Technium EcoGeoMarine Vol. 1, No. 2 pp.1-8 (2022)
ISSN: 2971-8112
www.techniumscience.com

Effects of different plant communities on fine particulate matter concentrations in green areas around Quancheng Road, Jinan

Hanwen Mi

Weifang University, College of Biology and Oceanography, Shandong, China
mihanwen@foxmail.com

Abstract. To study the effect of different plant communities on fine particulate matter $PM_{2.5}$ and PM_{10} concentrations in green areas attached to urban roads is an important basis for improving the air pollution control function of urban green areas and optimizing the configuration of green areas, and it can provide an optimal solution for plant configuration selection. In this paper, the intersection of Quancheng Road and the front street of the provincial government in the Lixia District of Jinan City was selected as the research object, which has certain research value because of its important political and commercial functions and therefore has a large flow of people and vehicles. The CEM DT-9880 particle counter was used to measure the concentration of fine particulate matter at 1m and 2m height, respectively, and to analyze and compare the effect of different plant communities on fine particulate matter concentration and dust removal ability. The design optimization strategy of road accessory green space was proposed to regulate and improve the fine particulate matter.

Keywords. $PM_{2.5}$; plant community; green space attached to urban roads; fine particulate matter

1. Preface

1.1. Overview of road accessory green space

In recent years, the ecological disasters caused by environmental pollution have become more serious, and the whole Shandong region is enveloped in serious fine particle pollution, which seriously threatens residents' health and daily life. One of the main sources of fine particulate matter is road dust and car exhaust emissions, car in the process of road travel, engine exhaust will produce a large number of fine particulate matter, while the car will also produce a lot of dust so that fine particulate matter pollution increased. Especially in Jinan, a city with high traffic flow, developed traffic road network and serious congestion, the fine particulate pollution from motor vehicles and roads is quite serious. In a reasonable layout, plant community with a perfect urban road accessory green space can effectively reduce the problem of fine particulate matter pollution caused by vehicles driving on urban roads. At the same time, a beautiful green road space can enhance the impression of foreign tourists to the city. A beautiful road to the first impression of tourists will often significantly impact the entire tour. Good greenery also has a positive impact on the safety of drivers driving their vehicles.

1.2. Hazards of $PM_{2.5}$

The link between fine particle pollution and health problems has been noticed since the 1970s. Fine particulate matter can be a very serious health hazard. It can affect the respiratory, cardiovascular, and central nervous systems by causing inflammatory reactions in the lungs and oxidative damage, triggering systemic inflammatory reactions and neuromodulation changes [1]. The toxic effects of fine particulate matter on the respiratory system have been studied in animal experiments, and the results showed that fine particulate matter could cause oxidative stress damage and inflammatory responses in rat lung tissue. Epidemiological studies have shown that cardiac arrhythmias, myocardial infarction, heart failure, atherosclerosis, and cardiovascular diseases such as coronary artery disease are associated with long-term exposure to fine particulate matter [2]. In addition, high concentrations of fine particulate matter can seriously impact pregnant women, affecting embryonic development and correlating with increased perinatal and neonatal mortality, low birth weight, growth retardation, and congenital functional defects. High concentrations of fine particulate matter also aggravate the condition of patients with respiratory diseases, especially threatening the health of the elderly and children.

1.3. Basic relationship between plant communities and fine particulate matter

Related research shows that vegetation leaves can retain and fix atmospheric particles due to their surface properties (such as velvet and waxy epidermis, etc.), making fine particles out of the atmospheric environment and becoming an important filter to abate atmospheric environmental pollution. Therefore, the greater the dust retention capacity of plant leaves, the stronger the effect on the abatement of atmospheric particulate matter. The environmental effect of different types of vegetation varies [3]. At the same time, different types of plant communities have different landscape effects and their ecological effects are different. Plant communities have a certain adsorption effect on fine particulate pollution, but their adsorption capacity and adsorption effect are related to the type and manner of their plant mix.

2. Determination of the relationship between plant communities in green areas attached to urban roads and the effect of fine particulate matter

Experimental equipment: CEM DT-9880 particle counter.

Experiment content: $PM_{2.5}$ fine particulate matter index, PM_{10} fine particulate matter index of different plant communities.

Experimental method: measured at the height of 1m and 2m at each monitoring observation point in the experimental site for three consecutive days, measured every 10 minutes from 8:00 to 18:00 every day, and the average value of 6 measurements was taken as the experimental data of the hour.

Experimental objective: To monitor the relationship between different plant communities (tree-shrub-grass, tree-shrub, tree-grass, shrub-grass) and fine particulate matter in green spaces attached to urban roads.

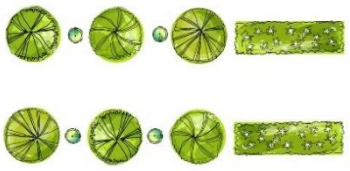
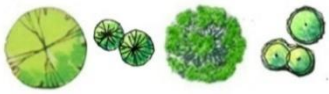
2.1. Observation site setup and environmental characteristics

Experimental site: Intersection of Quancheng Road and Provincial Prefectural Street, Lixia District, Jinan, Shandong, China. Quancheng Road is one of the main roads in Jinan, with heavy traffic flow in the morning and evening, and six lanes in both directions. The terrain is flat, and the plant species are more prosperous, mainly northern plant species.

Observation points were selected: observation point 1 (tree-shrub-grass structure), observation point 2 (tree-shrub structure), observation point 3 (tree-grass structure), observation point 4 (shrub-grass structure), and observation point 5 (control group, hardened road without vegetation) (Figure 1, Table 1).

Figure 1. Observation point selection

Table 1. Community types of observation sites

Observation Points	Plant community species	Plant species	Observation point plan
Observation point 1	Tree-shrub-grass structure	Sycamore Small-leaved boxwood Hibiscus	
Observation point 2	Tree-shrub structure	Sycamore Yulan Ligustrum Peony	
Observation Point 3	Tree-grass structure	Sycamore Ginkgo Sophora Willow	
Observation Point 4	Shrub-grass structure	Pomegranate Begonia Moonlight Lilac Waxy Plum Forsythia	

2.2. Monitoring results and data analysis

2.2.1. Effect of different plant communities in green areas attached to urban roads on $PM_{2.5}$. The average $PM_{2.5}$ index measured at 1m and 2m from the ground at each observation point was compared and analyzed (Tables 2 and 3). It can be seen that the $PM_{2.5}$ index increased continuously from morning to noon, reached a peak at 11:00-13:00 during the noon period, then decreased, and then increased again

from 15:00-16:00. On the whole, the $PM_{2.5}$ index decreased in the areas with plant communities compared with the control group. The greatest difference with the control group was between 9:00 and 12:00, which can be seen that this is the most effective time for the road accessory green space to reduce the $PM_{2.5}$ index of fine particulate matter. Among the four plant communities, the tree-shrub-grass structure is the least $PM_{2.5}$ index, indicating that it is the most effective for fine particulate matter control, and the least effective is the shrub-grass plant, with some values not much different from the control group. From the vertical direction, the higher the height of the plant community containing tall trees, the smaller the $PM_{2.5}$ index, and the shrub-grass plant structure at 2m height has the particle concentration almost equal to the control group.

Table 2. $PM_{2.5}$ values ($\mu g/m^3$)at different plant communities at 1m at different times

	8:00-9:00	9:00-10:00	10:00-11:00	11:00-12:00	12:00-13:00
Tree-shrub-grass	45	49	54	56	53
Tree-shrub	47	53	56	53	55
Tree-grass	46	54	57	64	59
Shrub-grass	53	56	58	62	57
Control group (hardened roads)	61	72	77	79	69
	13:00-14:00	14:00-15:00	15:00-16:00	16:00-17:00	17:00-18:00
Tree-shrub-grass	47	49	48	54	55
Tree-shrub	49	52	48	53	59
Tree-grass	51	53	52	55	61
Shrub-grass	53	56	59	58	62
Control group (hardened roads)	67	67	66	68	72

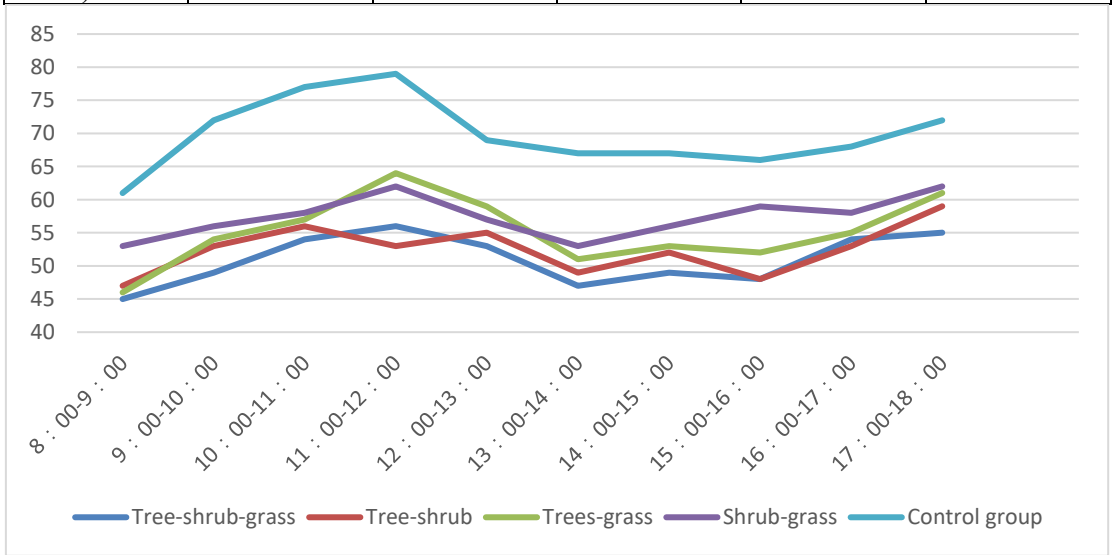


Figure 2. Folding line of $PM_{2.5}$ values at different plant communities at 1m for different periods

Table 3. $PM_{2.5}$ values ($\mu g/m^3$)at different plant communities at 2m at different times

	8:00-9:00	9:00-10:00	10:00-11:00	11:00-12:00	12:00-13:00
Tree-shrub-grass	36	37	40	41	40
Tree-shrub	38	41	42	43	40
Tree-grass	45	44	47	50	48
Shrub-grass	56	57	59	60	58
Control group (hardened roads)	59	59	64	68	60
	13:00-14:00	14:00-15:00	15:00-16:00	16:00-17:00	17:00-18:00
Tree-shrub-grass	42	44	43	46	47
Tree-shrub	43	42	44	46	48
Trees-grass	49	50	48	47	49
Shrub-grass	57	55	56	58	59
Control group (hardened roads)	61	62	60	61	63

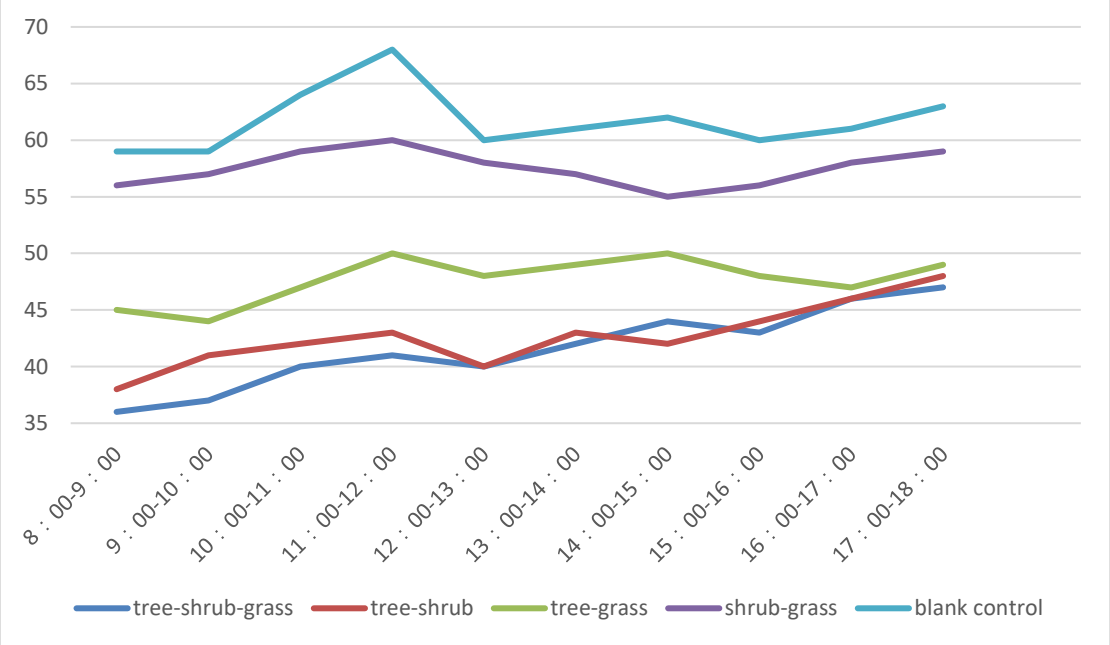


Figure 3. Folding line of $PM_{2.5}$ values at 2m at different times for different plant communities

2.2.2. Effect of different plant communities on PM_{10} in green areas attached to urban roads. Overall, the PM_{10} index showed an overall increasing trend, with the lowest fine particulate index during 8:00-9:00 and the peak during 12:00-13:00. The PM_{10} index of the four experimental groups with plant communities decreased compared with the control group. In contrast, the PM_{10} index of the shrub-grass structure decreased insignificantly, and the difference with the control group was small. Among the measured plant communities, the tree-shrub-grass structure was the best control of fine particulate matter PM_{10} index among all communities, and the PM_{10} index of tree-shrub was relatively flat. Vertically, the PM_{10} index at 2m was significantly lower than that at 1m, and the plant community with tall trees had a

great advantage in controlling PM_{10} index. The PM_{10} indices of tree-shrub-grass communities were basically the same at 2m.

Table 4. PM_{10} values ($\mu g/m^3$) at different plant communities at 1m at different times

	8:00-9:00	9:00-10:00	10:00-11:00	11:00-12:00	12:00-13:00
Tree-shrub-grass	19	20	20	22	23
Tree-shrub	18	21	22	22	24
Tree-grass	20	22	24	26	30
Shrub-grass	23	24	27	30	33
Control group (hardened roads)	33	40	43	44	49
	13:00-14:00	14:00-15:00	15:00-16:00	16:00-17:00	17:00-18:00
Tree-shrub-grass	22	22	23	24	24
Tree-shrub	24	25	25	26	27
Tree-grass	29	33	32	31	33
Shrub-grass	34	34	35	37	40
Control group (hardened roads)	46	51	53	56	57

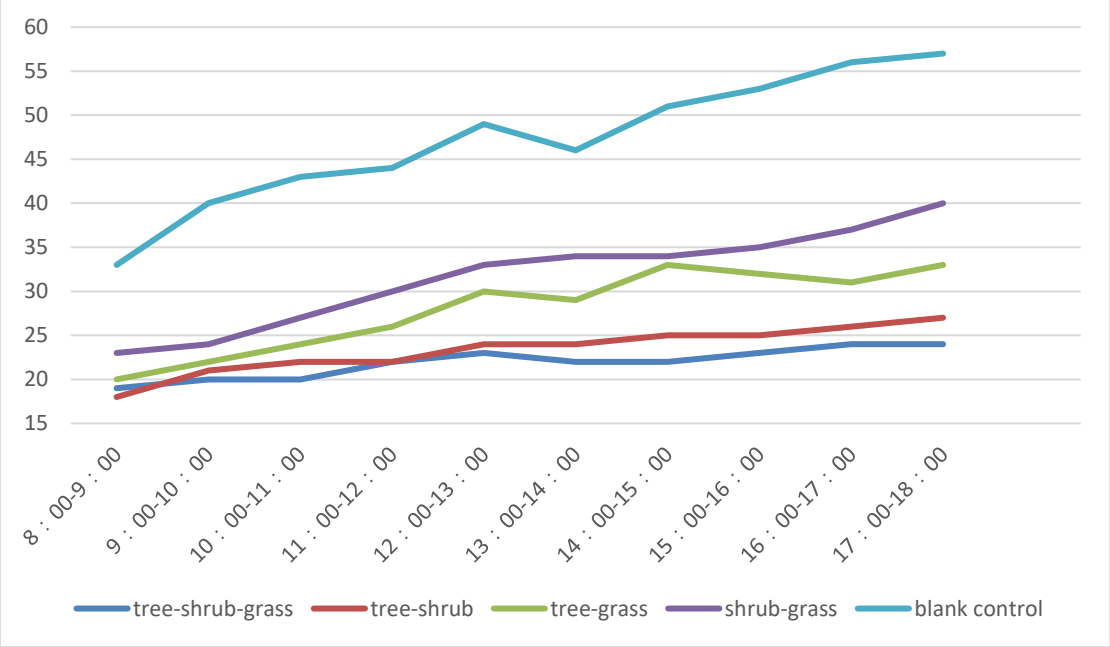


Figure 4. Folding line of PM_{10} values at 1m for different plant communities at different times

Table 5. PM_{10} values ($\mu g/m^3$) at different plant communities at 2m at different times

	8:00-9:00	9:00-10:00	10:00-11:00	11:00-12:00	12:00-13:00
Tree-shrub-grass	16	17	18	18	20
Tree-shrub	15	16	19	20	21
Tree-grass	15	19	20	21	22

Shrub-grass	18	19	22	24	27
Control group (hardened roads)	26	29	33	34	36
	13:00-14:00	14:00-15:00	15:00-16:00	16:00-17:00	17:00-18:00
Tree-shrub-grass	22	22	21	22	23
Tree-shrub	22	24	25	25	27
Tree-grass	23	24	26	25	26
Shrub-grass	26	29	29	34	36
Control group (hardened roads)	40	43	44	46	49

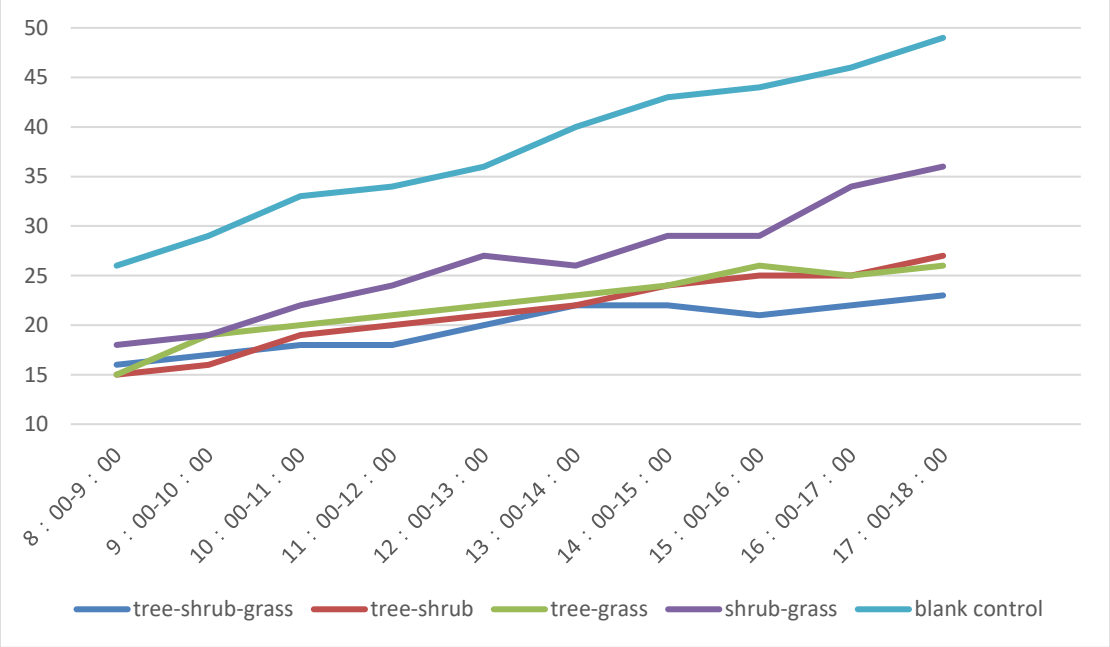


Figure 5. Folding line of PM_{10} values at 2m for different plant communities at different times

2.3. Implications for planting design of green space attached to urban roads

2.3.1. Strengthening the degree of the vertical cover of plant communities. In the design of urban roads in Jinan, strengthening the vertical plant coverage is beneficial to the control of the fine particulate matter index, and tall trees have obvious advantages for the adsorption of fine particulate matter and can intercept airborne dust to a certain extent. The $PM_{2.5}$ and PM_{10} indices in the plant communities with extensive vertical coverage were lower than those with small vertical coverage, according to the data from the actual sites. Therefore, the planting of plant communities with large canopy trees to enrich the vertical coverage is beneficial to the control of the fine particulate matter index.

2.3.2. Enrich the plant species of the plant community and select plants with strong transpiration. The data from the actual observation sites showed that the tree-shrub-grass plant community had the best control of fine particulate matter index among all plant communities. And the $PM_{2.5}$ index showed a huge difference from the control group in the morning. Plant transpiration is strongest at noon, and plant transpiration produces large amounts of water vapor through the action, which rapidly increases the

relative humidity of the air. Related studies have shown that there is a significant inverse correlation between relative humidity values and $PM_{2.5}$ values, which indicates that the higher the air humidity, the relatively lower the $PM_{2.5}$ concentration, and the lower the air humidity, the relatively higher the $PM_{2.5}$ concentration [4]. Thus, it can be seen that a rich plant community has a good effect on controlling $PM_{2.5}$, PM_{10} and other fine particulate matter. At the same time, the selection of plant species should focus on selecting plants with strong transpiration and good humidifying properties for planting.

3. Conclusion

In today's increasingly serious global climate problems, the construction of urban road green space should not only focus on its landscape effect but also use more scientific and reasonable means to form a kind of urban road green space that can effectively regulate and improve the microclimate environment and locally reduce fine particulate pollution. The reasonable combination of green space plant communities has an obvious role in regulating the microclimate environment and suppressing fine particle pollution. In this paper, we conduct targeted experiments by collating the plant species and planting methods within the investigated plant communities, obtain the data indexes of fine particulate matter $PM_{2.5}$ and PM_{10} at 1m and 2m under different plant communities, summarize and analyze the fine particulate matter index and its overall changes in different plant communities, and also analyze and compare the changes of fine particulate matter index in the vertical direction, and put forward the suggestions for the design of urban street accessory green space The recommendations are proposed to improve the regulation of fine particulate matter pollution by green road space.

This experiment is a preliminary determination of the effect of green space attached to urban roads on fine particulate matter index, while the mechanism of $PM_{2.5}$ and PM_{10} generation and reduction is very complex, and the influence of plant communities on them is also worth further investigation. Many environmental and meteorological factors influence $PM_{2.5}$ and PM_{10} concentrations in the air, so the study of $PM_{2.5}$ concentration changes in plant communities should be carried out from multiple perspectives in order to design urban roadside green spaces in a more targeted manner.

References

[1] Liu Jieling,Jiang Wenju. The current situation of $PM_{2.5}$ research and prevention and control measures. Guangzhou Chemical Industry,2012,40(23):22-24.

[2] Oberdo rster G. Sharn 7,A tndoroi V. Extrapulmonary translocation of ultrofin carbon narticles followingwhole-boby inhalation eyncnreof catc. Toxicol EnvironHealth A, 2002, 65(20):1531-1543.

[3] Wang Zhanhong, Li Jibiao. Dust retention capacity of evergreen shrubs and tree leaves in urban streets and the morphology of dust retention particles. Ecological Environment 2006 (02) 327-330.

[4] Xu J,Kuang HY,Wang WQ. An analysis of the relationship between PM2.5 and relative humidity of air. Agriculture and Technology, 2017, 37(09): 148-149+157.