Samarawickrama, Sumanthri, et al (eds), 2018, "Sustainability for people - *envisaging multi disciplinary solution": Proceedings of the 11th International Conference of Faculty of Architecture Research Unit (FARU), University of Moratuwa, Sri Lanka, December 08, 2018 Galle* pp. 308–315. ©

APPRAISING THE INFLUENCE OF LANDSCAPE DESIGN ON TRAFFIC GENERATED AIR POLLUTION OF URBAN PARKS

I. RAJAPAKSHA[1] & M. EKANAYAKE[2]
University of Moratuwa, Moratuwa, Sri Lanka
[1]indrika_rajapaksha@ymail.com, [2]indrika@uom.lk

Abstract

Urban parks are predominant constituents of an urban design which contributes to enhance the quality of life of city dwellers. Location of an urban park is an important design decision and the Public Outdoor Recreational Space (PORS) standard of Sri Lanka prioritizes the criterion of easy accessibility of park users. As the air pollution levels exaggerates in localities closer to major traffic routes it's vital to appraise the concentration of airborne pollutant levels in roadside parks. This study experimentally investigated roadside park of Independence Square (ISP) and the Water's edge (WEP). Onsite field investigation was performed on a typical weekday and weekend of each park. Traffic induced air pollution levels are interpreted with the ultrafine particle number (PNC) concentration levels amalgamated with the outdoor microclimatic thermal parameters. Results explicitly confirm air pollution levels inside the parks are lower than the roadside. Mean PNC of the core of ISP is 93.4% lesser than the corresponding road. Mean PNC of the core of WEP is 83% lesser than the roadside. Reduction of pollution inside the park is inversely related to Crown volume coverage of trees. Impact of pollution levels on distance from the road closely follows the roadside pollution levels and the distance of high pollution zone is different in both parks. Thus the findings of this study informs far reaching landscape design implications in composition and layouts to promote less polluted roadside urban parks in developing cities of tropics.

Keywords: *Roadside Parks; Landscape design; Ultra-fine particles; Particle number concentration.*

1. Introduction

Urban parks are integral part of an urban fabric, which contributes to enhance the quality of life of urban dwellers. With the burgeoning urban population in developing countries of Asia for next 30 years, tropical urbanization is an appealing global issue. Increasing population densities in the cities of Asia restrict the land availability for urban green spaces and evident for less prioritization of Public Open Recreational Space standards.

This phenomenon is not an exception for megacities in Sri Lanka. Furthermore, the specific criterion on easy accessibility has promoted robust integration of urban green spaces with prominent traffic arteries. With the increasing number of commuting vehicles and considerable slowing down of travel speeds demonstrates higher air pollution levels closer to major traffic routes. Thus informs the importance of understanding the impact of traffic emission air pollution on road side urban green spaces.

Studies on park users exposure to outdoor air pollution is an increasing research attention globally. Few studies have explored outdoor pollution dispersion profiles, exposure modelling and attenuation effect of urban vegetation in cities such as France, Belgium (Berghmans et.al, 2009), Tel-Aviv, Israel (Cohen.et al.2014), Thessaloniki, and Greece (Georgi et al.2006). Available limited research on countries in tropical Asia are Shanghai, China (Shan, Y.et.al. 2011), Hong Kong (Xing,Y.et .al.,2018), Bangalore, India (Vailshery, L. et al.,2013). Moreover a growing interest is evident on adverse health effects on parks users' exposure to traffic emissions (Brugge et al., 2007; Tam et al., 1987; Zhang and Batterman, 2013).
Impact of landscape design of urban parks on air pollution levels has been explored using field measurements and numerical simulations. Parametric studies of China inform urban trees and shrubs could ameliorate air quality by absorbing gaseous pollutant and trapping particulate matter (Beckett et

al., 1998, 2000). Moreover, confirms the pollution levels decreases with the distance from the road (Xing,Y.et .al ,2018).

Research on air pollution is less prioritised in Sri Lanka and no studies have been focused on the impact of traffic generated air pollution on urban open green spaces and its users. Thus, this study experimentally investigated the personal exposure to ultrafine particle concentration levels of adjacent traffic arteries and varying landscaping settings of the most popular urban parks in the Western province of Sri Lanka. Highly populated places of parks were considered in appraising the influence of vegetation characteristics in dispersion of traffic generated air pollution of each park.

2. Experimented Urban Parks

This study was performed in two highly popular urban parks situated in the city of Colombo (6.9° N, 79.8° E) in Western, Sri Lanka. City of Colombo represents the highest population density of the country with 3438 persons/Km² and it is the most congested city due to urban sprawl for economic and employment activities (Dept. census & Statistics, 2012). Moreover 60% of the vehicular fleet in Sri Lanka commute within the Western Province and the annual growth of national vehicular population is 12% (Jayarathne et al., 2015). Thus characterises the status of traffic densities and severity of traffic generated emissions on outdoor air pollution in City of Colombo and its suburbs. Location of the urban parks and its robust integration with adjoining roads are shown in Figure 1. Independence square (ISP) is an historical commemoration park positioned in highly urbanized area of Colombo. The façade landscape design of this park spreads in 2 Hectares with dense vegetation. Water's Edge Park (WEP) is a suburban wetland in Sri Jayawardhanapura, Kotte. This park contains 12 Hectares of land amalgamated with watershed environment and averagely dense vegetation. Both parks provide facilities for active and passive mode of exercises such as relaxing, walking and jogging.

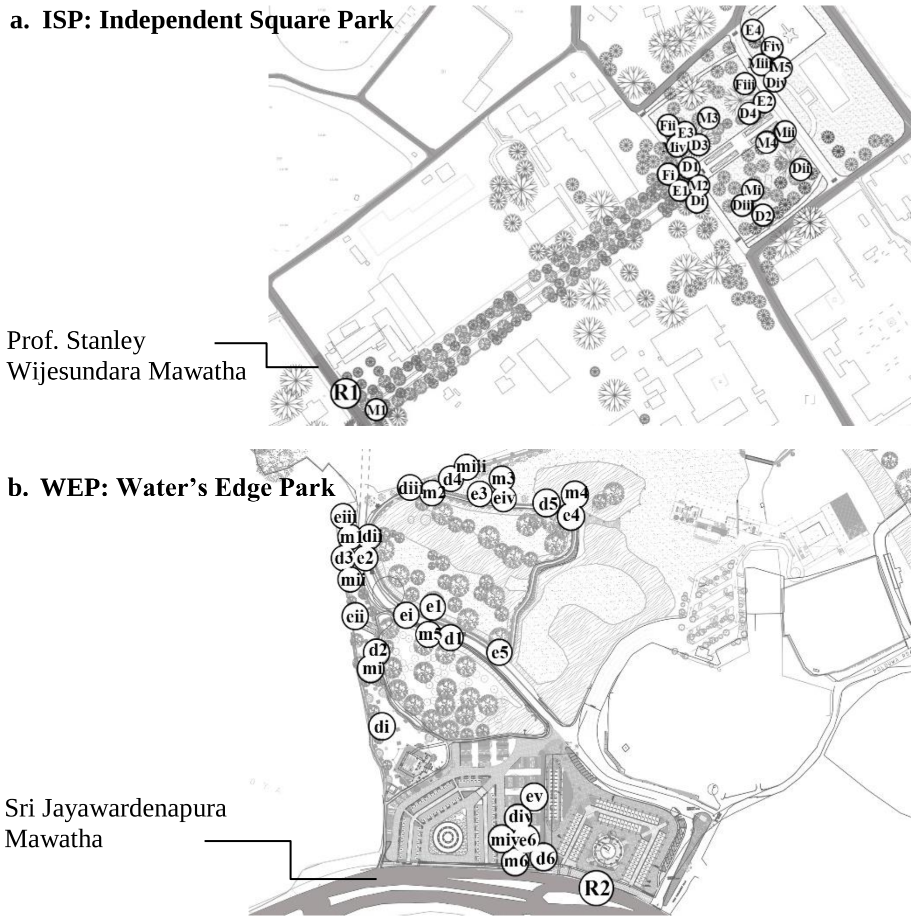

Figure 40, Landscape design including weekday and weekend peak usage profiles of experimental urban parks; (a) ISP *(microclimatic settings of M1 to E4 and Mi to Eiv and roadside measurement point R1)* and (b) WEP *(microclimatic settings of m1 to e6 and mi to ev and roadside measurement point R2)*

2.1 EXPERIMENTAL METHODOLOGY

The experimental methodology of this study is consists of a walk through survey, formulation of a tree inventory and an onsite field experiment to quantify the park users exposure to ultrafine particle concentration levels in varying microclimatic settings of the investigated parks.

2.1.1 Walkthrough survey: Mapping of the peak usage profiles

A walkthrough survey was performed on a typical weekday and weekend during three peak usage time slots such as Morning (M), Daytime (D) and Evening (E). Time periods for morning, daytime and evening are from 8 to 11am, 12 to 3pm and 4 to 6pm respectively. These peak usage profiles represent landscaping settings and park usage profiles of a typical weekday and weekend during the hot summer month of September, 2018 as shown in Figure 1. Figure 1a and b represent 25 and 31 peak usage settings of ISP and WEP respectively.

Table 1 include the details the Park usage profiles of each identified place such as number of park users, its distance from the road and Tree Crown Volume for weekday and weekend of ISP and WEP. Park usage profile of ISP and WEP in a typical week day and weekend consist of 12, 13 and 13, 18 places respectively. Moreover, both figures show peak usage profiles of each park and corresponding data acquisition location on the adjoining road as R1 and R2 in ISP and WEP respectively.

2.1.2 Recording of Landscaping characteristics

Landscaping characteristics of 56 places were recorded by developing tree inventories. This inventory is consists of four main variables of trees such as Species, quantity, height and diameter of the crown (Nowak, 2008). A three dimensional green quantity model was used as an indicator to characterise urban vegetation structure and which is represented as Crown Volume Coverage (CVC).

$$CVC = \text{Total Crown volume } (m^3) / \text{ Surface area } (m^2) \qquad (1)$$

This model considers the geometrical difference of the crown of tree species and combines the diameter (x), height (y) and coverage of the crown to calculate its CVC per unit area (Zhou, 2001). Crown volumes of all inventoried live trees were calculated using equation 1 and the common growth of each tree species was recorded by calculating the mean of diameter Xp and height Yp of the crown.

In addition the normalized crown volume (Vn) and CVC of the tree species were calculated. Total crown volume coverage (CVC) of identified microclimatic settings represents tree species located within 100m² coverage.

Table 1, Identified microclimatic settings of ISP and WEP representing details of peak usage profiles during a typical weekday and weekend (unit for distance: m and TCV: m³)

Day & Time	Independence Square Park ISP				Water's Edge Park WEP			
Weekend	Place	Users	Distance	TCV	Place	Users	Distance	TCV
Morning	M1	10	16.4	82.7	m1	30	322.3	128.6
	M2	20	345.4	202	m2	20	346	175.3
	M3	05	397.3	286.4	m3	40	321	61.6
	M4	10	421.9	151.5	m4	15	303	440.5
	M5	20	362	106.1	m5	08	222.8	186
					m6	50	35	93.8
Daytime	D1	15	345.4	202	d1	35	223.2	164.7
	D2	25	395	106.1	d2	25	267.6	233.5
	D3	10	364.7	329.2	d3	10	359	192
	D4	08	437.8	262	d4	08	378	330.5
					d5	20	325.9	250.4
					d6	40	31	75

Evening	E1	30	345.4	175	e1	20	260.7	214.3
	E2	10	422.9	187.5	e2	50	114.9	183.8
	E3	15	363.4	273.1	e3	90	322	235.6
	E4	15	486.5	31.3	e4	20	293.9	63.6
					e5	30	180	132.6
					e6	95	40.1	112.5
Weekday, Morning	Mi	06	360.4	279.2	mi	10	275.9	164.66
	Mii	05	419.8	133.6	mii	20	339.02	192.23
	Miii	20	477.7	31.3	miii	25	340.89	166.18
	Miv	05	359.2	242.7	miv	35	32.12	84.375
Daytime	Di	08	320.4	263.6	di	10	244	212
	Dii	12	431.6	170.4	dii	9	274.3	199.2
	Diii	25	377	97	diii	20	334.8	336.7
	Div	05	476.82	171.53	div	50	31	103.1
Evening	Ei	07	340.4	201.6	ei	7	244	106.2
	Eii	08	366.1	90.1	eii	14	274.3	172.7
	Eiii	15	379.3	31.3	eiii	25	334.8	128.6
	Eiv	30	428.6	261.9	eiv	30	314.1	182
	-	-	-	-	ev	40	33.2	131.3

2.1.3 Onsite experimental Investigation: Measurements of personal exposure to Ultrafine particles and microclimate of peak usage settings

Personal exposure to UFP levels were collected by two trained assistants carrying identical backpacks each containing newly calibrated NanoTracer with a sampling tube. Concurrent exposure to UFP was recorded on the road and corresponding microclimatic setting within the park. Sampling protocol was established to collect data for 10 minutes in each microclimatic setting with an acquisition time of 10 seconds. Moreover, microclimatic parameters such as air temperature (Ta), relative humidity (RH), and wind velocity (v) were measured in 56 places of investigated two parks. Prevailing wind direction was obtained from the Google Earth pro 2013.

3. Results and Discussion

3.1 EXPOSURE TO PARTICLE NUMBER CONCENTRATIONS

Park user's exposure to Particle number concentration (PNC) at the reference point on the roads and within microclimatic settings of ISP and WEP was appraised for a typical weekday and weekend.

*3.1.1 Independence Square Park (ISP) and adjoining road*Figure 2, shows the exposure to PNC levels in peak usage profiles of ISP and on the Sri Jayawardenapura Mawatha during a typical weekend and weekday. Typical weekday is consists of 13 places and (M1 to E4) and weekend represent 12 places (Mi to Eiv). Results explicitly prove exposure to PNC levels of all 25 places of ISP is lower than its corresponding road.

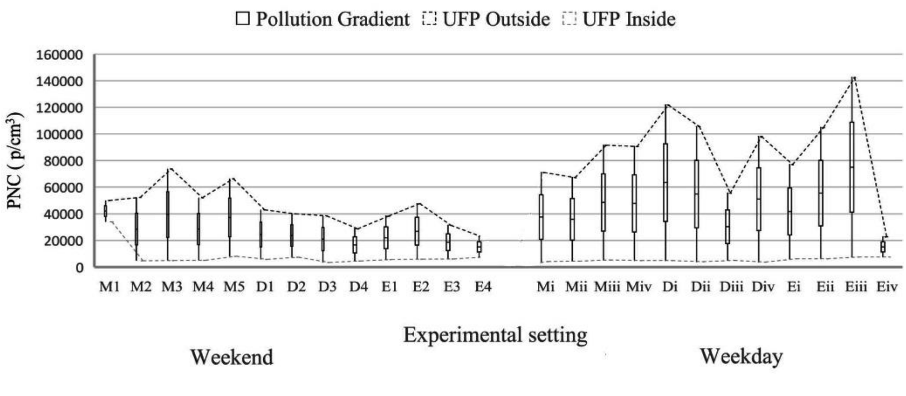

Figure 2, Exposure to PNC levels in ISP and road: Weekday and Weekend

In a typical day of the weekend, exposure to maximum PNC levels of 13 places within the park and adjacent road are 5820 and 98990 particles/cm^3 respectively. Similarly, in a typical weekday exposure to maximum PNC levels of 12 places within the park and adjacent road are 3795 and 128246 particles/cm^3. Exposure to typical UFP concentration on the pavement of Sri Jayawardenapura Mawatha is high in weekdays than the weekends. Thus informs the exposure to PNC levels in 25 microclimatic settings within a park during a weekend and weekday is 93.4% lesser than the roadside exposure.

3.1.2 Water's Edge Park (WEP) and adjoining road

Park user's exposure to PNC levels of the microclimatic settings of the peak usage profiles of WEP and Sri Jayawardenapura Mawatha during a typical weekend and weekday is shown in Figure 3. Peak usage profile of a typical weekday is consists of 13 Places (mi to ev) and 18 places (m1 to e6) represents the typical weekend. These profiles are categorised into the peak usage settings during morning, daytime and evening time periods.

Maximum PNC levels of the 31 places of WEP are 17576 and 11916 particles/cm^3 during a typical day in the weekend and weekday respectively. PNC levels of the adjacent road varies in the range from 49850 to 61975 particles/cm^3 during a typical day in the weekend and weekday respectively. Significant difference in exposure to PNC levels is not evident for road side during a typical day in the week and weekend.

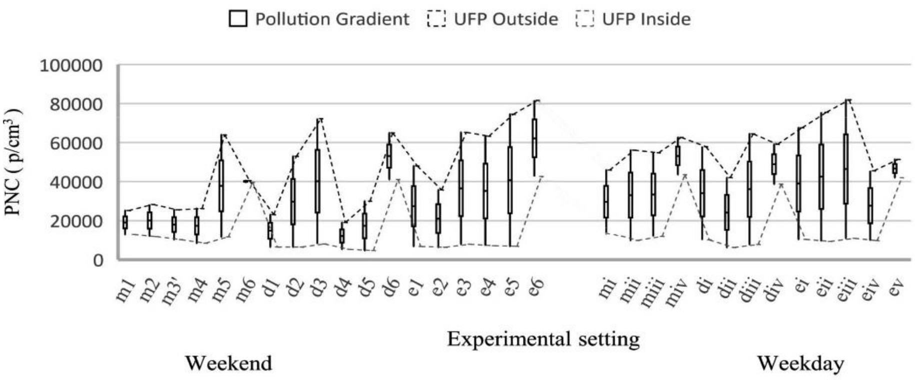

Figure 3, Exposure to PNC levels within WEP and its adjacent road during a typical weekday and day in the weekend

3.2 COEFFICIENT OF VARIANCE OF PARTICLE NUMBER CONCENTRATIONS

Coefficient of Variance and Mean PNC levels during three time periods of a typical weekday and weekend of adjacent road and all places of peak usage profiles of ISP and WEP is given in Table 2.

Table 2, Mean and Coefficient of variation of PNC during three time periods of a typical weekday and weekend of ISP and WEP

		ISPWEM	ISPWED	ISPWEE	ISPWDM	ISPWDD	ISPWDE
Mean (p/cm^3)	Out	58900.51	37509.4	35000.70	80079.2	95231.20	103937.6
	In	11357.88	5339.31	6347.84	4754.98	4466.49	6459.17
CV%	Out	17.86	16.46	30.36	16.0	29.68	27.00
	In	111.8	31.52	13.31	10.79	14.55	12.17
		WEP WEM	WEP WED	WEP WEE	WEP WDM	WEP WDD	WEP WDE
Mean (p/cm^3)	Out	34959.84	43686.94	61386.70	54906.28	55879.34	64403.50
	In	15814.27	12015.67	12932.44	19696.04	15742.63	16480.36
CV%	Out	43.83	51.98	27.67	12.53	17.29	24.13
	In	74.41	119.1	11.25	81.27	98.04	86.73

(WEM: Weekend Morning; WED: Weekend Daytime; WEE: Weekend Evening; WDM: Weekday Morning; WDD: Weekday Daytime; WDE: Weekday Evening)

Mean and the percentage of CV were used as numerical descriptors to analyze the time series dispersion and distribution of PNC levels of ISP and WEP. The statistical indicators show a lesser CV% on roadside in comparison to places within the park. The high CV% measures inside for ISP and WEP evident high exposure levels within the park. Comparatively higher CV is recorded inside the WEP more than the ISP respectively which evident the agglomeration of lower PNC levels to increased PNC levels inside the park precincts. The results highlight the uniqueness of urban parks in attenuation of traffic emitted air pollutants, thus informs the importance of landscape design to mitigate PNC level to maintain lower CV% which will ensure lesser exposure of park users in roadside urban parks.

3.3 INFLUENCE OF LANDSCAPE CHARACTERISTICS ON EXOSURE TO PNC LEVELS

3.3.1 Effect of vegetation cover

Normalized crown volume (Vn) of trees was measured by applying the three-dimensional green quantity model in respective to the tree composition of the identified 56 places of both parks as showed in table 3.

Table 3, Crown volume of 17 common tree species in investigated parks. (CVC- Crown volume Coverage)

Tree Species	3D Geometric Figure	CVC	n	$\overline{X}$ (m)	$\overline{Y}$(m)	$\overline{V}$(m^3)
Terminalia arjuna	Oval	$\pi x^2 y/6$	3	3.5	4.8	30.78
Persea americana	Oval	$\pi x^2 y/6$	5	3.9	6.3	50.17
Mangifera indica	Oval	$\pi x^2 y/6$	4	4.1	`3.8	33.44
Averrhoa bilimbi	Sphericity	$\pi x^2 y/6$	6	2.1	4.2	9.69
Roystonea regia	Segment	$\pi(3xy^2-2y^3)/6$	8	3.3	4.3	31.26
Peltophorum pterocarpum	Oval	$\pi x^2 y/6$	6	6.1	7.2	140.27
Polyalthia longifolia	Cone	$\pi x^2 y/12$	5	2.8	11.7	24
Plumeria obtusa	Segment	$\pi(3xy^2-2y^3)/6$	8	3.2	4.3	9.68
Millettia pinnata	Oval	$\pi x^2 y/6$	11	3.2	3.5	18.75
Samanea saman	Sphericity	$\pi x^2 y/6$	8	10	7.5	196.34
Delonix regia	Segment	$\pi(3xy^2-2y^3)/6$	4	5.3	4.1	77.62
Azadirachta indica	Oval	$\pi x^2 y/6$	6	4.1	7.1	62.49
Lagerstroemia speciosa	Oval	$\pi x^2 y/6$	14	3.5	4.3	27.56
Syzygium caryophyllatum	Oval	$\pi x^2 y/6$	8	3.5	4	25.6
Aegle marmelos	Oval	$\pi x^2 y/6$	2	4.5	6	63.585
Pagiantha dichotoma	Oval	$\pi x^2 y/6$	1	2.1	3.5	8.07
Dillenia triquetra	Oval	$\pi x^2 y/6$	7	5.2	7	99.05

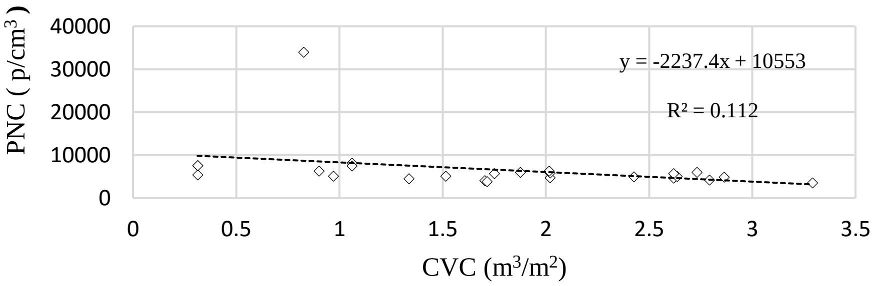

Figure 4, Relationship of CVC and PNC levels for ISP

Figure 4 and 5 show the impact of CVCs on PNC levels in ISP and WEP respectively. Results demonstrate a negative co-relationship between PNC and CVC for both parks.

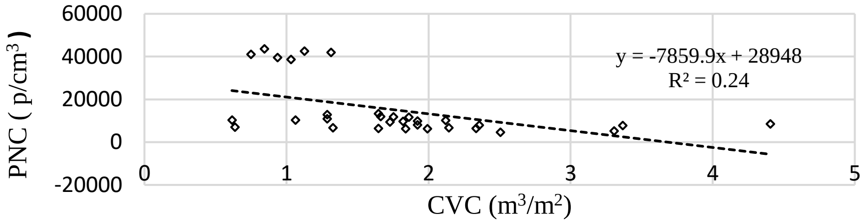

Figure 5, Relationship of CVC and PNC levels for WEP

Results inform an inverse co-relationship between PNC level and measured direct distance from the corresponding location on the adjoining roads of both parks. It is apparent that the PNC levels decreased from a distance of 300m and 100m from the roadside in ISP and WEP respectively. Thus proves less polluted zones of each park is different and informs the need of place specific landscape design strategies to lessen the park users exposure to traffic generated air pollution in roadside parks.

In addition PNC levels of both parks were compared using vegetation characteristics such as calculated tree crown volumes (TCV). Vegetation demonstrates a potential to control dispersion of particles. Thus highlights the importance of an effective layout and vegetation structure to reduce traffic emitted pollution dispersion within the roadside parks.

3.3.2 Distance from the road and exposure to PNC levels

Figure 6 shows the variation of exposure to PNC level in relation to distance for the adjoining road for both parks

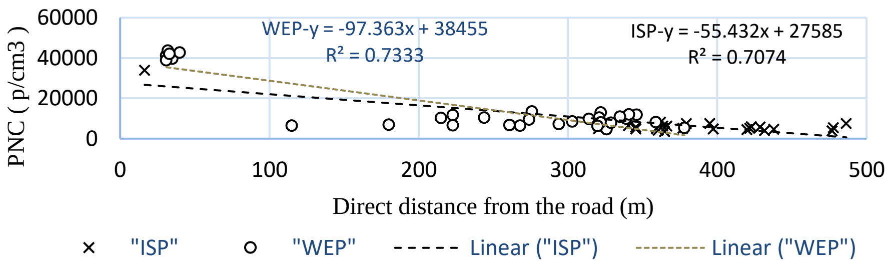

Figure 6, Relationship of distance from the road and PNC levels

3.4 OUTDOOR MICROCLIMATE

Figure 7 shows the relationship between measured microclimatic parameters and PNC levels in relation to an agglomerating correlation matrix. Mean correlation matrix indicate a positive correlation between T and PNC level (P>0). A moderate inverse correlation was observed between PNC count and the RH and *V* (P<0). In WEP the correlation matrix shows steady fluctuation comparing to the ISP. Thus, the results inform differences in co-relation of microclimatic parameters and PNC levels.

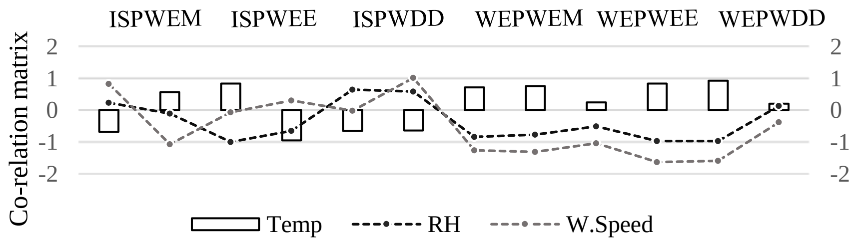

Figure 7, Correlation matrix for PNC varying with T,RH and V

Thus, this preliminary investigation shows the potential of landscape design in generating varying thermal microclimate to mitigate traffic generated PNC levels within the parks and exposure of park users.

4. Conclusion

Influence of landscape design on traffic generated air pollution of roadside urban parks of Independence Square (ISP) and Water's Edge (WEP) were explored in this study. Peak usage profiles of the parks identified 56 microclimatic settings for both parks. An onsite experimental investigation was conducted to measure park users exposure to Particle Number Concentration of Ultrafine particles and microclimatic parameters. Moreover characteristics of vegetation were recorded to evaluate the effect of landscape designs of the urban green spaces.

Dispersion profile of traffic generated air pollution is comparatively less than the adjoining roads thus prove the potential influence of urban green spaces in reduction of outdoor air pollution. Mean PNC levels within the parks were 80 to 90% lesser than roadside. It's evident that the pollution levels inside the suburban park of WEP is higher than the urban park of ISP which controlled by different vegetation coverage. Furthermore, mean CVC of parks confirms the air pollution reduction levels of both parks.

Significance of thermal microclimates in PNC levels demonstrates the landscape design generates microclimatic diversities which influences in reduction of traffic generated air pollution within the park. Thus, the study informs far reaching landscaping design implication on vegetation structure and its morphology in promoting healthy open green spaces in urban settings.

5. Acknowldegment

This research was funded by the SRC/ST/2018/23 grant of the Senate Research Council, University of Moratuwa

6. References

Beckett, K.P., Freer-Smith, P.H., Taylor, G., 1998. Urban woodlands: their role in reducing the effects of particulate pollution. Environmental Pollution 9, 347e360.

Berghmans et.al, 2009.Exposure assessment of a cyclist to PM10 and ultrafine particles. Sci.Total Environ. 407(4):1286-98

Brugge, D. Durant, J.L., Rioux, C., 2007. Near-highway pollutants in motor vehicle exhaust: a review of epidemiologic evidence of cardiac and pulmonary health risks. Environment Health 6.

Cohen P., Potchter,O.,Schnell .I,2014.The impact of an urban park on air pollution and noise levels in the Mediterranean city of Tel-Aviv, Israel. Sci.Total Environ. 195 Pages 73-83

Department of census & Statistics, 2012. Census of Population and Housing 2012 Sri lanka - Final Report

Georgi,N., Zafiriadis K.,2006.The impact of park trees on microclimate in urban areas. Urban Ecosystems. 9, pp 195–209

Jayarathne, R.,Jayawardhane,N. Premasiri,H., Rajapaksha.,K,2015.Air pollution levels in major urban cities in the Western Province in Sir Lanka.NBRO -Innovation for Resilient Environment.

Nowak, D.J., 2008. Assessing urban forest structure: summary and conclusions.

Arboriculture & Urban Forestry 34, 391e392.

Shan,Y .,Shen,Z., Zhou,P., Zou, X., Che,S.,Wang,W., 2011.Quantifying air pollution attenuation within urban parks:An experimental approach in Shanghai, China: Environmental Pollution. 159 pg., 2155-2163

Tam, N.F.Y., Liu, W.K., Wong, M.H., Wong, Y.S., 1987. Heavy metal pollution in roadside urban parks and gardens in Hong Kong. Sci. Total Environ.

Vailshery,L., Jaganmohan,M ., Nagendra ,H., 2013.Effect of street trees on microclimate and air pollution in a tropical city. Urban Forestry & Urban Greening. 12 pg. 408–415

Xing, Y., Brimblecombe, P., 2018. Dispersion of traffic derived air pollutants into urban parks. Sci.Total Environ. pg. 576–583

Zhang, K., Batterman, S., 2013. Air pollution and health risks due to vehicle traffic. Sci.Total Environ. 450:307–316.

Zhou, Y., Zhou, J.H., 2001. The urban eco-environmental estimation system based on3-dimension crown volume. Chinese Landscape Architecture 5, 77e79.