Commentary

Are nature-based solutions a missing link in air quality management in South African cities?

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Foreword

Air quality in urban centres is notoriously poor: almost 50% of cities which are home to 100 000 residents or more, and more than 97% of cities in low- and middle-income countries of that size, do not meet the recently updated WHO Global Air Quality Guidelines (WHO, 2021; Jennings et al., 2021). Estimates are that 61 out of every 100,000 deaths in urban areas worldwide – totalling 1.8 million excess deaths – were due to particulate matter exposure in 2019 alone (Southerland et al., 2022). In addition to traditional air pollution reduction and mitigation methods, nature-based solutions (NBS) are increasingly being trialled to reduce air pollution exposure in cities globally. Here we discuss the potential value and necessary considerations of NBS in improving the air we breathe, and we consider how this could be applicable to a uniquely South African context. Are NBS a missing link in air quality management in South Africa?

Introduction

Because urban centres are characterised by large and dense human populations, tackling air pollution and reducing exposure to health-damaging air pollutants is a public health priority (Jennings et al., 2021). However, due to its many sources (e.g., vehicle emissions, industry and manufacturing, waste burning and outdoor cooking, to name a few), as well as complex socio-economic factors and the presence of confounding urban micro-climates, air pollution in cities remains difficult to manage, especially in developing countries (Menon et al., 2021).

In addition, cities are prone to the urban heat island effect, which presents another health threat for residents and can exacerbate the health burden placed on humans from exposure to air pollution (Menon et al., 2021).

With projections that 80% of the South African population will reside in urban areas by 2050 (Mlambo, 2018), and with ambient temperatures set to rise over the coming decades due to global climate change, it is critical that a combination of cost-effective and sustainable interventions are identified and implemented in South African cities to protect human health and biodiversity, and enhance the resilience of urban ecosystems (Liu et al., 2021).

Nature-based solutions for urban resilience

Solutions to protect, sustainably manage, and restore natural or modified ecosystems, which effectively and adaptively address societal challenges and simultaneously provide human well-being and biodiversity benefits are known as "nature-based solutions" (Cohan-Shacham et al., 2016). They include urban forests, green roofs/ walls, green spaces and parks, stormwater and detention ponds, rain gardens and bioswales, and even restored ecosystems (Liu et al., 2021; World Bank, 2021).

Nature-based solutions can be used to enhance urban resilience in the face of a wide range of urban challenges (Liu et al., 2021). When used as "green infrastructure" to complement traditional built infrastructure in urban areas, NBS have been found to contribute to improved air quality, reduced ambient air temperatures, reduced flooding, and enhanced carbon sequestration (Anderson and Gough, 2020). Over and above this, NBS have been shown to improve human mental and physical health and well-being (Ascenso et al., 2021), and when designed and implemented in a participatory manner, can favourably benefit women, youth and low-income communities (Pagano et al., 2019; Bechauf, 2021). Nature-based solutions can also be used as effective biomonitoring tools to determine the presence, quantities, temporal or spatial changes and effects of pollutants on the environment (Calfapietra, 2020; Fusaro et al., 2021; Shagjjav et al., 2022). For example, a study by Molnár et al., (2020) which assessed the usefulness of an Air Pollution Tolerance Index for environmental health, particularly considering air quality, showed that quantifying the amount of deposited dust on the surface of urban tree leaves can be an effective method for monitoring urban air quality. Similarly, some plant species can act as useful bioindicators, by developing leaf injuries or changes in vegetative periods if exposed to high concentrations of specific pollutants (Fusaro et al., 2021).

A nuanced approach to NBS for air quality management

If chosen strategically, NBS can be highly effective in taking up or removing air pollutants from the ambient air, by reducing ozone, particulate matter, nitrogen oxides and sulphur dioxide concentrations (Abhijit et al., 2017; Letter and Jaeger, 2019). Air quality improvements can occur through different ways, for example through enhanced deposition of particles on plant surfaces or the absorption of gases through plant stomata (Xing and Brimblecombe 2019). Despite their promising potential, careful planning should inform the design of NBS aimed at addressing air pollution, as shortcomings include oversimplification of design and underestimation of costs and maintenance requirements, the consequences of which could inadvertently lead to the deterioration of air quality (Schroeter at al., 2022).

A study from multiple cities in South Africa illustrated the ability of the lichen species *Parmelia caperata* to accumulate Mercury (Hg) from the ambient air, which suggests the potential to use this lichen to monitor atmospheric Hg deposition across the landscape (Panichev et al., 2019). Similarly, the lichen thallus of *Parmelia sulcate* has been used to assess the concentrations and possible sources of trace elements in the city of Tshwane, South Africa (Olowoyo et al., 2010). Vegetation barriers, e.g., shrubs or dense tree canopies can directly remove and reduce air pollution levels, but they can also present a physical barrier between humans and pollution sources (e.g., shrubs planted between roads and walk-ways in cities). This has been tested in a study in Khayelitsha, Cape Town, South Africa, where planting windbreak trees proved effective in reducing residents' exposure to ambient PM10 (Muchapondwa, 2010).

Despite evidence that promotes the use of NBS to improve air quality, research also shows that NBS are site- and context-specific, require a nuanced approach, and must be designed with specific benefits in mind (Cohan-Shacham et al., 2016; Jennings et al., 2021; Seddon et al., 2020). Care must be taken when designing NBS to ensure that unforeseen negative consequences on air quality or other important factors, such as biodiversity, do not arise. For example, trees could worsen pollution levels by preventing circulation of airflow or by producing air pollution themselves (e.g., pollen or biogenic volatile organic compounds) (Liu et al., 2022), and afforestation with non-native monocultures can negatively impact biodiversity and result in maladaptation (Seddon et al., 2020). Even though maintenance of NBS can be lower than that of traditional infrastructure, for interventions to be successful in the long-term, funding for adequate maintenance must be set aside during the design phase (Le Coent et al., 2021).

Other trade-offs need to be considered when using trees to improve air quality, including roots which can cause damage to infrastructure like roads or water pipes or the seasonal consideration of deciduous species that lose their foliage and pollution reduction potential in winter (Abhijit et al., 2017). Care must also be taken when choosing plant species for NBS, as the impacts of air pollutants can negatively impact the growth and survival of vegetation as well as the resilience of urban ecosystems.

Despite growing awareness of the potential of NBS, additional empirical evidence on their intended benefits, cost effectiveness, resilience to climate change and reliability is needed. More research and collaboration between atmospheric, natural and social scientists, NBS practitioners, and policy makers is required to ensure that NBS can be used as effective air pollution reduction interventions at a city level.

In developing contexts, where overlapping exposure to environmental health risks is a reality, it must be understood that urban greening and NBS alone cannot compensate for the systemic inequalities that lead to disproportionate burdens from environmental health risks like air pollution. Reducing this burden requires a combination of technical and socio-economic interventions (Jenings et al., 2021). This "Green Apartheid" (Venter et al., 2020) illustrates the clear need to understand the complex links between green infrastructure and human health and well-being, especially in a South African context.

Conclusions

Air pollution is one of the largest environmental health threats, causing millions of deaths annually (Landrigan et al., 2018; Jennings et al., 2021). The far-reaching benefits of well-designed NBS should be considered in cities in South Africa to improve air quality, enhance ecosystem resilience and holistically improve human health and well-being.

If weighed properly, the co-benefits and trade-offs of NBS could solve a wide range of environmental, social and economic challenges (Liu et al., 2021). If the scale of the intervention, the context and conditions of the site and the target air pollutant type are understood, the selection of plants that exhibit certain biophysical traits can enhance air pollution mitigation (Barwise and Kumar 2020).

Though NBS cannot replace the efforts which are underway to reduce or eliminate air pollution sources, they should not be discounted as cost-effective, complementary methods for holistic air quality management in South African cities, where emphasis must be placed on equitable access to green infrastructure, clean air and a healthy environment for all.

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