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Review

Rates of urbanisation and the resiliency of air and water quality

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ABSTRACT

Global human population and urban development are increasing at unprecedented rates and creating tremendous stress on local, regional, and global air and water quality. However, little is known about how urban areas vary in their capacity to address effectively air and water quality impacts associated to urban development. There exists a need to better understanding the factors that mediate the interactions between urbanisation and variations of environmental quality. By synthesizing literatures on the relationship between urban development and air and water quality, we assess the amount of scholarship for each of these cities, characterize population growth rates in one hundred of the largest global cities, and link growth trends to changes in air and water quality. Our results suggest that, while there is a growing literature linking urbanisation and environmental quality, some regions of the globe are better represented than others, and that these trends are consistent with our characterization of population growth rates. In addition, the comparison between population growth rates and air and water quality suggest that multiple factors affect the environmental quality, and that approaching rates of urbanisation through the lens of 'resiliency' can be an effective integrative concept for studying the capacity of urban areas to respond to rapid rates of change. Based on these results we offer a framework for systematically assessing changes in air and water quality in megacities.

Contents

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1. Urban system and global change

The global population in urban areas is growing at an unprecedented rate. Since the first issue of STOTEN was published in 1972, the human population has almost doubled (from 3.8 billion to over 6.6 billion), and by 2030 more than two-thirds of the world's human inhabitants will live in urban areas (Population Division of the Department of Economic and Social Affairs of the United Nations Secretariat, 2007). Much of this growth is occurring in the developing world, where the pattern of growth of urban regions is often uncoordinated, more fragmented and originating from multiple nuclei. Numerous reports suggest that these changes in the number of people living in urban areas result in serious environmental and social problems and accelerate global environmental change (Bengtsson et al., 2006; Grimmond, 2007; Parnell et al., 2007). There exist multifaceted global water issues that include intermittent flows, desalination and its impact on environment, climate change and extreme events and its impacts on freshwater resources, inadequate supply, and water security and risks (see for example, Shiklomanov and Rodda, 2003; Gleick, 2006). Half the world's population lacks basic sanitation, and population growth without proper sanitation and hygienic resources currently causes over 1.6 billion child deaths each year, making water-related deaths the third leading cause of mortality in children under the age of 15 in middle- and low-income countries (WHO, 2005). In addition, every year 1.5 billion urban residents breathe air that exceeds World Health Organization standards, with over 800 thousand deaths each year due to urban air pollution. Impact of urban development also degrades local and global ecosystems by reducing and fragmenting natural habitats, introducing exotic organisms, and severely modifying energy flow and nutrient cycles (Collins et al., 2000; Pickett et al., 2001; Groffman et al., 2004; Mills, 2007).

Increasing awareness of the human and ecosystem impact of cities on global environmental conditions has been the topic of special issues of scientific journals, e.g., *Science*, Volume 319 (5864) in 2008; *Journal of Industrial Ecology* Volume 11(2) in 2007, and countless national and international meetings involving scientists, policy makers, and natural resource managers. Additionally, cities throughout the globe are actively attempting to improve living and environmental standards by, among other approaches, developing urban sustainability goals. In recent years the emergence of a small industry examining the 'greenest' or most sustainable city (see for example Sustainlane, 2006; Greenbiz, 2008; Popular Science, 2008) speaks to the active interest in understanding and mitigating adverse impacts of urban development on human welfare and ecosystems.

While laudable, the concept of sustainability as a mitigation tool contains several challenges that limit an understanding of the dynamics operating in an urban environment. While recent research suggests that several interacting factors affect urban environmental quality, there have been far more theoretical explorations than empirical studies on the sustainability of urban ecosystems (White and Whitney, 1992; Bartone et al., 1994; Mega, 1996; Register, 2006). Empirical studies examining the sustainability of cities in terms of impact on natural resources typically examine patterns of urban development (e.g. land use, land cover) at single points in time to predict changes to air or water quality, with a few exceptions in such cities as Paris and London where a large inventory of data exists (see the special issue of STOTEN on urban regeneration in London, STOTEN, 2006, volume 360, (1–3) by Leeks et al., 2006 and on the Seine River 2007, volume 375, (1–3) by Billen et al., 2007). These 'snap-shots' of urban development provide valuable information, for example, about what types of urban development may be associated with degraded environmental conditions, but the limited analysis of temporal dimensions precludes understanding time-dependent factors that contribute to or detract from the ability of urban areas to rebound from rapid rates of population growth or urban development. An empirical understanding of the dynamics (i.e., time dependence, interactions, and feedbacks) operating in an urban environment may be especially important in developing mitigation tools for urban areas where large population changes are occurring at unprecedented growth rates.

While many cities have improved their air and water quality in the past two decades, several urban areas are in need of counteractions to reduce adverse health impacts to urban ecosystems at a faster pace. In several countries such as Nigeria, Brazil, and China where urban population growth rates are associated with degradation in air and water quality, reports suggest a concomitant decrease in the overall health status of urban residents (El-Fadel and Massoud, 2000). Because a few such assessments have occurred on a global scale, it is not clear to what magnitude and at what rate the environmental degradation accompanies population growth, and at what level of growth in urban system will cause irreversible damage to human inhabitants and the natural systems. In studies of ecosystems, research suggests that natural habitats with low resiliency were susceptible to sudden, unexpected, and large changes in response to disturbance (Carpenter et al., 2001; Scheffer et al., 2001; Folke et al., 2002;