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Key Points:
- Pollution accounts for a high percent of total global health burdens, largely borne by low-income nations and marginalized populations
- New approaches using citizen science and community-engaged research have proven effective at reducing lead burdens in many communities
- Creative approaches need to be developed and adapted to provide tools for middle- and low-income countries to confront pollution exposure

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Addressing Pollution-Related Global Environmental Health Burdens

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Abstract New analyses are revealing the scale of pollution on global health, with a disproportionate share of the impact borne by lower-income nations, minority and marginalized individuals. Common themes emerge on the drivers of this pollution impact, including a lack of regulation and its enforcement, research and expertise development, and innovative funding mechanisms for mitigation. Creative approaches need to be developed and applied to address and overcome these obstacles. The existing "business as usual" modus operandi continues to externalize human health costs related to pollution, which exerts a negative influence on global environmental health.

Plain Language Summary The growing burden of pollution on global health cannot be ignored, particularly because it disproportionately impacts the health and future of those nations and peoples least capable of confronting and eliminating it.

1. Introduction

A bombshell report from the Lancet Commission (Landrigan et al., 2017) on global pollution and health states that pollution is linked to 16% of all premature deaths worldwide, a statistic that belies our medical focus on treating symptoms rather than the causes of disease. However, more troubling is that the report states that "… in countries at every income level, disease caused by pollution is most prevalent among minorities and the marginalized." (Landrigan et al., 2017).

It seems that the burden of environmental injustice on minority and marginalized people is not just felt among developed nations with large income disparities, such as the United States, but is a worldwide phenomenon. Compounding this is the fact that 92% of pollution-related deaths occur in low-income and middle-income countries (LMICs) (GBD, 2015), providing evidence it is a true global environmental issue. Many of those countries have little in the way of local expertise or environmental regulations, which results in poor knowledge transfer from high-income countries to address well-studied and soluble issues. For example, it is well known that exposure to fine particulate matter (PM 2.5) from indoor and outdoor combustion is a major cause of premature death, a problem faced by people largely in LMIC (Landrigan et al., 2017). This is a classic "wicked problem" because although the solution is a relatively straightforward issue to address with emission regulations and relatively low-cost technologies (e.g., Barn et al., 2018), it is proving resistant to remedy because of organizational and political constraints.

The common themes shared by global environmental exposure hazards from air, soil, and water are (1) lack of adequate regulations or their enforcement to mitigate or cleanup pollution, (2) lack of adequate research and data coverage on extant and emerging pollutants, and (3) lack of resources, including money, expertise, and capacity to mitigate legacy and ongoing challenges. While LMIC tend to suffer from all three of these challenges, it is evident that one or more of these structural deficits burdens also high-income countries. Reducing the global burden of disease requires attention to these deficits, which is a major challenge given that they typically lie in different "sectors" of national and international governance frameworks.

2. Regulations to Avoid Pollution and Pollution Exposure

Adoption of protective environmental regulations at the national and international levels has resulted in positive environmental change and protected human health. Indeed, this is the underpinning of the enormous improvements in health and longevity that have been enjoyed by many of the upper-middle and

upper-income countries (e.g., Henneman et al., 2017). For example, national legislation in the United States that removed the harmful toxicant lead from gasoline resulted in an immediate and continued decline in blood lead levels of children (Annest et al., 1983), and the avoidance of substantial lifetime economic losses (Gould, 2009) and associated health problems. This policy intervention is broadly seen as a great public health success story. However, the lead that was emitted from gasoline in the twentieth century is persistent in the environment and continues to disproportionately impact poor communities of color.

At an international level, the Minimata Convention signed in 2013 implemented a global agreement to reduce the emissions of the harmful toxicant mercury into the environment from multiple sources. The Paris Climate Agreement goal of significantly modulating global net carbon emissions will result in multiple positive benefits for environmental and human health especially from the likely reduction in particulate matter for which there appears no safe level of exposure (Wang et al., 2018). Indeed, perhaps most concerning is that there is not only no safe lower level of exposure for a range of common environmental toxic pollutants but that their effect on human health is "proportionately greater at the lowest dose or levels of exposure" (Lanphear, 2017).

The fact that the current U.S. administration pulled out of the Paris agreement is troubling on multiple fronts, especially when it comes at a time when there is a growing sense of the purposeful erosion of environmental protection in the United States itself. Even though the U.S. government has decided to withdraw from the Paris agreement, its existence provides a strong roadmap that will still likely guide business, industry, and state governments to attain many of the national carbon targets.

3. New Ways to Develop Data and Research Through Citizen Science and Community-Engaged Research

Evidence-based policy formulated from research into pollutants, their sources, and human health impacts has resulted in a marked reduction of pollution-related disease burden in higher-income countries over the last three decades (e.g., Pope III et al., 2009). Higher-income countries have monitoring systems in place to measure pollution levels and to identify pollution sources. These are often drivers of research into the impacts of pollutants on environmental and human health along with the assessment of effective mitigation techniques to reduce exposures.

But even higher-income countries have structural flaws in their pollution protection systems in that monitoring does not always equate to intervention (e.g., Taylor et al., 2014). A classic example of this structural flaw is lead poisoning in children, where intervention only occurs after a child has presented with an elevated blood lead level (>5 μg/dL in the United States). While levels of lead in children have dropped significantly since the elimination of the use of lead additives in gasoline and its removal from other sources (paint, food, and toys), some 500,000 U.S. children still have an elevated blood lead level. It is a fact that exposures are disproportionately greater in lower-income children of color (e.g., Filippelli et al., 2015). This impact and the inherent environmental injustices are particularly evident in U.S. cities. Most of the exposure to lead in urban children is from legacy sources that have accumulated from over a century of industrial activity, which now resides in surface soils and dust. These now lead-rich deposits continue to be remobilized causing contamination of human (e.g., Laidlaw & Filippelli, 2008), food, and ecological systems (Zhou et al., 2017).

Although we do monitor air and water for potential contaminants, there is no systematic program to map urban soil geochemistry and thus to identify and eliminate hot spots from this persistent and toxic pollutant. Indeed, we typically resort to analyzing maps of children's blood lead levels to find these particular pockets of high lead exposure—in other words, authorities wait until children are exposed so that we can find the source of the pollutant (Taylor et al., 2011). Obviously, this approach fails the gold standard of public health, which is primary prevention. Moreover, such an approach is a backward approach to public health protection, particularly given our understanding of lead toxicity and that we know how to prevent harm to the most vulnerable section of the population—young children.

Several efforts are underway to flip this equation and to actively engage with community members to address this gap. Some of these approaches are now utilizing citizen science and community-engaged research, which are emerging as effective and powerful mechanisms to collect data and to engage with communities to take action to find and reduce personal exposures to contamination in their own homes (e.g., Filippelli et al., 2015; Leech et al., 2016). Recent examples from soil and dust lead exposure include

Indianapolis (Healthy Cities Project, 2018, https://www.facebook.com/search/top/?q=healthy%20cities%20project), New Orleans (Lead Lab, 2018, https://plus.google.com/102811471396098140243), Sydney (VegeSafe, 2018, https://www.facebook.com/MQVegeSafe/), and an emerging global dust network (360 Dust Analysis, 2018, www.360dustanalysis.com). While these citizen science and community-engaged research programs do not preclude publication in traditional academic journals (e.g., Rouillon et al., 2017), they are designed to provide evidence-based advice to participants to help them better manage pollution risks in their home environment. For such citizen science programs, it is more important that the data can be used to trigger new knowledge and positive changes within local communities. Deeper reach of science and scientists into our wider communities about research that matters to individuals can be accelerated by use of social media platforms, improving the community relevance and impact of science. However, while some progress is being made in LMICs that are heavily burdened by contaminants (e.g., Shih, 2018), further work is required.

4. Creative Approaches to Mitigating and Eliminating Global Pollutants

Mitigation and elimination of pollutant sources and legacies are perhaps the most challenging of the three exposure burden themes (lack of adequate regulations, research, and resources), particularly in LMICs. This is due to a lack of funds and creativity around solutions, often compounded by poor governance that results in wasting precious financial resources through poor management and/or corruption before they can do public good (Morse, 2006). A lack of funding for mitigation and protection is often addressed through international assistance (e.g., World Bank, Global Environment Fund, and various national and NGO programs). A lack of creativity is exampled by the application of "industry standard" mitigation approaches to environments without adequate resources to pay for infrastructure support to maintain these protections. Instead, we need big picture models like the Bill and Melinda Gates Foundation Grand Challenges that aim to conceive, develop, and apply solutions that are appropriate to the setting. Simple, yet effective locally based solutions for remediating contaminated soils are required because they not only reduce exposure risks but also build local capacity (e.g., Ericson et al., 2018). However, inadequate attention has been paid to developing workable solutions to very large-scale contamination issues, like the widespread lead poisoning devastating children in the Zambian city of Kabwe (Bose-O'Reilly et al., 2017). That said, promising outcomes are achievable at low cost such as those associated with improved cooking stoves to reduce soot and indoor air pollution in homes (Dybas, 2013) or the use of solar lights to eradicate pollution from kerosene lamps (Webster, 2012).

5. Our Collective Future

Collectively, the solutions to the reduction and ultimate elimination of pollution cannot be achieved via technology alone but need to be resolved with and alongside the very people and communities that require solutions—these are the real drivers for sustained change. Communities and individuals are too often left out of the conversation, even when ample evidence exists that the human burden of environmental exposures can be reduced both by limiting exposure sources and by relatively simple modification of behaviors.

Without recognizing and addressing the three keys themes of global pollution burdens, it is entirely possible that pollution-related morbidities and mortalities in 20 years might be worse than those outlined in the recent Lancet Commission report on pollution and health. Imagine a future Earth where resource extraction and utilization continue to follow the reckless trajectory of "business as usual" (profit over pollution), leaving poorer and disadvantaged populations to absorb the externalized costs of environmental pollution. Ultimately, failure to reduce chemical exposures costs the whole of society (e.g., Trasande et al., 2015).

Given that the knowledge and resources to combat pollution are available, we have a responsibility to do so for future generations. If we do not accept that responsibility, not only will we burden them with our failure of inaction but they will not reflect favorably on our profligate use of the environment, for which there is no replacement.

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