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Stimulus Project 2016

Green Junkie: Plant powered air cleaning?

Project report for Stimulus Projects

Project title: Green Junkie: Plant–powered air cleaning?

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Lead Project partner: Wageningen University and Research

Project partners: MyEarth; Gemeente Amsterdam, Ingenieursbureau; Urban Roofscapes

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Preface

This report presents the results of the AMS Stimulus Project 'Green Junkie: Plant-powered air cleaning'.

AMS Stimulus Projects are meant to give support to innovative ideas that have a strong upscaling potential. The projects may quickly assess the feasibility of ideas, or seek for a completely new and promising avenue of innovation. Typically, Stimulus Projects are relatively small research projects that realize short-term output, which acts as a catalyst of a new solution direction, concept or approach. Stimulus projects aim at generating major follow-up research projects (or programmes).

Amsterdam, as many other cities, suffers from high particulate concentrations which have a negative impact on the air quality and the health of citizens. In this project, the authors tested the idea that a specially developed plant named Green Junkie could increase air quality along roads intensively used for car traffic. MyEarth had bred this variety of the Honeysuckle, with extra hairy and scaled leaves, and anticipated an extra reduction of particulate concentration in the air in comparison to other plants.

Meeting the requirements of a Stimulus Projects – an innovative solution to an urban challenge in Amsterdam, with upscaling potential and involvement of stakeholders (MyEarth, Engineering Department Amsterdam, Urban Roofscapes) – the project was taken on to research the possibilities to reduce particulate concentration with plant-powered air cleaning. This topic – and its valuable potential outcome - received much media attention from the very start.

The results of the study showed that the Green Junkie only reduced the amount of soot air pollution by appr. 1.5%. Therefore, the plant is not considered effective in significantly removing removing soot from traffic related sources and thereby does not sufficiently contribute to improving the air quality along roads intensively used by car traffic.

With the outcomes of the report AMS Institute sees no justification for follow-up research and will – for the time being – not invest in plant-powered air cleaning.

Henk Wolfert
Program Manager Research Vital City

1. Project information

1.1 Project title

Green Junkie: Plant–powered air cleaning?

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Urban Roofscapes: J. Voeten

1.4 Summary

In this research. we focus on the fine particulate matter air pollution removal characteristics of vegetation with hairy leaves. The plant is a honeysuckle variety named Green Junkie (GJ). A mathematical model was constructed to test the collection efficiency of the plant hairs. The model study showed that the GJ plant hairs are effective above 2.5 µm diameter particulate matter. Of more interest is the collection efficiency at smaller sizes because of greater impact on health. It was therefore decided to investigate the soot removal efficiency (typical soot particle diameter <0.5 µm). Soot mass concentration was measured with an Aethalometer. The plants were tested under real traffic pollution conditions. Plants were placed inside a portable wind tunnel near a busy street. The tunnel was designed such that it can be placed over a living plant and draws air from a nearby street through the tunnel filled with vegetation. The roadside experiment and additional experiments near a diesel truck did not show any significant soot particulate matter collection. A literature investigation indicated that plants are capable of collecting ultrafine particulate matter (diameter <0.1 µm) but this was not revealed by our measurements possibly because of their small weight.

2. Project description and results

2.1 Keywords

Air quality, particulates, plants, green cities

2.2 Introduction and theory

Traffic air pollution is a complex mixture of toxic gasses and aerosols (solid particles). EU legislation regulates the maximum allowable air pollution concentrations. The legislations for particulate matter focus on mass concentration within a certain particle size range such as fine particles PM2.5 as mass concentration (smaller than 2.5 μm) but not on composition. However, recent studies have shown that the soot fraction of PM2.5 is much more relevant to public health (Janssen et al., 2011; Shah et al., 2015). Traffic related soot particles are usually smaller than 1 μm. Older diesel engines that produce visible smoke may have larger particles but these sighting have become rare due to the tighter emission regulations. Still the average concentration of soot (also called elemental carbon (EC)) for The Netherlands is 1 μg m-3 and is responsible for a 6-month reduction in life expectancy (Planbureau leefomgeving).

This research was triggered MyEarth (The Netherlands) who development a hairy variety of the fast-growing evergreen honeysuckle. This variety was named Green Junkie (GJ) because it appears addicted to particulate matter (lots of dust visible on its hairy leaf surface). One hypothesis was that the hairy leaf surface properties may enhance particulate matter deposition and removal from the passing air. In this research, we focus on the fine particulate matter air pollution removal characteristics of vegetation. Due to the strong impact on health we decided to use soot removal efficiency as the main criterion.

The Dutch health institute RIVM presented a rather negative summary report on the impact of vegetation on air quality (Wesseling et al., 2011). They discuss that a considerable amount of deposition particles can be found on roadside vegetation but that this is a negligible fraction of emission. Note that soot interception by vegetation was not discussed. Even hedges that separate a busy street from a nearby neighbourhood seem to be less effective than a solid screen. These findings may seem to contradict a recent study on indoor air quality improvements caused by front garden trees along a busy road (Maher, 2013). Another study shows that vegetation can be very effective in capturing nanoparticles (<50 nm) (Lin et al., 2012). They studied ultrafine particle (<100 nm) removal with a 1 m long wind tunnel (0.16 x 0.18 m wide) packed with pine or juniper leaves and a remarkable reduction of 40% at 0.5 m/s flow was observed. Their leaf packing density seemed natural. Vegetation that limits clean air transport into a street canyon reduces air quality although the vegetation also captures air pollution. However, strategically placed vegetation can improve air quality along pedestrian zones (Vos et al., 2013) if vegetation is dense and high enough.

Burtscher (2005) & Caroca et al. (2010) show that diesel exhaust particle size distribution consists mainly of ultrafine particulate matter smaller than 200 nm and peak well below 100 nm (ultrafine particles) (EURO IV diesel), see Fig. 1. It appears that soot is only a small fraction of PM2.5 due to its small particle size (thus low weight).

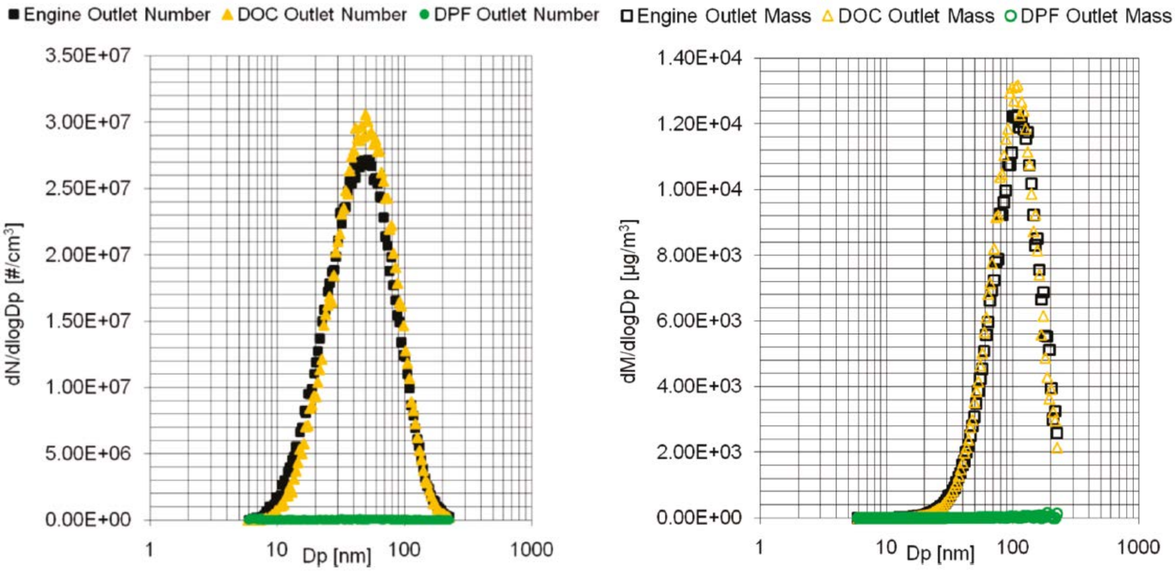


Figure 1: Diesel engine particle size number and mass distributions (Adapted from Caroca et al., 2010).

Particle size distribution down to nano-particle size (<50 nm) is difficult to measure and still does not reveal the health relevant soot concentration. It was therefore decided to focus on soot particle collection by the GJ.

2.2.1 Filter theory

The concept of filtration is that the filter fibres or fine hairy plant leaves will act as a barrier or deposition surface area for particulate matter that passes through.

There are several mechanisms that explain the fine aerosol interception by plant leaves.

1. Impaction
2. Interception and deposition with the leaf Boundary layer
3. Interception of nanoparticles through Brownian motion

The Green Junkie plant hairs have an estimated diameter of around 20 µm (Fig. 2), much thinner than a human hair (about 65 µm). The plant hairs act as fibres of air filters. Particles that impact on its surface are assumed to be removed from the air stream.

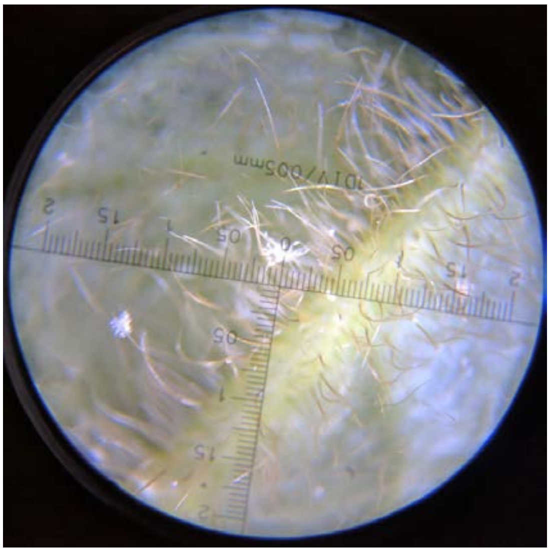


Figure 2: Leaf surface and leaf hairs of Green Junkie (50 μm per division).

The second process of leaf boundary layer deposition should improve all three processes due to the increase in residence time. Also, small particles with long settling times may then deposit.

The third process appears promising since soot mainly consists of ultrafine particles. Lin et al. (2012) report nanoparticle (<50 nm) collection by pine and juniper trees. A reduction of up to 50% was found in a wind tunnel experiment for particles <100 nm (flow rates of 0.3 m/s), see Fig. 3. A low wind speed (left panels) and a higher packing density (lower panels) and a smaller particle diameter (see horizontal axis of each panel) all increase deposition rate.

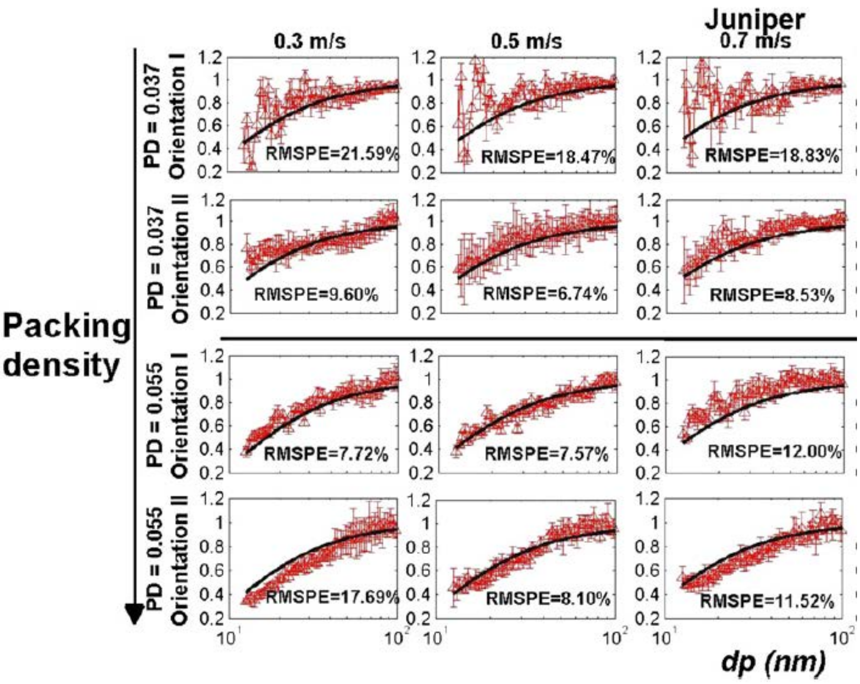


Figure 3: Nanoparticle collection efficiency of Juniper as a function of wind speed, particle size and packing density (Adapted from Lin et al., 2012).

2.2.1 Modelling result

A numerical filter model of aerosol particle capture on fibre filters (Brown and Wake, 1991) was adapted to estimate the theoretical collection efficiency of plant hairs and focusses on the first process (impaction). It is the weight of airborne particles that makes it harder to follow the flow around obstacles and results in collision. This collision process removes airborne particles from the air stream passing through the filter.

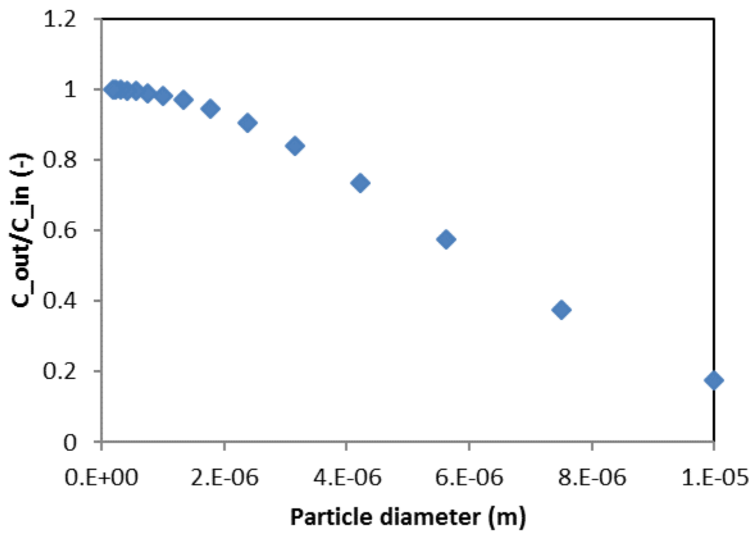


Figure 4: Simulation of the ratio of fine dust concentration output over input concentration, filter fibre diameter 20 μm, flow 0.1 m/s and a packing density resulting in a pressure drop of 2 Pa.

The plant seems promising in the particle range of 4 μm and larger (Fig. 4). Impact on PM10 mass concentration may be significant since the large particles contribute to total mass most. However, the impact on PM2.5 may be limited. The model shows that there is no significant filtration below 1 μm (<1%). Note that the simulation (Fig. 4) assumes that all filter mass consists of these fine hairs and therefore the plant will perform less efficient. Note also that the model is only valid to about 100 nm (where brownian motion impaction takes over).

2.3 Measurement strategy

Particle collection on vegetation and its impact on air concentration is difficult to measure outdoors. Problems are the turbulent nature of wind and the impact that vegetation has on airflow. Changing weather conditions make it very difficult to compare air quality before and after a vegetation intervention. Parallel measurements are also challenging because it is nearly impossible to find two identical locations that are exposed to the same traffic load and have the same source area. A flow obstruction can lead to an increase in concentration although the vegetation may intercept air pollution (as was discussed in the RIVM report).

Initially, we proposed to execute onsite testing by applying two measurement sensors on both sides of a green fence (see figure 5). By placing the fence in the direction of the airflow, it was suggested that the effect of the plants on the air quality could be detected. During the literature review it became clear that this set up would not give usable results. The airflow could not be controlled fully and it could not be detected whether the air flow with the particulates had moved fully through the fence or another source of particulates had influenced the air quality. Only controlled airflows and sources of pollution could lead to trustful results.

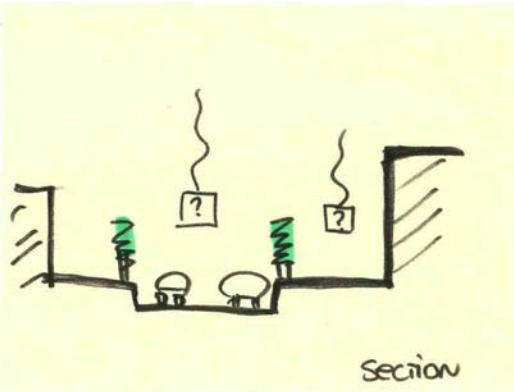


Figure 5: Section of initial research set-up: The air condition would be measured at two sides of fence setup.

Therefore, we decided to integrate two research steps: wind tunnel experiments and onsite testing. We concluded that a wind tunnel experiment would be the only way to find quantitative evidence of air pollution removal by vegetation. However, a lab experiment would not represent the real air pollution cocktail along a busy roadside. Therefore, a portable wind tunnel was designed that can be placed over a living plant and draws air from a nearby street through the vegetation (fig. 6). By using onsite particulates, we use the polluted source, and by boxing the airflow we could analyse exactly what would be the quality of the air inlet and air outlet.

Collaboration with the municipality of Amsterdam was crucial for the execution of onsite testing. As severe complains by the residents at the Kennedylaan were briefed to the municipality, it was decided in close collaboration with the municipality that this location had an urgency for attention.

Because of the negative health effects, it was decided to measure soot concentration at the inlet and outlet of the wind tunnel. Soot can be reliably measured with so called Aethalometers (Aethlabs, AE51, USA). Aethalometers measure black or elemental carbon aerosol particles ('BC' or 'EC'). They are equipped with a quartz fibre filter and a small air pump draws sample air through this filter and particulate matter is deposited onto the filter material. Meanwhile the light transmission of near infrared light is measured through this filter. The change of light transmissivity is then related to a mass concentration. The light transmission loss is highly related to soot. Soot absorbs over 1000x more light than for example mineral dust and therefore ensures that the instrument is mainly sensitive to soot. The high soot sensitivity makes it a very reliable and reproducible measurement technique. Note that several measurements can be done with one filter (until it saturates with soot).

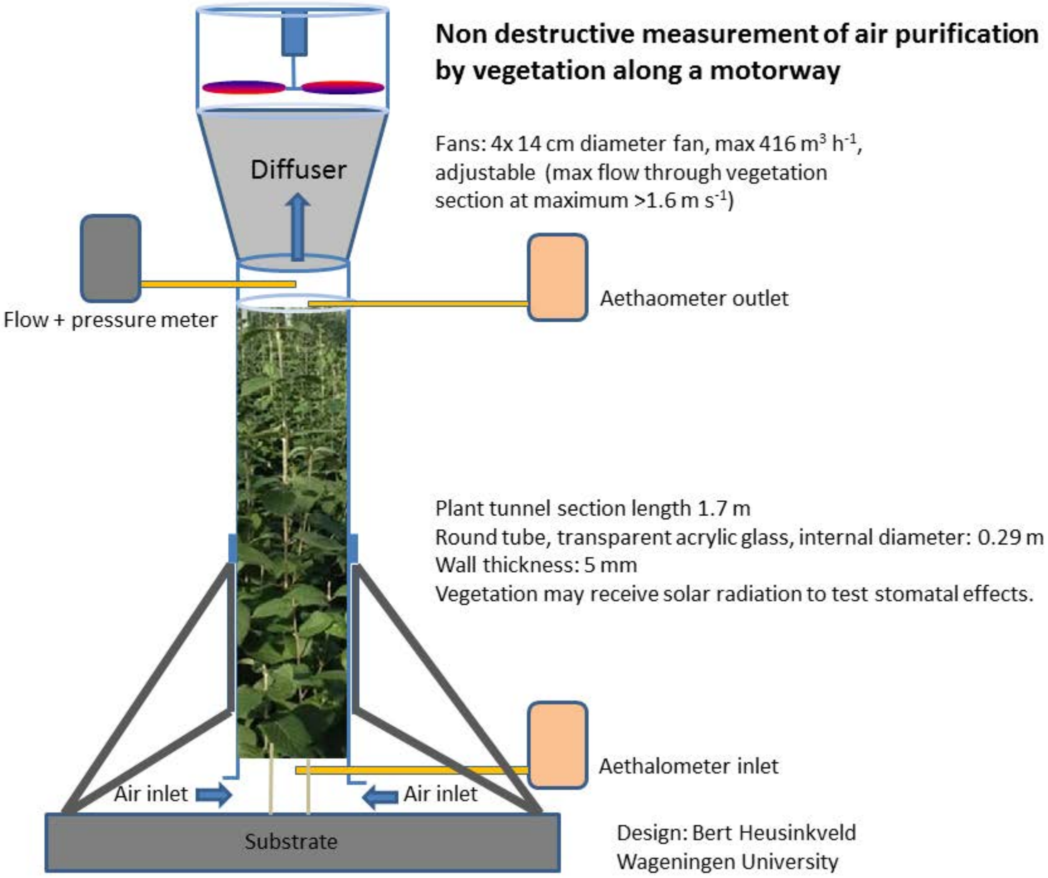


Figure 6: Schematic overview of the wind tunnel design.

The wind tunnel flow needs to be controlled within 0.01 m/s and the soot concentration was measured near the inlet and inside the tunnel at a location after the air has passed the through the vegetation.

A vertical tunnel orientation was selected because this would result in a more homogeneous and natural distribution of plant leaves. In a horizontal placement the plant leaves would be compacted by gravity possibly resulting in a lower filling of the tunnel on the upper side.

Seven Pulse Width Modulation (PWM) fans were selected because their speed can be controlled very accurately (controller: Zalman PWM mate) and energy efficiently (Fans: Bequiet-pure-wings-2-140mm-pc-fan PWM). The plant tunnel section is constructed from a transparent acrylic glass tube. The glass tube enables visual inspection and the vegetation can also receive light.

2.4 Measurement results

Outdoor measurements were performed along the Kennedylaan (Amsterdam, The Netherlands) (Fig 7.). The wind tunnel with a Green Junkie (Hairy Honeysuckle) plant was located 2 m from the edge of a 4 lane road during traffic rush hour (Fig. 7; note 14:15 till 15:45 h UTC corresponds to 16:15 till 17:45 Dutch summertime).

Figure 7: Experimental setup along the Kennedylaan, Amsterdam, The Netherlands.

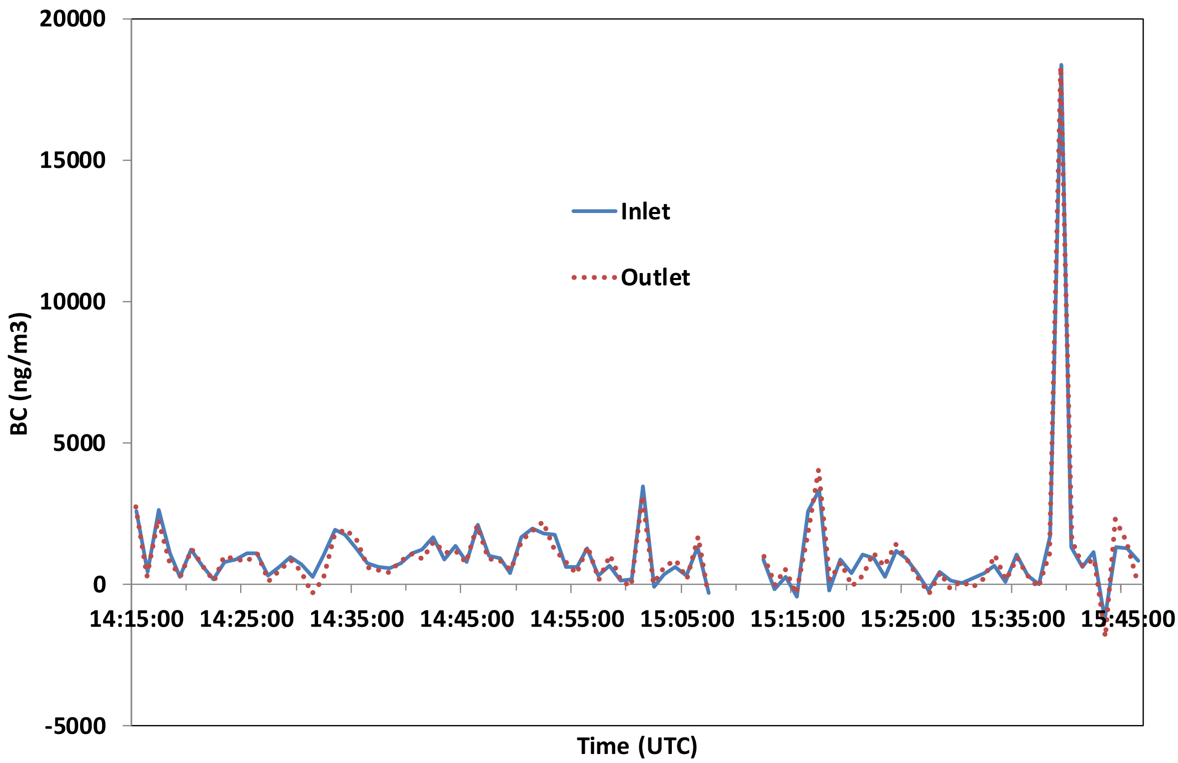


Figure 8: Measurements along the Kennedylaan on June 10, 2016 (tunnel velocity 0.2 m/s).

The experiment (fig. 8) was interrupted around 15:10 h (UTC) and the aethalometers were reversed and continued after about 5 minutes to compensate for possible systematic measurement errors. The data for each instrument was renamed again (inlet became outlet, etc.). Negative measurements don't seem to be realistic but they are actually a result of instrumental noise (optical transmission change) and need to be included in the analysis. No significant reduction of soot concentration was found at the outlet of the tunnel (Fig. 8). Note that the signal of a passing truck around 15:40 h (UTC) is similar on both inlet and outlet measurements. The first impression was that the poor GJ performance may have been attributed to the low tunnel packing density.

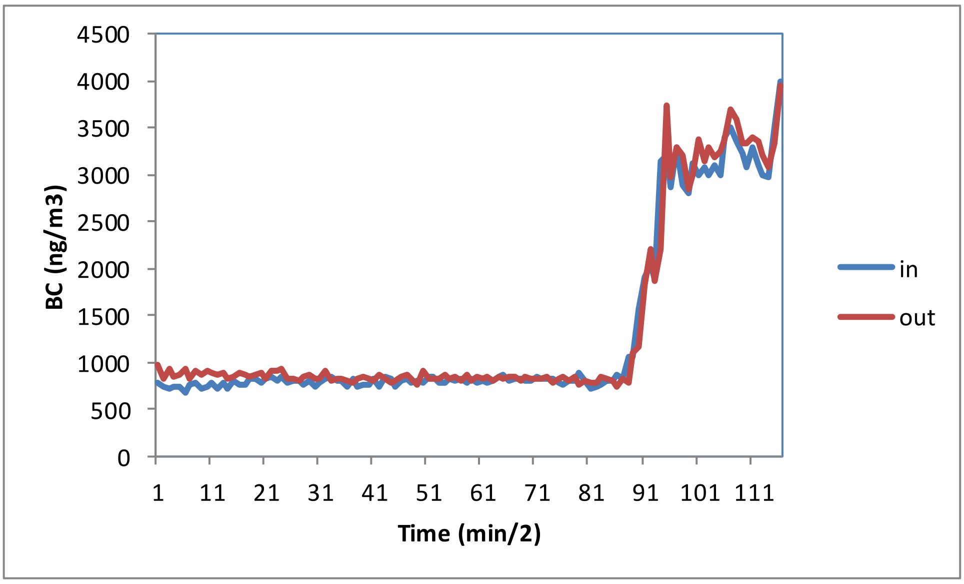
For this research, we were dependent on the GJ provision of the supplier. During this research, we were guaranteed by the provider that the GJ provision was sufficient for execution of the experiments. However, when visiting the supplier, we did not find a sufficient amount of GJ to execute the experiments. Although we postponed our research it became clear that a sufficient amount of GJ could not be met in the timespan of this research. Nonetheless, we executed the research as the place was reserved and permits for onsite testing were given. In order to attain sufficient data, we lowered the airflow in order to realize a higher contact time between the airflow and the plants

In order to analyse whether the poor package density was the reason for the lack of soot concentration reduction we continued extra experiment in an indoor setting. For this research, we used additional planting in order to get an indication of the general effects of plant on air quality.

2.4.1 Indoor experiment

In order to analyse the impact of plant density, we had to wait until enough GJ plants were available. On 21th of July enough plants were available for a new experiment (Figs. 9 & 11). Although this was an indoor experiment, we had to rely on background soot concentrations for the first part of the experiment, as busy motorways were within 200 m. Later on, to test the response to higher concentrations a light diesel van was placed in the street next to the laboratory (at ground level) and doors could be opened to allow air ventilation from the street into the laboratory. Green Junkies were placed inside the vertical wind tunnel and additionally plants were cut and used to fill the tunnel as high and dense as possible. Note that this resulted in a very high leaf area density (estimated at >20 m^2 m^{-3}) and probably >5 times larger than under natural conditions. The inlets of both aethalometers are visible in Figure 9. The air enters the tunnel from below and passes through the glass tube filled over a length of 1.6 m with vegetation. A hot bulb anemometer located in the upper part of the tube measures flowrate through the tunnel.

Figure 9: Green Junkie in the vertical wind tunnel.



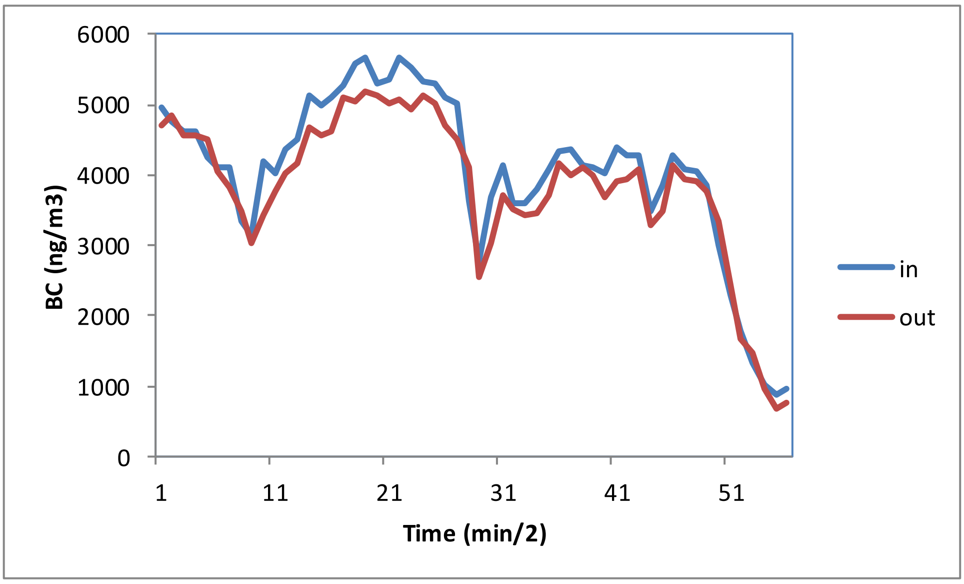


Figure 10: Green Junkie in wind tunnel, flow 0.10 m/s, first part is background pollution, then a diesel truck in idle mode located about 3 m upwind (last part). Lower panel is the continuation of the upper panel but with reversed measurements (30 s measurement interval) (21 July 2107, around 11:07 – 12:34 h UTC).

During the experiment the meters were swapped twice (Fig. 10). This resulted in 2 measurements in normal order and 1 measurement in reverse (not all data shown). For a fair comparison, the 2 measurements in normal order were averaged together and this was averaged with the average of the reversed reverse measurements. This resulted in a soot reduction of 1.5% (uncertainty estimated >1% minimal). The first 45 minutes the measurements represent background concentration (about 1000 ng)/m3. After those 45 minutes a light diesel van was started and left running idle near the entrance of our laboratory. The engine was stopped about 10 minutes before the end of this experiment.

2.4.2 Additional experiment with Taxus

The Taxus coniferous plant is known to collect aerosols with its numerous needles. A potted Taxus was squeezed inside the tunnel and the remaining holes were filled with fresh cut branches from above (Fig. 11).

Figure 11: Taxus, high density packing and low flow rate (0.07 m/s).

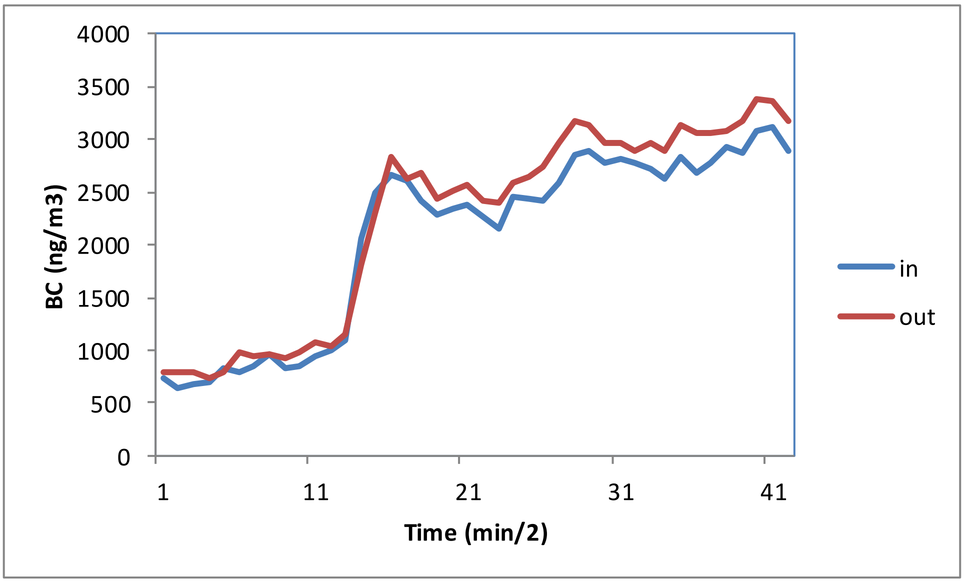


Figure 12: Taxus, flow 0.07 m/s (30 s averages) (offset visible in the outlet sensor) (21 July 2017, 14:50-15:10 h. UTC).

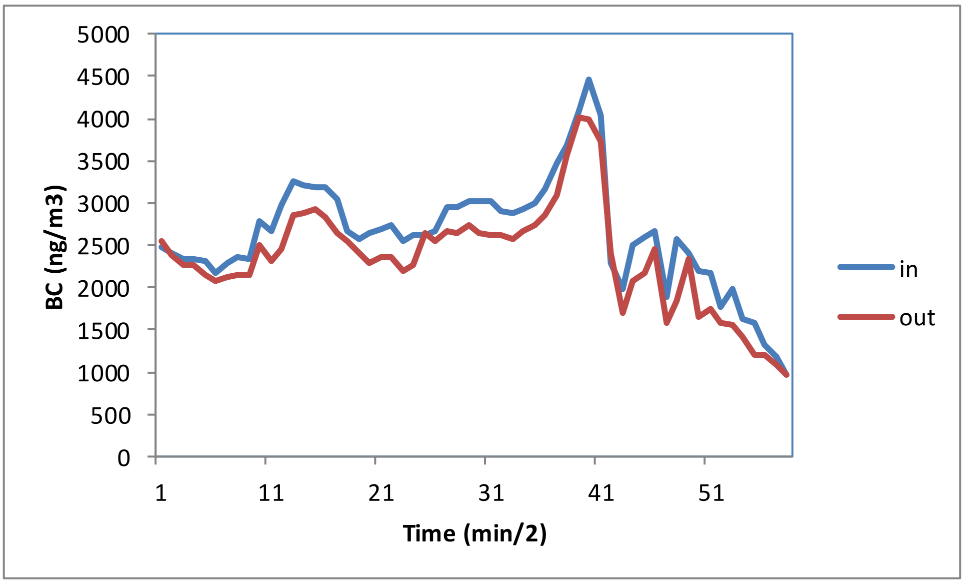


Figure 13: Taxus, meters reversed (15:12-15:41 h. UTC).

Averaging all Taxus measurements (Figs. 12 & 13) with sensors in normal order and averaging all measurements with a reverse order reveals the amount of soot that is collected by the plant. The Taxus plant extracted 2.9% of soot (uncertainty estimated >1% minimal). Note that sensor offset deviated from the Green Junkie experiment due to an exchange of soot deposition filters (and a 1 m drop on the floor of sensor 1001) at the start of the Taxus experiment.

The leaf area density (m^2 m^{-3}) in the lab experiments was estimated to be much denser than in a natural situation (>4 times larger). This high density was chosen to increase the detectability of soot interception. A more detailed measurement of leaf area density is not considered relevant because of the insignificant amount of measured soot interception.

2.5 Conclusion, discussion, recommendation and final thoughts

2.5.1 Main conclusion

The impaction filter theory simulations showed that the Green Junkie plant hairs are too thick to have a significant impact on PM2.5.

We specifically tested soot deposition and soot can be classified as fine particulate matter <PM1. Soot has a particle size range of 10 nm to 600 nm. Green Junkie reduced the amount of soot air pollution by 1.5% (uncertainty +/- 1%, by weight) in the range 0-2.5 PM while air passed through a densely (not naturally) filled tunnel (length: 1.7 m) at a very low flow rate (0.1 m/s).

2.5.2 Discussion and recommendation

Our experiments have shown that the GJ plants do not appear to be effective in removing soot (mass) from traffic related sources. This seems related to the particle size distribution of traffic related soot, it is too small for the plant hairs be intercepted. The effectiveness of GJ plants in removing particles smaller than 100 nm (including soot and other nanoparticles) could not be verified since the aethalometers measure a mass equivalence of all soot particles (nanoparticles are very light). Still, removal of nanoparticles is also considered as a health benefit because of their large chemically reactive surface area (compared to a similar mass of larger particles). However, with time, nanoparticles tend to accumulate into larger particles. A plant with a rougher surface area may collect more nanoparticles according to Lin et al. (2012). Leaf hairs make a leaf surface rougher but it was not part of this research to test if this type of roughness is effective for nanoparticle collection.

During the roadside testing the assumption was made that the low packing density could have led to insignificant results in soot concentration reduction. Indoor experiments with higher densities of GJ and Taxus has shown that even with a fully stacked wind tunnel no significant effects can be found. This means that the roadside test cannot be indicated as a methodological error.

As our research was measuring the total mass of soot particles in the air, it can be discussed that the monitoring of concentration particles as a function of particle size will give a more detailed insight into the effects of plants on fine particulates. When comparing a similar mass of small particles with one large particle (comparable to an amount of tennis balls that occupies the same volume as one bowling ball) one can see that the small particles will have a larger total surface area. This large surface area will enhance chemical reactions and thus may have a larger impact on health.

Wet vegetation was not tested but soot is hydrophobic and therefore wet leaves may not enhance interception.

Although the Taxus seems to collect a larger percentage of soot than the GJ, this was mainly due to the lower flow rate and larger pressure drop inside the tunnel. The Green Junkie probably would have performed similarly under those conditions (larger packing density). In other words, the soot as a percentage of soot per m^3 that passed through the tunnel may therefore be similar. This would also indicate that the plant hairs are not contributing much to the fine particle removal (see also Fig. 3). However, the measured concentration reduction is almost equivalent to the estimated measurement noise.

The wind tunnel flow and length cannot be compared with the performance of large forests or large parks and those are considered more effective due to their size. If one wind-tunnel length removes 1%, then 70 wind-tunnel lengths would halve the soot pollution. Such vegetation belt widths are realistic scenario's for urban parks for example.

Technological innovation and the demand to reduce greenhouse gasses seem to accelerate the transition to zero emission vehicles (electric). However (ultrafine) particle emissions from tires and brake systems may still pose a health risk. The electric vehicle particulate matter emissions may be larger than from conventional vehicles due to the increase in weight of the batteries.

This research strengthens the outcomes of previous researches who only looked at PM2.5. So we extended our knowledge by looking at how plants interact with particulate matter by focussing on the current roadside soot concentration (particulate matter even smaller than PM1). There is however a strong base of research [Lin et al, 2012] demonstrating a great impact of greenery on UFP. So if all older diesel cars would be replaced by cleaner ones we will see an increase in UFP and for this scenario vegetation could have an impact on UFP reduction. (It would be interesting to look at particle number concentration since this would add more importance to UFP (small by weight). New cars have to comply with new legislation limiting the particle numbers per km. TNO has shown that the particle number concentration along the Amsterdam roads is up to 8 times larger than expected from emission standards, see Keuken et al., 2016. So it is clear that nanoparticle pollution needs more attention.

Note that the aerodynamic size of particulate matter is very relevant for human health. Particles smaller than 2.5 μm penetrate deep into the lungs. The lungs have filter mechanisms to prevent deep lung penetration. An important defence mechanism are the lung cilia hairs and their width is smaller than 1 μm. Note that the cilia has a much smaller diameter than the Green Junkie plant leaf hairs. One can speculate that in order to have a significant health benefit the plant hairs need to be thinner than cilia hairs.

The result does not indicate that Green Junkie does not affect the air quality at any scale. This research only shows us that GJ isn't effective in capturing pollution that consists of soot dust particles that are typical for the current road traffic (that seems to have a size distribution peaking at a few hundred nm). It may be more effective in capturing ultrafine particles (UFP) with a size range smaller than 100 nm (Linn et al., 2012). Modern diesel engines emit much more ultrafine particles than older diesels (as a mass fraction), so we would expect better results with UFP (ultrafine particulates). With this in mind it is relevant to note a recent study on the very high ultrafine particle concentrations at and around Schiphol airport (Weijers, et al., 2015). This is in line with a study by Liati et al. (2014), they show that jet engine emissions produce a huge amount of very small particles (Fig. 14).

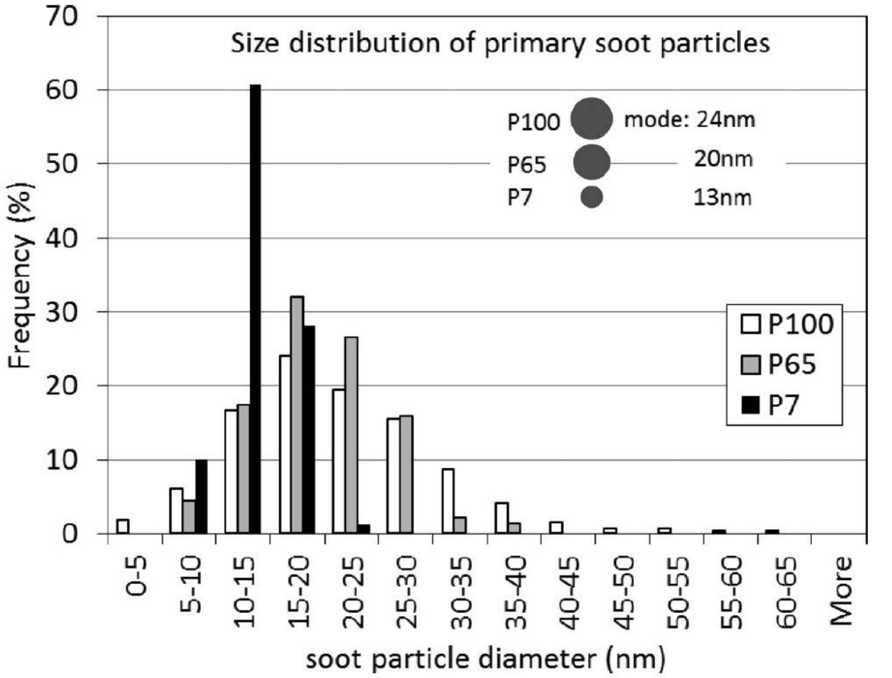


Figure 14: Aircraft jet engine soot particle size distribution (Adapted from Liati et al., 2014).

2.5.3 Final thoughts in bullets:

- The measured carbon aerosol particle (BC) reduction in mass was almost as high as the noise in the measurement.
- The large packing density of the Taxus plant did not show a more significant reduction in BC.
- Tunnel experiment packing density of both Taxus and GJ was much higher than in a natural setting (so the tunnel collection should have been significant)
- The thickness of the GJ leaf hairs makes them efficient for larger particles mainly (>PM2.5).

- The leaf hairs increase surface roughness and may improve ultrafine particle collection to some extent (Linn et al., 2012).
- The Honeysuckle or another plant that covers the surface of sound barriers along motorways may have some benefit because they do not obstruct flow but offer a larger deposition surface area (than a bare sound barrier).
- Plants also interact with gas phase air pollution (through their stomata) but this was not part of this study.
- Due to the small particle size dimensions of the soot, further research should also focus on particle number concentration.

2.6 Impact and benefits for the Metropolitan Region Amsterdam

The air quality of Amsterdam has been under considerable amount of discussion. Last year there was a lot of media attention on this subject (“Amsterdam meest vervuilde stad van Nederland”, Parool, 11 mei 2016). This was also visible at the amount of media attention that this research project attained. The Amsterdam municipality and the citizens of Amsterdam have been following our project with great interest.

Large effects on the increase of air quality can be realized by control at the source, e.g. reduce the amount of construction and motorized vehicles. As traffic flows are needed in the city, other solutions should be found. Research has shown that vegetation does impact air quality, the question was how this impact can be monitored and used as a tool for a healthy living environment.

This stimulus call has gained insight on this topic. The GJ plant seems effective in reducing course particulate matter (> 2.5 μm). More important are the collection efficiency for smaller particulate matter. Soot is part of the particulate matter air pollution and has a strong impact on health. There was detectible no air quality benefit regarding soot particulate matter reduction potential. There may a reduction potential of ultrafine particulate matter.

2.7 Upscaling Plan

The study showed that the Green Junkie only reduced the amount of soot air pollution by appr. 1.5%, so that the plant does not appear to be effective in removing soot from traffic related sources and cannot really improve the air quality along roads intensively used by car traffic.

Consequently, the AMS Institute stopped working on a follow-up and will – for the time being – not invest in research of this type.

2.8 Key references

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3. Dissemination activities

- http://www.fastcoexist.com/3061328/in-amsterdam-researchers-are-testing-a-flower-grown-to-suck-up-smog
- http://www.citylab.com/cityfixer/2016/08/amsterdam-road-tests-a-pollution-zapping-flower/494099/
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- http://www.amsterdamfm.nl/ams-institute-kamperfoelie-in-de-strijd-voor-een-schonere-lucht/
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- https://www.amsterdam.nl/zuid-gebied/nieuws/nieuws-stadsdeel/2016/06/proef-green-junkie/
- CityLab: Amsterdam Road Tests a Pollution-Zapping Flower
- FastCoexist: In Amsterdam, Researchers Are Testing A Flower Grown To Suck Up Smog
- Progrss.com: Is Green Junkie The Answer To Urban Air Pollution?
- Wonderful Engineering: This Flower That Can Suck Up Smog Is Being Tested In Amsterdam
- MNN: Can a flower help cities reduce air pollution?
- Design Trends: Plant Filled Tube Experiment Designed to Filter Smog in Amsterdam:
- Talk Asia: Can a flower help cities reduce air pollution?
- Design in Daba: Can hairy plants clean up Amsterdam's air pollution?
- PSFK: Can A Flower Help Lessen Pollution In Amsterdam?
- IDA Universe: Plante Kan Mindske Smog
- Builder Online: In Amsterdam, Researchers are testing a flower grown to suck up smog
- Croen Ergo: Nizozemska: Ova Biljka Ovisna je o zagadenju iz prometa
- Rozhlas: Holandští vědci vypěstovali Green Junkie – rostlinu, která bojuje proti znečištění
- Inhabitat: Dutch researchers grow carbon-hungry plants to suck up pollution
- Elgrannino: Investigadores holandeses siembran plantas hambrientas de carbono para absorber la contaminación.

4. Key data-sets realized by project

A digital dataset containing the wind tunnel measurements is available upon request.