Forest Research

Benefits of green infrastructure
EVIDENCE NOTE

Improving air quality

Introduction

The role of vegetation in mitigating the effects of air pollution has been highlighted as one potential benefit of urban green space. Vegetation intercepts airborne particulate matter (PM_{10}), reducing concentrations in air, thereby improving air quality. This reduces the amount of PM_{10} exposure to humans and, in turn, reduces the incidence of respiratory illness.

Sources of PM_{10} within urban areas of the UK include road traffic, industry and power production. Results from numerous investigations of human respiratory and other diseases show consistent statistical associations between human exposure to outdoor levels of PM_{10} and adverse health impacts. Health effects range from alveolar inflammation in the lungs and respiratory-tract infection (specifically pneumonia) to acute cardiovascular disorders. These often lead to substantially increased morbidity and mortality, particularly among elderly people. Air pollution is currently estimated to reduce the life expectancy of every person in the UK by an average of 7-8 months.

Benefits

Benefits to human health include reductions in premature mortality, respiratory hospital admissions, GP consultations and referrals.

Economic evidence

- The health costs incurred by PM_{10} pollution in the UK have been estimated to range between £9.1 and 21.4 billion per annum (Defra, 2007).
- An assessment economic model developed by Regeneris Consulting indicates that the total monetised benefit of The Mersey Forest's Objective One funded investments (£7 million) in relation to air pollution absorption is £116,000 per annum or £2,717,000 Net Present Value (NPV). Note that benefits are assumed to apply at the point of maturity of the site; NPV is calculated over 50 years.
- The table shows monetary values of health impacts (Defra, 2007).

Health effect	**Form of measurement to which the valuations apply**	**Central value (2004 prices)**
Acute mortality	Number of years of life lost due to air pollution, assuming 2-6 months loss of life expectancy for every death brought forward. Life-expectancy losses assumed to be in poor health.	£15,000
Chronic mortality	Number of years of life lost due to air pollution. Life expectancy losses assumed to be in normal health.	£29,000
Respiratory hospital admissions	Case of a hospital admission, of average duration 8 days.	£1,900 – £9,100
Cardiovascular hospital admissions	Case of a hospital admission, of average duration 9 days.	£2,000 – £9,800

Evidence linked to improving air quality

- A recent case study covering a 10 km by 10 km area of the East London Green Grid (ELGG), estimated two premature deaths and two respiratory hospital admissions being averted per year. The study also showed that a scenario comprising 75% grassland, 20% sycamore and 5% Douglas fir was estimated to remove 90.41 t of PM_{10} per year (Tiwary, 2009).
- A study on urban air quality management in the UK predicted that by reducing PM_{10} levels in Westminster (Central London) from 1996 to 1998 roadside levels to achieve an annual mean PM_{10} (gravimetric) target of 20 mg m^{-3}, an estimated 8–20 premature deaths would be averted in that area due to reduced short-term exposure and up to 100 deaths from long-term exposure (Mindell and Joffe, 2004).
- There is epidemiological evidence to support the assumption that changes in air pollution impact on GP consultations (Wong *et al*., 2002).
- A recent study, which looked at asthma prevalence in 4–5-year-old children in New York found that the presence of street trees was associated with a 29% reduction in early childhood asthma (Lovasi *et al*., 2008).
- Woodlands collect three times more PM_{10} than grassland (Fowler *et al*., 2004).
- Chicago's trees removed an estimated 5575 t of air pollutants, providing air cleansing worth $9.2 million (McPherson *et al*., 1997).
- One hectare of mixed forest can remove 15 t of particulates per year from the air while a pure spruce forest may filter two or three times as much (cited in Bolund, 1999).
- It has been demonstrated that green roofs help to reduce air and noise pollution (Goode, 2006).
- Apart from trees' ability to mitigate PM_{10}, there are many other benefits to tree establishment; these include additional improvements in air quality, for example through the uptake of O_3, SO_2 and NO_X. The proportion of gaseous pollutants absorbed depends on a number of factors; these include tree species, stomatal conductance, environmental conditions and pollutant concentration in the atmosphere (Broadmeadow and Freer-Smith, 1996).
- Jouraeva *et al*. (2002) found that trees can also reduce the quantity of polycyclic aromatic hydrocarbons (PAHs) in the atmosphere by accumulating particles of less than 2.5 µm in diameter ($PM_{2.5}$) on the surface of leaves and bark. If PAHs are bound to $PM_{2.5}$ they are harmful to human health as they are deposited directly into the alveoli of the lungs. Also, the deposition of PAHs on soil beneath trees can lead to the degradation of particles by bacteria in the rhizosphere (Spriggs *et al*., 2005).

Practical considerations

There are marked species differences in the ability of trees to capture pollutant particles. Conifers capture larger amounts of particulate matter than broadleaved trees (Freer-Smith *et al*., 2005). Due to the larger total surface area of needles, coniferous trees have a larger filtering capacity than trees with deciduous leaves (Stolt, 1982). This capacity is also greater because the needles are not shed during the winter, when the air quality is usually worse. However, coniferous trees are sensitive to air pollution and deciduous trees are better at absorbing gases (Stolt, 1982). A mix of species therefore seems to be the best alternative. In general, vegetation is much better than water or open spaces for filtering pollution from air.

Uptake of SO_2, NO_2 and ozone pollutant gases has been found to be higher in broadleaved species than conifers, due to higher stomatal conductance. However, evergreen conifers can take up pollutants all year round and throughout the night due to their open stomata, and they also have a higher leaf surface area (Broadmeadow and Freer-Smith, 1996).

Air pollution filtering capacity increases with more leaf area, and is thus higher for trees than bushes or grassland (Givoni, 1991). Among the broadleaved species that have been studied, those with rough leaf surfaces are most effective at capturing particles.

Uptake of pollutants is lower during poor light and during drought. However, the planting of suitable drought-tolerant species may maximise uptake during summer. The concentrations of NO_x and SO_2 are highest in winter and therefore evergreens have greatest influence on uptake of these pollutants. Ozone is a significant problem in summer and so broadleaved trees are most effective at reducing levels of this pollutant (Broadmeadow and Freer-Smith, 1996).

The location and structure of vegetation is important for the ability to filter the air. Up to 85% of air pollution in a park can be filtered out, and in a street with trees, up to 70% (Bernatzky, 1983). Thick vegetation may simply cause turbulence in the air while a thinner cover may let the air through and filter it (Bernatzky, 1983).

Modern green space aims to be multifunctional and as such must be designed to meet a number of objectives. Considering the wide range of drivers for development, of which air quality improvements are only a small part, the relevant proportion of the green space taken up by trees is likely to be relatively low. As such, pollutant-tolerant trees should be planted in high-pollution 'hot-spots' in order to absorb contaminants and, therefore, improve air quality. There is also value in planting a relatively small proportion of conifer species, which could also be targeted around ‘hot-spots’ of PM_{10} pollution in order to realise the maximum benefit.

The most significant impacts of tree establishment are likely to be during peak traffic densities when vehicular emissions are greatest. These are also likely to be the time periods of greatest exposure to air pollution, for example when people are out of their houses or places of work and travelling to work or school.

People’s behaviour will also have a significant impact on how the reductions in PM_{10} concentrations affect health. The most significant reductions in PM_{10} concentrations were estimated to be within the green spaces themselves, suggesting that, in order for their full effects to be realised, the local residents would need to use the green spaces.

Encouraging people to walk or cycle through green space rather than walking along the roadside may result in even greater benefits in terms of human exposure, although this will depend on a number of other factors including the perception of crime, ease of access and the attractiveness of the site. Alternatively, street trees could be used to provide localised improvements in air quality along busy roads or pathways.

Potentially detrimental aspects of green space and tree establishment include VOC emissions, which are implicated in the formation of O_3, pollen production, damage to property and maintenance costs. VOC emission is known to be dependent on different tree species, temperature and light (Fulton *et al*., 1998). Trees can therefore also increase the formation of ozone due to the interaction of VOCs with NO_x in the troposphere (AEA Technology, 2002)

Links to climate change

In many ways, local authorities are well placed to pursue measures which improve air quality and reduce greenhouse gas emissions. For example, policies designed to reduce the impact that transport has on air quality by tackling congestion and encouraging a shift to public transport, walking and cycling should also reduce carbon dioxide emissions. Measures to improve energy efficiency and cut energy demand should also reduce air pollutants that are produced during electricity generation. In developing Air Quality Action Plans and, where appropriate, LTPs, local authorities should bear in mind the synergies between air quality and climate change, and the added benefits to the local, regional and global environment of having an integrated approach to tackling both climate change and air quality goals (Defra, 2007)

Tools

An integrated modelling approach provides a tool which, in combination with other models (e.g. to quantify climate amelioration, health and well-being), could be used to assess the potential benefit of green infrastructure initiatives and provide the evidence base for their continuing role within urban environments. For example:

ADMS-Urban
This is used to assess current and future air quality with respect to air quality standards such as the EU Air Quality Directive, UK NAQS. It is used to model the impact of major developments such as airport expansion and traffic management schemes.

The Urban Forest Effects (*UFORE*) *Model*
This computer model for quantifying urban forest structure and functions calculates the structure, environmental effects and value of urban forests. The tool uses air dispersion and particulate interception models to predict the PM10 concentrations both before and after green space establishment.

Cambridge Tropospheric Trajectory model of Chemistry and Transport (*CiTTyCAT*)
This model investigates ozone production and transport based on factors such as temperature, humidity, pressure and surface pressure.
CITYgreen
This analyses the ecological and economic benefits of tree canopy and other green space, in order to calculate the economic/cost benefits for calculates the pollutant removal capacity of tree canopy. CITYgreen reports the annual quantity of pollutants removed and the dollar value associated with these services.

TRIM:FaTE
A multimedia fate and transport model that includes logarithms for pollutant deposition. The output concentrations from TRIM.FaTE can also be used as inputs to a human ingestion exposure model, such as TRIM.Expo-ingestion, to estimate human exposures.

Case study

The Chicago Urban Forest Climate Project
An integrated tool for assessing the role of new planting in PM_{10} capture and the human health benefits.

Knowledge gap

Research is needed on the extent to which policies for large-scale tree planting within the UK and elsewhere within Europe would influence air quality in high temperature summer pollution episodes. Wider impacts of land-use change upon both air quality and global pollutants also need to be considered (AQEG, 2007).

Citations of national policies/priorities

Air Quality Strategy for England, Scotland, Wales and Northern Ireland 17 July 2007
http://www.official-documents.gov.uk/document/cm71/7169/7169_i.pdf

Parliamentary Office of Science and Technology post note Air Quality in the UK.
http://www.parliament.uk/post/pn188.pdf

UK and International Air Pollution Policy
http://www.jncc.gov.uk/pdf/comm05D05.pdf

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