

THE IMPACT OF POLLUTION ON PLANETARY HEALTH: Emergence of an Underappreciated Risk Factor

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Pollution is a massive, overlooked cause of disease, death and environmental degradation. To address the neglected problem of pollution, we formed the Lancet Commission on Pollution and Health. The goals were to raise awareness of pollution's great magnitude, end neglect of pollution-related disease (PRD), and mobilize the resources and political will needed to control pollution and prevent PRD.

Pollution was responsible in 2015 for 9 million premature deaths – three times as many deaths as caused by AIDS, tuberculosis and malaria combined. 92% of PRD occurs in low and middle-income countries (LMICs), and in the hardest hit countries, PRD is responsible for more than 1 death in 4. Household air and water pollution, the traditional forms of pollution, are decreasing, and deaths from pneumonia and diarrhea are down. But ambient air, chemical and soil pollution are all on the rise, and non-communicable diseases (NCD) caused by these forms of pollution are increasing. Pollution and climate change are closely linked; both arise from the same sources, and both can be controlled by similar solutions. PRD causes great economic losses. These include productivity losses that reduce gross domestic product in LMICs by up to 2% per year as well as health care costs that account for 1.7% of health care spending in high-income countries and up to 7% in LMICs. Welfare losses due to pollution are estimated to amount to \$4.6 trillion per year, 6.2% of global economic output.



Pollution and PRD are not the unavoidable consequences of economic development. The notion that LMICs must pass through a phase of pollution and disease as they grow is obsolete data and not well substantiated. Proven, cost-effective pollution control strategies are available today to countries at every income level. These solutions are based on law, policy and technology, and the most effective eliminate pollution at source.

Pollution control and PRD prevention will require that affected countries, international agencies, major foundations, research institutions, and civil society make pollution prevention a high priority; to set firm targets for PRD reduction; to establish data systems for monitoring pollution and PRD; and to end the externalization of pollution by enforcing the 'polluter pays' principle. The donor community can provide much needed technical and financial support. Advocacy for the issue is also critical, and the upcoming UN Environmental Assembly is an ideal forum to move pollution into the center stage. Pollution control is a winnable battle.

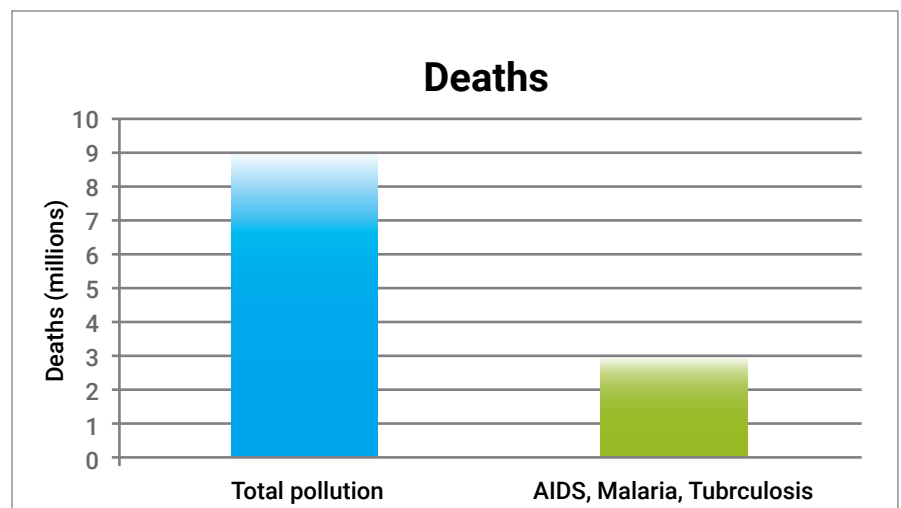
What is Pollution? And what are its effects?

Pollution is one of the great existential challenges of the 21st century. It threatens the stability of the earth's ecosystems, undermines the economic and social development of nations, and endangers the health of billions (Rockström et al. 2013).¹ Pollution – especially pollution of air, water and soil caused by industrial emissions, motor vehicle exhausts, and toxic chemicals – has risen sharply in the past century, and in the absence of aggressive intervention ambient air pollution is on track to increase an additional 50% by 2050. The greatest increases will be seen in the growing cities of rapidly industrializing low- and middle income countries (Lelieveld et al. 2015).²

Despite the great magnitude of its effects on human health and the environment, pollution from industrial, automotive and chemical sources has been gravely 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 US Agency for International Development, and bilateral development agencies all direct only meager resources to control of these modern forms of pollution (Greenberg et al.

2016; Nugent 2016).^{3,4} No major foundation has made pollution control its priority. The two panels below illustrate the striking imbalance between pollution's great impacts on human health and the scant international resources directed towards its control. (Figure 1)

Figure 1. Deaths due to pollution v. resources directed to pollution control



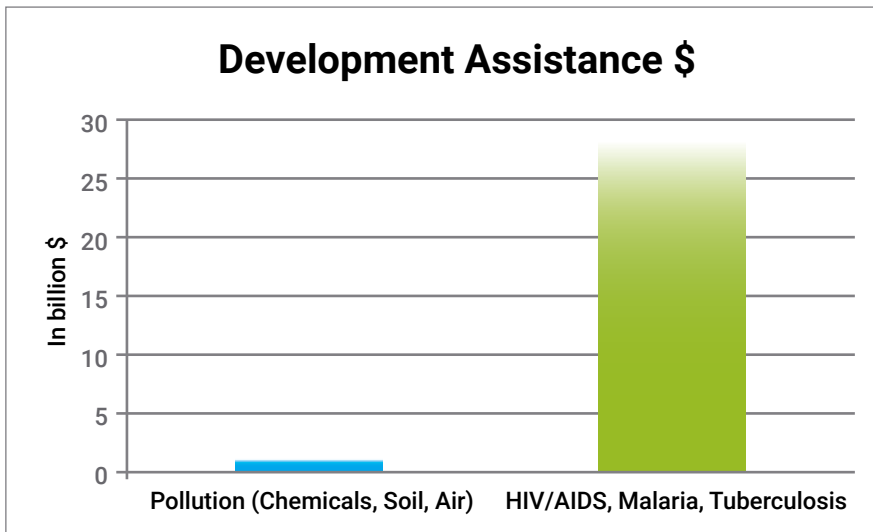


Figure 1. Deaths due to pollution v. resources directed to pollution control

The Lancet Commission on Pollution and Health

To address the neglected global problem of pollution, we formed the Commission on Pollution and Health under the sponsorship of The Lancet (Landrigan et al. 2017).⁵ The Commission was launched in 2015 and conducted its work over a two-year period. Based on a definition proposed by the European Environment Agency (European Union, 2010),⁶ the Commission defined pollution as “Any material introduced into the environment by human activity that endangers human health or harms living resources and ecosystems”.

The Commission on Pollution and Health was deliberately modeled on the path-breaking Stern Review on Climate Change (Stern 2007).⁷ The Stern Review, commissioned by the government of the United Kingdom and directed by economist Lord Stern, examined the costs of global climate change and predicted that without intervention these costs will consume at least 5% of global economic output now and forever. That conclusion has been enormously influential. By reframing global climate change as a massive social challenge, the Stern Review moved the conversation from the halls of academia to the center stage of global policy and has been a key catalyst for change. It was

in emulation of the Stern review that the Commission’s analysis included analyses of the economic consequences of pollution.

Findings

The Commission’s main finding on health was that all forms of pollution combined 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) (Forouzanfar, 2016a).⁸ The number of deaths due to pollution was three times greater than the number due to AIDS, tuberculosis, and malaria combined and 15 times more

than the number resulting from all wars and other forms of violence (Forouzanfar, 2016b).⁹ In the most severely affected countries, PRD is responsible for more than one death in four.

Air pollution was responsible for 6.4 million deaths – 2.8 million from household air pollution and 4.2 million from ambient air pollution. Water pollution caused 1.75 million deaths. Occupational pollutants caused 0.85 million deaths. Soil pollution, heavy metals and toxic chemicals caused 0.5 million deaths.

In many parts of the world, the burden of disease and death due to pollution is increasing. Deaths attributable to household air and water pollution, the forms of pollution associated with profound poverty and traditional lifestyles have been declining over the past two decades. These hopeful trends reflect many years of work by United Nations agencies and NGOs to control household air and water (Bartram et al. 2014; Florez et al. 2016; Yadama 2013),^{10, 11, 12} pollution coupled with the introduction of new vaccines,

antibiotics, and pediatric treatment protocols. But at the same time, the numbers of deaths due to ambient air pollution, chemical pollution, and soil pollution are on the rise. The main drivers are uncontrolled urbanization, globalization of heavy industry, the unregulated proliferation of toxic chemicals and pesticides, and the growing global use of cars, trucks, and buses. Cities in rapidly industrializing countries are very hard hit.

Non-communicable diseases account for the great majority of the deaths caused by pollution – 71%. Pollution is responsible for 21% of all cardiovascular disease deaths worldwide, 26% of ischemic heart disease deaths, 23% of stroke deaths, 51% of deaths from chronic obstructive pulmonary disease, and 43% of deaths due to lung cancer (Forouzanfar, 2016a; Forouzanfar, 2016b).^{13,14} Pollution appears also to be linked to adverse reproductive outcomes, obesity, diabetes (Meo et al. 2015),¹⁵ and neurodegenerative diseases (Cacciottolo et al. 2017; Heusinkveld et al. 2016),^{16,17} but the global burden of disease due to these health effects has not yet been quantified. The Commission noted that despite its very substantial contributions to the causation on non-communicable disease, pollution is barely mentioned in the World Health Organization's Global Action Plan for the Prevention and Control of Non-Communicable Disease (World Health Organization, 2013),¹⁸ an omission that the Commission characterized as a "major missed opportunity".

The Commission's main economic finding was that pollution is extremely costly and has impacts on the economies of countries around the world that are so large they can undermine the developmental trajectories of nations. Productivity losses resulting from disease and premature death that take people out of the workforce are one component of these economic impacts, and the Commission

found that PRDs are responsible for productivity losses that reduce gross domestic product in low-income to middle-income countries by up to 2% per year. In addition, PRD is responsible for health-care costs. The Commission found that these costs account for an estimated 1.7% of annual health spending in high-income countries and for up to 7% of health spending in a heavily polluted, rapidly developing low- and middle-income country such as Sri Lanka. Welfare losses due to pollution, calculated by the willingness-to-pay methodology, are estimated to amount to US\$4.6 trillion per year – 6.2% of global economic output. These cost estimates almost certainly underestimate the full economic impacts of pollution and will likely increase as additional associations between pollution and disease are identified. The Commission's analysis did not include the costs of damages to agriculture, fisheries and ecosystems caused by pollution.

Chemical pollution is a great and growing global challenge. Its effects on human health are not well defined and its impact on the global burden of disease is undercounted. 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 2011).¹⁹ Far too few have been tested for safety or toxicity and thus their possible contribution to the global burden of disease cannot at present be assessed.

The Commission found that pollution control will advance attainment of many of the sustainable development goals (SDGs), the 17 goals established by the United Nations to guide global development in the 21st century. In addition to improving health in countries around the world (SDG 3), pollution control will help to alleviate poverty (SDG 1), improve access to clean water and improve sanitation (SDG 6), promote social justice (SDG 10), build sustainable

cities and communities (SDG 11), and protect land and water (SDGs 14 and 15).

The Commission found that pollution is linked through multiple pathways to global climate change (McMichael 2017; Perera 2017).^{20,21} Energy production and use are major sources of both pollution and climate change. Fuel combustion accounts for 85% of airborne particulate emissions, for almost all emissions of sulfur oxides and nitrogen oxides, and is a major source of the greenhouse gases and short-lived climate pollutants responsible for climate change (Scovronick et al. 2015).²²

The pollutome

Much is still not known about pollution and its health effects. To frame current knowledge about pollution and guide future research, the Commission developed the concept of the pollutome, defined as the totality of all forms of pollution that have potential to harm human health. The pollutome is a wholly contained (nested) subset of the exposome. Because scientific knowledge of pollution's effects on health varies by type of pollution, the Commission divided the pollutome into 3 zones (**Figure 2**).

Zone 1 includes well-established pollution-disease pairs for which there are robust estimates of contributions to the global burden of disease. The associations between ambient air pollution and non-communicable disease are the prime example.

Zone 2 includes the emerging, but still unquantified health effects of known pollutants. Examples include the reported associations between fine particulate air pollution and diabetes (Meo et al. 2015)²³ preterm birth (Cacciottolo et al. 2017; Malley et al. 2017)^{24,25} and diseases of the central nervous system including autism (Casanova et al. 2016; Heusinkveld et al. 2016; Perera 2017; Perera et al. 2014),^{26,27,28,29} and

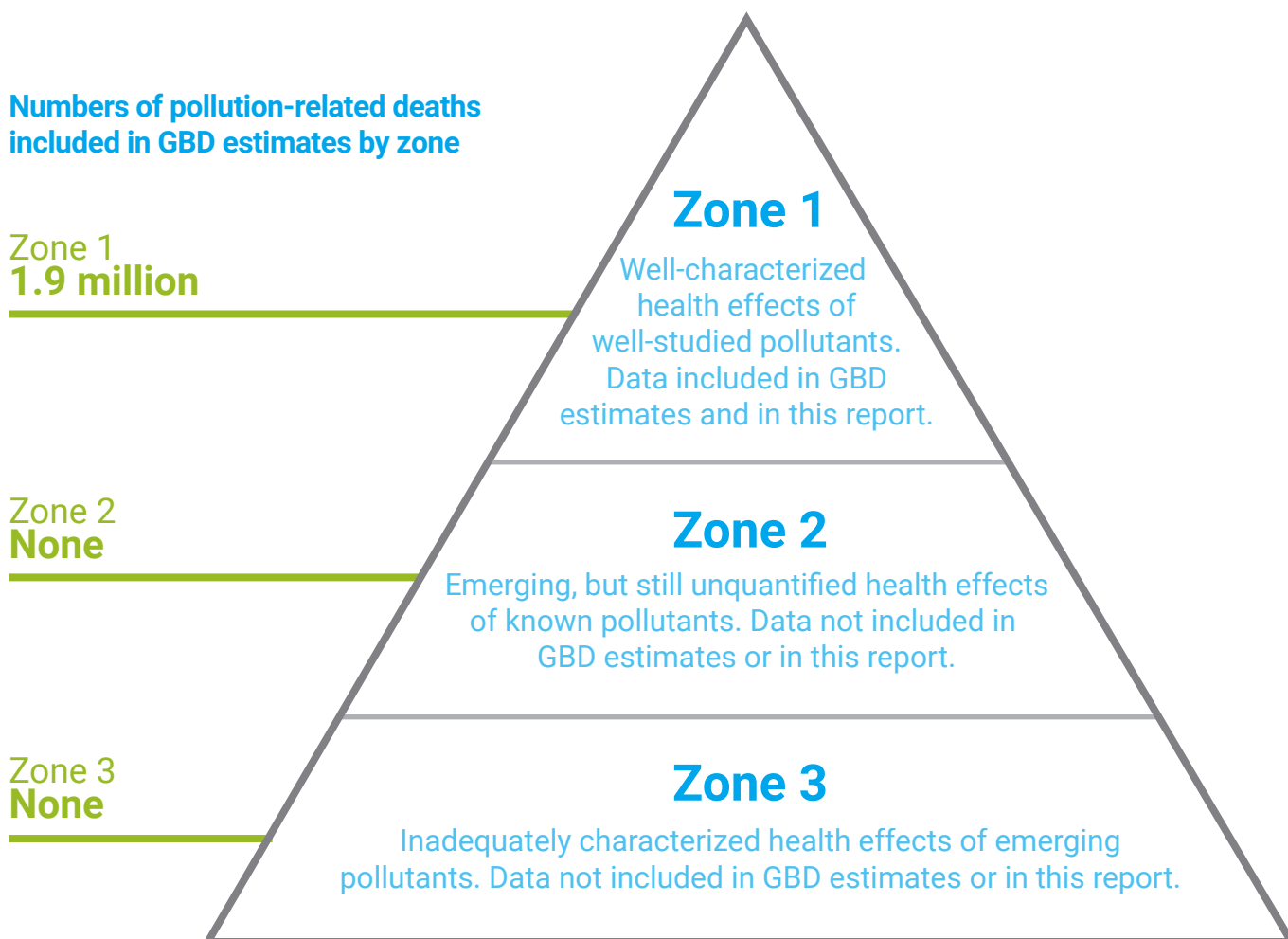
dementia (Cacciottolo et al. 2017; Kioumourtzoglou et al. 2015).^{30,31} Soil pollution by heavy metals and toxic chemicals at contaminated industrial and mining sites is another example (Prüss-Ustün et al. 2011).³²

Zone 3 includes new and emerging pollutants (Grandjean and Landrigan 2014; Landrigan and Goldman 2011),^{33,34} materials that have become extensively disseminated in the global environment but whose effects on human health are only beginning to be recognized and are not yet quantified. These include emerging chemical pollutants such as developmental neurotoxicants,

endocrine disruptors, chemical herbicides, newer classes of insecticides such as the neonicotinoids, and pharmaceutical wastes.

It is likely that the list of diseases attributed to pollution will expand as the health effects of newer chemical pollutants are better defined and new associations between pollution and disease are discovered. The result could be that some pollution-disease pairs currently placed in Zones 2 and 3 of the pollutome will move up to Zone 1 and be counted in future estimates of the global burden of disease.

Figure 2. The pollutome



Prospects for prevention

A key message of the Commission is that with leadership, resources and clearly articulated, data-driven strategies, pollution can be controlled and PRD prevented. The experience of the many cities and countries that have developed, field-tested and successfully implemented pollution control policies provides strong support for this conclusion. Pollution control strategies are based on law, policy and technology; are held to targets and timetables; are subject to continuous evaluation; are backed by strong enforcement; eliminate tax breaks and subsidies for polluting industries; and are grounded in the 'polluter-pays' principle. They mandate clean air and clean water, require that chemicals be tested for safety and toxicity before they come to market, and strictly control the disposal of hazardous wastes. Their goal is to eliminate the externalization of unwanted materials into the environment at no cost to the polluter, the current modus operandi of modern-day pollution generators.

A second key message is that implementation of pollution control strategies can provide multiple benefits, both short-term and long-term for human health, the economy and the environment for societies at every level of income. The air and water in countries that have controlled pollution are now cleaner, the blood lead concentrations of their children have decreased by more than 90% (Grosse et al. 2002)³⁵, their rivers no longer catch fire, their worst hazardous waste sites have been remediated, their cities are less polluted and more livable. Health has improved and people are living longer. Moreover these gains can be achieved while at the same time growing regional and national economies. In the United States, for example, levels of the six principal air pollutants have been reduced by nearly 70% in the 45 years since passage of the Clean Air Act of 1970 while in the same time GDP has grown by nearly 250% (Samet et al. 2017).³⁶

The Commission found that pollution control can be highly cost-effective. Air quality improvements in the United States have not only reduced deaths from cardiovascular and respiratory disease but have also yielded an

estimated \$30 in benefits (range, \$4 - \$88) for every dollar invested since 1970 – an aggregate benefit of \$1.5 trillion against an investment of \$65 billion (US EPA, 2011).³⁷ Likewise the removal of lead from gasoline has returned billions of dollars to the economies of countries around the world through the increased intelligence, creativity and economic

productivity of children exposed since conception to only low levels of lead.

The Commission concluded that many of the pollution control strategies that have proven successful and cost-effective in high-income and middle-income countries are now ready to be exported and adapted to cities and countries at every level of income. Their application in carefully planned and well-resourced campaigns that are modified to suit local circumstance can boost economies, increase GDP, and enable countries to avoid and leapfrog over the worst of the human and ecological disasters that have plagued industrial development in the past.

The Commission rejects the claim that pollution control stifles economic growth and that poor countries must pass through a phase of pollution and disease on the road to prosperity. That assertion, sometimes termed the 'environmental Kuznets hypothesis', has repeatedly been proven to be untrue (Cavlovic et al. 2000; Lee et al.).^{38, 39}

Recommendations

To advance pollution prevention and disease control, the Lancet Commission on Pollution and Health offered six major recommendations:

- (1) Make pollution prevention a high priority nationally and internationally and integrate it into country and city planning processes.
- (2) Increase the funding dedicated to pollution control within cities and countries as well as internationally.
- (3) Establish robust systems to monitor pollution and its effects on health.
- (4) Build multi-sectoral partnerships for pollution control that include Ministries of Finance, Development, Transport and Energy as well as Health and Environment as well as industry, environmental groups and civil society.
- (5) Integrate pollution mitigation into planning processes for non-communicable diseases and make pollution prevention a core component of the Global Action Plan for the Prevention and Control of Non-Communicable Diseases.
- (6) Support an interdisciplinary research portfolio on pollution and pollution control.

Future directions

To operationalize these six recommendations, the following actions will be needed:

Elevate the priority of pollution prevention

A critical first step in elevating the priority of pollution prevention and building civil and political will for pollution control is to engage in a structured scoping process that identifies the most important sources of pollution within a city or country with emphasis on those that most directly affect human health. Effective plans to control pollution require support from many sectors of society and, therefore, must involve collaborations among many agencies and organizations within and outside government. Leadership by the head of government – the President, Prime Minister, Governor or Mayor – is of the utmost importance. Heads of government are uniquely well positioned to educate the public and the media about the importance of preventing PRD and can create a vision for a country or a city without pollution.

The upcoming UNEA3, with its focus on pollution, is an excellent example of this strategy. This is a first for the world, bringing representatives from over 190 countries together with the intent of making pollution a priority for action. The assembly is an opportunity for all to see pollution as the scourge that it truly is, damaging health and economies across all continents, and most affecting low and middle-income countries.

The Global Alliance on Health and Pollution, with UN Environment a key contributor, has developed a blueprint to guide scoping processes within countries – the Health and Pollution Action Plan. In addition to identifying key pollution sources, Health and Pollution Action Plans map the geographic distribution of

pollution and estimate health and economic impacts. These plans are implemented with involvement where possible and appropriate, with partners that include the UN Development Programme, UN Environment, the World Health Organization and the World Bank. Plans are designed over a period of 12-24 months through a series of workshops. These workshops bring together senior management of key government agencies – Environment, Health, Development, Finance, Industry, and Transport – along with key stakeholders from the private sector, the business community and civil society, often for the first time. The workshops review pollution's impact from a health and economic perspective, identify the pollution sources that represent the most urgent targets for investment by governments and the international donor community, and design interventions. This strategy has been tested to date in Thailand, Madagascar and Colombia, and demand from additional countries and cities is strong.

Civil society organizations and individual citizens are also key players in the development of Health and Pollution Action Plans because community engagement provides major impetus for governments to act against pollution. To facilitate the involvement of civil society in pollution control, a new geocoded website is being developed by the Global Alliance on Health and Pollution that links databases showing air pollution, water pollution, and soil contamination in cities and countries across the world. This website can be accessed at www.pollution.org. It will show current and, in some cases, real-time data on pollution at a local level. Users can zoom down to the communities where they live, view the available information, and

post their own stories and pictures about pollution. The website will also incorporate a link for people to connect with local government organizations for solutions.

Increase funding for pollution control

Increased funding for pollution control and prevention of PRD is an overarching need. (Figure 1) Increased funding is needed both within countries and internationally.

International development organizations, including UN agencies, multilateral development banks, bilateral funding agencies, private foundations, research institutions, and nongovernmental organizations all have important responsibilities in pollution control that complement and extend the role of city and country governments. If pollution is to be controlled in cities and countries across the world, international agencies must elevate pollution prevention within their agendas, substantially increase the resources they devote to pollution, establishing it as a priority in funding mechanisms.

To increase the international funding devoted to pollution control, providing resources that will assist countries in their work on pollution, the Commission calls on international foundations and private donors to come together with governments around the world to establish dedicated international development funding specifically dedicated to the control of industrial, vehicular, mining, and chemical pollution. Such funding will be most effective when its award is contingent upon host countries' implementation of the polluter-pays principle and ending financial subsidies and tax breaks for polluting industries.

In addition to providing funding, international agencies can also provide much-needed technical assistance that will enable cities

and national governments in low- and middle-income countries to reduce pollution and prevent PRDs by:

- (1) Encouraging the development and implementation of Health and Pollution Action Plans;
- (2) Building data tracking systems to collect information on pollution and disease;
- (3) Supporting direct interventions against pollution where such actions are urgently needed to save lives, or when international action can leverage local action and resources;
- (5) Building professional and technical capacity;
- (6) Strengthening the capacity of universities to conduct research in environmental health science and to train future health and environmental professionals; and
- (7) Fostering partnerships in environmental health science between universities and other research groups in low-income and middle-income countries and international academic institutions.

Global Pollution Observatory

To fulfill the Commission's Recommendation 3, "Establish robust systems to monitor pollution and its effects on health", there is need for a Global Pollution Observatory, an international, multidisciplinary collaboration that will close gaps in data and coordinate, analyze and publish information on all forms of pollution in countries around the world. This Observatory will operate in close partnership with the Institute for Health Metrics

and Evaluation, UN agencies if appropriate, the Planetary Health Alliance, and other major non-governmental organizations concerned with the wellbeing of the Earth's environment.

A major function of the Observatory will be to provide data that assist countries to launch and implement Health and Pollution Action Plans, prioritize pollution initiatives and track progress against pollution. The Observatory will use a range of pollution control metrics and make these data publicly and easily available. The precise metrics to be followed are under consideration, but possibilities include monitoring country-by-country data on the status of regulations against each type of pollution; tracking levels of investment against pollution; measuring exposures to key pollutants, country-by-country and regionally; reporting detailed country-by-country statistics on disease and premature death by pollution risk factor; and developing a database to report the cost-efficacy of interventions against pollution, measured in terms of health outcomes and health-related costs averted.

In partnership with *The Lancet*, the Observatory plans to publish periodically updated information on global trends in pollution, PRD and pollution control. In these updates, the Observatory will share information on solutions to pollution and successes achieved. The Observatory will also explore hosting a biennial conference on pollution to include UN agencies, governments, and representatives of civil society. The Global Pollution Observatory will be housed within the Global Alliance on Health and Pollution, the NGO that served as Secretariat for the Commission.

Research

Research is needed to expand the knowledge base on pollution, both globally and in affected countries. The health and economic impacts of pollution have not been adequately studied. Large gaps in knowledge impede effective implementation of policy and interventions. The science correlating pollution exposures to health impact is substantially incomplete – and is available for only a limited number of toxicants and diseases. Research is needed to expand knowledge of the pollutome, enhance the burden of disease analysis, and to support country-level programs to ascertain exposures and economic viability of programs.

Conclusion

Increases in ambient air, soil, and chemical pollution – the modern forms of pollution – over the past century as well as global climate change can both be directly attributed to the currently prevalent, linear, wasteful, take-make-use-dispose economic paradigm – termed by Pope Francis “the throwaway culture” (Francis, 2015)⁴⁰ – in which natural resources and human capital are viewed as abundant and expendable, and the consequences of their reckless exploitation are given little heed (Raworth 2017; Whitmee et al. 2015).^{41, 42} This economic paradigm focuses single-mindedly on GDP and is ultimately unsustainable. It fails to link the economic development of human societies to social justice or to maintenance of the earth’s resources (McMichael 2017; Steffen et al. 2015; Whitmee et al. 2015).^{43, 44, 45}

Sustainable long-term control of pollution and mitigation of climate change will require that societies at every level of income move away from pollution control to prevention of pollution at source by fundamentally changing societal patterns of production, consumption and transportation. This transition will require

movement away from the linear economic paradigm towards a new paradigm rooted in the concept of the circular economy (World Economic Forum, 2014).⁴⁶

The steps needed for transition towards a circular economy include large-scale transition to non-polluting sources of energy – wind,

solar, and tidal; the production of durable products that require lower quantities of materials and less energy to manufacture than those being produced at present; incentivization of recycling, re-use, and repair; replacement of hazardous materials with safer alternatives such as those that have been developed using the technologies of Green Chemistry (Ahmed, 2012);⁴⁷ and the development of new transportation strategies that include safe, accessible and affordable public transport coupled with an emphasis on active transportation – walking and cycling.

Transition towards a circular economy will reduce PRD, improve health and slow the pace of global climate change. This transition is essential for promoting smart, sustainable, and inclusive growth that permits the continued existence and well-being of human societies (World Economic Forum, 2014).⁴⁸

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Authors

Commission Co-Chair Philip J. Landrigan, M.D., M.Sc., Arnhold Institute for Global Health, Icahn School of Medicine at Mount Sinai, New York, NY.

Dr. Landrigan is a pediatrician and an international leader in public health and preventive medicine. His pioneering research on the effects of lead poisoning in children led the U.S. government to mandate removal of lead from gasoline and paint, actions that have produced a more than 90% reduction in incidence of childhood lead poisoning over the past 25 years. His leadership of a National Academy of Sciences Committee on pesticides in children's diets generated widespread understanding that children are uniquely vulnerable to toxic chemicals in the environment. The findings of the NAS Committee secured passage of the Food Quality Protection Act in 1996, a major U.S. federal pesticide law and the first environmental statute to contain specific protections for infants and children. Dr. Landrigan served as Senior Advisor to the U.S. Environmental Protection Agency where he was instrumental in helping to establish the EPA's Office of Children's Health Protection. Dr. Landrigan has been a leader in developing the National Children's Study, the largest study of children's health and the environment ever launched in the United States.

Commission Co-Chair Richard Fuller, BE, President, Pure Earth (formerly Blacksmith Institute), New York, NY, USA; Global Alliance on Health and Pollution, New York, NY, USA.

Richard Fuller founded Pure Earth (formerly known as the Blacksmith Institute) in 1999 as the only organization focused on pollution cleanup on a global scale. Over the years, he has assembled a comprehensive database of knowledge and information that is being used by

Pure Earth's network of project managers around the world to clean up the worst polluted sites efficiently and effectively. This includes Pure Earth's global inventory of polluted sites, the Toxic Sites Identification Program, the world's worst polluted places reports, the Health and Pollution Planning Process for low- and middle-income countries, and more. In 2012, Fuller began building an international alliance with the Global Alliance on Health and Pollution, an international collaborative body formed by Pure Earth, World Bank, UNEP, UNDP, UNIDO, Asian Development Bank, the European Commission, Ministries of Environment and Health of many low- and middle-income countries to address pollution and health at scale. This led to the creation of the Commission on Pollution and Health.

Born in Australia, Fuller graduated with a degree in engineering from Melbourne University and began his career at IBM. He left Australia in 1988 to work directly on global environmental issues. He spent two years in the rainforests of Brazil with the United Nations Environmental Programme creating forest reserves promoting the preservation of both the rainforest and its inhabitants. He then headed to New York City, establishing Great Forest Inc., now one of the most successful sustainability consulting companies in the US, and among the first to bring sustainability practices to the business world, helping to pave the way for the rise of corporate social responsibility. But even as he helped big businesses become more sustainable, Fuller realized that he had to deal with the problem from both ends to really make a difference. So he shifted his focus to poor countries and to global pollution.

He is the author of the book *The Brown Agenda*, in which he chronicles cleanup efforts in some of the world's worst polluted places.

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