Pollution and global health – A time for action

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ABSTRACT: Pollution is a major threat to health and the global economy that was responsible in 2015 for an estimated 9 million deaths and enormous economic losses and high associated health care costs. Despite these great impacts, pollution has been overlooked in the international development and global health agendas. To end this neglect and advance potential solutions, we formed the Commission on Pollution and Health under sponsorship of *The Lancet*.

This Commission examined pollution's health and economic effects; studied the interconnections between pollution, poverty and social injustice; identified strategies that have cost-effectively curbed pollution; and outlined an agenda for intervention. The Commission noted that over 70% of the diseases caused by pollution are non-communicable diseases (NCDs). To identify gaps in knowledge and highlight opportunities for research and prevention, the Commission developed the concept of the pollutome, a taxonomy that classifies pollutants according to knowledge about their effects on health.

The Commission concluded that control of pollution is a winnable battle. The worst forms of pollution and pollution-related disease could be curbed in all countries by applying technical and legal strategies that have proven successful and cost effective in controlled pollution in high-income and, more recently, in some middle-income countries.

Progress against pollution and pollution-related disease will require that leaders at the highest levels of international organizations to unequivocally and forcefully integrate the pollution and NCD control agendas. Because the vast majority of pollution-related disease occurs in low- and middle-income countries, new pollution control efforts must be developed and undertaken at the country level with financial support from wealthier countries and international development partners, and technical guidance from countries that have implemented successful interventions.

To track progress toward control of pollution and prevention of pollution-related disease, the Commission recommended creation of a Global Pollution Observatory that will aggregate, analyze and archive data on pollution and pollution-related disease and make this information available to researchers, policy makers, the media and the global public.

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). 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 is projected to increase further. The greatest increases will be seen in the cities of rapidly industrializing low- and middle income countries. (Lelieveld et al. 2015).

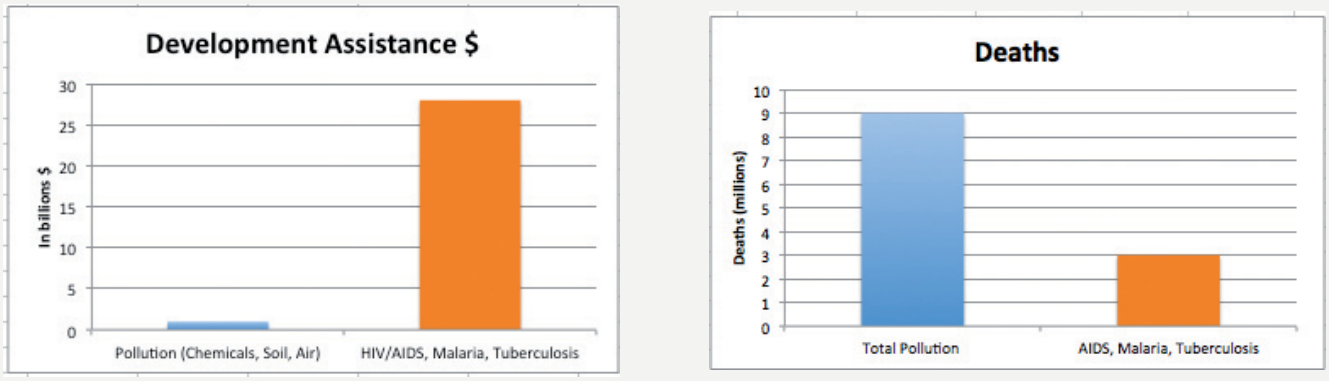
Despite the great magnitude of its effects on human health and the environment, pollution from industrial, automotive and chemical sources has been gravely neglected in the international development and global health agendas as well as in the planning strategies of many countries. The foreign aid budgets 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 and to prevention of the diseases that they cause (Greenberg et al. 2016; Nugent 2016). 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.)

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). The Commission was launched in 2015 and conducted its work over a two-year period. The Commission's goals were to raise awareness of the great magnitude of the problem of pollution, end neglect of pollution-related disease, and mobilize the resources, the political leadership and the civil will needed to control pollution and prevent disease in cities and countries across the world.

Based on a definition proposed by the European Environment Agency (European Union, 2010), the Commission defined pollution

FIGURE 1. DEATHS DUE TO POLLUTION V. RESOURCES DIRECTED TO POLLUTION CONTROL



Source: Fuller R. Personal communication

as "Any material introduced into the environment by human activity that endangers human health or harms living resources and ecosystems".

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-ears (DALYs. (Forouzanfar, 2016a) 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) In the most severely affected countries, pollution-related disease 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. (Yadama, 2013) Water pollution caused 1.75 million deaths. Occupational pollutants, including carcinogens caused 0.85 million deaths. Soil pollution, heavy metals and toxic chemicals caused 0.5 million deaths.

The burden of disease and death due to pollution is growing in many parts of the world. Increases are seen in particular in the numbers of deaths due to ambient air pollution, chemical pollution, and soil pollution. 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. Rapidly growing cities in industrializing countries are very hard hit 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). Human exposure to manufactured chemicals is virtually universal. Far too few of manufactured chemicals in wide use have been tested for safety or toxicity and thus their possible contribution to the global burden of disease cannot at present be assessed.

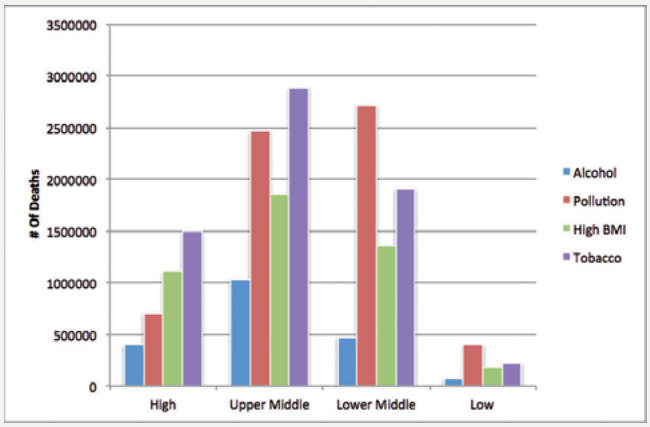
Non-communicable diseases account for 71% of deaths caused by pollution. Pollution is responsible for 21% of all cardiovascular deaths worldwide, 26% of deaths from ischemic heart disease, 23% of stroke deaths, 51% of deaths from chronic obstructive pulmonary disease, and 43% of deaths due to lung cancer (Forouzanfar, 2016a; Forouzanfar, 2016b). Pollution appears also to be linked to adverse reproductive outcomes, obesity, diabetes (Meo et al. 2015), and neurodegenerative diseases (Cacciottolo et al. 2017; Heusinkveld et al. 2016) , but the global burden of disease due to these health effects has not yet been quantified.

The impact of pollution on NCD mortality varies greatly among countries by national income (**Figure 2**). (Fuller et al., 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. But 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 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 closely linked to global climate change (McMichael 2017; Perera 2017). 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).

FIGURE 2: GLOBAL NCD DEATHS BY RISK FACTOR AND INCOME GROUP



Source: Fuller R, Rahona E, Fisher S, Caravanos J, Webb D, Kass D, Matte T, Landrigan PJ. Pollution and non-communicable disease: time to end the neglect. The Lancet Planetary Health 2018; 2: e96-e98.

The pollutome

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.. Because scientific knowledge of pollution's effects on health varies by type of pollution, the Commission divided the pollutome into 3 zones (**Figure 3**).

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) preterm birth (Cacciottolo et al. 2017; Malley et al. 2017) and diseases of the central nervous system including autism (Casanova et al. 2016; Heusinkveld et al. 2016; Perera 2017; Perera et al. 2014),and dementia (Cacciottolo et al. 2017; Kioumourtzoglou et al. 2015). Soil pollution by heavy metals and toxic chemicals at contaminated industrial and mining sites is another example(Prüss-Ustün et al. 2011).

Zone 3 includes new and emerging pollutants (Grandjean and Landrigan 2014; Landrigan and Goldman 2011), 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 the total number of deaths attributed to pollution will increase and that some pollution-disease pairs currently placed in Zones 2 and 3 of the pollutome will move to Zone 1 and be counted in future estimates of the global burden of disease.

Health Care Cost of Pollution

Annual expenditures on health care related to pollution ranges from US$660 billion (upper bound) to US$240 billion (lower bound) depending on the methodology used to estimate costs or approximately three to nine percent of global spending on health care in 2013 (the reference year for the health care cost analysis). Although only 14 percent of global total for pollution related health care spending is in lower- and middle-income countries (LMICs) in our primary (lower bound) model, the relative share of spending for pollution related illness is substantial, especially in very low-income countries. Cancer, chronic respiratory and cardio/cerebrovascular illnesses account for the largest health care spending items linked to pollution even in LMICs (Preker et al 2016).

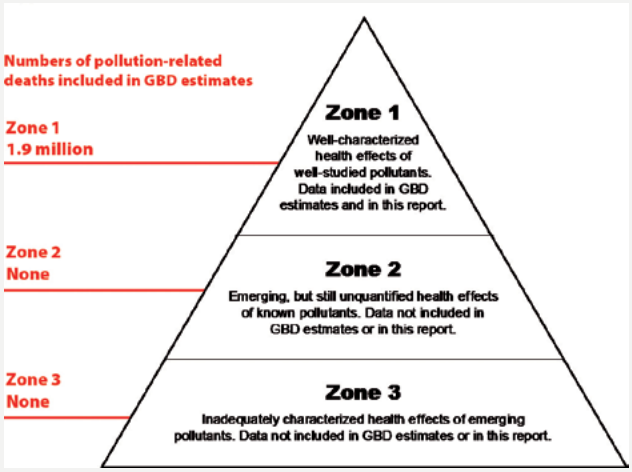
Other studies suggest that intangible costs associated with environmental pollution include lower productivity and reduced income which also have an indirect impact on health and health care costs. The financial and health impacts therefore substantial even when intangible costs are excluded. In addition, in many LMICs poor households simply forgo medical treatment and lose household income as a result of man-made environmental degradation. When evaluating the value of public health or environmental programs which prevent or limit pollution-related illness, policy makers should consider the health benefits, the tangible cost offsets (estimated in our models) and the opportunity costs.

Prospects for prevention

A key message of the *Lancet* Commission is that with leadership, resources and clearly articulated, data-driven strategies, pollution can be controlled and pollution-related disease 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 proposition. Successful 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 polluters.

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,

FIGURE 3: THE POLLUTOME



Source: Lancet Commission on Pollution and Health (Landrigan et al. 2017).

the blood lead concentrations of their children have decreased by more than 90% (Grosse et al. 2002), 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).

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.

Policy implications

Strategies for success within countries require a cross-sectoral approach. Such have been developed, field-tested, and proven cost-effective in high-income countries and are now moving into middle-income countries. They are based on law and regulation, rely heavily upon technology, are subjected to continuous evaluation, are backed by strong enforcement, and incorporate the polluter-pays principle. These programs are held accountable to targets and timetables. These successful, effective strategies for pollution control can be used as models and adapted to local circumstances in cities and countries at every level of income. Their application can enable developing cities and countries to leapfrog over the worst of the human and ecological disasters that have plagued economic development in the past.

A key message is that control and prevention of pollution provide several benefits, both short-term and long-term, for societies at every level of income. The direct benefits of pollution mitigation include improvements in air and water quality and improvements in health. The health benefits include reductions in disease incidence and prevalence, improvements in children's health, reductions in the numbers of premature deaths, increasing longevity, and substantial enhancements in quality of life. Indirect benefits include enhancing gender equity, alleviating poverty, increasing tourism, improving education, and enhancing political stability. Pollution control makes cities more livable and attractive, benefits ecosystems, improves the economy and, when coupled with efforts to transition to clean fuels and to control emissions of greenhouse gases, pollution control can help to slow the pace of global climate change and accelerate the transition to a cleaner, more sustainable, circular economy.

These many benefits of pollution control underscore the reality that pollution is much more than merely an environmental challenge; pollution is a profound and pervasive threat that affects many aspects of human health and wellbeing.

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 governments, and nationally and internationally. These stakeholders must be fully integrated into a city's or a country's development agenda. If they are to be successful, these efforts must include not only ministries of health and environment, but also ministries of finance, energy, industry, agriculture, and transport. Pollution control policy cannot exist in isolation.

A key mechanism currently being tested in a number of countries is the Health and Pollution Action Plan (HPAPs). This series of workshops brings together Ministries of Health, Environment, Finance, Transport, Interior, Mining and Industry and others to review the key pollution issues facing a country or city. Working together, a review of current programs is undertaken, and an assessment is made to determine if they are sufficient to be able to reduce mortality and morbidity. If not, the group examines additional interventions to implement. The outcome of this work is a number of new programs designed to mitigate pollution adequately. These HPAPs are, if you like, a kickstart for a country who has paid scant attention to pollution, and with the participation of funding agencies such as the World Bank, can lead to substantive programs that can save lives.

Prioritize interventions

A good part of the processes needed involves adequate prioritization of interventions. Resources must be spent where they can do the most good. The key metric ought to be health impact (both death and DALY), but other imperatives, such as economic planning, tourism impact, public pressures are also likely to be a part of prioritization. Prioritization efforts require a reasonable (if not definite) assessment of health impact, environmental damages, and cost-effectiveness of control of various pollution sources. A robust system for assigning priority will avoid the pitfall of prioritizing interventions on the basis of political expediency or because they happen to be an item in the evening news.

Quick, highly visible successes are extremely important in

gaining public support for a pollution control program. It is therefore essential that intervention plans identify pollution sources whose early control will result in quick wins. Rapid, measurable improvements in public health, especially in the health of children, are powerful levers for building public and political support.

Key steps in ranking pollution sources in terms of their health effects, a key process of an effective health and pollution action plan, are as follows:

- Examine the frequency and severity of disease attributed to various types of pollution using data from national sources and data from the GBD study, and use this information to prioritize interventions against pollution;
- for each type of pollution apportion the relative contributions of different exposure sources;
- evaluate the efficacy of new programs that have potential to reduce health effects from each pollution source, review existing programs for efficacy and reach, and identify performance gaps and legal, regulatory, and enforcement gaps;
- identify potential interventions (new and expanded) for those exposures for which there are dramatic effects on health outcomes and measurable indirect benefits, and evaluate these interventions for cost-effectiveness;
- focus not only on high-visibility sources of pollution, but also on pollution sources that historically have received less attention, such as household air pollution, contaminated sites, lead (including lead in pottery glazes, lead in paint, and lead from other source that might be specific to a specific culture), and occupational risks, including asbestos;
- review the benefits of interventions against pollution and health improvement, considering the roles of gender equity, alleviation of poverty, slowing of the pace of climate change, increased tourism, economic growth, improved education, and political factors
- bring all relevant agencies into the prioritization process, including senior representatives of ministries of health, environment, industry, development, finance, transportation, energy, planning, and legislative branches, and civil society, if possible; and
- begin implementation with those program areas where past experience will be a strong return on investment, as measured by benefit to public health and the possibility for early victories: examples include removing lead from paint or pottery, cleaning up highly visible toxic hotspots, banning asbestos, or publishing a ranked list of the most important pollution sources in a city or country, involving the media in advertising early successes.

Successful interventions rely on a mix of primary prevention approaches that eliminate pollution at source, coupled with downstream pollution control technologies, such as filters and stack scrubbers, that remove pollutants from the waste stream after they have already been formed. Examples of highly transformative strategies for pollution control that are based on primary prevention include shifting the mix of energy sources in a city or country away from polluting fuels toward non-polluting, renewable fuels; use of safer feedstocks in industrial production, such as feedstocks produced by the burgeoning technologies of green chemistry, which eliminate use of hazardous feedstuffs and production of materials that can cause injury to human health and the environment; incentivizing the adoption of clean production technologies; and enhancing access to efficient, affordable public transportation. Primary prevention can also be achieved by banning highly hazardous and carcinogenic materials such as asbestos, benzene, PCBs, and DDT, as has been successfully achieved in many countries. Primary prevention of pollution based on the elimination of pollution at source is inherently more effective than downstream control technologies, such as stack scrubbers or water filters that reduce the amount and toxicity of pollutant emissions after they have already been formed. Primary prevention of pollution at source is also essential for accelerating transition to a more sustainable, circular economy.

High quality metrics that monitor pollution and track progress towards national and local pollution prevention and disease control goals are essential to the success of any health and pollution action plan. Early establishment of public health and environment monitoring systems should therefore be a priority Targets and timetables are essential for programs to control pollution; these provide benchmarks and metrics for assessing progress towards pollution control. Establishing specific targets at the country, state or city level, along with deadlines for pollution control are critical to success. Of course, pollution control targets must be appropriate for each country's level of income and development and guided by the WHO pollution control targets. These targets will be most effective when they are focused on pollution sources that are established to be priorities and must be integrated into commitments to meet the SDGs and to reduce greenhouse gas emissions.

Engagement with the private sector, international agencies, and funders

Multiple stakeholders should be involved in controlling pollution and preventing pollution-related disease, including top government leaders, but also key civil servants, business, academia, and civil society. Carefully listening to the views of the most important and influential stakeholders (both formal and informal) can help to ensure that all the parties who can advance (or derail) programs are taken into account.

Enlightened business leaders can be powerful advocates for pollution control and disease prevention. The creation of incentives by governments for non- polluting industries can be powerful catalysts for innovative action, as seen by the rapid development of solar power systems and the organic food industry.

International development organizations, including UN agencies, multilateral development banks, bilateral funding agencies, private foundations, and non- governmental organizations, have important responsibilities in pollution control and prevention of pollution-related disease that complement and extend the role of governments. These agencies should elevate pollution prevention within the agendas of international development and global health and substantially increase the resources they devote to pollution, establishing it as a priority in funding mechanisms.

These agencies should build on existing global data platforms to develop a central platform to monitor and coordinate information

on all forms of pollution globally and should consider convening a bi-annual conference on pollution.

International agencies should also provide resources to reduce pollution-related disease in low-income and middle-income countries by:

- encouraging the development of action plans regarding health and pollution, both nationally and regionally, and of specific pollution control projects that set time targets;
- building data tracking systems to collect information on pollution and disease;
- supporting direct interventions against pollution where such actions are urgently needed to save lives;
- supporting interventions against pollution when international action can leverage local action and resources;
- building professional and technical capacity within governments;
- strengthening the capacity of universities in low-income and middle- income countries to research environmental health science and to train future health and environmental professionals; and
- supporting research program in environmental health science in partnership with international academic institutions, including clinical and epidemiological studies to learn more about the undiscovered links between pollution and non- communicable disease.

Responsibilities of health professionals

Physicians, nurses, and other health professionals have important responsibilities in helping societies to confront the challenges of pollution and pollution-related disease as they have educated societies around the world about the dangers of nuclear war and global climate change.

Health professionals can begin by controlling pollution and reducing carbon emissions from hospitals and health-care facilities and by reducing pollution and carbon-intensive energy sources in their own lives. Health professionals can support local, regional, and national planning efforts and emphasize the links between pollution and health, develop new transdisciplinary educational curricula that build knowledge of environmental health science and about the health effects of pollution, and support research in exposure science, environmental science, health policy research and health economics.

Partnerships between government, civil society, and the health professions have proven powerfully effective in past struggles to control pollution. For example, in the ultimately successful effort to remove lead from gasoline, which was fiercely resisted for many years by the lead industry, partnerships were built between government agencies, health professionals, and civil society organizations.

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. Leaders of government at all levels - Mayors, Governors, and Heads of State - need to elevate pollution control to a high level within their agendas, integrate pollution prevention into development planning and link pollution prevention with commitments to advance the UN Sustainable Development Goals, slow the pace of climate change, and control non-communicable diseases.
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

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 pollution-related disease and can create a vision for a country or a city without pollution.

Increase funding for pollution control

Increased funding for pollution control and prevention of pollution-related disease is an overarching need. Increased funding is needed both within countries and internationally.

To increase the international funding devoted to pollution control, 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 and foundations 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 pollution-related diseases.

Global Pollution Observatory

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 *Lancet* Commission recommended creation of a Global Pollution Observatory. 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 modelled on the disease surveillance programs of the Centers for Disease Control and Prevention. (Langmuir, 1963)

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). In the throwaway culture, 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). 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).

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) an economic model that decouples development from the consumption of non-renewable resources and minimizes the generation of pollution and other forms of waste through the creation of durable, long-lasting products; large-scale recycling, reuse, and repair; the removal of distorting subsidies; the substitution of hazardous materials with safer alternatives, and strict enforcement of pollution taxes (HEAL, 2015). A circular economy conserves and increases resources, rather than taking and depleting them. In a fully circular economy, the only new inputs are renewable materials, and all non-renewable materials are recycled. The underlying assumption is that waste is an inherent inefficiency, a loss of materials from the system and thus a cost (World Economic Forum, 2014).

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); 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.

Finally, the juxtaposition of two recent events suggests that global neglect of pollution may be coming to an end. The release on October 19, 2017 of the *Lancet* Commission on Pollution and Health followed by the convening of the Third UN Environment Assembly on 4-6 December in Nairobi, in which pollution prevention was the overarching theme, suggests that pollution is beginning to receive the high-level attention that has long needed. With the impetus of these events and growing recognition of pollution's enormous human and economic costs, the time has come to end the neglect, to acknowledge that pollution is a major NCD risk factor, especially in poor countries, and to make pollution prevention a core component of the global NCD strategy.

The *Lancet* Commission concluded that control of pollution and prevention of pollution-related disease are winnable battles.

Biographies

Richard Fuller is an Australian born environmentalist, founder and President of Pure Earth, a non-profit dedicated to solving pollution problems in lower income countries. Mr. Fuller initiated and leads the Secretariat of the Global Alliance on Health and Pollution, and in October 2017 cochaired the seminal Lancet Commission on Pollution and Health.

Philip J. Landrigan, MD, MSc is Professor of Biology and Director of the Global Public Health Initiative at Boston College and Professor Emeritus of Preventive Medicine and Pediatrics in the Icahn School of Medicine at Mount Sinai. From 2015 to 2017, he co-chaired the Lancet Commission on Pollution & Health. For four decades, Prof. Landrigan has been a thought leader in environmental medicine.

Alexander S. Preker is President and CEO of the Health Investment & Financing Corporation and a member of the board of several of the companies in which the group has invested. Mr. Preker is one of the Commissioners for the Global Commission on Pollution, Health and Development, and is an Executive Scholar and Adjunct Professor at Columbia University, New York University and Icahn School of Medicine at Mt. Sinai.

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