Ecological Engineering 36 (2010) 154–162

Contents lists available at ScienceDirect

Ecological Engineering

journal homepage: www.elsevier.com/locate/ecoleng

Quantifying the deposition of particulate matter on climber vegetation on living walls

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ARTICLE INFO

Article history:
Received 22 July 2008
Received in revised form 4 February 2009
Accepted 7 February 2009

Keywords:
Particulate matter (PMx)
Living walls
Façades
Common ivy
Hedera helix
Vertical greening
Building surfaces
Noise barrier
Ecological engineering

ABSTRACT

The beneficial effect of vegetation on particle deposition is often stated in arboricultural literature but has rarely been researched in detail. To quantify these filtering effects of façade greening, it is necessary to study the accumulation properties of leaf surfaces on particle adsorption. In this paper attention will be given to a measure technique for particle adsorption on vegetation. The presented preliminary study aims to classify the total amount of particles by counting of particles on ESEM photographs. In the PhD research more attention will be given on the relation between particle reduction and the effect of vegetation on air quality improvements. Two locations were investigated, namely: leaves from near a traffic road and from a woodland. A difference in the particle amount was found at the underside and upper side of the leaves. For example, in a sampling at early autumn for the road location roughly 7000 particles (per 1275 × 950 μm) were counted for the upper side, and, roughly 3200 particles for the underside. Also a difference in particle amount was found between the two different locations, respectively roughly 7000 particles for the upper side of the leaf at the road location and roughly 3300 for the woodland location. The comparison must give more insight into the sink capacity of vegetation, but also between the environments. In the paper, results of counting particles on leaves from both locations are provided via a factorial design approach with four independent factors at two levels (height, leaf, time and environment). The outcome of the factorial design shows that there is a difference between the collecting capacity of the leaf (upper side/underside) and between the environments (road/woodland). Fine and ultra-fine particles (i.e., the fractions that are potentially the most harmful to human health) were more abundantly found on the leaves than coarser particles. Also some energy dispersive X-ray analysis (EDS) of the adhered particles is provided. As the main conclusion of this research, it can be said that counting particles instead of weighing particles on a specific leaf area seems to be a proper way to classify aerosol deposition on vegetation.

1. Introduction

1.1. Background

In recent decades living walls, vertical greening of façades of buildings or noise barriers have been realized. Vertical greening offers an outstanding number of public and private benefits such as: aesthetical, social, ecological and environmental, and fits in the principle of ecological engineering as defined by Odum (1995). Therefore the vertical greening of commonly used building materials (concrete, brick, etc.) can be an attractive tool to counteract the (local) air pollution. Vertical greening of façades has more potential to increase the particle collecting area of a building than only a green roof (for example: greening a façade of a cubical building encompasses four times the area of the roof). This paper in the framework of a PhD research on vertical greening deals among other things with the possibility of air- and ecological quality improvements by the use of vertical greenery. Vertical green can be defined as the growing of plants directly on or with the help of plant guiding constructions alongside the building façade. Green or greened façades typically feature woody or herbaceous climbers either planted into the ground or in planter boxes in order to cover buildings with vegetation. Living wall systems (LWS) involve planter boxes or other structures to anchor plants that can be developed into modular systems attached to walls to facilitate plant growth without relying on rooting space at ground level (Köhler, 2008). Vertical greenery implies all suitable vegetation such as algae, lichens, herbaceous plants, climbing plants and small shrubs.

The presented experimental work investigates the adsorption of particulate matter on leaves near a traffic road (N259) in the

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doi:10.1016/j.ecoleng.2009.02.007

Netherlands and leaves from a woodland. The species which has been investigated is the common ivy (*Hedera helix*). Common ivy is an evergreen climbing plant which grows easily up 20–30 m height and is commonly used as a cover on façades or on sound barriers.

Particles can be removed from the atmosphere by dry, wet or occult deposition (NEGTAP, 2001). Dry deposition is the removal of pollutants by sedimentation under gravity, diffusion processes (i.e., Brownian motion) or by turbulent transfer resulting in impaction and interception (Beckett et al., 2004). Vegetation is an efficient sink for particulate matter (Fowler et al., 1989). Particles from the air are mainly adhered to the outside of plants. This in contrast to air polluting gases and very small particles (<0.1 μm) which are assimilated for an important part via the stomata into the leaves (Fowler, 2002). The efficiency on the collecting capacity of particles (aerosols/particulate matter) out of the air by vegetation depends on the following factors (Tonneijck and Blom-Zandstra, 2002; Wesseling et al., 2004):

- Plant variety (shape and surface of the leaves, deciduous or evergreen plants).
- Structure of the vegetation (width and altitude, roughness, porosity or penetrability).
- Exhibition (source of the component, exhibition level).
- Location (distance to the source of emission, presence of building structures).
- Circumstances (growing circumstances, micro-climate).

Particles are classified in fractions according to their size. The fractions are expressed in μm and refer to the maximum aerodynamic diameter of a spherical particle. The usual monitored size fraction is called PM_{10} (particles with an aerodynamic diameter smaller than 10 μm). Below PM_{10} the range of particle sizes found in the atmosphere is usually considered in three groups namely: coarse particles, fine particles and ultra-fine particles (Beckett et al., 2004; NEGTAP, 2001).

In this preliminary research the removal of particulate matter out of the air has been chosen because atmospheric particles, especially those with an aerodynamic diameter of <10 μm (PM_{10}), pose a long-term threat to human health, mainly to the human respiratory functions (Pekkanen et al., 2000). The research investigates different parameters that can have an effect on particle adherence by vegetation. One of those parameters, for example, is the surrounding environment. Therefore leaves from nearby a traffic road and leaves from the wood were investigated in this research. Also other parameters are investigated; e.g. difference between the upper side and underside of the leaves, difference in picking height and difference between weather exposure or time effects.

Research techniques such as the Environmental Scanning Electron Microscopy (ESEM) and Energy Dispersive X-ray (EDS) analysis were used to classify particle size and particle distribution on the leaves and to characterize (the elemental composition) the particulate matter on the leaves.

1.2. Research questions

Since the objective of the PhD study is the improvement of the air quality and ecological value of green façades or noise barriers, this has led to the formulation of this first sub-research with as objective: the development of measure techniques to count particle accumulation on leaves growing under certain circumstances and environments.

Therefore the following research question(s) have been formulated:

1. How are we going to measure?
2. Is there any difference perceptible with a counting method between leaves from the urban area or from the rural area on the total amount of particle adherence?
3. Is there any difference on the adherence capacity between leaves of the same species on different heights?
4. Is there any difference on particle adherence between the upper side or underside of the leaves?
5. Is there any difference on particle adherence during exposure under weather influences (early autumn and late autumn)?

(1) Because of the special interest in the capability of particle adherence by vegetation, the standard air quality measurements of particles in the air, which have been specially designed to control whether the concentration in the air exceeds the permitted value(s), seems not to be suitable. The approach to measure the mass of particles collected on the leaves ignores the actual amount of the total particle collecting on leaves. Since the particle size is positively correlated with lung diseases it is important to know how many of those fine or ultra fine particles are adhered on the leaf surface. Counting particles on a specific leaf area seems therefore more suitable for this experiment.

(2) From the literature (NEGTAP, 2001) it is known that concentrated emitting sources will influence the deposition of air pollution substances. The leaves that are examined in this experiment to classify and characterize the particulate matter are therefore coming from two different locations, namely:

A. Leaves of *Hedera helix* picked on a sound barrier (Fig. 1a) near a local traffic road (N259) near Bergen op Zoom in the Netherlands. For this location we expect more particles in the air, because there is an emitting source (the driving cars) very closely to the vegetation.

B. Leaves of *Hedera helix* picked in the woods (Fig. 1b) near Bergen op Zoom in the Netherlands. For this location we expect fewer particles on the leaves, because no direct emitting sources are present in the surrounding.

The chosen green façade (in this case a sound barrier) for investigation is situated directly near an intensively used cargo transport road (N259). Near the side of the green façade/sound barrier also a traffic light installation is present. The observed growing strength and overall condition of the vegetation is very well. Also the covering of the façade is entirely over the full height (±2.5 m). The plantation is mainly at the roadside and only the traffic side is monitored in this experiment. The observed sound barrier is located on the south side and stands parallel to the road. The façade stands approximately 4 m out of the road axis and 1 m from the verge.

The wood location is mainly shadowy due to the canopies of the surrounding trees. The chosen ivy is climbing on a tree which gives the ivy the needed support to reach the canopy. The height of this tree is approximately 15 m. The observed growing strength and overall condition of the vegetation is very well.

(3) Because of the growing height and the possibility of application of vegetation on façades, also the height can play a role in the collecting capacity of vegetation. The sampling procedure of the leaves for this experiment were the same on both locations. Only complete green and full-grown leaves of the leafy surface were chosen, and only leaves with an angle of approximately 45 degrees relative to the vertical wall have been picked. In this experiment a distinction was made between the picking heights, respectively 0.25 m, 1.50 m and 2.50 m from ground level, see Fig. 2.

(4) It is important to know which side of the leaf (upper side or underside) has the highest potential to adhere particles. Not only the amount of captured particles per leaf side is important