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ANALYSING THE INFLUENCE OF DIFFERENT STREET AND PHYSICAL ENCLOSURE ON REDUCING THE AMOUNT OF SUSPENDED PARTICLES IN THE PEDESTRIAN STREETS

Mahdis Mobarhan[1], Mansour Yeganeh[2],
1. Mahdis Mobarhan, M.A Landscape architecture,
Islamic Azad University, Pardis Branch, Teharn, Iran
2. Mansour Yeganeh, Corresponding Author,
Tarbiat Modares University, Tehran, Iran
*Email Address: yeganeh@modares.ac.ir

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Abstract: The research seeks to answer these questions: What is the relationship between the amount of enclosure in the pedestrian streets urban spaces and the amount of suspended particles (PM10)?The research method in this paper is descriptive analytic and simulation using Envi-met software. Methods for collecting data is using database about climate variables and bases for measuring air pollution (Meteoblue, ASPA's STREET). The software analysis technique is done with leonardo software. The results of the research show that in the critical wind conditions, reducing the amount of physical enclosure is less pollution. And the optimal time is when the height ratio of the pedestrian sidewall to its width is 1.1. The concentration of suspended particles also increases with decreasing breeding distances. Changing the spacing of trees with low density does not have a significant effect on the air suspended particles.

Key words: "Enclosure of space ", "dispersion of suspended particles", "vegetation type", "plant size and distance", "Envi-met"

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1. Introduction

Because of its adverse effect on human health, air pollution is an environmental problem of major concern. Due to the high traffic density, cities often face increased concentrations of air pollutants in comparison with its surroundings. The World Health Organization (WHO) and other international agencies have long identified urban air pollution as a critical public health problem. According to the United Nations Environment

Programme (UNEP), more than one billion people are exposed to outdoor air pollution annually, with urban air pollution being linked to up to one million premature deaths and one million pre-natal deaths each year. Many of the air pollutants that are directly emitted, or indirectly produced through photochemical reactions, represent a serious hazard for human health (Dab et al., 2001; Hoek et al.,2000; yeganeh, Bemanian, 2012; yeganeh, Kmalizadeh, 2018).

Nowak and Crane (2000) have developed a deposition model that is able to estimate the pollutant removal capacity. Many studies using this model have reported impressive mass removal estimates for different cities (McPhersonet al., 1994; Nowak et al., 2002; Tallis et al., 2011) in order to demonstrate the beneficial effect of urban green on the air quality. However, the resulting decrease in ambient concentrations is much less reported and if so, the effect of the urban forest on the city averaged air quality appears to be rather limited, often not exceeding an improvement of 1-2% (Tallis et al., 2011).

Urban vegetation object, trees and shrubs, on air pollution in built environments, with specific attention paid to its combined influence on the removal and dispersion of air pollutants. The aim of the study is to investigate the effects of different vegetation and street configurations in a systematic way. The evaluation was performed using the three-dimensional microclimate model ENVI-met (Bruse, 1999; Bruse and Fleer, 1998 see www.envi-met.com),traffic-induced particles at street level to be simulated.

Section 2 proposes a brief description of the ENVI-met model and the methodology used before presenting the results of the analysis in Section 3 and discussing them in Section 4. and conclusions for this study in section 5.

2. Methodology: use of the microscale model ENVI-met

All simulations in this work are performed by the ENVI-met model.

ENVI-met (Bruse and Fleer, 1998) is a three dimensional computational fluid dynamics (CFD) model that is particularly tailored for simulating different urban atmospheric processes such as pollutant dispersion and microclimate effects. The flow solver is based upon the Reynolds averaged NaviereStokes (RANS) equations and uses an E-ε model for describing the turbulence effects.

2.1. Vegitation

The exact geometry of vegetation (i.e. leaves and branches) is not explicitly modelled in ENVI-met. The presence of vegetation is represented by introducing additional terms in the governing equations in order to mimic its effect. For the computational cells that coincide with the location of the vegetation, a sink term is added to the momentum equation in the RANS equations in order to account for the flow resistance (or pressure drag) induced by the

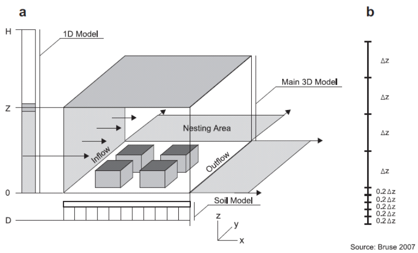

Fig. 1. Schematic overview over the ENVI-met model layout (a) with Z the height of the main 3D model, H the height of the 1D model providing the vertical profiles of all model variables for the inflow boundary of the 3D model and D the depth referring to the base of the soil model. Soil properties are modelled separately in the soil model. The soil model is one dimensional except of the first grid point below the soil where the temperature is calculated three-dimensional to avoid unrealistic sharp temperature gradients at the surface. (b) The vertical grid layout of the main model is equidistant with identical vertical extension of all grids except the first grid that is split in five sub-boxes.

vegetation. This is analogue to the way porous media are often dealt with in CFD. Also the E-ε equations are equipped with an additional term to simulate the effect of vegetation on the turbulence variables(Esfahanian, Yeganeh, 2019). As explained in Bruse and Fleer (1998) these terms describing the aerodynamic effect of vegetation in ENVI-met only depend on a single plant parameter, i.e. the leaf area density (LAD, total leaf area divided by total volume of vegetation).

The filtering capacity of trees is represented by a sink term in the dispersion equation. In ENVI-met this term reads (Bruse, 2007).

Leaf Area Density (LAD) profiles defined the crown shape and height of trees and hedges, which were based on standards described in the literature (with forest tree data used as this was the only available information). Tree types were defined: with no distinctive crown and sparse leaves and another with a distinct crown and densely foliated. Tree-types have a leafless stem up to 2 m. The crown of the very densely foliated tree reaches its maximum density between 6 and 7 m, the sparsely foliated tree increases in density only slightly and the hedge was densely foliated throughout its whole profile. These LAD profiles deliberately represent two extreme cases of tree-growth in urban areas to reflect varying environmental conditions and pruning(yeganeh, 2015).

2.2. pollution

ENVI-met uses a Eulerian approach to study the dispersion of pollutants. Both gaseous and particulate pollutants can be included. In this work, we have focussed on PM10 and the more traffic related pollutants NO2 and elemental carbon (EC). As elemental carbon mainly resides in the smaller size fractions of the particulate matter (Healy et al., 2012), it is accounted for in ENVI-met as if it were PM0.2. For the dispersion of NO2, we also take into account the chemical reaction between NO2, NO and O3 (De Maerschalck et al., 2010). The traffic emissions are in principle represented by line sources. However in order to account for the mixing by the traffic induced turbulence, they are spread out over the entire width of the traffic lane and a height of 1.5 m, see Figs. 2.

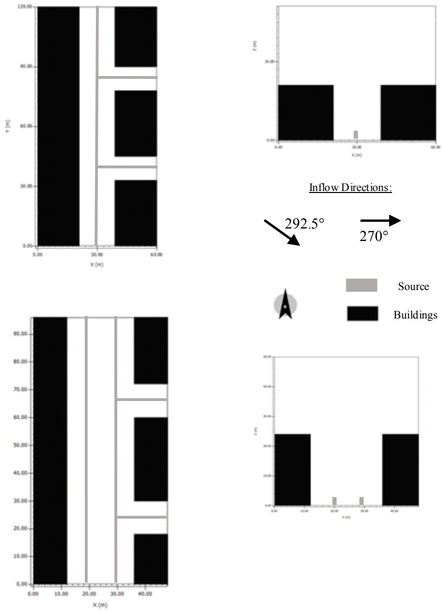

Fig. 2 Configuration of model areas: a) cross section of two aspect ratios, b) plan view of model areas with (bottom) scenario with the widely spaced row of trees in the canyon with aspect ratio 0.9 and (top) scenario with continuous row of trees/hedge in the canyon with aspect ratio 1.

A comprehensive overview over the particle dispersion model can be found in Bruse (2007). The model includes a dispersion and deposition model to simulate the dynamic behaviour of particles and inert gases. The concentration of a component (gas or particle) is calculated with the standard atmospheric dispersion equations (Eulerian approach). Processes that induce a local increase or decrease in the concentration of a component are included by adding source and sink terms in the atmospheric dispersion equation. The main forcing factors of sedimentation and deposition (sink terms) in the model are gravitational settling and any dry deposition on surfaces such as soil, buildings and/ or plants(Yeganeh et al. ,2015).

3. Results

After implementation of the modeling, the outputs of the climatic model presented in Graphs using the Leonardo software. Their results are investigated separately in the following components:

3.1. Impact of enclosure on suspended particles (pm10)

Fig.3 Considering the simulation for two different levels of pedestrian enclosure, in which the densely foliated trees are planted continuous rows and spaced apart. The densely foliated trees planted continuous rows, increasing the amount of suspended particles, but this increase is higher in H/W: 0/9 than H/W: 1/1. It was found that by increasing the physical enclosure of the pedestrian, the level of PM10 increases. In the case of planting trees with greater distance, it shows that the concentration of suspended particles is less in the case of planting trees as continuous rows.

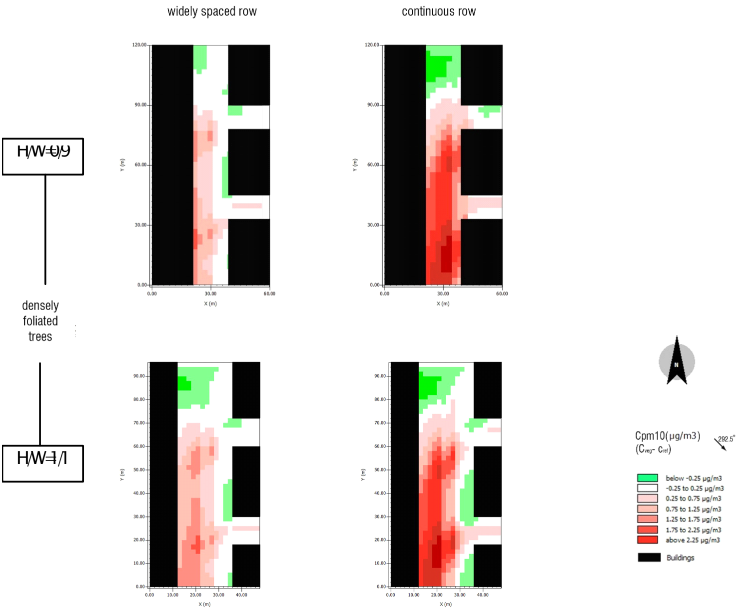

Fig 3. Particle concentrations in the calm wind simulation (1 m/s) with inflow directions: oblique inflow And different aspect ratio(H/W): 0.9 and 1

3.2. Investigating the effect of vegetation on suspended particles (PM10)

In this simulation, four different tree types have been planted on both sides of the axis. Acer platanoides is the main and most widely used plant in streets and all over Tehran, which is considered as one of the aspects of landscape identity and vegetation in Tehran, the first planting pattern is planting acer platanoides in two diferent distance: 16 meters and 8 meters. The results of the simulation show that the planting of this tree in the axis increases the amount of suspended particles compared to the non-vegetation state. In the simulation pattern with a spacing of 8 meters (the distance between the crowns of trees), the amount of suspended particles in the air increases compare to simulation pattern with a spacing of 16 m. Regarding the results, it shows that the reduction of air flow in the axis increases the amount of suspended particles.

The next simulation is the fraxinus excelsior. The planting distance is 16 m. Planting of this tree also increases the amount of suspended particles in the axis, but does not significantly affect the concentration of suspended particles compared to the acer platanoides.

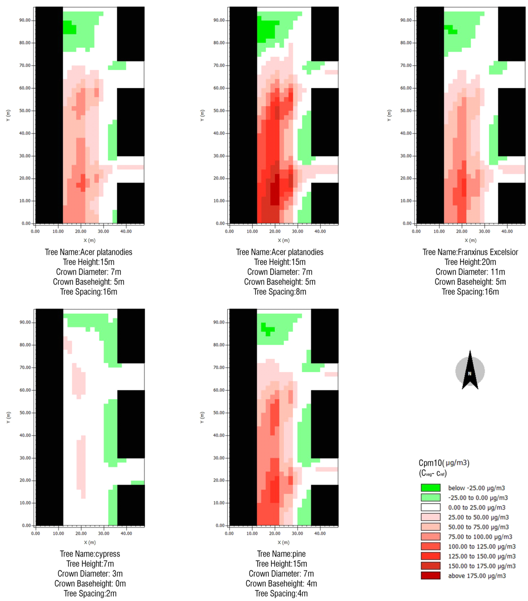

Fig 4. Influence of vegetation on particle concentrations for inflow direction 292.5 and wind speed 3.2 m/s. Comparison between the simulations without vegetation (reference case cref), with the four tree scenarios (vegetation scenarios cveg). Red indicates increase and green decrease of concentrations.

The next tree is planted with a distance of 2 meters. The results of the simulation indicate that planting cypress has reduced the pollution in the axis. The fourth simulation is a pine tree planted with a spacing of 4 meters. The simulation result also show that the amount of suspended particles has increased.

In all simulations, it observed that at the beginning of the axis, the concentration of pollutant particles is lower, which seems to be due to the return of the wind flow after collision with the front and exit of the pollutants from the axis. It also shows that at the intersections the amount of suspended particles increases. By planting trees in the main axis, no appreciable changes happened in the concentration of pollutant particles in the subaxes.

Fig5. shows that the concentration of suspended particles is higher on the left side and we can see reduction of suspended particles at the windward, The source of pollutants is located in the middle of the axis. Simulation shows that by increasing the distance from the source, the concentration of suspended particles decreases significantly.

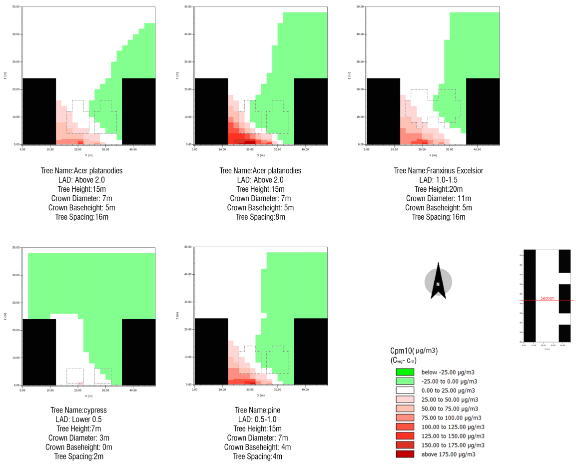

Fig 5. Influence of different vegetation on particle concentrations (cross sections), simulation with wind speed 3.2 m/s (reference case cref, vegetation scenarios cveg)

Fig 6. shows that in all simulations at the beginning of the axis, the amount of pollutants is lower, but this increases with taking distance from the beginning of axis.

As shown by the simulation outputs, the amount of pollutant emissions does not equal and does not follow a pattern. the amount of contamination along the entire path at leeward is more than the windward.

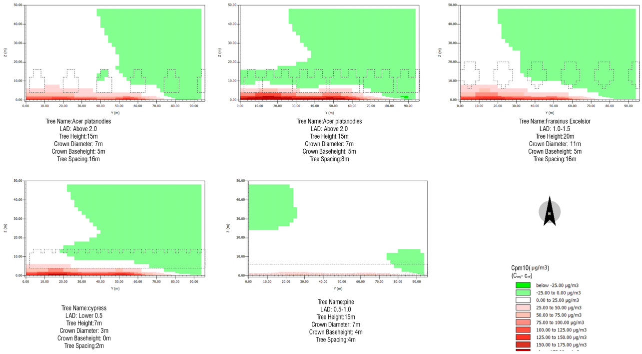

Fig 6. . Influence of different vegetation on particle concentrations (cross sections), simulation with wind speed 3.2 m/s (reference case cref, vegetation scenarios cveg)

4. Conclusions

The effect of vegetation on particle dispersion was modelled and analysed in simplified, symmetric street canyons using the ENVImet model. The results reveal the effect of vegetation on canyon ventilation and consequently particle dispersion. By analysing the effect of vegetation and the amount of H/W with Envi-met, it can be concluded that the concentration of pollutant particles increases with increasing enclosure and the planting dense tree with low distance.

Also, the results of simulations for 4 vegetation scenarios show that the density of trees, whether in terms of distance or leaf area density, can increase the concentration of suspended particles; this can be explained by reducing the ventilation of axis, . Air quality is additionally reduced in configurations with poor ventilation, such as at low wind speeds, as well as in deep canyons.

It is suggested that cypress might be an alternative in deep canyons as they appear to retain more particles due to their position closer to pollution sources, as well as reducing concentrations at the height of the human respiratory tract.

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