Discussion Paper

Greening the Urban Landscape: Implications for Air Quality and Public Health Promotion

Norman Anderson, MSPH
Consultant to the Heinz Endowments' Environment Program
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1. Introduction

This paper is based on five underlying themes.

First, we need to re-connect with the underlying goals of environmental health. Rather than viewing environmental acceptability in terms of lowering pollution to levels at which no negative consequences can be discerned, we need to return to the basic visions embodied within the World Health Organization. Specifically, the WHO in 1948 defined health as the *"state of complete physical, mental, and social well being, and not merely the absence of disease or infirmity."* Further, *"the enjoyment of the highest attainable standard of health is one of the fundamental rights of every human being without distinction of race, religion, political belief, economic or social condition."* (WHO, 1948)

Second, we need to strive towards a more integrated strategy that recognizes the interactions of environmental quality, community design, behavioral factors, and genetics in the attainment of healthy communities.

Third, optimization of community health must recognize the increasing importance of climate adaptation and that, like Lewis Carrol's Red Queen, we will have to run as fast as we can to keep in the same place. We are experiencing a climate that will be increasing warmer and unpredictable, as well as less habitable due to progressively more heat, drought, and sea level rise. Embedded in this adaptation is not only the urgency of reducing the social cost of carbon, but also the social cost of air pollution (https://www.ncbi.nlm.nih.gov/pmc/articles/PMC2553058/).

Fourth, integration of green space development with air quality improvement can transform our thinking of community health towards a more sustainable future. Health benefits of both accrue around common endpoints (e.g., cardiovascular, lung, child development, obesity, mental health outcomes). Further, the benefits of green space development can move beyond health metrics towards matters of social cohesion, lower crime, and increased public safety, particularly if done in conjunction with measures to lower racial and economic disparities. We need not have to choose between the health benefits of green spaces versus the health consequences of air pollution, as both factors are under the power to modify through human agency.

Finally, we need to develop a comprehensive tracking system that constantly monitors, evaluates, and modifies our holistic efforts to maintain and enhance a healthy environment. Much of public health tracking indicator development has been focused on the information that is available versus what is needed. The technical ability to implement a set of metrics around environmental health sustainability is already available. All that is lacking is the political will.

2. Organization of the document.

This paper is organized around three focal areas. The first is a summary of the health impacts associated with green spaces in general, specifically when considering the health impacts of air pollution. The second is a summary of the current guidance associated with the health benefits of vegetation barriers in reducing air pollutant levels, particularly pollution associated with areas of high traffic. The third is the beginnings of a conceptualization of how we can best integrate public health promotion goals. These goes focus on chronic disease prevention and societal co-benefits as they relate to community green space design, behavioral risk factors, and air quality.

3. Methodology.

As a discussion paper, the intent of this document is to highlight the potential health benefits and considerations around green spaces, not to provide a critique of the literature or the individual studies. All of the health outcomes identified as potential benefits are multi-factorial in nature, and there are multiple conditions that can either increase or decrease risks. Studies have cautioned against making simplistic assumptions on interventions (Bixby et al, 2015; Lee and Maheswaran, 2010). The need to consider both community environmental factors (such as green space and PM levels) as well as socio-demographic factors has been emphasized (Kim and Kim, 2017; Villanueva, 2016).

Information for this document was gathered through two different approaches. First, reports were retrieved from respected entities in this field, including the World Health Organization, the Environmental Protection Agency, the California Air Resources Board, and the Sacramento Air Quality District. In addition, two literature searches under the general topic of “green spaces and public health” were done. One was a general google search. The other was a search of PubMed with the same subject heading. Results of these searches yielded approximately 1,000 journal articles and abstracts. Approximately 75 of these documents were considered reflective of the current state of inquiry and findings.

There are two important related areas to this discussion paper that were not included due to limitations in time and scope. One was noise, which like air pollution and lack of green space, is associated with adverse health outcomes such as hypertension, Type 2 diabetes, and cardiovascular disease. Another is the impact of air pollution deposition on green spaces (including community gardens), many of which may be located in close proximity to major roadways.

4. Potential Public Health Benefits of Green Spaces

Urban green spaces date back a couple hundred years, in large part through the recognition of their public health benefits (WHO, 2016, Feldman, 2015). While there is no universally accepted definition of green spaces, they typically include public parks, along with along with private gardens, woodlands, children's play areas, roadside verges, riverside footpaths, and beaches (WHO, 2016). There has been substantial research attention in recent years focused on the health benefits of urban green spaces. The findings of these investigations have been summarized in a recent World Health Organization document titled *Urban green spaces and health* (WHO, 2016), as well as other publications. These publications describe benefits to both physical and mental health. Even small parks and green spaces have been shown to confer health benefits (Wolf, 2017).

Measures to Assess Green Spaces

The studies have employed several measures for evaluating green space. These measures focus on <u>availability, accessibility, or usage</u> of green spaces (WHO, 2016) as well as park quality (i.e., per capita spending on parks, green space perception) (Larson et al, 2016; Kothencz et al, 2017). The most commonly used measure for the amount of greenness <u>availability</u> is the Normalized Difference Vegetation Index, derived through remote sensing. Criteria for <u>accessibility</u> have been developed by Natural England (described in WHO, 2016), including:

- At least 2 hectares in size, no more than 300 meters linear distance (5 minutes' walk) from home;
- At least one accessible 20 hectare site within two kilometers of home;
- One accessible 100 hectare site within five kilometers of home;
- One accessible 500 hectare site with ten kilometers of home; and
- A minimum of one hectare of statutory Local Nature Reserves per thousand population.

<u>Usage</u> measures include (WHO, 2016):

- Surveys of population usage of local green space;
- Tracking of individual usage through Global Positioning Systems (GPS);
- Observational data of specific green space usage.

As the research in this area evolves, the contributions of all these attributes need to be systematically considered (Houlden et al, 2017; Shanahan et al, 2016; Browning and Lee, 2017; Cox et al, 2017). For example, a framework for an urban forest ecosystem classification has been developed (Steenberg et al, 2015).

Many Common Health Endpoints Concerning Green Space and Air Quality

Importantly, several of the beneficial impacts of green spaces on health also parallel the beneficial impacts of good air quality. These include risk reduction regarding mortality (Van den Berg et al, 2015), obesity, cardiovascular disease (Gasoon et al., 2016; Grazuleviciene et al, 2016; Putrik et al, 2015), type 2 diabetes, low birth weight (Cusack et al, 2017; Abelt and McLafferty, 2017; Hystad et al, 2014; Ebisu et al, 2016), mental illness (Van den Berg, et al., 2015; McEachan et al, 2016; Van den Berg et al, 2016; Mukherjee et al, 2017), neurodevelopmental, behavioral and weight gain outcomes in children (Wu and Jackson, 2017; Amoly et al, 2014; Dadvand et al, 2015b; Sanders et al, 2015), cognitive decline, dementia, and mental health outcomes among the aging population (Zilemma et al, 2017; Wu et al, 2015), and stress (Egorov et al, 2017). Also on the list of potential benefits are increased social cohesion, reduced crime, reduced aggressive behavioral among adolescents - a key precursor to violence and mental illness, lower air pollution levels (under certain circumstance), overall well-being, economic vitality, as well as increased climate resiliency (e.g., regarding heat waves and floods) (WHO, 2016, Roe et al, 2016; Dadvand et al, 2015a; Laden, 2016; Branas, C.C., et al, 2011 Younan, undated; Larson et al, 2016; Zhang et al., 2017; Bogar and Beyer, 2016; Kondo et al, 2015). Finally, there are qualitative considerations to take into account, such as the quality of physical activity in recreational spaces; improved mindfulness and creativity; restorative mental health benefits; and a heightened sense of environmental awareness and concern among children that exposure to green spaces can promote (WHO, 2016).

Benefits of green spaces can produce ***equigenic*** effects, or benefits that may be the strongest among the lowest socioeconomic groups (WHO, 2016; McEachan et al., 2016; Dadvand et al, 2012a; Mitchell, RJ, et al, 2015; Mitchell and Popham, 2008)). At the same time, it is recognized that wealthier areas of cities have substantially higher tree cover rating than lower income areas, findings that recently led Philadelphia to launch a program to convert vacant lots into publicly accessible green spaces (Feldman, 2015). Further, studies in Los Angeles found that there are fewer parks in the most environmentally burdened communities (Younan, undated). Moreover, there is the concern that greening strategies could have the unintended consequence of gentrification (Wolch et al, 2014).

Benefits of green space development are often nuanced

Along with the potential benefits, however, there are potential negative consequences of green space development. These include: 1) risks of allergies and asthma (pollen, volatile organic compounds); 2) exposure to disease vectors and zoonotic infections; 3) accidents and injuries; 4) excessive exposure to ultraviolet radiation; 5) vulnerability to crime; and 6) exposure to air pollutants trapped by the tree canopy (WHO, 2016; Jariwala et al, 2017; Lohmus and Balbus, 2015). The need for a multi-disciplinary that addresses both positive and negative impacts has been advocated (Livesley et al, 2016).

From a health promotion perspective, the interactions between green space and air pollution on human health can be complex. Tradeoffs have generally trended towards the increased public health benefits of green space and physical activity over the detrimental effects of poor air quality (CARB, 2016; Andersen et al, 2015). A recent study indicated that sufficient green space (e.g., 40%) around residences could have protective effects against childhood asthma in areas of high traffic (Feng and Astell-Burt, 2017). Similarly, Dadvand et al (2015b) found a positive effect of green spaces around schools on cognitive development in primary school children, though this effect was partially mediated by reductions in exposure to air pollution. Dadvand et al (2012b) found lower levels of personal exposure to air pollution among pregnant women living in greener areas. Further, Thiering et al (2016) found that correlations between higher greenness and lower insulin resistance may be due to lower NO2 exposure from traffic related air pollution (Thiering et al, 2016).

At the same time, policies that promote both green space development and optimal air quality levels could avoid these current conflicts. High levels of stroke mortality was found in areas with low income level, high air pollution, and low level of exposure to green space (Hu et al, 2008). There is evidence that physical activity is lower in areas of high air pollution (Roberts et al, 2014), leading the authors to postulate that "those interventions which improve physical activity and reduce air pollution such as transportation interventions will have both primary and secondary benefits." The National Heart, Lung and Blood Institute recommends against anyone with asthma exercising outdoors when air pollution levels are high.[1] While individual levels of physical activity are matters of personal choice, social interventions such as combinations of green space development and air pollution reduction polices can support environments that make such personal choices more likely to happen.

5. Potential Public Health Benefits of Vegetation Barriers

In recent years, we have seen a magnification of concern regarding the impacts of major roadway emissions on the development and aggravation of chronic health conditions. Traffic related pollutants consist of both tailpipe emissions and non-tailpipe emissions such as tire/break wear and road dust (Cal EPA, 2017). According to the US Environmental Protection Agency, more than 50 million people in the US are estimated to live, work, or attend school within 100 meters of a large highway or transportation facility and over 2 million children attend classes within 200 meters of a major highway (Baldauf, 2017). Near road air pollutant exposures have been linked to increases higher rates of asthma onset and aggravation, cardiovascular disease, impairment lung development in children, premature mortality, and cancer (USEPA, 2016; Baldauf, 2017).

[1] Specifically, Patients who have asthma at any level of severity should: Avoid exertion outdoors when levels of air pollution are high. https://www.nhlbi.nih.gov/files/docs/guidelines/06_sec3_comp3.pdf

Specific air pollutant mitigation strategies that are focused on vegetation barriers need to be considered within a comprehensive array of interventions, as well as community planning activities focused on infill and compact development. Ultimately, the preferred strategy focuses on reducing pollutant emissions at the source. Absent that, the California EPA (2017) outlined a broad array of interventions to reduce traffic emissions, including: 1) speed reduction mechanisms such as roundabouts; 2) traffic signal management; 3) speed limit reductions on highways to 55 mph; 4) designs that promote air flow and pollutant dispersion along street corridors; 5) vegetation and sound barriers; and 6) indoor high efficiency filtration. Further, with respect to vegetation and sound barriers, Baldauf (2017) noted that they provide near term mitigation options as emission standards may take a long time to implement and implementation of buffer zones may not be feasible in many urban areas.[2]

When properly designed to site specific characteristics, vegetation and sound barriers can be effective in reducing air pollutant exposures from major roadways, particularly if used in combination (Baldauf, 2016, CARB, 2012).[3] Some studies have observed as much as a 60% reduction in leeward pollutant levels through combined approaches (Eisinger, 2015), an intervention that may be especially warranted for sensitive use buildings such as schools (USEPA, 2015). Evidence of effectiveness comes from a variety of investigative methods, including field measurements, wind tunnel studies, and modeling.

Particular ways that vegetation barriers reduce downwind pollutant exposure are through direct impaction, absorption of gases through leaf stomata, and modifying pollutant transport and dispersion. Consequently, it is important to emphasize that effectively can vary significantly depending on the pollutant under consideration (e.g., nitrogen oxides, PM2.5, ultrafines) as well as meteorological variations in seasonal and diurnal patterns that can influence downwind pollutant concentrations.

There are many parameters that must be taken into consideration when implementing vegetation barriers as an air pollutant mitigation measure, detailed in a recent EPA guidance document (Baldauf, 2016). These include porosity, seasonal effects, vegetation thickness and height, and leaf surface characteristics, along with the influences of the surrounding built environment. To ensure effectiveness, there must no gaps within the barrier, either horizontally or vertically. The EPA guidance also noted that effectiveness is optimal at low wind speeds and when the direction of the air flow is perpendicular to the barrier.

In addition, other important parameters to consider are roadway safety, species selection (e.g., considering native species, non-invasive species, low allergen and VOC emissions, pest management,

[2] Beyond the direct air quality benefits, Baldauf (2017) also noted other positive attributes of vegetation/noise barriers, such as reduced noise and improved aesthetics, climate (stormwater, heat island, carbon sequestration), water quality, and community livability. These areas will be touched on in the next section.

[3] Sound barriers on their own, when properly sized to avoid edge effects impacting sensitive use buildings, such as schools or hospitals, have been shown to be effective in reducing air pollutants as well as noise on the leeward side of the barrier through altered dispersion and transport. It is important to note, however, that altering dispersion and transport for both vegetation and sound barriers can result in higher pollutant concentrations on the windward side and surrounding areas.

vegetation resistance to air pollution and drought), and maintenance (Baldauf, 2016). Further, the guidance notes that considerations regarding soil impacts need to be taken into account regarding the temporary nature of pollutant impaction on leaf surfaces, which can be deposited on the ground through wind and precipitation.

Given the variety of local and regional characteristics that have to be considered when implementing vegetation barrier strategies, it is necessary to develop local planning strategies that go beyond general technical guidance. In that regard, the USDA has developed an i-Tree model to assist in such efforts (https://www.itreetools.org/). Further, the Sacramento Metropolitan Air Quality Management District is developing specific landscaping guidance for improving air quality near roadways (SMAQMD, 2017).

6. Developing a Health Promotion Strategy that Integrates a Greening Landscape with Air Quality and Social Determinants of Health

Urban greenness is emerging in its own right as a legitimate indicator of public health, in many ways paralleling the increasing concern with ambient air pollution. Health impact assessments and epidemiological studies have shown significant decreases in premature mortality, poor mental health, as well as improvements in working memory among school children with increasing green space (Nieuwenhuijsen and Khreis, 2017). Jakubowski and Frumkin (2010) have developed a proposed set of metrics for community health metrics that include both green space and air quality, along with other environmental measures. Kabisch et al (2016) stressed the need to include natural areas among the social health indicators to assess intra-urban health inequities. There are also significant public health benefits that can be achieved through coordinated planning around active transportation; air and heat abatement strategies; and green infrastructure (Mueller et al, 2017; Nieuwenhuijsen, 2016a; De Ridder et al, 2004; Nieuwenhuijsen et al, 2016).

Importantly as well, Flacke et al (2016) have shown that multiple environmental burdens track with inequalities related to socioeconomic status, consistent with findings that zip codes, rather than genetics, correlate with health status (https://www.hsph.harvard.edu/news/features/zip-code-better-predictor-of-health-than-genetic-code/). While it is commonly understood that most chronic diseases are outcomes of gene-environment interactions, such findings underscore the priority of considering the environmental side of the equation. Moreover, as we begin to enhance our understanding of the underlying mechanisms of oxidative stress and metabolic disruption in chronic disease development, the boundaries should further merge between social and environmental determinants of health. Frameworks have been developed to integrate ecological, environmental, and social determinants of health, including the emerging importance of microbiomes in the built environment, as recently assessed by the National Academy of Sciences (http://nas-sites.org/builtmicrobiome/) (Jennings et al, 2015, 2016; Prescott and Logan, 2016; Craig et al, 2016).

Finally, the collective value of the various metrics employed to evaluate the health benefits of green spaces can serve as the foundation for a more coordinated environmental public health tracking strategy for the built environment. Established metrics that can motivate and inform public health goals will enhance the legitimacy of green space as a social intervention. This rapidly evolving field of inquiry provides a wonderful opportunity for public health to broaden both its mission and its community engagement.

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Section 3

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