

Grand challenges in sustainable cities and health

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Introduction

The size of global urban population has increased exponentially since the advent of the industrial revolution, with urban centers attracting large numbers of workers and families looking for opportunities for employment, education and better quality of life. The growth of large urban centers initially in Europe and North America was followed by even larger megacities in Latin America, Asia and Africa. Currently, more than half of the world's population lives in cities, with this figure projected to reach two-thirds of the world's population by 2050.

Historically, urban populations have on average been healthier and more affluent compared to their rural counterparts. Improvements in education, housing, and public health (including better hygiene and sanitation), and better access to primary care (including wider vaccination coverage) resulted in longer life expectancy and healthier populations. However, as infectious diseases and malnutrition declined in many cities, non-communicable diseases (NCDs), including physical and mental illness, became more prevalent. Currently, rapid urbanizing countries around the world are facing an NCD epidemic with high rates of obesity, diabetes, cardiovascular illness and cancers associated with sedentary lifestyles, unhealthy diets, and environmental pollution ([Leon, 2008](#) ; [The Lancet, 2012](#)).

Although population health in cities has generally improved, not everybody has benefited from these improvements. People living in urban slums, as well as socioeconomically deprived and migrant populations, have been

disproportionally affected by pollution, climate extremes, and lack of clean water and sanitation, particularly in low and middle-income countries. This can create a “double burden” of communicable and non-communicable diseases for these disadvantaged urban populations ([Sverdlik, 2011](#)). The elderly, young children, and those with pre-existing illness are more vulnerable to extreme temperatures, floods, and pollution affecting cities ([Hajat et al., 2007](#)). People living in urban centers are disproportionately exposed to heat due to the Urban Heat Island effect (i. e., higher ambient temperatures in built up areas compared to surrounding suburban and rural areas) and building overheating ([Heaviside et al., 2017](#)). These factors conspire to create significant health and environmental inequities across generations, socioeconomic strata, and urban areas.

Rapid urban development has exacerbated environmental problems linked with unsustainable transport, housing, waste, energy, and land use management. Exposure to urban pollution (in air, water, and soil) has been associated with increased cardiovascular and respiratory mortality and morbidity and cancer incidence. For example, long-term exposure to urban air pollution shortens lifespans ([Pope et al., 2009](#)), and reduces lung growth in children ([Gauderman et al., 2015](#)). Short-term exposure to air pollution has been associated with increased daily mortality in cities ([Liu et al., 2019](#)) and asthma exacerbations in children ([Bouazza et al., 2018](#)). Overall, exposure to outdoor and indoor air pollution accounts for about 1 in 9 deaths every year worldwide ([World Health Organization, 2016a](#)). Outdoor particulate air pollution causes around 4.2 m (3.7–4.8 m) premature deaths annually worldwide, with over 50% of them in India and China. Indoor air

pollution, mainly associated with burning solid fuel for cooking or heating, accounts for around 2.9 m (2.2–3.6 m) premature deaths annually, with much of the burden falling on women and young children in low and middle-income countries ([Global Burden of Disease, 2016](#)).

Climate change and related (more frequent and intense) extreme weather events, such as heatwaves and floods, in conjunction with demographic change, have exacerbated NCD mortality and morbidity in cities, with the elderly being more severely affected ([Vardoulakis et al., 2014](#)). Heatwaves have affected cities across the income spectrum, including some of the highest income world capitals. For example, 506 (± 51) heat-related deaths in Central Paris and 64 (± 3) in Greater London were attributed to anthropogenic climate change during the summer of 2003 ([Mitchell et al., 2016](#)).

On the other hand, cities are often centers of policy and technological innovation and economic development. They are in many cases developing and implementing solutions to current public health and environmental problems associated with climate change, pollution, and unsustainable use of natural resources. For example, compact cities can help reduce car dependency and minimize the use of energy for transport ([Dieleman et al., 2002](#)). Sustainable transport systems and housing can save energy and minimize emissions of pollutants and greenhouse gases ([Haines and Ebi, 2019](#)). Increased active travel (i. e., more walking and cycling) and reduced red and processed meat consumption can directly improve cardiovascular health, as well as reduce greenhouse gas emissions ([Haines et al., 2009](#)). Well-designed and maintained urban vegetation and high reflectance roofs

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can help reduce the Urban Heat Island effect and building overheating ([Salmond et al., 2016](#)).

The UN Sustainable Development Goals (SDGs), the UN New Urban Agenda, and the WHO Urban Health Initiative ([World Health Organization, 2016b, 2019](#)) have focused the attention of researchers, practitioners and decision-makers on policies and interventions that have the potential to provide multiple benefits for health, the environment, and the economy in urban settings. However, more scientific evidence is needed to evaluate policies and interventions and underpin innovation that will improve health in cities. A number of international projects, activities and networks have raised awareness of the challenges and opportunities facing cities and health focusing on the need for inter-disciplinary systems based thinking ([Vardoulakis et al., 2016](#)).

Low-cost sensor technologies, crowd sourcing, social media, and mobile applications have enabled active involvement of urban populations in “ citizen science” projects, e. g., by collecting and linking environmental and health data. In addition to raising awareness, citizen science together with innovative big data analysis, linkage and visualization methods open up opportunities for stronger and more interactive engagement with stakeholders at all levels of urban governance ([Buytaert et al., 2014](#) ; [Fleming et al., 2014](#) ; [Den Broeder et al., 2018](#)). The recently proposed “ urbanome” framework (i. e., a complete set of data describing the physical, social, operational, and structural characteristics of a city) aiming to characterize cities and people living in them in a holistic manner can further enhance our ability to diagnose problems, identify actionable solutions and

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test future scenarios, policies and interventions using a holistic systems approach ([Morawska et al., 2019](#)).

Grand Challenges

A lot of scientific effort has traditionally concentrated in characterizing associations between environmental and behavioral risk factors and health outcomes. This has included, for example, the effects of different air pollutants (as well as pollutant mixtures), high and low temperatures, noise, diet, physical activity, and proximity to greenspace on non-communicable diseases ([Mitsakou et al., 2019](#)). Novel assessment techniques have been increasingly used in these studies. For example, “ multi-hazard” and “ exposome” approaches have been introduced to assess human exposure in different environments over the life-course ([Juarez and Matthews-Juarez, 2018](#)). These approaches have helped characterize health effects from chronic (low-level or intermittent) exposures to a variety of chemical or physical hazards in cities. However, less research has focused on evaluating policies and interventions aiming to improve the health and environment of urban dwellers. In particular, there is a dearth of observational studies that can strengthen the evidence on the effectiveness of interventions, including barriers and enablers for successful implementation, in different geographic and socioeconomic contexts. In this article, we are aiming to outline grand challenges for science and innovation that will promote health and sustainability in cities around the world.

Urban and Transport Planning

Land use planning and urban form have a strong influence on transport and accessibility, and consequently on traffic-related air pollution, sedentary

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lifestyles, noise and GHG emissions and associated effects on health. Reallocation of road space, road closures, cycle paths, and the creation of pedestrian areas can all promote active (walking and cycling) and public transport in cities. Specific measures to reduce congestion and road traffic emissions, e. g., Low Emission Zone, car, bike and scooter sharing systems, Congestion Charging Zones, Clean Air Zones, and other road use pricing, parking and access restriction schemes have been introduced in many cities ([Wang et al., 2016](#) ; [Vardoulakis et al., 2018](#)). These measures have the potential to provide substantial health benefits associated with improved physical activity, community cohesion and road safety, and reduced air pollution, GHG emissions and noise. However, unintended negative effects are also possible, e. g., migration of polluting sources, road injuries or exacerbation of health inequities, if the measures are not well-designed or implemented. There is therefore a need for comprehensive studies examining the effectiveness, co-benefits and unintended consequences, of such interventions. Although modeling studies have shown promise, there is currently a lack of observational studies that holistically assess the health benefits/impacts of real-world planning interventions using system-based approaches.

Built and Indoor Environment

We spend most of our time in indoor environments (house, school, office) which determine to a large extent our exposure to chemical and biological contaminant, our vulnerability to extreme weather (heat, cold, floods), and consequently our physical and mental health and well-being. The built environment is very complex and requires holistic solutions that take into

account the multiple interrelated factors that determine indoor environmental quality. Poor indoor environmental quality may be due to inadequate ventilation, indoor pollution sources (including biomass burning for cooking and heating in low income settings), overheating, poor lighting, mold, and noise ([Wu et al., 2007](#)). Furthermore, demographic and climate change are likely to alter many of these risks in the future ([Vardoulakis et al., 2015](#)), particularly in rapidly urbanizing environments. Co-benefits and trade-offs for health may arise where action to reduce GHG emissions and adapt to climatic extremes lead to changes in the building fabric, ventilation, air conditioning, or energy usage.

Green and Blue Infrastructure

There is increasing recognition that proximity to, and interaction with, urban green and blue spaces can have a significant benefits on our health and well-being. A number of mechanisms have been identified, including localized cooling, noise abatement, water purification, flood risk reduction, and improved physical activity and mental health. Urban green infrastructure has also been associated with several environmental and societal co-benefits, such as air pollution and climate change mitigation (i. e., vegetation has the capacity to remove carbon dioxide, gaseous pollutants, and airborne particles) and cultural-aesthetic and recreational benefits ([Salmond et al., 2016](#)). On the other hand, potential negative effects include emissions of pollen and volatile organic compounds, urban ticks, safety concerns, and energy input and cost of maintenance of urban green spaces. The ecosystem services approach has increasingly been used to evaluate the benefits of green and blue infrastructure in cities ([Hansen et al., 2015](#) ; [Salmond et al.,](#)

[2016](#)). But there is an urgent need for better knowledge on how to design urban green spaces that maximize both environmental and human health benefits.

Urban Food Systems

The ecosystem services approach can also be used to assess the multiple dimensions of urban food systems, including healthy diets, food safety and security, and urban food infrastructure (for food production, storage, and distribution). Low red meat diets can substantially reduce greenhouse gas emissions from livestock farming and simultaneously provide health benefits associated with reduced saturated fat consumption ([Friel et al., 2009](#)).

Linking urban and rural food supply is essential for optimizing the complex food production and consumption system. However, greater quantities of food grown in urban areas could be of concern because of their higher risk of legacy contamination in urban soils ([Lake et al., 2012](#)). Holistic perspectives are clearly needed to maximize the benefits of healthy, low-carbon, resilient urban food systems, minimize related health inequalities and other potential dis-benefits (e. g., food waste), and manage emergencies associated with climate extremes.

Sustainable Energy and Waste Management

Urbanization and raising living standards are projected to increase energy demand and waste generation, particularly in rapidly urbanizing low and middle-income countries of Asia and Africa. China has become the largest generator of municipal solid waste in the world with its rapid urbanization, population growth and raising living standards ([Wang et al., 2018](#)).

Unsustainable patterns of consumption, energy and waste generation in cities have negative consequences for population and environmental (“planetary”) health ([Gupta et al., 2019](#)). There is an urgent need for evidence-based solutions for more sustainable energy and waste management in cities. Urban energy solutions require full life cycle analysis, taking into account the full spectrum of positive and unintended negative impacts of transition to renewable energy ([Scovronick et al., 2019](#)). The circular economy, which aims to minimize waste by making the most of available resources, has the potential to generate environmental, health and societal benefits in cities that are currently not fully appreciated.

Urban Health Equity

Health equity is a crosscutting issue, and emerging research theme, in urban sustainability studies. Climate change, pollution, inadequate housing, and unsustainable production and consumption are threatening environmental justice and health equity across generations, socioeconomic strata, and urban settings. Vulnerable groups (young children, the elderly, the poor, and those with compromised health) are likely to suffer more from environmental pollution and climate extremes, such as heatwaves, floods and droughts. These groups also have the most to gain from well-designed interventions to improve urban environmental quality. Certain urban policies and interventions may reduce, or inadvertently exacerbate, inequalities; therefore they require careful impact assessment across the population ([Costa et al., 2019](#)). More gender and age-sensitive strategies can help address inequities in urban health, particularly between those living in informal settlements and other urban residents ([Sverdlik, 2011](#)).

Future Directions

Technological advancements in sustainable transport, energy and waste management, zero carbon building design, pollution abatement, urban food systems, wearable sensors, mobile applications, and big data analysis provide opportunities to improve the health of urban populations while reducing their pollution and carbon footprint. However, technology solutions alone are unlikely to solve the persistent environmental, societal and health problems that twenty-first century cities are facing around the world. To achieve sustainable, long-term solutions we need concerted action from key stakeholders—government, planners, health professionals, researchers, businesses—as well as individual citizens. Importantly, we need to develop a better understanding of complex societal, technological and behavioral barriers and enablers for effective change toward healthier and more sustainable cities. This requires holistic, system-based approaches that address multiple environmental and health hazards, taking into account co-benefits, and unintended consequences.

The challenges of translating the emerging science of urban health into effective policy are complex. Over-emphasizing a single process, such as building energy or vehicle fuel consumption, can have unintended consequences, for example on indoor or outdoor air quality. Furthermore, a place-based understanding of potential impacts and opportunities for health improvement that takes into account the social and cultural context of cities around the world is required for developing effective solutions. Importantly, this requires effective public, policy, and business engagement to ensure translation of scientific outputs into actionable long-term solutions.

Author Contributions

SV drafted the article. SV and PK contributed intellectual input, text, and edits.

Conflict of Interest

The authors declare that the research was conducted in the absence of any commercial or financial relationships that could be construed as a potential conflict of interest.

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