 |

outcome, the Commission divided the pollutome into three zones (Figure 2).

## Future Directions in Pollution Research

To address gaps in knowledge about pollution and its effects on human health, the Commission called for an expanded pollution research agenda. Transdisciplinary research in multiple areas, including exposure science, epidemiology, data science, engineering, economics, law, and health policy, will be needed to close gaps in knowledge about pollution, its health effects, its contributions to the global burden of disease, and its economic consequences. In Table 1, the authors propose high-priority research topics based on our judgment that research on these topics advance scientific understanding of pollution and its effects on health and provide a science-based blueprint for control of pollution and prevention of pollution-related disease (Table 1).

To track pollution and pollution-related disease in cities and countries around the world, monitor progress toward prevention, and generate hypotheses for further research, the Commission recommended creation of a Global Pollution Observatory. Following is our vision for the objectives, structure, and prioritized research agenda for a Global Pollution Observatory.

We envision that the Global Pollution Observatory will be a new transnational, multidisciplinary collaboration that continues the work of *The Lancet* Commission on Pollution and Health (Landrigan et al. 2017). The core mission of the Observatory will be to aggregate, analyze, archive, and disseminate data on pollution and pollution-related disease in cities and countries around the world. The Observatory will be modeled on the disease surveillance programs of the Centers for Disease Control and Prevention (Langmuir 1963).

The Observatory will examine trends and patterns of pollution and provide early warnings of emerging problems. It will make carefully curated, validated information on pollution and pollution-related disease widely available to researchers, policy makers, civil society, the media, and the global public. The intent is that these data will generate hypotheses that guide research; inform the development of public policy; educate civil society and the media; and assist cities and countries to identify their worst forms of pollution, prioritize interventions, and track progress toward pollution control. The Observatory will highlight and disseminate information on advances and best practices in pollution control and disease prevention.

The Observatory will place strong emphasis on ensuring the rigor and validity of the data included in its analyses. It will model its data-assurance program on that developed by the Institute for Health Metrics and Evaluation (IHME) (Forouzanfar et al. 2015b).

Sources from which the Global Pollution Observatory plans to assemble data could include:

- The annual Global Burden of Disease report and disease–risk factor reports produced by the Institute for Health Metrics and Evaluation at the University of Washington (Forouzanfar et al. 2015a and 2015b).;
- WHO reports.
- World Bank Country Environmental Analyses.
- Google Earth.
- Data from the U.S. Geological Survey on mineral production, import and use by country.
- Data from CDC's National Biomonitoring Program to track exposures to pollutants.
- Customs records to track imports into countries of hazardous materials, such as asbestos and banned pesticides.
- Data from the Secretariats of the Rotterdam and Basel Conventions.
- Satellite monitoring to track toxic emissions to air, and possibly water (Rice et al. 2018).
- Country-level surveys (Ericson et al. 2013; Steckling et al. 2017) to identify hazardous waste in soil, groundwater, and surface water and to provide a basis for developing estimates of the size and demographic characteristics of exposed populations.
- Country-level estimates of lead use and exposure.

The Global Pollution Observatory will rely on a series of validated metrics to track pollution and disease. The precise metrics to be followed are still under consideration but could include data on levels of key pollutants in air, water, and soil, country-by-country and regionally; detailed country-by-country statistics on burden of disease and premature death by pollution risk factor; country- or city-specific data on the status of regulations against each type of pollution; country-level data on levels of investment into research on pollution and pollution-related disease, which can be examined by source of investment; and a database on the cost efficacy of interventions against pollution. This metrics-based approach to tracking pollution and pollution-related disease is modeled on that of the *Lancet* Countdown on Climate Change, which is tracking progress globally and country by country in addressing global climate change (Watts et al. 2017).

Mapping will be an important function of the Global Pollution Observatory. Data collected from various sources will be geocoded and entered into a multilayered Geographic Information System (GIS) model for each country. This approach will have the following benefits:

- By correlating data on pollution sources with census data, maps will facilitate identification of exposed populations.
- Geocoded maps will permit the addition of multiple layers of information as new data sources on pollution are discovered or created.
- Maps are an effective tool for translating scientific information to the public, even in areas of low literacy, and in building political will to control pollution, because they can clearly show that pollution is a local problem.
- Maps facilitate development of data on the economic costs of pollution because they make it possible to visualize the geographic extent of ecological damage and the size of affected populations.
- Pollution maps can be integrated with disease maps and economic maps to discern patterns in need of further investigation.

The Global Pollution Observatory will headquartered in the Schiller Institute for Integrated Science and Society at Boston College and based on collaboration between the Schiller Institute and the Center for Health and the Global Environment at the Harvard T.H. Chan School of Public Health. It will plan to work with a series of carefully chosen partners that could include the Institute for Health Metrics and Evaluation, WHO, U.N. Environment, the U.N. Development Program, the World Bank, the Planetary Health Alliance, the *Lancet* Countdown on Climate Change, the Consortium on Biodiversity and Health, the World Resources Institute's Global Resource Watch, the Icahn School of Medicine at Mount Sinai, Pure Earth, the Global Alliance on Health and Pollution (GAHP), the Global Air Pollution Observatory (GUAPO), and major universities, government agencies, and nongovernmental organizations around the world. In partnership with *The Lancet*, the Observatory would publish periodically updated information on global trends in pollution, pollution-related disease, and pollution control.

The Global Pollution Observatory will utilize a variety of media and data platforms to disseminate its findings to multiple audiences. In partnership with *The Lancet*, the Observatory plans to regularly publish updated information on global trends and patterns in pollution and pollution-related disease as well as on progress in pollution control. The Global Pollution Observatory will also produce a series of scientific reports and analyses on specific topics. These could include:

- Analyses of the effects of pollution on children's health and adolescent health.
- Analyses of the impact of pollution on cardiovascular disease and death.
- Analyses of the impact of pollution on cancer.
- Updated analyses of the global burden of disease due to various occupational toxicants and carcinogens such as asbestos.
- Updated analyses of the global burden of disease due to lead incorporating new data on the association between low-level exposure to lead and risk of death from cardiovascular disease (Lanphear et al. 2018).
- Updated analyses of the global burden of disease due to mercury based on data on mercury use, environmental contamination and exposure collected under the Minamata convention (Ha et al. 2017).
- Analyses of the loss of human capital caused by early-life exposures to developmental neurotoxicants.

To guide the development of pollution control and disease prevention policies internationally and within cities and countries, the Global Pollution Observatory will undertake and publish economic and policy analyses. Examples might include:

- Analyses of the burden of disease due to pollution in cities and countries that include options for pollution control and disease prevention.
- Source apportionment studies that analyze the amounts of pollution and the burden of disease due to various pollution sources in cities and countries. These studies are essential for identifying the pollution sources with most significant effects on human health and for prioritizing interventions.
- Country-level analyses of the burden of disease and loss of human capital attributable to various pollutants and all pollution in specific countries (or cities) and examine prospects for prevention.
- Economic analyses that examine the cost–benefit ratios of various interventions against pollution.

The *Lancet* Commission on Pollution and Health concludes that pollution is a winnable battle (Landrigan et al. 2017). The Commission offered the view that the key tools and technologies needed to control pollution in all countries have been developed and are ready today to be taken to global scale. The Commission opined that, with visionary international and country-level leadership, strong support from civil society, and sufficient resources, the worst forms of pollution could be controlled within a generation. The Global Pollution Observatory will provide the path forward.

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Figure 1: Bar graph plotting number of deaths attributed to alcohol, pollution, high BMI, and tobacco (y-axis) across income groups, namely, high, upper middle, lower middle, and low (x-axis).

Figure 2: Conceptual diagram of a pollutome divided into three zones.

Table 1: Table 1 lists agenda items and their corresponding reference citations in the first and the second columns, respectively.