

RESEARCH REPORT

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Experimental mapping of Ultra-Fine Particle incidence in roadside urban schools: A critical case approach for Colombo Metropolitan Region

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1. INTRODUCTION

Indoor air pollution is a major global public health threat requiring greatly increased efforts in the areas of research and policy making. There is an escalating scientific and medical evidence that exposure to fine ($<2.5 \mu\text{m}$) and ultrafine ($<0.1 \mu\text{m}$) particulate matter could have relatively more significant health implications than exposure to larger particles or to other airborne pollutants (WHO, 2002).

In urban settings there are diversities in particle number concentrations in urban backgrounds and localities closer to major traffic arteries. While urban backgrounds represent few thousands (10^3) to 20,000 (10^4) particles per cm^3 , particle concentration exceeds to the levels of 10^5 particles per cm^3 near roads and increases up to ten times higher than the levels of urban background (Morawska, 2004). Moreover, the highest pollutant levels prevail within 150 m from roadways and remain high up to 300 m away from the roadway (Zhu, 2002). Thus, the people living or working near major urban roads are likely to be exposed to high ultrafine particle levels. Numerous studies suggested an association between living near traffic roads and the occurrence of health-related problems or diseases (Hoek *et al.*, 2002; McConnell *et al.*, 2006; Nitta *et al.*, 1993).

Rapidly increasing trend in the vehicle fleet is not an exception for Sri Lanka. The latest statistics of the Department of Motor Traffic shows a remarkable growth of 44% in the vehicle fleet of Sri Lanka from the years 2006 to 2013. Moreover, the composition of this vehicle fleet with 20% of high polluting diesel vehicles, 52% of motorcycles and 16% of three wheelers reinforce vehicular emissions as the main source of outdoor air pollution, which contributes to 60% of the total emissions in Colombo.

Colombo Petroleum Corporation and Lanka Indian Oil Company data on sales of auto diesel reveals that the highest consumer purchases are in the Colombo district and the demand increases by 30% from the year 2013 to 2014. Thus, it is paramount important to investigate the concentration of traffic generated fine and ultrafine particles in highly urbanized region of Colombo and to understand its effects on indoor built environment and occupants.

Although the indoor contaminants are composed of a mixture of pollutant gases and particulate matter, considerable quantity of fine and ultrafine particles originated from exhaust gases of motor vehicles penetrates to interiors through infiltration (Lin *et al.*, 2002). Poor indoor air quality is associated with higher risk of chronic obstructive pulmonary disease and acute respiratory infections, particularly for vulnerable groups such as children (Bruce *et al.*, 2000; Kumar *et al.*, 2008).

The burgeoning trend in the prevalence of respiratory illnesses among children is a crucial public health threat for Sri Lanka. Hospital admissions data of two leading national hospitals reveals the total outpatient morbidity of 45% was due to diseases in the respiratory system. Thus, the respiratory illnesses are accountable for second leading cause of hospitalization in Sri Lanka over past 5 years and the second foremost cause for death of children aged 5 to 14 years.

School is the major indoor environment for school-age children. A child typically spends 1300 hours in a school building each year (Day DR, 1995). However, several studies have shown that the school environment is often poor with high concentrations of pollutants, low air exchange rates and high room temperatures (Daisey *et al.*, 2003; Shendell *et al.*, 2004; Simons *et al.*, 2010).

Several studies detected high indoor PM (Particulate Matter) levels in school classrooms (Fromme *et al.*, 2007; Janssen *et al.*, 2001; Keeler *et al.*, 2002; Roorda-Knape *et al.*, 1998; Scheff *et al.*, 2000; Smedje and Norback, 2001; Stranger *et al.*, 2007). Poor indoor air quality of schools is evident for an increase in health symptoms and impair student performance (Mendell and Heath, 2005; Wargocki, 2008).

A comprehensive literature review on air quality and health research in Sri Lanka reveals that, there are ten and six epidemiologic studies on outdoor and indoor air pollution respectively. Even though the studies on indoor air pollution focus on respiratory health of children the major methodological limitations of these studies are on air quality measurements and questionnaire based on personal exposure assessment. Moreover, these studies are primarily focused on indoor environments with clearly identified pollutant sources such as firewood smoke of cooking, mosquito coils and also industrial environments (Lankathilaka *et al.*, 2000; Karunasekara *et al.*, 2001 & 2005).

However, it is apparent that the few available research on respiratory health of school children in Colombo, Ampara and Kandy districts are based on the coarse particles above 10 μm (PM₁₀) in the immediate vicinity of the schools. Thus, proves a limited research attention on indoor air quality of school buildings.

Characteristically urban schools are positioned along major roadways and majority of the classrooms are predominantly naturally ventilated. Thus, assures the significance of investigating the relationship between the traffic exhaust emissions and indoor environments of classrooms in urban schools of Sri Lanka.

Findings of this research will instigate a prominent breakthrough in indoor air pollution research in Sri Lanka by quantifying and identifying the range of fine and ultrafine particles in classrooms and school environments in Colombo and its impact on respiratory health of school children.

1.1. Distribution of Roadside schools in Colombo District

The focus of this research is to experimentally investigate the ultrafine particle number concentration levels inside the classrooms and immediate outside of roadside urban schools. Thus, it is important to compare the distribution of roadside schools and major traffic route network in Colombo district as a strategy to justify 'critical schools' selected for onsite experimental investigation of this research. Figure 1a and b illustrate the distribution of roadside schools and major traffic routes in Colombo district respectively.

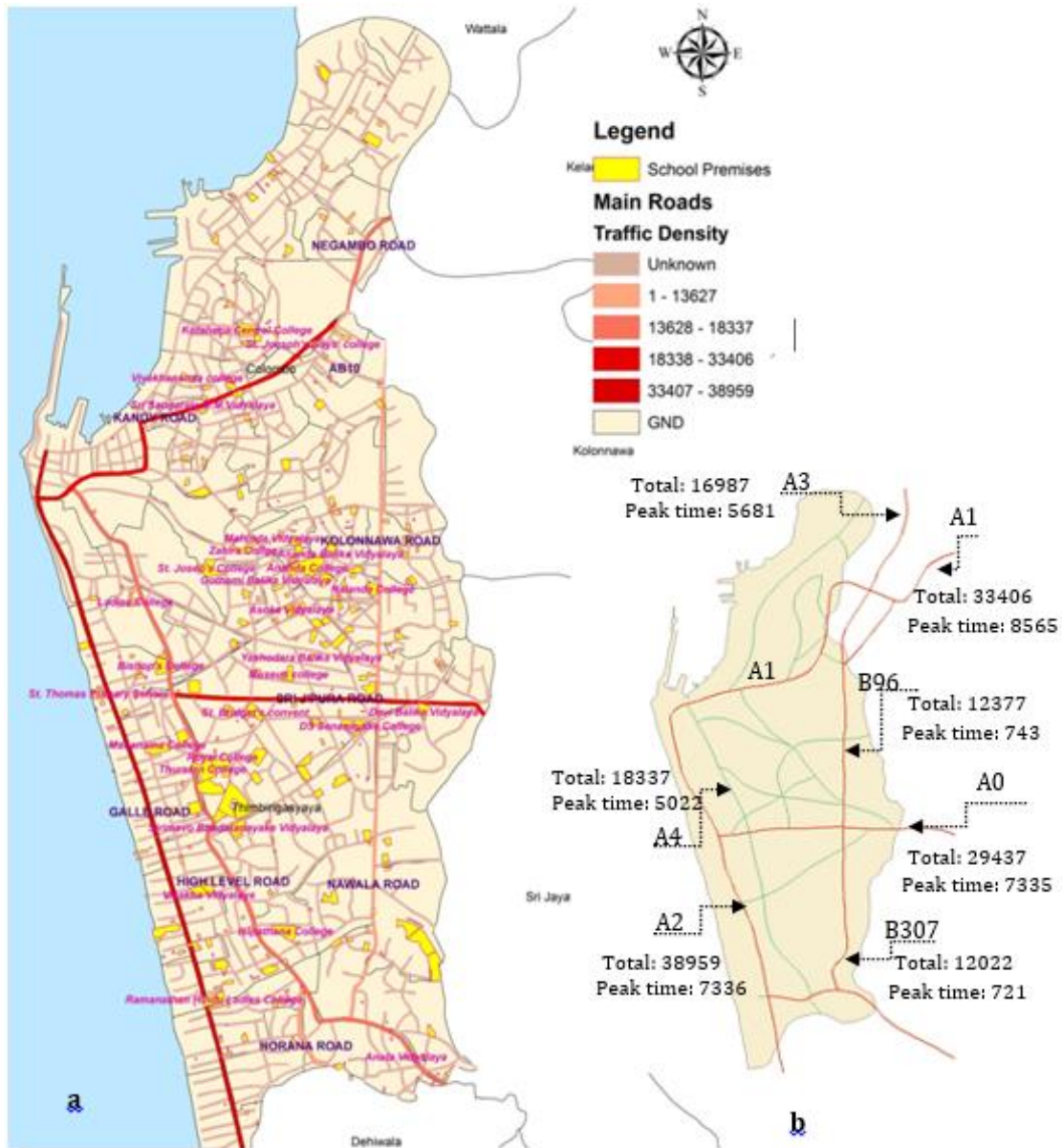


Figure 1 - Distribution of schools in Colombo District and their relationship with the traffic network

As shown in Figure 1, majority of the schools in Colombo district are located proximity to a road and the integrated roads differs with a variation in traffic density. Figure 1b, shows the characteristics of traffic route network in Colombo district and the associated data is illustrated in Table 1.

As shown in Table 1, Class A roads are mostly congested and with high traffic densities compared to class B roads. All schools in the Colombo district are positioned in relation to the network of most of the major roads of Class A and few of class B roads are integrating to the Class A roads.

Table 1 - Characteristics of the major traffic arteries flows through Colombo District

Class	Code	Road	Total Vehicles/hr	Vehicles/Peak
A	A2	Galle road	38959	7376
	A1	Kandy road	33406	8565
	A0	Sri Jayawardena Pura road	29437	7335
	A4	High Level road	18337	5022
	A3	Negombo road	16987	5681
B	B435	Avissawella road	14113	988
	B84	Horana road	13627	4616
	B96	Kolonnawa road	12377	743
	B307	Nawala road	12022	721
	B62	Kotte road	10623	531
	B152	Canal road	7395	296

1.2. Assessment on positioning of roadside schools

Positioning of school in relation to the major traffic route is one of the predominant criteria in selection of critical schools for onsite experimental investigation of this research. Thus, Table 2 and Table 3 show the positioning of schools in relation to ‘Class A’ and ‘Class B’ roads and the distance from the road, respectively. As shown in Table 2, 19 schools are integrated with ‘Class A’ roads classified as A₂, A₄, A₁ and A₀.

Table 2 - Positioning of schools along Class A’ roads in Colombo

Class	Code	School	Distance from road (m)
A	Galle road A2	Holy Family Convent	65
		St. Peter’s College	120
		St. Thomas College	162
		Ramanathan Hindu Ladies College	210
		Visakha Vidyalaya (Colombo 5)	250
		Mahanama College (Colombo 3)	275
	A4: High Level road	Anula Vidyalaya	25
		Lumbini College (Colombo 5)	115
		Bishop’s College	120
		Thurstan College	150
		Royal College	250
		Isipathana College	275
		A1: Kandy road	St. Joseph’s College
Sri Sangaraja M.M.V	80		
Vivekhananda College	115		
Kotahena Central College	150		
A0: Sri J’Pura road	St. Bridget convent	CWW Kannangara Mw.	155
		Dudley Senanayake Mw.	195
	Museaus College	CWW Kannangara Mw.	350
		Wijerama Mw.	200
	Devi Balika Vidyalaya	200	

All schools are positioned within the distance of 300 m from the respective road. Among them 16 schools are positioned proximity to high density traffic routes in Colombo such as Galle road (A₂), High Level road (A₄) and Kandy road (A₁).

As shown in Table 3 integrated roads of Class B are classified as B96 and B307. The road B96 is the Baseline Road which represents an extension of road B307. Class B roads are integrated with 5 schools. Other than the respective Class B Road, all these schools are integrated with other roads.

Furthermore except for a single school (Gothami Balika Vidyalaya) all other schools are positioned within the distance of 300 m from all integrated roads.

Table 3 - Positioning of schools along 'Class B' roads of Colombo

Class	Code	School	Other roads	Distance from road (m)
B	B96: Dr. Danister De Silva Mawatha (Baseline road)	Weluwana College	Kolonnawa road	200
		Nalanda College	Sri Dhamma Mw.	100
			Dr. Danister De Silva Mw.	245
		Gothami Balika Vidyalaya	P.D.S. Kularathna Mw.	250
			Ananda Rajakaruna Mw.	200
		Dr, Danister De Silva Mw.	600	
	B307	D.S.Senanayake College	DS Senanayake Mw.	145
			RG Senanayake road	75
			Wijerama Mw.	150
		Rathnavali Balika M.V.	Gunarathna Pradeepa Mw.	90
Borella crossroad	200			

Table 4 - Schools positioned alone by roads of the major roads

Class	Code	School	Closely integrated road	Distance from road (m)
A & B	B ₉₆ & A ₄	Mahinda Vidyalaya	Baseline road (B ₉₆)	550
		Zahira College	Baseline road (B ₉₆)	1250
			High Level road(A ₄)	1500

Schools positioned away from major roads of Class A and B are shown in Table 4. These two schools are positioned beyond 300 m from the corresponding major roads of B96 (Baseline road) and A4 (High Level road). These schools represent the criterion to be considered as the reference school of this experimental investigation and Mahinda Vidyalaya was selected.

1.3. Roadside schools affected by other pollutant sources: Sea breeze

The primary objective of the experimental investigation is to assess the impact of traffic air pollution. Since the geographical positioning of City of Colombo proximity to western coastal line sea breeze will promote an association in air pollution levels of schools. The impact of multiple pollutant sources is predominantly evident for schools positioned closer to the Galle road. Table 5 shows the list of schools along Galle road and distance from sea. These 05 schools were not considered in the selection process of critical schools of this research due to the influence of multiple pollutant sources.

Table 5 - Roadside schools along Galle road and distance from sea

Class	Code	School	Distance from Sea (m)
A	A2: Galle road	Holy Family Convent	90
		St. Peter's College	575
		St. Thomas College	250
		Ramanathan Hindu Ladies College	625
		Visakha Vidyalaya (Colombo 5)	650

1.4. Justification for selection of 'Critical roadside schools'

A critical case is different from a case study. These cases provide evidence relating to more general characteristics of the issues of concern. As an example, it can contribute to the cumulative development of knowledge through the ability to summarize the findings into general positions and theories (Flyvbjerg, 2006). A study such as this contributes through its ability to delve into a particular cause and effect scenario, which is central to the decision-making process.

'Critical schools' of this experimental investigation were selected based on its location in respective to the distance from the major roadways and traffic emissions as the only pollutant source. The specified critical distance is positioning of a school within a distance of 300 m from the closest major road. Thus, the eligibility criteria for selection of 'critical roadside school' is as follows;

- Location of a school within 300 m distance from a major road
- Not exposed to other major air pollution sources other than traffic emissions
- Not in the vicinity of any major infrastructure project (construction sites)
- Schools with a primary section (Grades 3 to 5)
- School children within the age group of 8 to 11 years old
- Predominantly Naturally ventilated classrooms (with the option of ceiling fans)

1.5. Selected 'Critical roadside schools'

The selected critical roadside schools for onsite experimental investigations are shown in Table 6. Table 6 shows the positioning characteristics of the critical roadside school in respective to the distance from the adjacent major traffic artery and the distance from the sea.

Table 6 - 'Critical roadside schools' of the onsite experimental investigation

School	Major road	Other roads	Distance (m)	
			From road	From sea
Isipathana College	A4: High Level road	Park road	295	1500
			115	
Thurstan College	High Level road		150	2200
Mahanama College	Galle road	R. A. De Mel Mawatha	275	600
			120	
Nalanda College	Sri Dhamma Mawatha		100	3375
	Dr. Danister De Silva Mawatha		245	
Anula Vidyalaya	High Level road		125	2950
Mahinda Vidyalaya	Gunarathne Pradeepa Mawatha		545	3200
	Dr. Danister De Silva Mawatha		614	

Furthermore, the selected 05 critical roadside schools are consisting of school children in the age range of 8 to 11 years studying in naturally ventilated classrooms of Grade 3 to 5. The Mahinda Vidyalaya which is beyond the critical distance of 300 m from major road is considered as the reference school of this research. This reference school satisfies all other criterions except for its positioning of 300 m away from the major road.

2. ONSITE EXPERIMENTAL METHODOLOGY: Realtime Monitoring

Onsite experimental investigation was a significant component of this research. This onsite experimental investigation was composed of two main phases such as pilot and detailed investigations. During the onsite experimental investigations ultra-fine particle number concentration (PNC) of outdoor and indoor environments of the critical roadside schools were measured simultaneously. Ambient PNC of UFP was measured on roadside pavement towards the school and indoor PNC of UFP was measured inside all classrooms of Grade 3 to 5 of 06 critical roadside schools.

Table 7 shows the number of classes experimentally monitored during onsite investigations of each school.

Table 7 - Onsite experimental plan of critical roadside schools

School	Number of primary classrooms			Total
	Grade 3	Grade 4	Grade 5	
Isipathana	A – G	A – G	A – G	21
Thurstan	A – C	A – C	A – C	09
Mahanama	A – F	A – F	A – F	18
Nalanda	A – E	A – E	A – E	15
Anula	A – F	A – F	A – F	18
Mahinda	A – C	A – C	A – C	09
Total number of primary classrooms investigated				90



Figure 2 - Onsite experimental investigation within and immediate outside of the classrooms

The total number of 90 classrooms of Grade 3 to Grade 5 of 06 critical roadside schools were experimentally investigated to quantify particle number concentration of UFP in naturally ventilated classrooms. Moreover, Traffic intensity of corresponding roads were recorded through manual count of vehicles entering and exiting from the school zone during 03 primary time zones such as in morning, afternoon and evening. Onsite experimental investigations were performed from 7.30 am to 5.30 pm on weekdays continuously in all critical schools.

Figure 2 shows the equipment used in the experimental investigations of classrooms and measuring of air pollution levels along outdoor corridor. The distance from the major roads to the school premises and the target classrooms have been recorded. Some schools have very short distance to the indoor buildings while some having a considerable distance due to the playgrounds and the green spaces surrounding the schools.

2.1. Isipathana College

Isipathana College is located in Park Lane, Colombo 05. Park lane is a by road with less traffic and the school is positioned 295 m away from the High-Level road (Class A road: A4). The area between the school and major road contains an urban playfield. Figure 3 shows the master plan of Isipathana College with the associated road network and primary classrooms.

Table 8 - Positioning of school and primary classrooms from major road (A4)

Major road	Average distance from road (m)	
A4: High Level road	distance to front of the school	295
	distance to Grade 3-5 classroom blocks	340
	distance to Ground	405

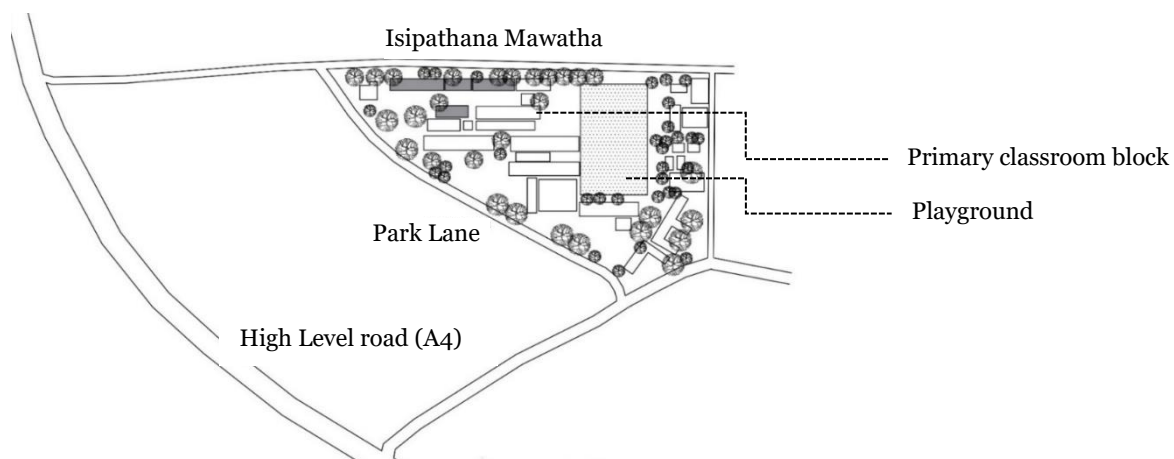


Figure 3 - Masterplan of Isipathana College with primary classrooms and immediate outdoor environment

As shown in Figure 3, the school closely associates with the Park Lane and rear edge is bounded by Isipathana Mawatha. Table 8 shows the distance to primary classrooms and the school playground from the major road (A4). Primary classrooms (Grade 3-5) are positioned 100 m away from the closest road, Park Lane. School contains considerable amount of vegetation within its premises.

As shown in Figure 3, all primary classrooms (Grade 3 to 5) are primarily naturally ventilated, and openings are protected with steel wire mesh. All classrooms are accessed through a corridor which opens to a paved playfield. Construction details of the primary classrooms are given in Table 9. As shown in Table 9, a typical primary classroom is finished with cement plastered floor, plastered and painted cement block walls and a roof covered with asbestos roofing sheets. There are no windows but the openings on walls are protected with steel wire mesh. Majority of the classrooms are fitted with O2 and O1 ceiling and wall mounted fan, respectively. Classrooms of Grade 3 to 5 are placed in the Ground and first floor of two building blocks constructed in 1974. Each grade consists of 06 classrooms with a student population of 243, 249 and 295 students in Grade 3,4 and 5, respectively.

Table 9 - Construction details of primary classrooms

Roof	Floor	Walls	Windows	Mode of ventilation
Gable roof with asbestos roofing sheets	Polished cement rendered	Cement blocks, plastered and painted	Steel mesh No daylight controls	Natural ventilation Mechanical ventilation from 03 fans

2.2. Mahanama College

Mahanama College is positioned along R.A. De Mel Mawatha and in addition, it connects with the Class A, Galle road (A2) due it's geographical positioning. Both roads run parallel to each other and connects to a loop through one-way traffic. Table 10 shows the distance of both roads to primary classrooms of the school. As shown in Table 10, primary classrooms are positioned at a distance of 200 m and 400 m from R.A. De Mel Mawatha and Galle road, respectively.

Table 10 - Positioning of school and primary classrooms from neighbouring roads

Major road	Average distance from road (m)	
R.A. De Mel Mawatha	Distance to front of the school	120m
	Distance to Selected classrooms	200m
Galle road	Distance to front of the school	275m
	Distance to Selected classrooms	400m

Figure 4, shows the masterplan and the monitored primary classroom block. As shown in the masterplan, school playground is positioned closer to the adjoining road and school buildings are positioned 100 away from the road. 80% of the playground is covered with grass and vegetation within the school premises is less.

As shown in Figure 4 all primary classrooms are naturally ventilated. Openings on walls are fixed with steel grills and there are no proper windows. Each classroom has O2 ceiling fans and a single wall mounted fan. Primary classroom block was built in 2001 and grade 3 to 5 is composed of 06 classrooms for each grade. The student population of grade 3,4 and 5 are 243, 249 and 295 students, respectively.



Figure 4 - Master plan of Mahanama College and surrounding environment of primary classroom block

Table 11 - Construction details of primary classrooms

Roof	Floor	Walls	Windows	Mode of ventilation
Gable roof with asbestos roofing sheets	Polished cement rendered	Cement blocks, plastered and painted	Steel grills No daylight controls	Natural ventilation Mechanical ventilation from o3 fans

As shown in Table 11, a typical primary classroom is finished with cement plastered floor, plastered and painted cement block walls and a roof covered with asbestos roofing sheets. There are two classroom blocks for grade 3 to 5 and both are similar o3 storied buildings. Other than the few classrooms of Grade 4 located in the ground floor majority of the classrooms of Grade 3, 4 and 5 are positioned in 1st and 2nd floors of both classroom blocks.

2.3. Nalanda College

Nalanda college is situated in Colombo 01 and bounded by a network of o3 roads. School maintains close association with Sri Dhamma Mawatha and the neighboring major road is Dr. Danister De Silva road (B96). Table 12 shows positioning of primary classrooms in respective to associating roads. As shown in Table 12 primary classrooms are placed 120 m and 210 m from Sri Dhamma Mawatha and Dr. Danister De Silva road, respectively.

Table 12 - Positioning of school and primary classrooms (Grade 3 to 5) from neighbouring roads

Major road	Average distance from road (m)	
Sri Dhamma Mawatha	Distance to school	100
	Distance to Selected classrooms	120
	Distance to playground	200
Dr. Danister De Silva Mawatha	Distance to school	245
	Distance to Selected classrooms	210

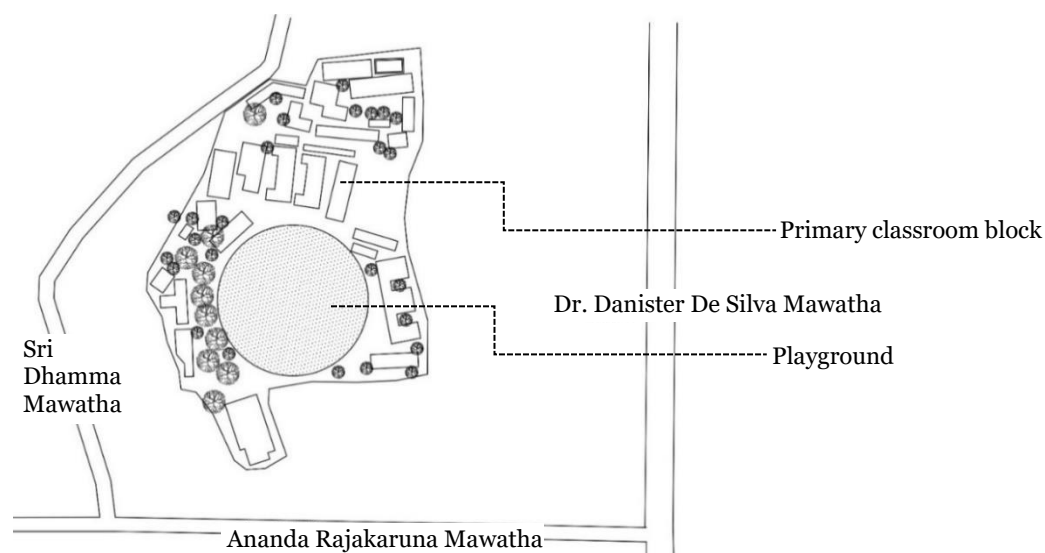


Figure 5 - Master plan of Nalanda College and surrounding environment of primary classroom block

Table 13 - Construction details of primary classrooms

Roof	Floor	Walls	Windows	Mode of ventilation
Gable roof with asbestos roofing sheets	Polished cement rendered	Cement blocks, plastered and painted	Steel grills No daylight controls	Natural ventilation Mechanical ventilation from O3 fans

Figure 5 illustrates the masterplan of the school along with surrounding primary classroom block. A circular playground amidst classroom buildings with all peripheries bounded by school buildings can be observed. All primary classrooms are predominantly naturally ventilated with fans and the openings on outer walls are protected with steel grills. Primary classrooms represent the typical physical characteristics of classrooms in national schools as given in Table 13.

2.4. Thurstan College

Thurstan College is situated along Reid avenue, a segment of the major road R. A. De Mel Mawatha. Reid avenue contains large trees, and the school premises is composed of vegetation. Table 14 shows the distance of road to primary classroom block and playground of the school.

Table 14 - Positioning of school and primary classrooms (Grade 3 to 5) from neighbouring roads

Major road	Average distance from road (m)	
R.A. De Mel Mawatha	Distance to school	150
	Distance to Selected classrooms	150
	Distance to playground	50

As shown in Table 14 primary classrooms are positioned 150 away from the road and the playground is placed closest to the road. Table 15 summarizes the construction details of the classrooms. The construction details are similar to the previous schools and vary very little. This proves that these schools attributed to similar architectural features as a whole.

Table 15 - Construction details of primary classrooms

Roof	Floor	Walls	Windows	Mode of ventilation
Gable roof with asbestos roofing sheets	Polished cement rendered	Cement blocks, plastered and painted	Steel grills No daylight controls	Natural ventilation Mechanical ventilation from O3 fans

Masterplan of the school is illustrated in Figure 6. As shown in Figure 6, primary classrooms are positioned towards the interior of the school and buffered by playground and thick vegetation of the school premises. However due to the old building structures and the old roof structures, there is a considerable effect on the air quality inside the classrooms. Moreover, the distance is also considerably less.

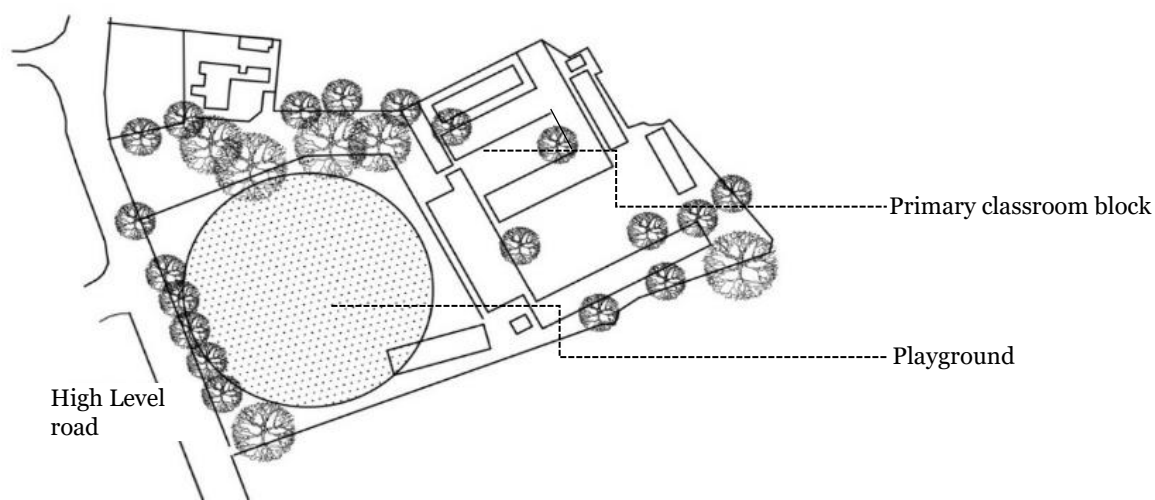


Figure 6 - Master plan of Thurstan College and surrounding environment of primary classroom block

2.5. Mahinda Vidyalaya

Mahinda College is located between an urban settlement. Have a same distance from the main roads. Located between Class A and Class B96 roads. Moreover, the route to the school is a crossover with highly traffic congested road network. However, as shown in figure 7, Mahinda College has around 600m of considerable distance from the road to the school, this is the school which has the furthest distance from the school. Due to this reason, Mahinda College is selected as reference school for the study.

Table 16 - Positioning of school and primary classrooms (Grade 3 to 5) from neighbouring roads

Major road	Average distance from road (m)	
Gunarathna Pradeepa Mawatha	Distance to school	614
	Distance to Selected classrooms	600
	Distance to playground	619
Dr. Danister De Silva Mawatha	Distance to school	545
	Distance to Selected classrooms	540

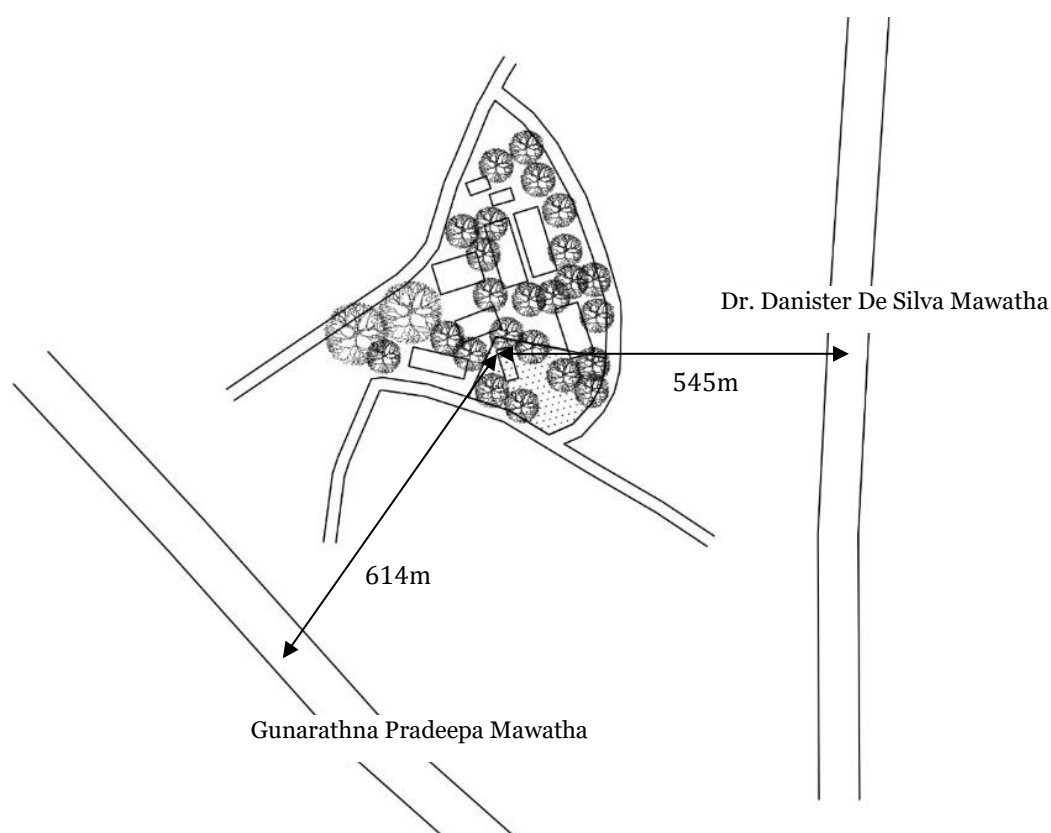


Figure 7 - Master plan of Mahinda vidyalaya and surrounding environment of primary classroom block

Table 17 - Construction details of classrooms

B1 B2 (Grade 3 to 5)- - Mahinda				
Roof			Foundation	Floor
Roof Type	Roof shape	Roofing Material	Foundation type	Finishing Material
Roof	Tiles	Asbestos	Deep foundation (piling)	Polished Cement
Walls			Windows	
Structural Material	Finishing material (Outdoor):	Finishing material (Indoor):	Type of Windows	Day light control method
Cement Blocks	Cement Plastering + painting	Cement Plastering + painting	steel /Protective grills	No

Building conditions and materials of the school classrooms were also recorded to identify the interior constituents as given in table 17. The school master plans were examined to identify the relationship of building layout and distance of the road.

Non-infectious diseases can spare due to physical factors. The nose, larynx, airways, and alveoli are the main affected parts of the body from nanoparticles. The mechanism may change due to partial depositions. Thus, the deposition fraction (DF) is calculated for the five critical schools. As this is an indicator of the number of particles of a given size depositing in a given region to the number of the same size entering the respiratory tract.

Each child's behavior is recorded by the travelling method, duration of urban exposure and symptoms as difficulties of the body are recorded regarding physical health. 670 children's' data among grade 3 - 5 was recoded from 6 schools. Finally, these were used to analyze the non-school exposure and Indoor air quality schools and its relationship with children's respiratory symptoms and several disease related illnesses. For the questionnaire, data was collected from all six schools including Anula Vidyalaya.

2.6. Questionnaire survey

Questionnaire survey was performed immediately after the onsite investigation. The self-administered questionnaire is based on the standardized core questionnaire of ISAAC - International Study of Asthma and Allergies in Childhood (ISAAC International Data Centre, 2000) validated for Sri Lanka. This questionnaire is used to assess the medical history of asthma and rhinitis.

Table 18 shows the structure of questionnaire which consists of 11 main sections and a total of 51 questions. This questionnaire and supporting documents were composed in all three languages of Sinhala, Tamil and English.

Moreover, other documents associated with the questionnaire are the information sheet and the consent form of parents. This questionnaire was distributed among 1425 students studying in 36 classrooms of Grade 3 to 5 in 06 critical schools. Selection criteria for classroom is based on the highest and lowest PNC level derived from the value of coefficient of variance.

The selected 06 classrooms of each school represent 02 classes of each grade from 3 to 5. The process of distribution of questionnaires were formally approved by the Ministry of Education. Research team had formal discussions with Principals of all schools, Head teacher

of primary section and the teacher in charge of selected class of each school. Distribution process was managed by 36 class teachers. Table 19 shows the respective classrooms of each school and management of the questionnaire survey.

Table 18 - Structure of the self-administered questionnaire – ISAAC questionnaire validated for Sri Lanka

Section	Question No.	Focus of questions
Basic details	1 - 5	Date of Birth; Home location; Gender
Ethnicity	6	Ethnic group
Medical history: Asthma	7-14	Wheezing conditions, conditions of chest infection
Medical history: Rhinitis	15-20	Sneezing, runny nose and fever
Medical history: Eczema	21	Itchy rash, skin creases,
Medical history: Cough	22-24	Cough and its duration
Family health	25	Parents medical history: Asthma, Eczema
Non-school exposure	26-27	Mode of transport
Exposure during transport	28-33	Travel associated activities
Home characteristics: exposure to allergens	34-49	Cooking mode, use of coil, pets at home etc.
Family characteristics	50-51	Education level of parents and income

As shown in Table 19, a total of 1425 questionnaires were distributed among the school children of Grade 3 to 5 of critical 5 schools and the response rate is 47%.

Table 19 - Administration of questionnaire survey

School	Classrooms	Distributed	Collected	% Submitted
Isipathana College	3D, 3F, 4B, 4F, 5B, 5E	239	160	67
Mahanama College	3B, 3D, 4B, 4E, 5C, 5D	269	187	69.5
Thurstan College	3B, 3C, 4A, 4B, 5B, 5C	261	132	50.6
Nalanda College	3A, 3E, 4B, 4C, 5C, 5E	274	107	39.1
Anula College	3D, 3F, 4B, 4D, 5A, 5B	170	31	18.2
Mahinda Vidyalaya	3A, 3E, 4B, 4C, 5C, 5E	212	53	25
Total	36 classrooms	1425	670	47

Above 50% of response was evident for Isipathana College, Thurstan College and Mahanama College with a response rate of 67%, 50.6% and 69.5%, respectively. The lowest response rate of 18.2% is apparent for Anula Vidyalaya followed by Mahinda Vidyalaya with a 25% of response rate. Thus, this school with the lowest rate was excluded in the detailed data analysis. The gathered data from the questionnaires were entered to an excel spreadsheet and SPSS file for statistical data analysis. This report contains few results of the questionnaire survey.

Several limitations were experienced during the questionnaire administration phase of this research due to less interest of parents in completion of questionnaires and lack of awareness on research. These attitudes clearly interpret in very low questionnaire response rate of 47%. Moreover, management of questionnaire survey was largely affected by activities of schools such as practices for sports meet and periods of term tests. Thus, this report prioritizes the analysis of respiratory health associated questions of the questionnaire.

3. RESULTS AND DISCUSSION

This section explains the results acquired during final onsite investigations and simultaneous questionnaire surveys conducted in 05 critical schools. Detail analysis of Anula Vidyalaya is not included since the geographical positioning of primary classrooms are different to all other critical schools. Data strength of onsite experimental investigation is described in Table 19. As shown in Table 20, data points of adjoining roads ranges from 2028 to 2768. Primary classrooms are evident for a range of datapoints from 1964 to 2768.

Table 20 - Measured onsite data strength on roads and critical schools

Road	Data points/PNC	School	Data points/PNC
Park Lane	2768	Isipathana College	2768
R. A. De Mel Mw.	2233	Mahanama College	2572
High Level road, Colombo 03	2167	Thurstan College	2342
Sri Dhamma Mawatha	2419	Nalanda College	2486
Gunarathna Pradeepa Mw.	2028	Mahinda College	1964
High Level road, Nugegoda	2488	Anula Vidyalaya	2570

3.1 Ultrafine particle concentration on roads

This section presents the measured ultrafine particle number concentration on adjoining roads of 06 critical schools. These measurements were acquired on the pavement of the road towards each school. Data collectors measured PNC of each road from morning to evening continuously for an average of 8 hours duration.

3.1.1. *Park Lane: Road front of Isipathana College*

Figure 8 shows the distribution pattern of particle number concentration in front of Isipathana College on Park Lane. Data was acquired continuously for 9 hours from 7.30 am to 16.30 pm for an interval of 15 seconds.

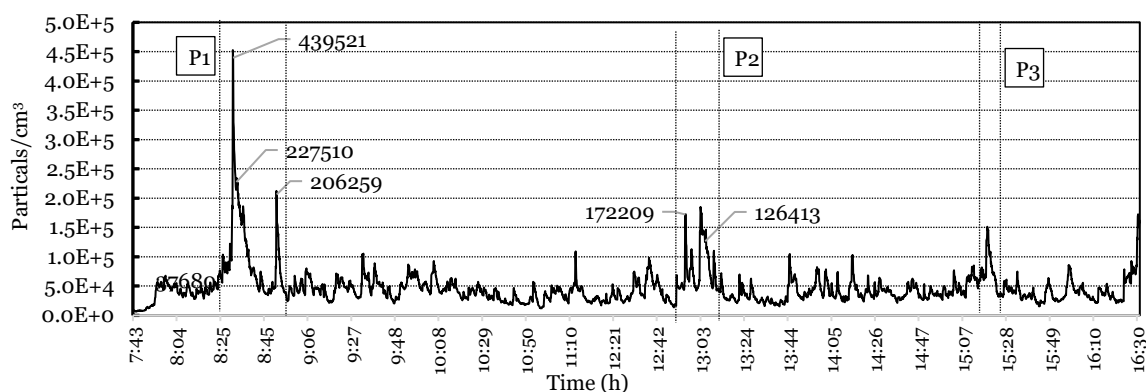


Figure 8 - Ultrafine particle number concentration at Park lane (road front of Isipathana College)

As shown in Figure 8 except for three time zones a constant distribution pattern of PNC is evident. PNC peaks at P1, P2 and P3 time zones and the corresponding times are 8.25 to 8.52 am, 12.55 to 13.11 pm and 15.15 to 15.30 pm, respectively. These time intervals integrate traffic demand pattern associates with the functions of school and its surrounding urban environment. Thus, the P1, P2 and P3 is evident for traffic induced functions such as office and commercial travels in the morning, school closing time and ending of after school

activities, respectively. PNC of Park Lane varies in the range of 6557 to 452,706 particles/cm³ with a mean PNC of 47088 particles/cm³.

3.1.2. R. A. De Mel Mawatha: Road front of Mahanama College

Figure 9 shows the distribution of particle number concentrations on R. A. De Mel Mawatha in front of Mahanama College. Onsite measurements were gathered continuously for eight and half hours from 7.49 am to 16.17 pm in 15 second intervals. As shown in Figure 12 the PNC dispersion on R. A. De Mel Mawatha is evident for a distinct variation in morning hours from 8.10 to 9.50 am (P1) in comparison to time duration from 9.50 am to 16.17 pm.

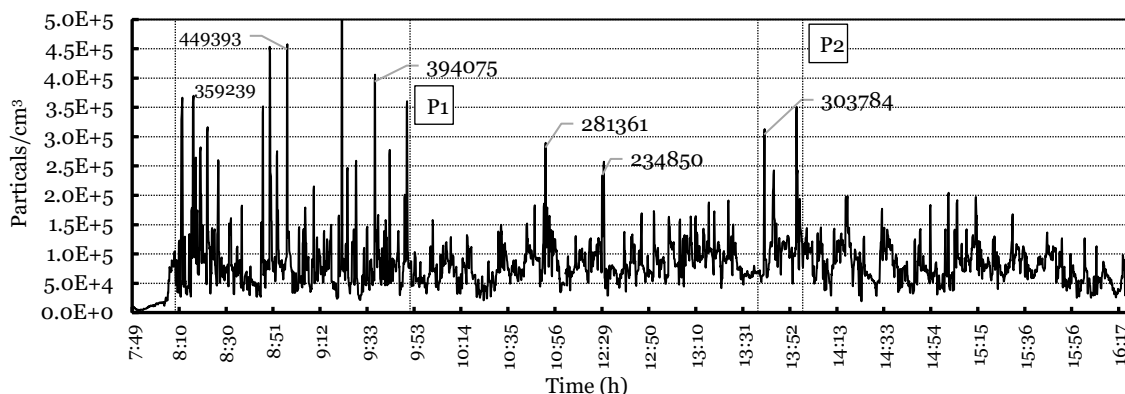


Figure 9 - Ultrafine particle number concentration at R. A. De Mel Mawatha (road front of Mahanama College)

P2 shows a time zone with increased PNC levels from 13.31 to 13.52 pm. P1 and P2 coincides with the traffic induced activities such as travels for work or commercial activities and school closing times, respectively. Moreover, connected loop of traffic in R. A. De Mel Mawatha with Galle road would have resulted relatively higher PNC levels during daytime hours. PNC on R. A. De Mel Mawatha varies in the range of 4085 to 694,157 particles/cm³ with a mean PNC of 83405 particles/cm³.

3.1.3. High Level road : Reid Avenue: In front of Thurstan College

Figure 10 shows the distribution of particle number concentrations on Reid Avenue (segment of High-Level road) opposite Thurstan College. Onsite measurements were gathered continuously for eight and half hours from 8 am to 16.30 pm in 15 second intervals. As shown in Figure 10 a constant pattern of PNC dispersion is evident on Reid Avenue.

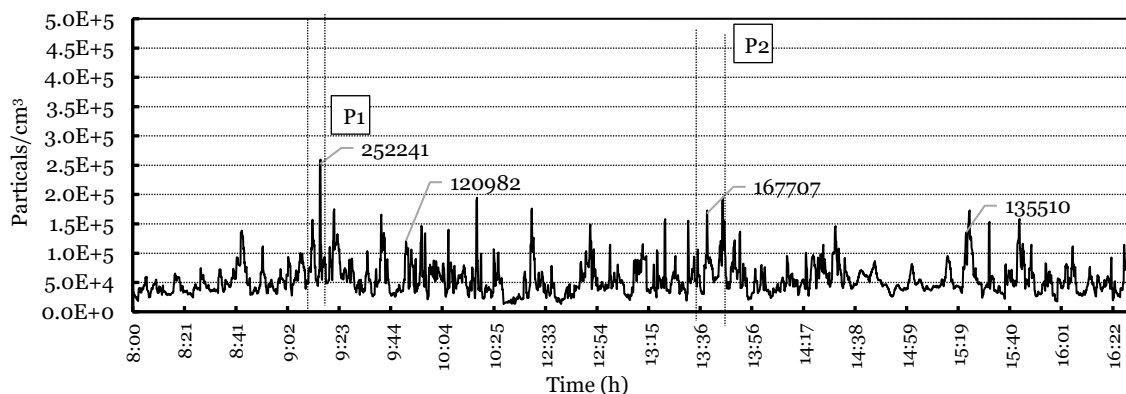


Figure 10 - Ultrafine particle number concentration at Reid Avenue (road front of Thurstan College)

Peak PNC levels are apparent in P1 and P2 time zones from 9.10 to 9.20 am and 13.36 to 13.45, respectively.

P1 and P2 time zones associate with the travels for work and closing time of school, respectively. PNC on Reid Avenue varies in the range of 13182 to 259,808 particles/cm³ with a mean PNC of 55175 particles/cm³. Morphology of the segment of road with large trees and wide canopies would have an impact on maintaining low levels of PNC of the major road.

3.1.4. Sri Dhamma Mawatha: In front of Nalanda College

Level of PNC distribution on Sri Dhamma Mawatha opposite Nalanda College is shown in Figure 11. Onsite measurements of PNC were collected continuously for 8 hours from 8.12 am to 16.20 pm for an interval of 15 seconds.

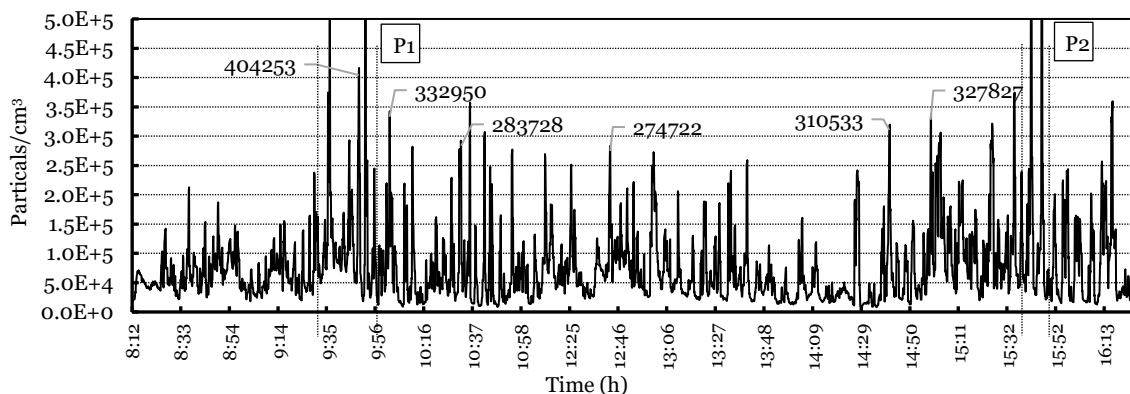


Figure 11 - Ultrafine particle number concentration at Sri Dhamma Mawatha (road front of Nalanda College)

As shown in Figure 11 frequent occurrence of peak PNC levels are evident. Time zones of P1 and P2 inform extreme peak PNC concentrations during 9.30 to 10 am and 15.40 to 15.50 pm, respectively. These times coincide with typical traffic induced activities of travel for work or other commercial activities during daytime hours. PNC on Sri Dhamma Mawatha varies in the range of 13182 to 259,808 particles/cm³ with a mean PNC of 55175 particles/cm³.

3.1.5. Gunarathna Pradeepa Mawatha: In front of Mahinda College

PNC dispersion on Gunarathna Pradeepa Mawatha opposite Mahinda College is shown in Figure 12. Data collectors acquired ultrafine particle measurements on Gunarathna Pradeep Mawatha continuously for 8 hours from 8.36 am to 16.30 pm in 15 seconds intervals. PNC distribution profile shows relatively a constant pattern with 03 occasions of peak PNC levels as P1, P2 and P3.

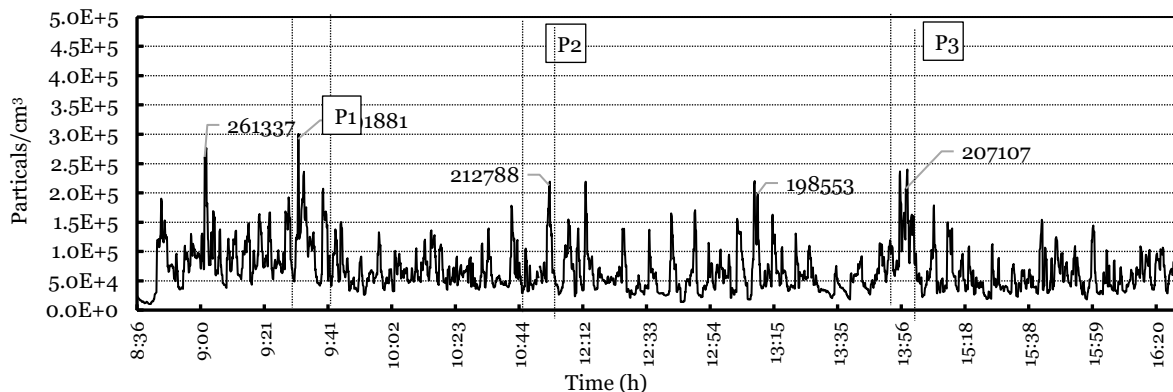


Figure 12 - Particle number concentration at Gunarathna Pradeepa Mawatha (road front of Mahinda College)

Time zones of P1, P2 and P3 correspond with the time segments of 9.30 to 9.41 am, 10.50 to 11 am and 13.46 to 2 pm, respectively. These times coincide with traffic induce activities such as travels for office and commercial needs and influx of vehicles at closing time of school. PNC on Gunarathna Pradeepa Mawatha varies in the range of 10282 to 300,638 particles/cm³ with a mean PNC of 68176 particles/cm³.

3.1.6. High Level road : Nugegoda: In front of Anula Vidyalaya

PNC dispersion on High Level road opposite Anula Vidyalaya is shown in Figure 13. Measurements of PNC were acquired on of High-Level road towards the school continuously for 9 hours from 7.11 am to 16.15 pm in 15 seconds intervals. PNC distribution profile shows a pattern of frequent changes for PNC levels and less evident for a peak time zone.

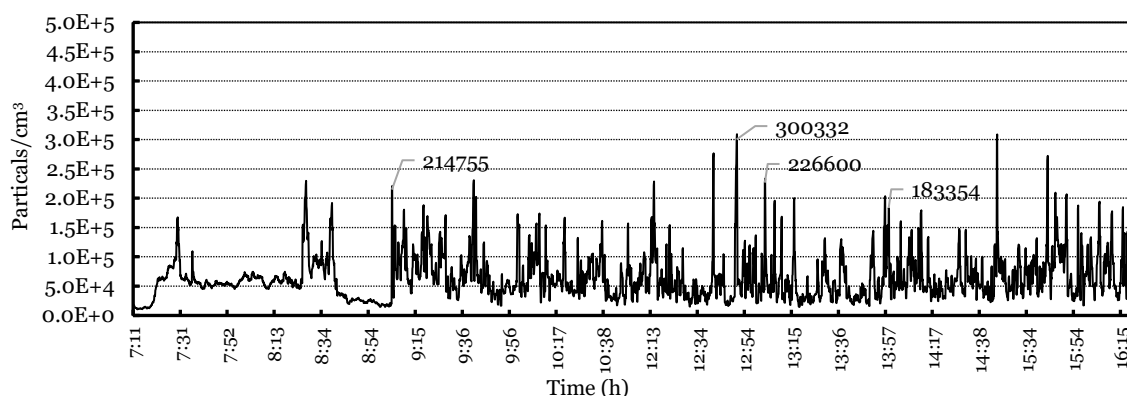


Figure 13 - Particle number concentration at High Level road, Nugegoda (road front of Anula Vidyalaya)

PNC on High Level road opposite Anula Vidyalaya varies in the range of 10471 to 309,342 particles/cm³ with a mean PNC of 63297 particles/cm³.

3.2. An overview: Dispersion of PNC on adjoining roads of the critical schools

Table 21 shows descriptive statistics of PNC on adjoining roads of the critical schools. Among the experimented 06 roads the highest maximum, minimum, and mean PNC levels were evident on R.A. De Mel Mawatha opposite Mahanama College. In contrary the lowest maximum and mean with the highest minimum was apparent on Reid Avenue of High-Level road in front of Thurstan College. Moreover, mean PNC of by roads such as Sri Dhamma Mawatha and Gunarathne Pradeepa Mawatha is higher than Class A, High-Level road in the locations opposite to Anula Vidyalaya and Thurstan College. Moreover, the highest maximum PNC level is at RA with the lowest maximum PNC levels at HL. The maximum PNC of PL is higher than HL in front of Thurstan College and Anula vidyalaya.

Table 21 - Descriptive statistics of PNC on adjoining roads of critical schools

School	Road	PNC (Particles/cm ³)			
		Maximum	Minimum	Mean	SD
Isipathana College	Park Lane	452706	6557	47089	31111
Mahanama College	R.A. De Mel Mw.	694157	4085	83405	49889
Thurstan College	High Level (Reid Av.)	259808	13182	55175	27283
Anula Vidyalaya	High Level (Nugegoda)	309342	10471	63297	39293
Nalanda College	Sri Dhamma Mw.	622424	8161	76533	68046
Mahinda Vidyalaya	Gunarathna Pradeepa Mw.	300638	10282	68176	39436

These results show the increase in mean PNC at by roads of SD and GP mawatha is not only dependent on vehicular density but also the geometrical characteristics of the roads, types of vehicles and vehicle movement patterns (such as idling, stopped or slow-moving).

In addition, the roads consist of large trees such as Reid Avenue and Park Lane were evident for the lowest mean PNC levels. These aspects were not considered in the data collection of this preliminary study but it's a salient aspect for future research.

3.3. Traffic pattern on a typical weekday – Composition of vehicles

The number and type of vehicles moving through the road in front of the critical schools were counted and recorded manually. Data was collected during three time slots similar to the PNC measurements during the morning, afternoon and evening time segments such as 8.30 to 10.30 am, 12.30 to 14.30 pm and 15.30 to 16.30 pm, respectively. Table 22, 23 and 24 shows the traffic pattern of the adjoining roads for time segments from 8.30 am to 16.30 pm.

Table 22 - Traffic pattern of a typical weekday: Morning (8.30 to 10.30am)

Road	Vehicle type and number						
	3-Wheeler	Van	Motorcycles	Bus	Car	Lorry	Total
Park Lane	910	165	460	55	1380	135	3105
R.A. De Mel Mw.	3715	195	1170	215	3150	85	8530
High Level (Reid Av.)	1065	445	785	445	1475	440	4660
Sri Dhamma Mw.	4380	830	2010	990	5700	320	14230
Gunarathna Pradeepa Mw.	1400	78	645	23	1233	46	3425
High Level (Nugegoda)	1390	590	640	630	1370	510	5130

Table 23 - Traffic pattern of a typical weekday: Afternoon (12.30 to 14.30pm)

Road	Vehicle type and number						
	3-Wheeler	Van	Motorcycles	Bus	Car	Lorry	Total
Park Lane	1080	260	500	100	1760	160	3860
R.A. De Mel Mw.	5120	735	1580	525	4685	270	12915
High Level (Reid Av.)	985	325	600	485	1145	335	3875
Sri Dhamma Mw.	4130	1050	2450	1540	5250	1135	15555
Gunarathna Pradeepa Mw.	2345	98	767	31	1345	57	4643
High Level (Nugegoda)	3210	1090	1780	950	4000	830	11860

Table 24 - Traffic pattern of a typical weekday: Evening (15.30 to 16.30pm)

Road	Vehicle type and number						
	3-Wheeler	Van	Motorcycles	Bus	Car	Lorry	Total
Park Lane	165	45	75	30	205	30	550
R.A. De Mel Mw.	1980	240	540	150	2400	180	5490
High Level (Reid Av.)	355	90	245	275	725	80	1770
High Level (Nugegoda)	960	480	520	240	1180	220	3600
Sri Dhamma Mw.	Data was not collected						
Gunarathna Pradeepa Mw.	1258	24	198	12	654	21	2167

As shown in Table 22 and 23, the highest and lowest number of vehicles during morning and afternoon moves along Sri Dhamma Mawatha and Park Lane, respectively. The morning

and afternoon hours exhibit similar levels of traffic movement on these roads. The vehicular movement along the Sri Dhamma Mawatha is higher than Class A High Level road, opposite to Anula Vidyalaya and Thurstan College. Moreover, in comparison to other roads Sri Dhamma road is evident for the highest number of buses with the least number of buses along Gunarathna Pradeepa Mawatha. This indicates that the type of road is not the only influential factor for increasing of particle number concentration levels.

As shown in Table 22, 23 and 24 the highest number of vehicles on all roads is evident during afternoon hours from 12.30 to 14.30 pm. All roads show similar pattern of vehicle types with a greater number of cars and three-wheelers in comparison to other types of vehicles. During the evening hours, the vehicular movement along the Sri Dhamma Mawatha was not recorded due some technical difficulties with the equipment.

The highest number of cars moves along Sri Dhamma Mawatha during morning and afternoon time segments. Although the highest number of 3-wheelers moves along Sri Dhamma Mawatha during the morning time segment, during afternoon hours the highest number of 3-wheelers moves along R.A. De Mel Mawatha opposite Mahanama College.

3.4. An overview: Distribution of vehicle types on a typical weekday

Composition of vehicle types and the percentage of each type of vehicle to the total vehicles on a typical weekday of the investigated adjoining roads are shown in Figure 14. Main vehicle types are cars, three wheelers, motorcycles, buses, vans and lorries. Except for Gunarathna Pradeepa Mawatha and R.A. De Mel Mawatha, the major vehicle type on all other roads are cars.

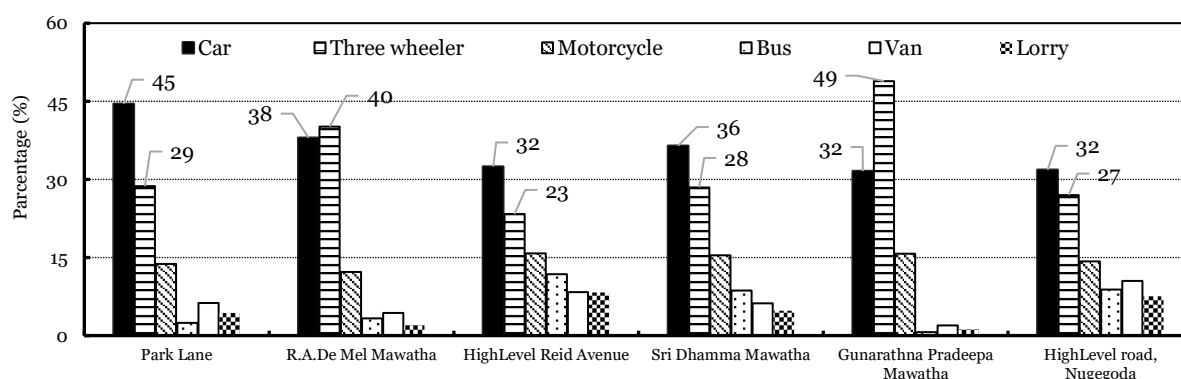


Figure 14 - Particle number concentration at High Level road, Nugegoda (road front of Anula Vidyalaya)

Three wheelers are evident as the highest percentage on Gunrathna Pradeepa Mawatha and R.A.De Mel Mawatha. Percentage of cars on a typical week day (8.30 to 16.30) of Park Lane, R.A.De Mel Mawatha, Reid Avenue of High level road, Sri Dhamma Mawatha, Gunarathna Pradeepa Mawatha and High level road at Nugegoda are 45:29, 38:40, 32:23, 36:28, 49:32 and 32:27, respectively.

Thus, more than half (above 50%) of the total vehicles are composed of cars and three wheelers on all investigated roads adjoining the critical schools. Third highest percentage signifies motorcycles which vary from 14 to 16% on all roads. The highest percentage of buses moves along High Level Road.

3.5. Particle Number Concentration on roads: School hours (9.00 to 14.00h)

Particle number concentration on adjoining roads during school hours from 9 am to 2 pm is presented and discussed in this section. Thus, the measured PNC levels on adjoining roads of the 05 critical schools were averaged for 01-minute interval. Data is presented in time segments of morning and afternoon, from 9 to 10.30 am and 12.15 to 14 pm, respectively. Morning and afternoon time segments are composed of 91 and 106 data points, respectively. Moreover, statistical analysis represents moving average trendline for 15 minutes. Due to a discrepancy in location characteristics of primary classrooms of Anula Vidyalaya, this school will not be considered for further analysis.

3.5.1. *Park Lane: Road front of Isipathana College*

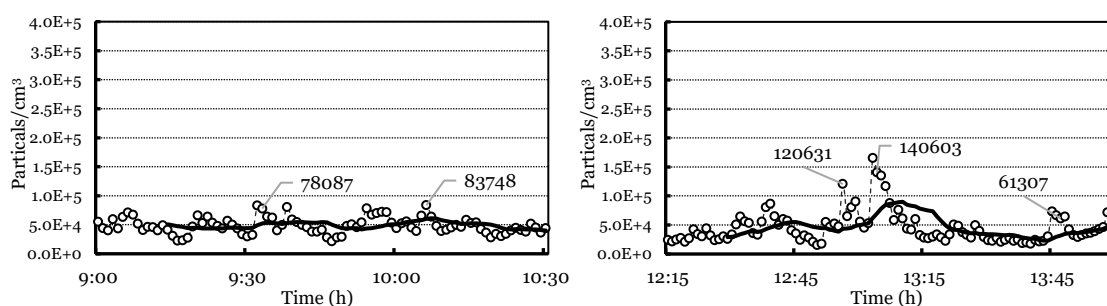


Figure 15 - Particle number concentration on Park Lane for time segments; A. Morning and B. Afternoon

Figure 15 shows the particle number concentration for time segments of morning (18A) and afternoon (17B). PNC dispersion is evident for a constant behaviour in morning hours from 9 to 10.30 am. During the morning hours the maximum, minimum and mean PNC levels are 83748, 21757 and 48647 particles/cm³, respectively. Moving average trendline of 15 minutes shows a constant PNC dispersion during morning hours with few increasing values at 9.35 am and around 10 to 10.10 am.

As shown in Figure 15B, the maximum, minimum and mean PNC levels of afternoon hours are 165605, 15312 and 45378 particles/cm³, respectively. In comparison with the morning hours, PNC dispersion pattern of afternoon shows several peak changes. Although the maximum PNC is twice the maximum PNC of morning hours, minimum and mean PNC represent lower values during afternoon hours. Std. Dev. of morning and afternoon hours are 14140 and 27084 particles/cm³, respectively.

3.5.2. *R. A. De Mel Mawatha: Road front of Mahanama College*

Figure 16 shows the particle number concentration for morning (16A) and afternoon (16B) time slots. Moving average trendline for 15 minutes time interval shows a similar pattern during both time segments of morning and afternoon. Traffic loop of R.A De Mel Mawatha and Galle road would have caused a constant PNC count for both time slots of morning and afternoon hours.

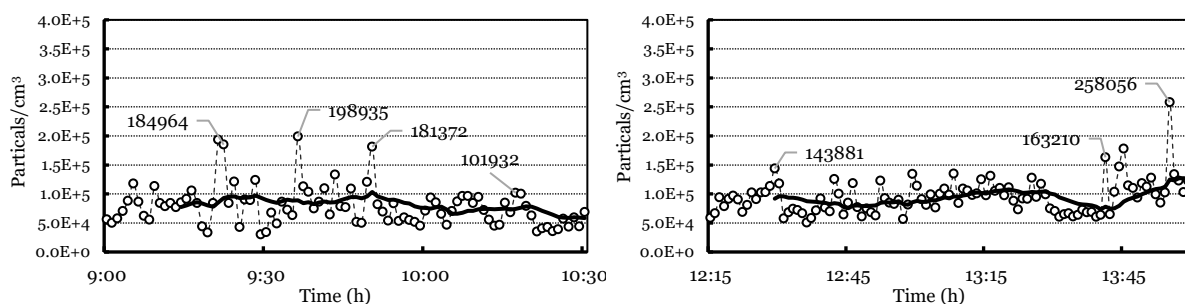


Figure 16 - Particle number concentration on R.A. De Mel Mawatha; A. Morning and B. Afternoon

The maximum, minimum and mean PNC levels are 198935, 30068 and 78171 particles/cm³, respectively. As shown in Figure 16B, the maximum, minimum and mean PNC levels of afternoon hours are 258065, 50705, 94870 particles/cm³, respectively. Although the maximum PNC is higher than the morning hours, minimum and mean PNC represent lower values with during afternoon hours. The Std. Dev. of morning hours is at a higher value than in the afternoon hours.

3.5.3. High Level road – Reid Avenue: Road front of Thurstan College

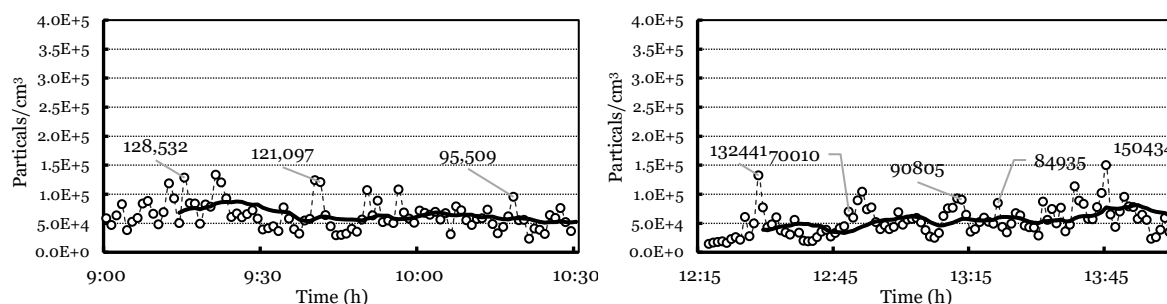


Figure 17 - Particle number concentration on Reid Avenue; A. Morning and B. Afternoon

Figure 17 illustrates the particle number concentration for morning (17A) and afternoon (17B) time slots. PNC dispersion is evident for a constant behaviour in morning hours from 9 to 10.30 am. The maximum, minimum and mean PNC levels are 133609, 23360, 63393 particles/cm³, respectively.

As shown in Figure 17B, the maximum, minimum and mean PNC levels of afternoon hours are 150434, 14703, 53647 particles/cm³, respectively. PNC is higher in the morning hours than during afternoon hours. The Std. Dev. of morning hours and afternoon hours do not indicate a difference.

3.5.4. Sri Dhamma Mawatha: Road front of Nalanda College

Figure 18 shows the particle number concentration for morning (18A) and afternoon (18B) time slots. PNC dispersion indicate a rise in morning hours from 9 to 10. 15 am., before dropping off till 10.30am

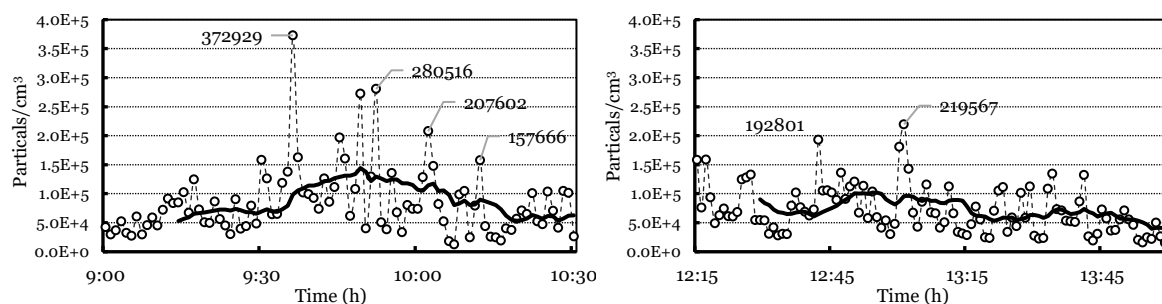


Figure 18 - Particle number concentration on Sri Dhamma Mawatha; A. Morning and B. Afternoon

The maximum, minimum and mean PNC levels during the morning hours are 372929, 12811, 83812 particles/cm³, respectively. As shown in Figure 18B, the maximum, minimum and mean PNC levels of afternoon hours are 219567, 14948, 70500 particles/cm³, respectively. The PNC is higher in the morning hours than during afternoon hours.. Std. Dev. of morning and afternoon hours are 59242 and 41293 particles/cm³, respectively.

3.5.5. *Gunarathna Pradeepa Mawatha: Road front of Mahinda Vidyalaya*

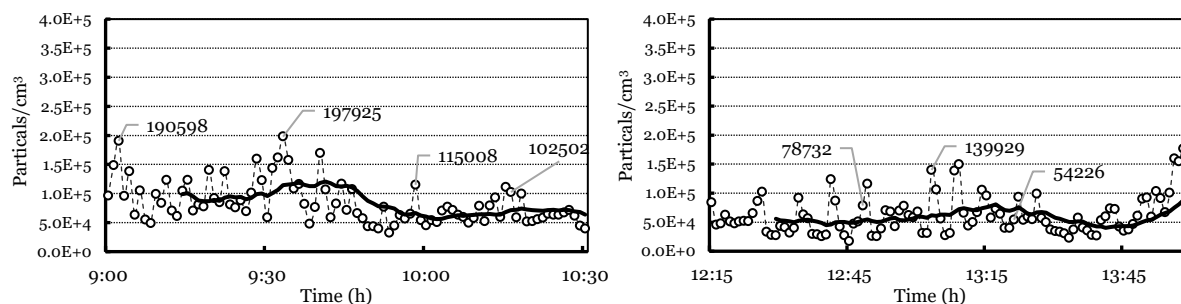


Figure 19 - Particle number concentration on Gunarathna Pradeep Mawatha; A. Morning and B. Afternoon

Figure 19 shows the particle number concentration for morning (19A) and afternoon (19B) time slots. PNC dispersion is evident for a fluctuating behaviour in morning hours from 9 to 10.30 am. The maximum, minimum and mean PNC levels during the morning hours are 197925, 32479, 83805 particles/cm³, respectively. As shown in Figure 19B, the maximum, minimum and mean PNC levels of afternoon hours are 176647, 17409, 62836 particles/cm³, respectively. There is no significant variation in the Std. Dev. of morning and afternoon hours.

3.6. An overview: Particle number concentration on adjoining roads

Particle number concentration on adjoining roads are shown in Table 25. As shown in the Table 25 mean PNC of all roads vary in the range of 48647 to 83805 particles/cm³ and 45378 to 94870 particles/cm³ during morning and afternoon time segments, respectively. As Park Lane is evident for the lowest mean PNC for both time durations of typical weekday.

However, the highest mean PNC apparent on Sri Dhamma and Gunarathna Pradeepa Mawatha in morning time duration changes R.A. De Mel Mawatha during the afternoon times.

Table 25 - Particle number concentration on roads during school hours (9 to 14h)

Statistics	Particle number concentration (Particles/cm ³) – Morning (9 to 10.30)				
	Park Lane	R.A.De Mel Mw.	Reid Av.	Sri Dhamma Mw.	Gunarathna Pradeepa Mw.
Maximum	83748	198935	133609	372929	197925
Minimum	21757	30068	23360	12811	32479
Mean	48647	78171	63393	83812	83805

Statistics	Particle number concentration (Particles/cm ³) – Afternoon (12.15 to 14)				
	Park Lane	R.A.De Mel Mw.	Reid Av.	Sri Dhamma Mw.	Gunarathna Pradeepa Mw.
Maximum	165605	258605	150434	219567	17647
Minimum	15312	50705	14703	14948	17409
Mean	45378	94870	53647	70500	62836

Table 26 - Total number of vehicles on adjoining roads during school hours (9 to 14h)

Total number of Vehicles– Morning (9 to 10.30)				
Park Lane	R.A.De Mel Mw.	Reid Av.	Sri Dhamma Mw.	Gunarathna Pradeepa Mw.
3105	8530	4660	14230	3425

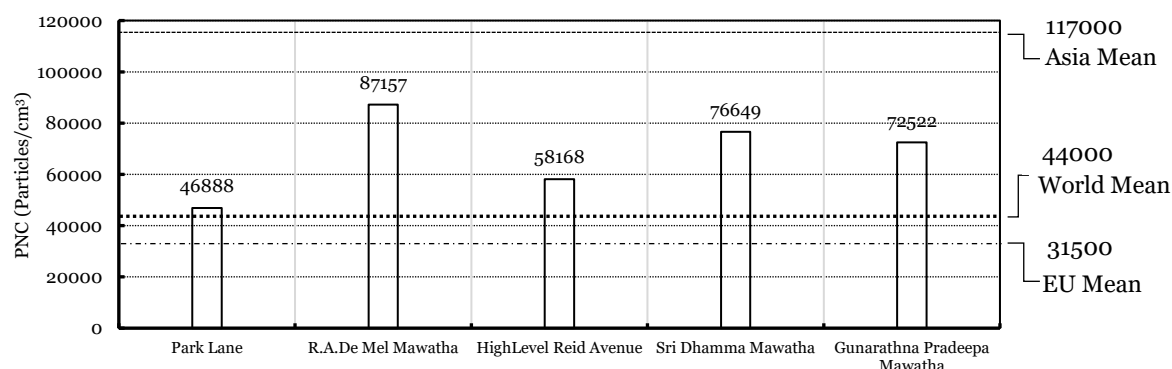
Total number of Vehicles– Afternoon (12.30 to 14.30)				
Park Lane	R.A.De Mel Mw.	Reid Av.	Sri Dhamma Mw.	Gunarathna Pradeepa Mw.
3860	12915	3875	15555	4643

Table 26 shows the total number of vehicles moved along adjoining roads during school hours. As shown in the table the lowest number of vehicles are moved along Park Lane. In comparison to other roads Reid Avenue of High Level Road and Gunarathna Pradeepa Mawatha signify a similarity with the total number of vehicles on Park Lane. However, the mean PNC of these roads are higher than Park Lane. R.A. De Mel Mawatha and Sri Dhamma Mawatha is evident for the highest mean PNC during school hours. Vehicle number on Sri Dhamma Mawatha is higher than R.A. De Mel Mawatha.

Thus, the results inform the PNC on roads is not only depended on vehicle number but also the morphology of roads, aspect ratio of road canyons and presence of vegetation on roads. These aspects were not considered in this study, however, informs a potentials for future investigations.

3.7. Comparison with UFP levels of roads: *International standards*

Figure 20 shows the mean PNC levels of investigated roads in comparison to international standards of UFP levels. UFP standards for Asia, World and EU are 117000, 44000 and 31500 Particles/cm³, respectively.

**Figure 20**- Comparison with mean PNC levels of local roads with International standards

As shown in Figure 20 mean PNC of the roads are below Asia mean UFP levels. However the UFP levels have exceeded the World and EU standards. The highest mean PNC is evident for R.A. De Mel Mawatha and the lowest on Park Lane.

3.8. Particle Number Concentration inside schools: 9 am to 2 pm

Ultrafine particle number concentrations inside primary classrooms (Grades 3 to 5) of all critical schools are presented in this section. Measured PNC levels inside primary classrooms of 05 critical schools were averaged to 01-minute interval. Thus, the results illustrate PNC of each school for a typical school day corresponding to time segments of morning (9 am to 10.30 am) and afternoon (12.15 to 2 pm). PNC of each school represents 91 and 106 data points for morning and afternoon time segments, respectively. Moreover, statistical analysis represents moving average trendline for 15 minutes.

3.8.1. PNC inside primary classrooms: Isipathana College

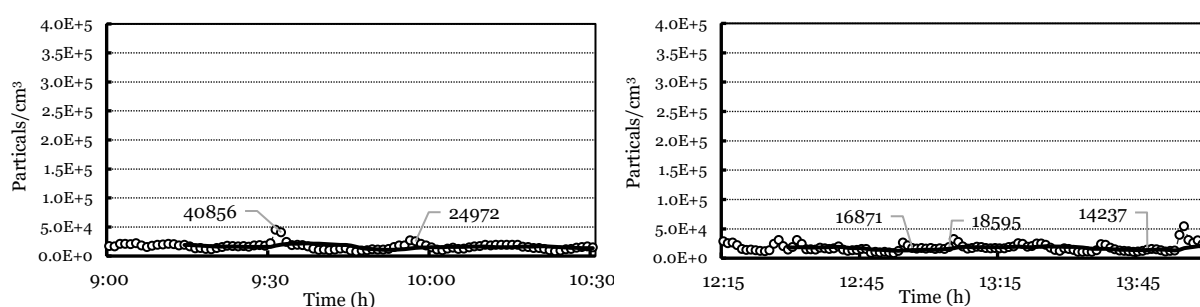


Figure 21 - PNC inside classrooms of Isipathana College during school hours; A. Morning and B. Afternoon

Particle number concentration inside primary classrooms of Isipathana College is shown in Figure 21. As shown in Figure 21 A and B, a similar PNC dispersion pattern is evident for morning and afternoon time segments. Maximum, minimum and mean PNC of morning and afternoon hours are 45287, 7707, 16154 and 54244, 8432, 17766 particles/cm³, respectively.

3.8.2. PNC inside primary classrooms: Mahanama College

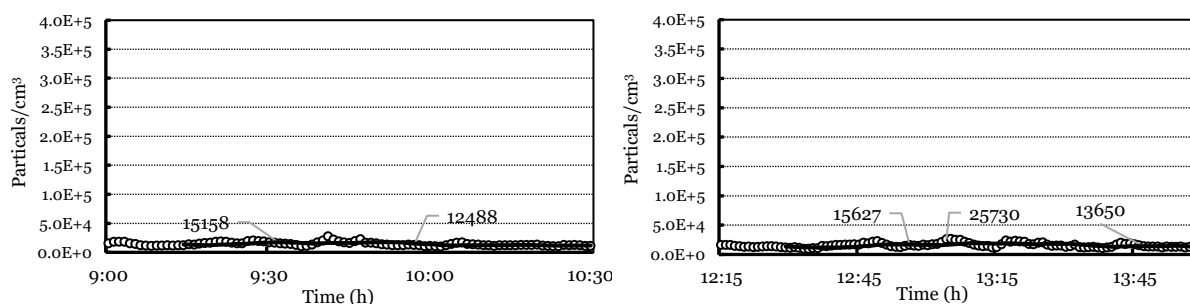


Figure 22 - PNC inside classrooms of Mahanama College during school hours; A. Morning and B. Afternoon

Dispersion of particle number concentration inside primary classrooms of Mahanama during a typical school day is shown in Figure 22. As shown in Figure 22 A and B, a similar PNC

dispersion pattern is evident for morning and afternoon time segments. Maximum, minimum and mean PNC of morning and afternoon hours are 29480, 12483, 19183 and 29984, 10664, 19014 particles/cm³ respectively.

3.8.3. PNC inside primary classrooms: Thurstan College

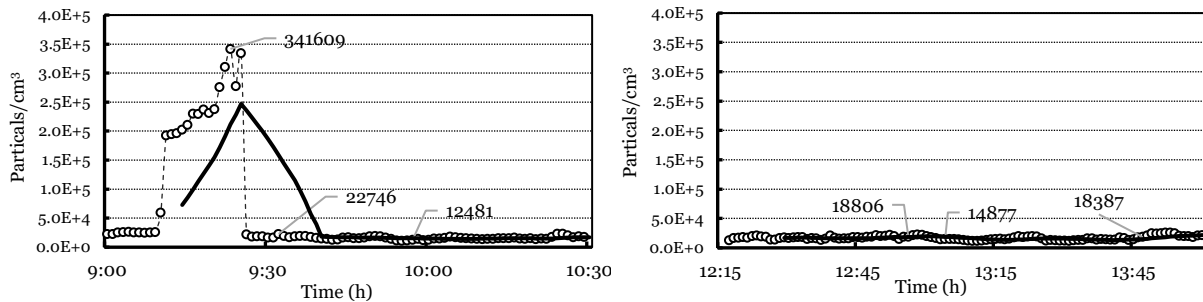


Figure 23 - PNC inside classrooms of Thurstan College during school hours: A morning and B. Afternoon

Particle number concentration inside primary classrooms of Thurstan College is shown in Figure 23. As shown in Figure 23 A and B, except for 9 to 9.30h in the morning, similar PNC dispersion pattern is evident for remaining morning and afternoon time segments. Maximum, minimum and mean PNC of morning and afternoon hours are 341609, 10830, 56181 and 25948, 11476, 16979 particles/cm³ respectively.

PNC from 9.11 to 9.24am is evident for extremely high in comparison to other times of the day. Moreover PNC levels of this time duration is higher than the PNC levels of the adjoining road, Reid Avenue of High level road. In contrary PNC of all remaining times of morning and afternoon times show a similar behaviour.

Higher PNC inside classroom informs existences of other pollutant sources. Identification of source of pollutant is beyond the scope of this study.

3.8.4. PNC inside primary classrooms: Nalanda College

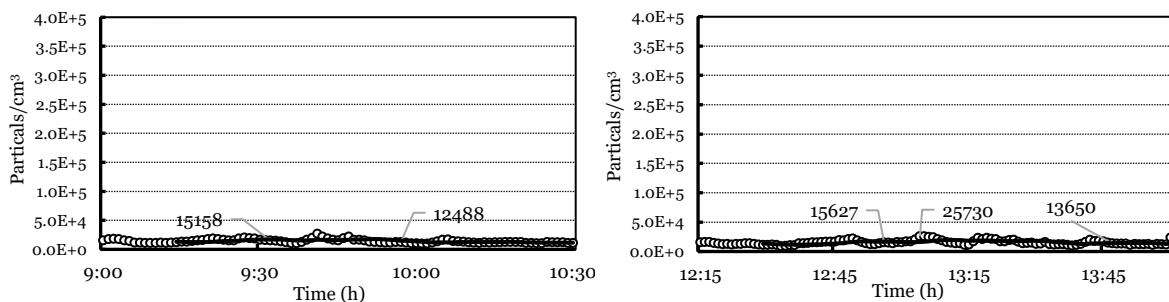


Figure 24 - PNC inside classrooms of Nalanda College during school hours; A. Morning and B. Afternoon

Figure 24 shows the Particle number concentration inside primary classrooms of Nalanda college during morning and evening sessions. As shown in Figure 24A and B, a similar PNC dispersion pattern is evident for morning and afternoon time segments. Maximum, minimum and mean PNC of morning and afternoon hours are 27152, 9789, 14027 and 26024, 9119, 15345 particles/cm³ respectively. Changing pattern of PNC levels during morning and afternoon segments shows a consistency.

3.8.5. PNC inside primary classrooms: Mahinda Vidyalaya

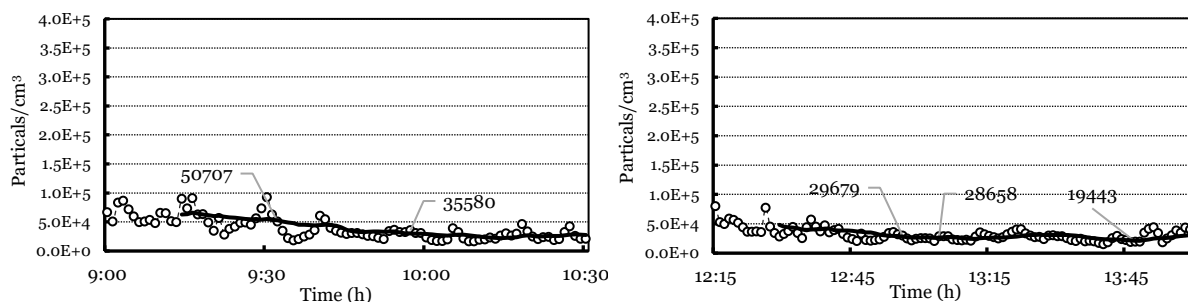


Figure 25 - PNC inside classrooms of Mahinda Vidyalaya during school hours; A. Morning and B. Afternoon

Particle number concentration inside primary classrooms of Isipathana College is shown in Figure 25. As shown in Figure 25 A and B, a similar PNC dispersion pattern is evident for morning and afternoon time segments. Maximum, minimum and mean PNC of morning and afternoon hours are 92531, 16472, 39417 and 80155, 15119, 31940 particles/cm³ respectively. Higher PNC levels are evident in morning times from 9 to 9.30 and all other times of morning and afternoon shows a similar behavior.

3.9. An Overview: PNC inside the classrooms of roadside schools

Comparison of PNC prevailing in primary classrooms of critical roadside schools are shown in Table 27. Mean PNC of morning and afternoon hours vary in the range of 16154 to 56181 and 15345 to 31940 particles/cm³ respectively. The highest PNC is evident at Thurstan College while the lowest at Isipathana College. Except for Thurstan College and Mahinda Vidyalaya (39147 particles/cm³) morning times of other roadside schools are apparent for similar mean PNC levels.

Table 27 - Comparison of PNC inside classrooms of roadside schools hours – Morning and afternoon sessions

Statistics	Particle number concentration (Particles/cm ³) - Morning (9 - 10.30)				
	Isipathana	Mahanama	Thurstan	Nalanda	Mahinda
Maximum	45287	29480	341609	27152	92531
Minimum	7707	12483	10830	9789	16472
Mean	16154	19183	56181	14027	39417
Particle number concentration (Particles/cm ³) - Afternoon (12.15 - 14)					
Maximum	54244	29984	25948	26024	80155
Minimum	8432	10664	11476	9119	15119
Mean	17766	19014	16979	15345	31940

Mean PNC of primary classrooms vary in the range of 15345 to 31940 particles/cm³ during afternoon hours from 12.15 to 14h. Except for all other schools the classrooms of Mahinda Vidyalaya are evident for the highest mean PNC, twice higher other roadside schools. Mean PNC of Nalanda, Thurstan, Isipathana and Mahanama are 15345, 16979, 17766 and 19104 particles/cm³, respectively. As illustrated in Table 27, Mahinda Vidyalaya confirms high Ultrafine pollutant levels in primary classrooms for both time durations of morning and afternoon. Except for morning hours of Thurstan College, primary classrooms of all other

schools informs a similarity in mean Ultrafine particle concentrations during school opening times of a weekday.

3.9.1. Comparison with Similar studies: International

Table 28 - Similar studies: UFP levels in Indoor air of primary schools

Country	Mean PNC (Particles/cm ³)	Reference
South Korea (Seoul)	18200	Kim et al., 2011
Australia (Brisbane)	8460	Laiman et al., 2014, Mazaheri et al., 2016
Portugal (Trofa-Porto)	10400	Cavelario Rufo et al., 2016
Bhutan (Kanglung block)	4540	Wangchuk et al., 2015

Table 28 shows similar studies on UFP levels in indoor air of primary schools. The lowest and highest PNC is evident in the primary schools of Bhutan and South Korea, respectively. Isipathana College, Mahanama College and Nalanda shows a similar trend in PNC levels of schools with South Korea. However, Mahinda Vidyalaya and morning times of Thurstan were evident for extremely high levels in classrooms.

3.10. Relationship of PNC: I/O ratio – Indoor (classrooms) and Outdoor (road)

Relationship of particle number concentration inside primary classrooms and adjoining roads of critical schools are explored in this section. This relationship is calculated as a ratio of PNC inside and outside (I/O). I/O ratio above and below 1 denotes higher and lower PNC levels inside classroom than corresponding adjoining road, respectively.

3.10.1. I/O ratio: Isipathana College

Figure 26 shows the relationship between PNC inside primary classrooms of Isipathana College and Park Lane opposite the school. Majority of the morning hours are evident for I/O ratio below 1.

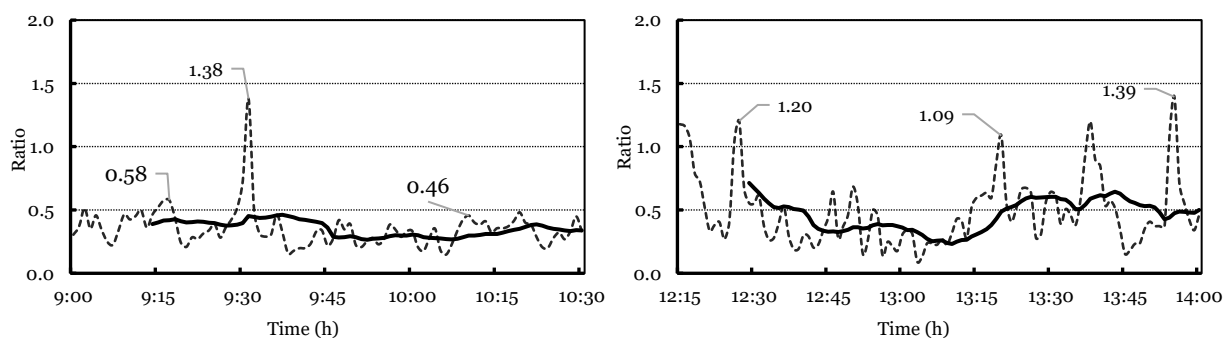


Figure 26 - Relationship between PNC inside classrooms and Park Lane: Isipathana College

Maximum I/O ratio for time segments of morning and afternoon are 1.38 and 1.39, respectively. Mean I/O ratio of morning times from 9 to 10.30h is 0.35 and evening times of 12.15 and 14.00h is 0.49. Results indicate PNC levels of classrooms are lower than the adjoining road. I/O ratio above 1 is evident at 9.30am and afternoon times of 12.17, 13.19, 13.38 and 13.54. These peaks of I/O ratio coincide with increasing traffic for commercial activities and during school closing times.

3.10.2. I/O ratio: Mahanama College

I/O ratio of morning and afternoon times of Mahanama College is shown in Figure 27. As shown in Figure 27, I/O ratio below 1 indicates the PNC of classrooms are lower than the PNC of adjoining road of R.A. De Mel Mawatha.

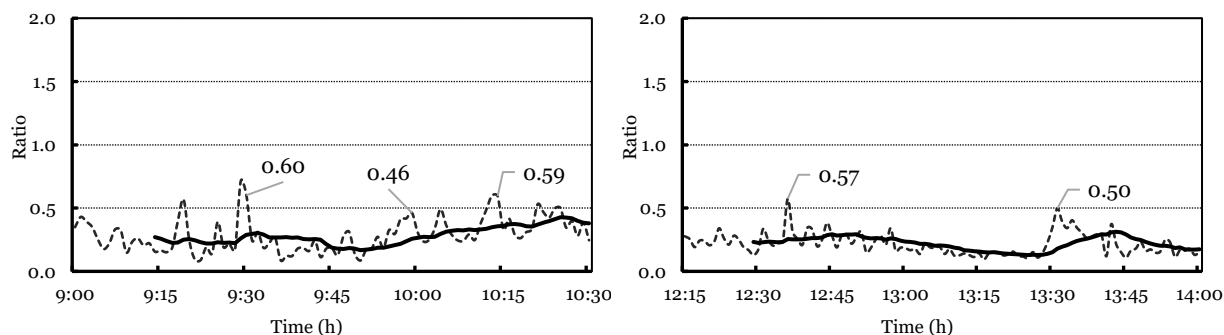


Figure 27 - Relationship between PNC inside classrooms and R.A.De Mel Mawatha: Mahanama College

I/O ratios of morning and afternoon time segments vary from 0.09 to 0.71 and 0.09 to 0.57, respectively. Mean I/O ratio of morning times is 0.29 and afternoon is 0.22. I/O ratio peaks at 9.30 and 10.15 in morning times with afternoon peaks at 12.36 and 13.30. The increasing I/O ratios evident for an association with school closing times. Extremely low mean I/O ratios during school functioning times inform negligible impact of PNC levels of adjoining road on primary classrooms.

3.10.3. I/O ratio: Thurstan College

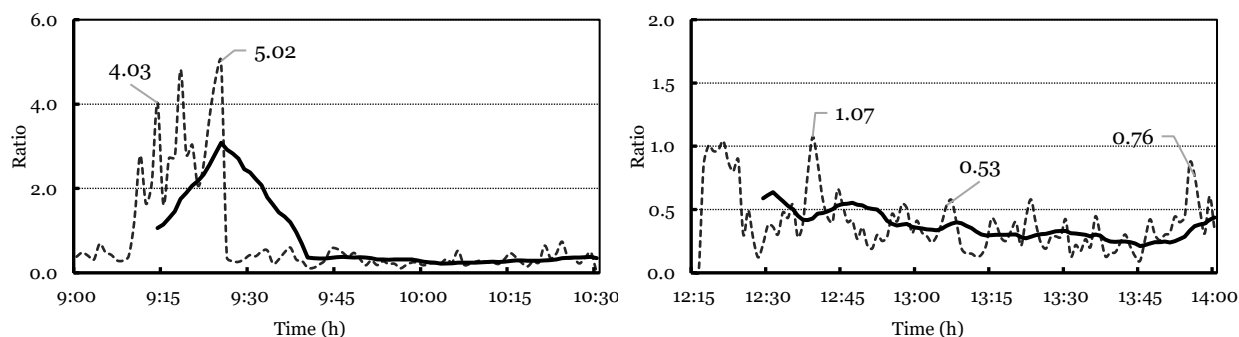


Figure 28 - Relationship between PNC inside classrooms and Reid Avenue, High level road: Thurstan College

Morning and afternoon I/O ratios of Thurstan College is shown in Figure 28. I/O ratio from 9 to 10.30am varies in the range of 0.11 to 5.0. Increase in I/O ratio above 1 begins at 9.10am and the maximum I/O ratio is evident at 9.24am. Thus, informs higher PNC level in primary classrooms than the adjoining road. Higher PNC within the classrooms indicates the influence of different pollutant sources within classroom or school premises. Except for the extreme PNC condition during 9.10 to 9.24 remaining times of the morning segment were evident for I/O ratio below 1. Mean I/O ratio of morning is 0.8. In contrary I/O ratio of afternoon times shows a constant pattern with maximum, minimum and mean of 1.07, 0.1 and 0.4, respectively. Classrooms were evident for lesser PNC levels than the adjoining roads during the afternoon session.

3.10.4. I/O ratio: Nalanda College

Variations in I/O ratio of Nalanda College is shown in Figure 29. Morning and afternoon time segments are evident for I/O ratios below 1. Maximum, minimum and mean I/O ratios of 1.58, 0.14, 0.51 and 1.86, 0.15, 0.63 are evident for morning and afternoon time segments respectively.

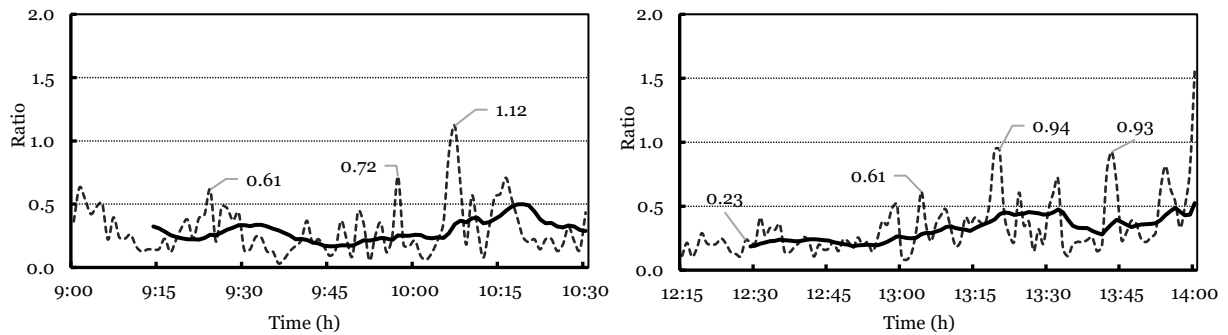


Figure 29 - Relationship between PNC inside classrooms and Sri Dhamma Mawatha: Nalanda College

I/O ratio increases at 10, 10.15 and 10.30 during morning and 13.20, 13.31, 13.42 during afternoon hours. These times associate with the increasing traffic for commercial activities and closing time of school. Increase in indoor PNC levels above outdoors are not prominent.

3.10.5. I/O ratio: Mahinda Vidyalaya

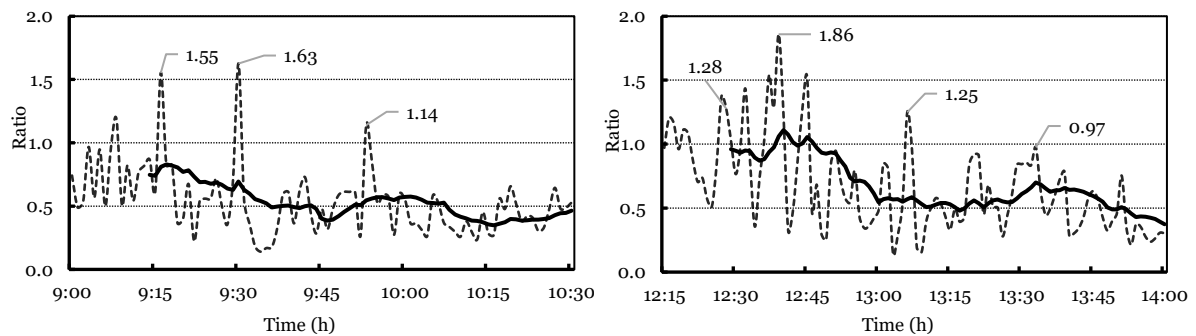


Figure 30 - Relationship between PNC inside classrooms and Gunarathna Pradeepa Mawatha: Mahinda vidyalaya

Figure 30 shows I/O ratio of morning and afternoon time segments. As shown in Figure 30, maximum, minimum and mean I/O ratios of 1.58, 0.14, 0.51 and 1.86, 0.15, 0.63 are apparent for morning and afternoon times, respectively. In comparison to morning time segment increased levels of indoor PNC is evident for afternoon times. Moreover, indoor PNC levels higher than the outdoor PNC levels and continuously changing pattern of I/O ratios is predominant.

3.11. Comparison of Mean I/O ratios: Five critical schools

Table 29 shows a comparison of mean I/O ratios of all schools. All schools are evident for lower PNC levels than the corresponding roads. Except for Thurstan and Mahinda college all other schools shows a low I/O ratio in the range of 0.25 to 0.35 during the morning times.

The highest I/O ratio for morning and afternoon times is evident for Thurstan college and Mahinda Vidyalaya, respectively. In comparison to other schools Mahinda Vidyalaya shows the highest I/O ratios of both time segments. Thus the interaction of PNC levels of road and classrooms of Mahanama and Nalanda is comparatively lesser than the other schools. However, further investigations are necessary to identify the source of pollutants in classrooms with higher PNC levels than the corresponding roads.

Table 29 - Comparison of mean I/O ratios of five critical schools during morning and afternoon time segments

Statistics	I/O ratio of schools				
	Isipathana	Mahanama	Thurstan	Nalanda	Mahinda
Mean - Morning	0.35	0.29	0.8	0.25	0.51
Mean - Afternoon	0.49	0.22	0.4	0.3	0.63

3.12. Profiles of Particle Size: Adjoining roads of critical schools

Particle size profiles of adjoining roads of the critical case schools are shown in Figure 31. As shown in Figure 31 particle size represents five groups in the range of 25 to 49nm.

All roads are evident for a similar pattern of particle size composition with the highest percentage of particles vary in the range of 35-39nm. In contrary the finest particle size of 25-29nm is evident in 1.02%, 3.05% and 0.52% in Park Lane, R.A.De Mel Mawatha and Reid Avenue, respectively. Particle sizes between 35-39nm incidence in Park Lane, R.A.De Mel mawatha, Reid Avenue, Sri Dhamma Mawatha and Gunaratna Pradeepa Mawatha represent 44%, 52%, 42% 43% and 63%, respectively.

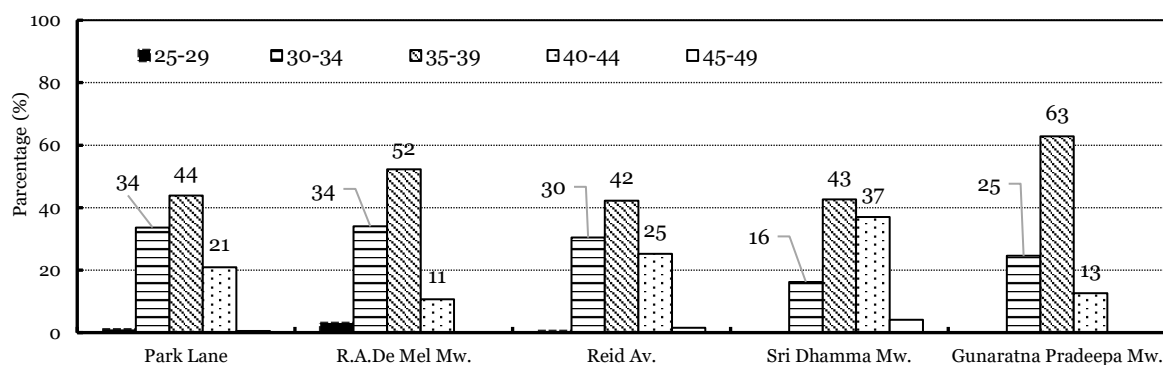


Figure 31 - Particle size profiles of adjoining roads of critical schools

Except for Sri Dhamma Mawatha the second highest percentage is apparent for particle sizes of 30-34nm. This particle size is evident for 34%, 34%, 30%, 16% and 25% in Park Lane, R.A.De Mel mawatha, Reid Avenue, Sri Dhamma Mawatha and Gunaratna Pradeepa Mawatha, respectively. However the particle sizes of 45-49nm is apparent only in Reid avenue and Sri Dhamma Mawatha. Thus, the findings inform except for the lowest and highest

particle sizes, particle sizes in the range of 30-44nm is prevalent in the atmosphere of all adjoining roads of the urban schools.

Descriptive statistics of the ultrafine particle sizes incidence on roads are shown in Table 30. As shown in Table 30 the largest and smallest particle sizes are 47 and 27nm.

Table 30 - Descriptive statistics of particle size: adjoining roads

Statistics	Particle size (nm)				
	Park Lane	R.A.De Mel Mw.	Reid Av.	Sri Dhamma Mw.	Gunarathna Pradeepa Mw.
Largest	45	43	47	47	42
Smallest	28	27	29	31	28
Mean	36	36	37	37	36

The largest particle size of 47nm is incidence on Sri Dhamma Mawatha and Reid Avenue of Highlevel road. Largest particle size of other roads vary in the range of 42 to 45nm. However, in comparison to other smaller particle sizes presense of the largest particle size is negligble for all roads. Particle size of 47nm is evident for 4.06% and 1.55% on Sri Dhamma Mawatha and Reid Avenue, respectively. The finest particle size of 27nm is apparent on Reid Avenue of R.A.De Mel Mawatha and the finest particle sizes of the other roads vary in the range of 28-31 nm. Furthermore the mean particle size of the investigated roads are between 36 to 38nm. Park Lane, Gunarathna Pradeepa Mawatha and R.A.De Mel Mawatha are consists of 36nm particles with 37nm and 38nm on Reid Avenue of HighLevel road and Sri Dhamma Mawatha, respectively. Thus the results confirm the predominant UFP size of the roads is between 36 to 38 nm.

3.13. Particle size profiles incidence in primary classrooms

Ultrafine particle size profiles in the indoor air of primary classrooms of critical roadside schools are detailed in Figure 32. Particle size groups represent 5 profiles as shown.

Except for Nalanda College the highest percentage of particles contain in the size range of 35 – 39nm. This percentage in Mahinda Vidyalaya, Thurstan College, Mahanama College and Isipathana College is 75%, 59%, 50% and 59%, respectively. The second highest percentage of particle size group of these schools is 40 – 44nm. In contrary the Nalanda College is evident for the highest percentage of 55% in particles size of 40 – 44nm. Except for Thurstan College, the smallest particle size group of 25 – 29 nm is evident in the indoor air of the primary classrooms of Thurstan College.

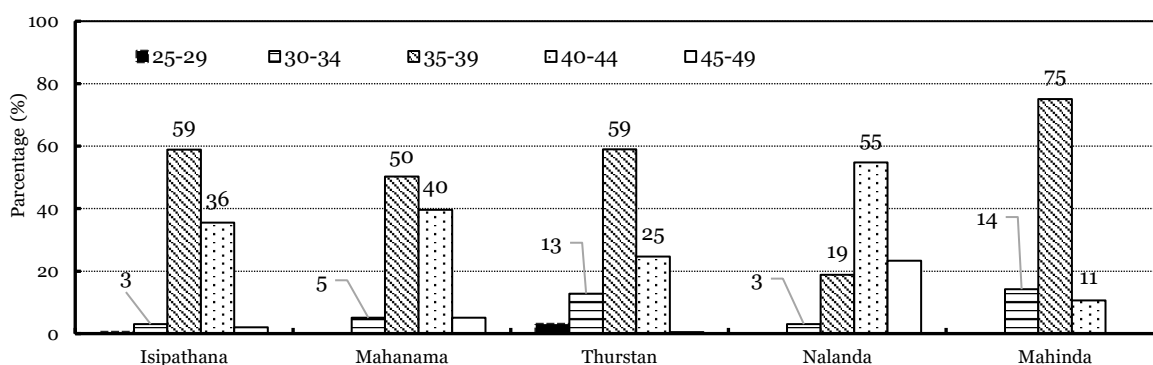


Figure 32 - Particle size profiles in primary classrooms of critical schools

Descriptive statistics of the UFP sizes incidence in the indoor air of primary classrooms of the critical schools are given in Table 31. As shown in Table 31, the mean UFP sizes vary in the range of 37 to 42nm. Mean UFP size of 37 is evident for both schools, Nalanda and Mahanama College. Similarly Isipathana College and Mahinda Vidyalaya is apparent for the mean UFP size of 39nm.

Table 31 - Descriptive statistics of particle size: Critical schools

Statistics	Particle size (nm)				
	Isipathana	Mahanama	Thurstan	Nalanda	Mahinda
Largest	46	42	49	45	47
Smallest	29	31	31	27	33
Mean	39	37	42	37	39

Largest and the smallest UFP size of the indoor air of all roadside schools vary in the range of 42 to 49nm and 27 to 33nm, respectively. The largest UFP size of 49nm is in the indoor air of primary classrooms of Thurstan College and the smallest of 27nm is evident in Nalanda College. Incidence of the UFP size of 27nm in the primary classrooms of Nalanda College is beyond the emissions of Sri Dhamma Mawatha. The smallest UFP size of this road is 31nm. Moreover, the largest UFP size of the indoor air of Isipathana College, Thurstan College and Mahinda Vidyalaya is apparent for a difference with the adjoining roads. Thus, the results confirms the UFP in indoor air of primary classrooms are not only affected by the traffic of primary adjoining road but by emissions of secondary roads and other emission sources. Identification of the emission source is beyond the scope of this study.

3.14. Deposition Fraction Analysis

The deposition fraction (DF) is an indicator of the number of particles of a given size depositing in a given region to the number of the same size entering the respiratory tract. In this study, the Cumulative nasal deposition fraction (CNDF) is the ratio of aerosol deposited in the extra thoracic region (during both inspiration and expiration) to aerosol entering the respiratory tract. Similarly, the Cumulative intrathoracic deposition fraction (CIDF) is the ratio of the aerosol deposited in the intrathoracic airways (during both inhalation and exhalation) to the aerosol entering the respiratory tract.

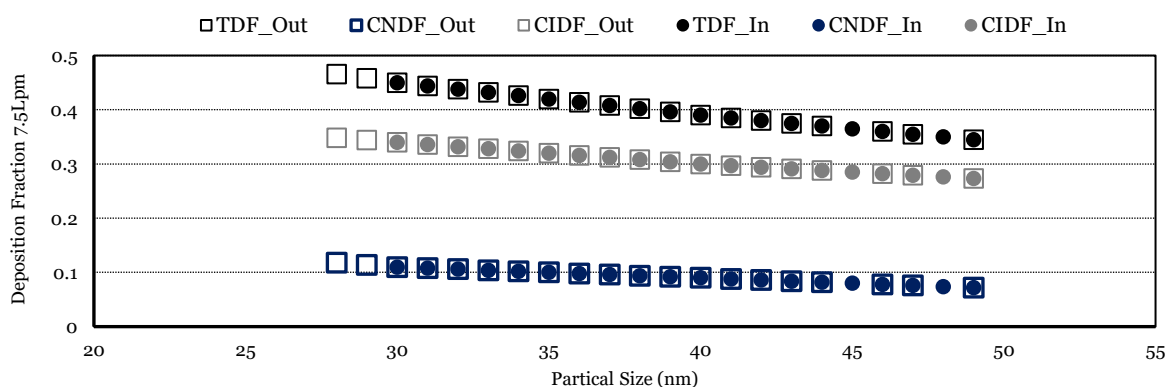


Figure 33 - Deposition fraction analysis of reference school inside and outside

The DF is calculated for average waiting relaxed student inside and outside the school. Figure 33 indicates the deposition fraction analysis inside and outside schools, The particle size is used to calculate the deposition fraction, and the particle size of the interiors and exteriors of the school varied between 27nm to 49nm. The DF of aerosols is higher outside when compared to interiors.

Table 32 - Covariance and correlation coefficient data and mean deposition fraction of outside (road) and inside (school)

Road	Covariance	Correlation coefficient	Mean Total Deposition Fraction	School	Covariance	Correlation coefficient	Mean total deposition fraction
GP	-	-	0.414231	Mahinda	-	-	0.41125
PL	0.000545	0.736986	0.413118	Isipathana	0.00038	0.625426	0.401188
SD	0.000451	0.694697	0.397647	Nalanda	0.000451	0.752233	0.397647
HL	0.000529	0.718047	0.403579	Thurstan	0.000451	0.630964	0.415421
RA	0.000396	0.590739	0.4262	Mahanama	0.000208	0.397297	0.391867

Covariance and correlation coefficient data and mean deposition fraction of outside and inside the schools are shown in Table 32. With the reference road, all other roads are positively related, and the schools have a strong positive correlation with GP road of the reference school. In Isipathana College, the total deposition fraction out 0.413 in terms of the mean is slightly higher than the total deposition fraction in 0.40. PNC particles are slightly higher on the roads than the interiors. In Mahinda Collge, the total deposition fraction out 0.414 in terms of the mean is almost similar to the total deposition fraction in, 0.411. This indicates since Mahinda College is located at a higher distance than the other schools from the road there is a little or no variation in the PNC particles on the road and the interiors.

In Nalanda College, the total deposition fraction out and in; 0.3976 are the same, which indicates that Nalanda College is located adjacent to two roads on the either side of the school. Although the classrooms are located away from the edges, the PNC particles coming from both roads have a direct impact on the interiors. In Thurstan College, the total deposition fraction out is lesser, 0.403 than the total deposition fraction in, 0.415. This attributes to presence of a vegetation screen on the exterior side the school and along the road, however on the interior, the building structure along with the roof is of old age, hence there is a considerable effect on the air quality of the interiors, increasing the number of PNC particles. Mahanama College has the highest value of the total deposition fraction out 0.426 out of the all the five schools, as the road RA De Mel Mawatha is located along the busy A2 Galle Road. The total deposition fraction of the interiors is low at 0.39, this is considerably lesser than the value of the outside.

3.15. Children’s background, relationship to the indoor and outdoor air pollution (Non-school exposure)

A total number of 670 individual students’ data were gathered, and 652 students provided clear and accurate details. These were used to analyze the non-school exposure and Indoor air quality of schools and its relationship with children’s respiratory symptoms. The house structure, traveling method, family background and medical history of each child is acquired. The considerable amount of PNC level exposure of the children during school hours is also recorded.

Out of 652 students, 77.45% were totally exposed to urban context in terms of living conditions and rest of the students had the minimum exposure. Travelling method of the students are given in figure 34. They use peak traffic hours 7.00am-8.00am and 1.30pm-3.00pm for travelling. Out of the sampled population a majority of 45% used a NAC car and only 22.5% used an AC car to get to the school. Among the total 2.91%, 8.9% and 12.12% of the students travel by foot, by bike and by bus respectively. These modes of transportation increase the exposure levels of the students to particle concentration mater. It is evident that students are exposed to different particle concentration levels along their way to the school. The level of exposure to PNC concentrations varies from student to student due to their mode of transportation to the school and their context of residence.

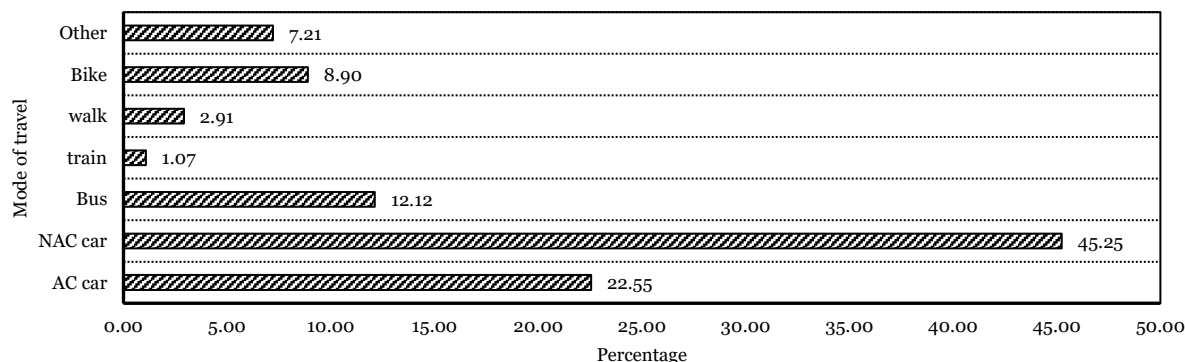


Figure 34 - Traveling method of the school children

Thus, the PNC concentration prior to the school visit is difficult to be determined due to the air quality difference in each Childs' home environment and it has a relationship to children's' health and behavioral pattern.

However, the state of the personal respiratory condition such as asthma and other diseases among the students can be determined from the questionnaire survey. The final part is based upon the relationship of the children's behavior and the respiratory conditions. The relationship between children's behavior and several illnesses such as asthma, rashes on the body, rhinitis and eczema have been studied through the questionnaire survey.

3.15.1. Asthma and its relationship to the children's behaviour

Asthma is a common chronic inflammatory lung disease that tend to cause repeated episodes of cough, wheezing along with breathing difficulties. Particle inhalation and deposition within lung airways causes development of chest infections and breathing difficulties along with fatigue and agitation.

There are 31% of children with Asthma and 13% of them are exposed to heavy traffic during weekdays. The students who travel on foot had their houses located in close proximity to urban areas, which creates a strong effect when compared with students in other contexts. Dr. Danister De Silva Mawatha and Sri Dhamma Mawatha in close vicinity to Nalanda collage has the strongest traffic conditions.

Frequency of students with asthma and number of children on early stage of Asthma is given in figure 35. Considerably a higher symptom level of 28.78% for Asthma students are

recorded in Mahanama College. The schools’ close proximity to the Galle Road is evident for the higher percentage of asthma amongst the students. Least percentage of 8.2% asthma students is recorded in Mahinda College which is the furthest away from the roads. Asthma student count of 23.63%, 21.38% and 18.01% is apparent for Isipthana, Thurstana and Nalanda college respectively and the asthma student percentage varied with the proximity to the roads and the traffic exposure.

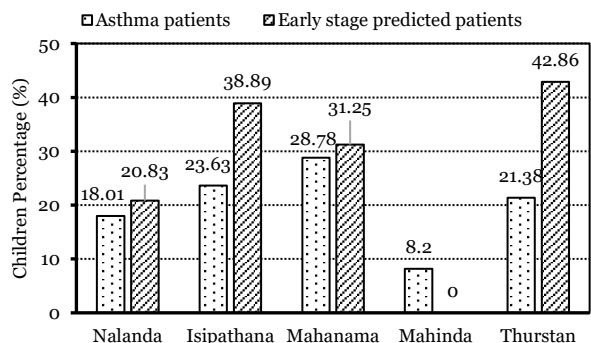


Figure 35 - Percentage of Asthma patients and early stage-predicted patients (with continuous cough and wheezing)

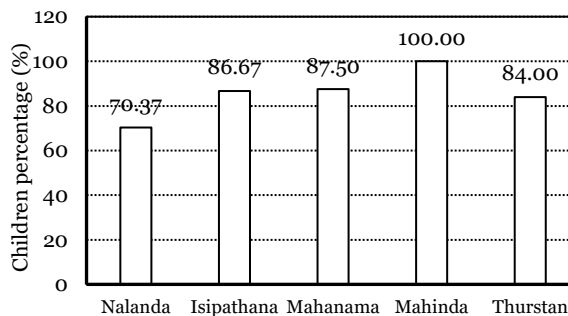


Figure 36 - Percentage of Asthma patients,

According to the the early stage of Asthma children, it indicates with close proximity to the roads, the chances of developing early-stage asthma is high. Mahinda college being the furthest from the road is evident for the absence of students showing any early-stage symptoms of asthma. Thurstan and Isipathana colleges show the highest early stages of asthma up to 42.86% and 38.89% accordingly. Some of the schools are located within a 200m range and these children are exposed to considerable PNC levels in peak traffic hours. A majority of the students are exposed to the traffic around 1 to 3 hours during peak traffic hours. An overall percentage 81.28% are exposed to a congested traffic situation from all the schools.

Figure 36 shows the asthma patients who are spending time in congested traffic conditions, weekly. From children having Asthma; Mahinda Vidyalaya, Isipathana College, Mahanama College, and Thurstan College has over 80% grade 3 -5 children who are exposed to urban traffic. From the total sample, of grade 3 - 5, more than half of them are exposed to a considerable time in traffic and thus high PNC concentrations. It has been recorded about 70% of grade 3 – 5 children who are exposed to congested traffic situation has developed Asthma. This was mainly depended upon the open travelling methods such as walking, using bikes and public transport.

3.15.2. Asthma and its relationship to the non- exposed children

During the traffic hours the children are totally abstained from the urban environment as children are occupied with their classroom activities. Data has to be collected in a time period where children are indoors and refrained from outside exposure, for this purpose, the survey is carried out when the children are occupied with classroom work. Figure 37 shows the percentage of children refrained from urban exposure. However, the results obtain show similar trends to the previous findings. Although the children are not exposed during a certain period of time, the chance of developing asthma is still the same within schools.

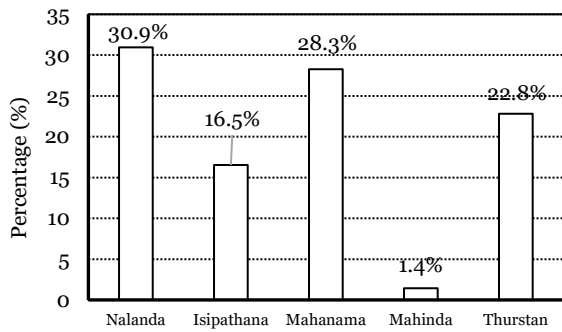


Figure 37 - Percentage of asthma children abstained from urban exposure

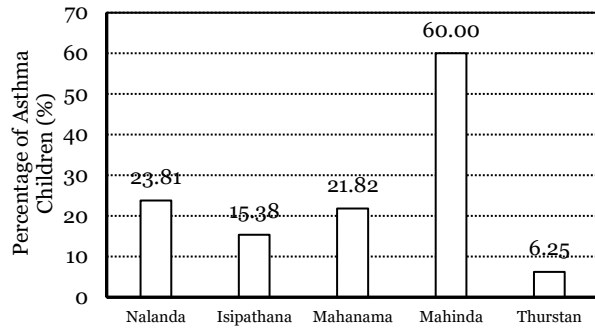


Figure 38 - Percentage of patients with Asthma in totally closed in traffic

Higher level of 30.9% is apparent for Nalanda College due to the two adjacent roads surrounding the school. Mahanama College and Thurstan College indicate values at 28.3% and 22.8%. It is evident although children are not exposed to traffic conditions during the peak hours, there is a significant percentage of children who suffer from asthma. The exposure to the roads regardless of being inside the classrooms creates the main ground for this condition. A mere percentage of 1.4% is apparent for Mahinda College which is a lesser value compared to the other schools. Mahinda College being located furthest away from the main and the sub roads attribute to these results.

Figure 38 shows the percentage of students in totally closed in traffic yet exposed with Asthma. Mahinda college has the highest percentage of asthma students with a 60% count and Thurstan college shows a 6.25% minority asthma patient count. The mean percentage of Asthma children in open congested traffic is 83.83% and the mean percentage of children in totally closed traffic is 27.18%. This gap shows that beside the school PNC level, the traffic condition does have a significant impact on Asthma and other symptoms.

3.15.3. Rash symptoms and its relationship to the children’s behaviour

Asthma and Rash are completely different type of symptoms. Some rashes show independent symptoms, but many cause itching, burning or other discomfort on one’s skin. However, a trend is observed on students having Rash and Asthma patients in the acquired data base. Figure 39 shows the pattern of Asthma and rash of the students.

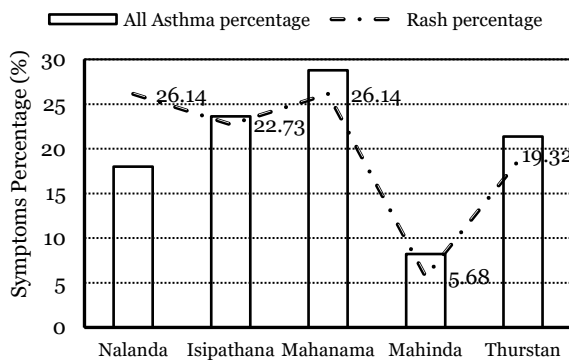


Figure 39 - Comparison of Asthma and Rash

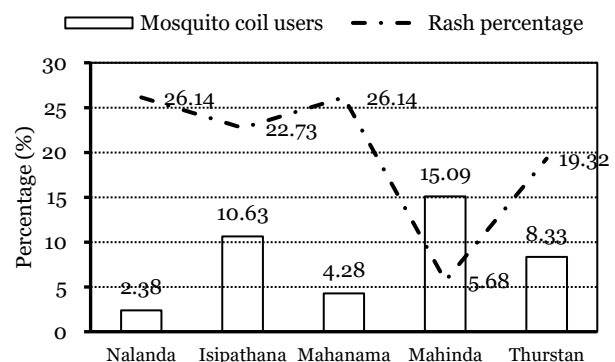


Figure 40 - Comparison of mosquito coil users and rash

The surrounding heat and the air quality of the environment may have direct connection to these attributes. Or the usage of mosquito coils, incense regularly can cause rash symptoms as well.

The analysis indicates that when students with rash symptoms increases, the asthma percentage also rises, thus this indicates that there is a correlation between the two variables: asthma and the possibility of developing a rash on the bodies of these children. Mahanama College indicates the highest asthma and rash percentage of 28.78% and 26.14%. It coincides with the school’s exposure to more heat conditions due to its’ location along the main Galle Road, whilst the lowest percentage values of the two variables are from Mahinda College; 8.20% for asthma and 5.68% for rashes, indicates the low impact of heat conditions as the school is the furthest away from the roads.

Relationship between the usage of mosquito oils and the rash percentage is analyzed as shown in figure 40. Results indicate the correlation between the two variables is not significant. For all five schools, with the increased use of mosquito coils, the percentage of children showing rash symptoms lowers indicating a contrast relationship between the two. The main stimulant for rash conditions could be the environment they live in or the exposure to PNC rather than other stimulants.

3.15.4. Rhinitis and its relationship to the children’s background

Rhinitis is when a reaction occurs that causes nasal congestion, runny nose and sneezing. Rhinitis can affect a person irrespective of their age, but Rhinitis known commonly to affect adults than children. Someone already experiencing Asthma and Eczema, it is more likely develop an allergic reaction to Rhinitis. The skin test for rashes can be used to identify Rhinitis. There are 15% of school students with Rhinitis.

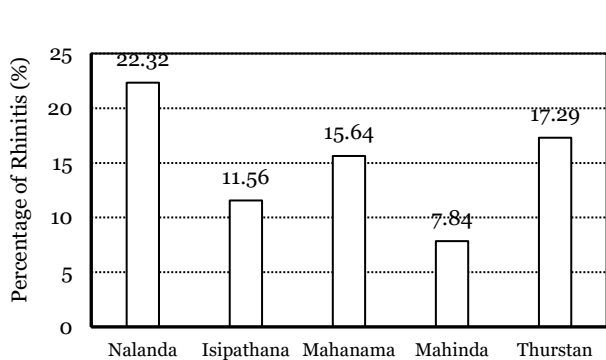


Figure 41 - Percentage of the students with Rhinitis

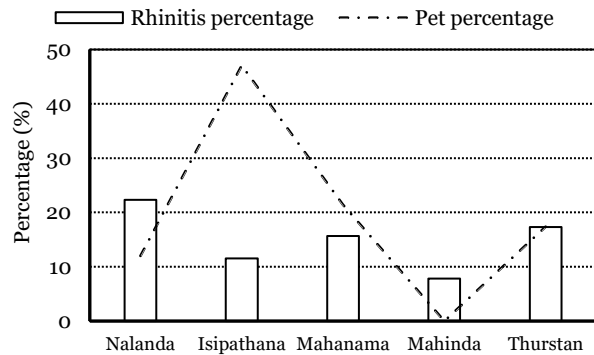


Figure 42 - Correlation with Rhinitis and home pets

Figure 41 shows that Mahinda Vidyalaya has the lowest percentage of rhinitis; 7.48%, this school is the furthest from the roads and Nalanda College has the highest percentage of 22.32% rhinitis cases, and this school is located adjacently to two busy roads on either side of the school.

Figure 42 indicates the correlation between student rhinitis cases and percentage of home pets with Isipathana College being the exception. It is evident for the impact of particles and its' direct consequence with the lung disease. For the rest of the schools, the rhinitis count is directly proportional to the presence of home pets.

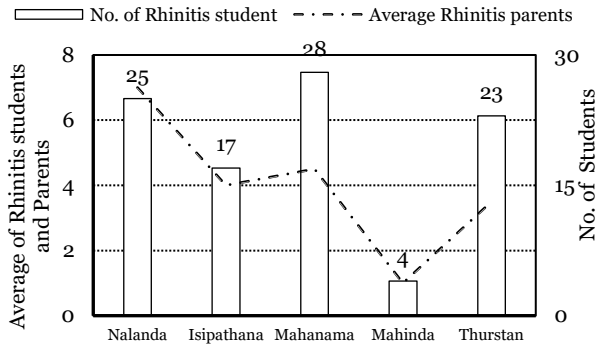


Figure 43 - Correlation with Rhinitis and Family History

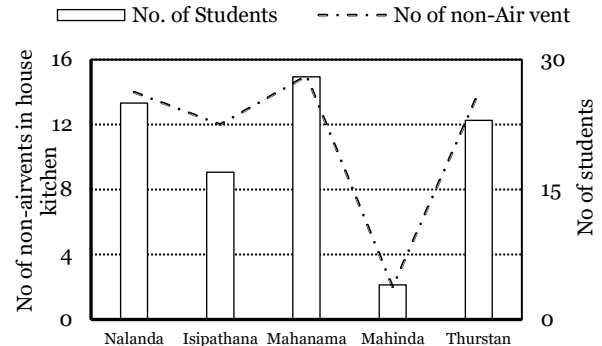


Figure 44 - Correlation with Rhinitis and air vent

Figure 43 shows the comparison of rhinitis and average number of family members who suffer from Rhinitis as the symptom of parentage is a direct consideration for the condition and a correlation is observed between these two variables.

The house air ventilation is considered as another factor affecting Rhinitis. As per figure 44, out of 104 Rhinitis children, 61 of them lack a vent in the kitchen which is 58% of the total population. With the decrease of air vents, the number of students suffering from rhinitis increases and vice versa. A direct relationship is evident for the number of children showing symptoms and the non-ventilated kitchens.

3.15.5. Eczema and its relationship to the children’s background

Eczema is a skin inflammation developed in any age, but most often onset from the early childhood. Children’s Rash can be identified with the Eczema. House dust, Climate change, pollution is known stimulants to trigger Eczema. About 2 in 3 children grow Eczema in mid-teen. For individuals with eczema, there is a chance of having Asthma or hay fever and there is a probability of having Eczema genetically if both parents suffer from the disease.

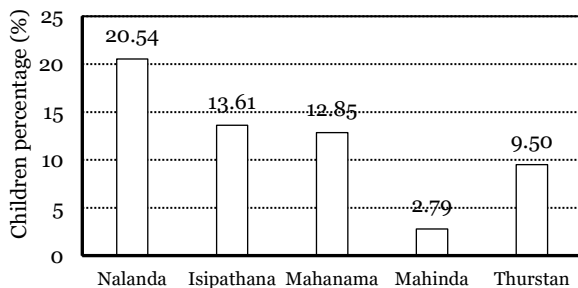


Figure 45 - Percentage of Eczema children

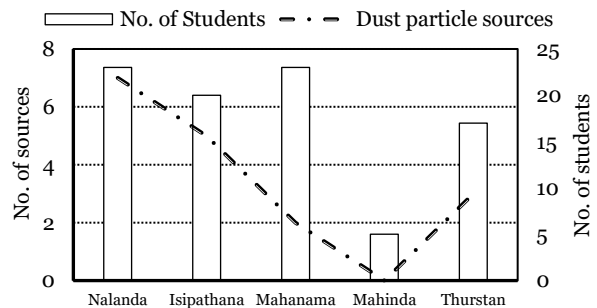


Figure 46 - Correlation with no of Eczema children and sources of dust particles

Within the total sample, 14.11% are identified with Eczema. As per figure 45, the highest number of students with Eczema 20.54% is recorded from Nalanda College. The lowest number of 2.79% is recorded for the students from Mahinda college.

Figure 46 shows that except Mahanama College, other students with Eczema have a correlation with sources of dust particles. This is directly correlated with the distance of the road at which the school is located. Also, another proven fact is the exposure to dust particles from mills, carpenter shops, metal workshops etc. contribute to symptoms of eczema amongst children. The students whose family members are occupied with jobs contributing to dust particles in the surroundings tend to show eczema signs in their bodies.

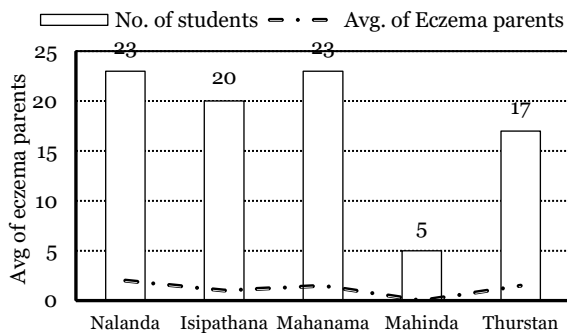


Figure 47 - Correlation with no of Eczema children and parents' disease history

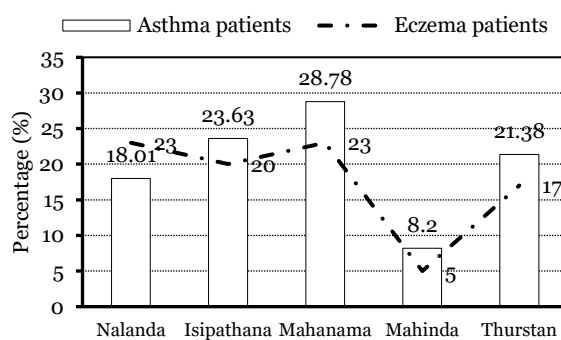


Figure 48 - Correlation with no of Eczema and asthma

Figure 47 shows that there is a significant correlation with parents' eczema history and children's Eczema, and the possibility of having Eczema genetically is proven scientifically. For all 5 schools the student count with eczema fluctuates in the same pattern as that of parents with eczema.

These findings are evident for the close link between hereditary connections and eczema levels and tends to show that the distance from the roads is not the only parameter that affect the student's chances of developing eczema. However, the distance from the road cannot be neglected as the children in schools with close proximity to the roads show higher cases of eczema when compared to the school which are further away.

Figure 48 shows that there is a significant correlation between the children with asthma and eczema. The chances of a person having eczema has a higher probability of exhibiting asthma conditions. The results are evident for all five schools to show the similar conditions. For Mahanama college, a higher percentage of 28.78% is apparent for asthma patients and a 23% is apparent for eczema patients. The lowest percentage of 8.2% for asthma and 5% for eczema is apparent for Children of Mahinda college. The main reason for these statuses varies according to the close proximity to roads where the close proximity schools such as Mahinda college indicate low symptoms and Mahanama college and Isipathana college show high symptom along with the children exposure to particles in the air. Since the two conditions are correlated, results show that the effect on children from both conditions increases with the distance to the roads.

4.0. CONCLUSION

- During the morning hours of 9.00am-10.30am the maximum level of PNC particles on the road is evident from the roads near Nalanda College, i.e. – Sri Daham Mawatha and Dr. Danister De silva Mawatha, and these same two roads constitute for the second highest particle count during the afternoon hours of 12.15-14.00pm.
- This is because Nalanda College is open to two roads whereas as the other schools open on to a single road only.
- The minimum particle count is recorded from the road near Mahinda Vidyalaya-Gunaratna Pradeep Mawatha in the morning, which is taken as a reference school.
- During the afternoon hours, the maximum particle count is from the road R.A De Mel Mawatha, near Mahanama College of 258065.4 pt. /cm³, as this road is situated along the main A2 Galle Road, and a heavy movement of traffic during the hours between, 12.15-14.00pm.
- The lowest PNC count during the afternoon hours is from the roads close to Nalanda College- Sri Daham Mawatha and Dr. Danister De Silva.
- The results indicate that particle number concentration of the correlation between Park Lane (Near Isipathana College) and Gunarathna pradeepa mawatha (near Mahinda College), is significant at the 0.01 level.
- Also, the particle number concentration of R.A. De mel mawatha (Near Mahanama college) and High Level Road (near Thurstan), shows a correlation at a significant level of 0.05. The Pearson's correlation also indicates that there is no correlation between the roads of any other schools.
- During the morning hours (9.00-10.30am), the maximum count of PNC particles from the interiors of the school is evident from Isipathana College, and the same school indicates the highest particle count during the afternoon hours as well.
- The minimum PNC count during the morning hours and the afternoon hours in the interiors is apparent for the reference school Mahinda College, as it is located at a greater distance from the roads.
- The particle number concentration correlation of Isipathana College and Thurstan College with Mahinda College (reference school) is significant at the 0.01 level.
- While the particle number concentration correlation of Mahanama College and Nalanda College is also significant at the 0.01 level.
- The reference school, Mahinda College indicates the highest peak of 1.86 in I/O ratio and the minimum I/O ratio is indicated from Nalanda College.

- The road near Isipathana College, Park Lane, implies a majority of the PNC particles, 43.88%, of the range in 35-39nm.
- The largest particle size of 0.51nm is the lowest with a 0.51%.
- The road near Mahinda College does not indicate any of the smallest and the largest particle sizes, the majority, 62.8% of the particles are in the size between 35-39nm.
- The roads near Nalanda College indicates the highest percentage of particles in the size range of 35-39nm and the lowest percentage is from the largest particle size.
- The roads along Mahanam and Thurstan College indicates a similar trend to Nalanda College. This proves that roads near all the schools consist of a majority of the PNC particle in the range of 35-39nm.
- In Mahinda College, the total deposition fraction out is 0.414 in terms of the mean is almost similar to the total deposition fraction in, 0.411.
- This proves that since Mahinda College is at a greater distance than other schools from the road there is little or no variation in the PNC particles on the road and the interiors.
- In Nalanda College, the total deposition fraction out and in are the same of 0.3976, this could be explained by the reason that Nalanda College is bounded by two roads on the either side of the school. Although the classrooms are located away from the edges, the PNC particles coming from both roads have a direct effect on the interiors.
- In Thurstan College, the total deposition fraction out is lesser, 0.402 than the total deposition fraction in, 0.414. This could be attributed to the fact that on the exterior the school and the road is covered with a vegetation pattern, however on the interior, the building structure along with the roof is old in age, hence there is a considerable effect on the air quality of the interiors, increasing the number of PNC particles.
- Mahanama College has the highest value of the total deposition fraction out 0.426 out of the all the five schools, as the road RA De Mel Mawatha is located along the busy A2 Galle Road.
- Mahanama College PNC level is closely similar to the Asia mean PNC level out of the five schools, moreover Nalanda comes in second which has the highest traffic level.
- All the five schools have surpassed the World mean and the European mean by a significant margin.
- Out of 652 students, 77.45% were totally exposed to an urban context in terms of living conditions and remaining minority of the students had a minimum exposure level.
- Nalanda college at Dr. Danister De Silva Mawatha and Sri Dhamma mawatha had the strongest traffic conditions. Considerably 24.10% of the highest symptoms for Asthma is recorded in Nalanda College.

- Moreover the 3% of students who walks are the mostly exposed to a considerable outdoor particle concentration level and tend to develop asthma at a faster rate.
- The mean percentage of Asthma children in open congested traffic is 83.83% and the mean percentage of children in totally closed traffic is 27.18%. This gap shows that beside the school PNC level, the traffic condition does have a significant impact on Asthma and other symptoms.
- There are 15% of school children who have Rhinitis and has a direct correlation with house pets.
- The air ventilation in house is another consideration which is related to Rhinitis. Out of 104 Rhinitis children, 61 of them lacks a kitchen vent.
- There is a significant correlation with parents' eczema history with children's' Eczema and supports the possibility of passing on Eczema genetically.

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Annexure**SELECTION OF THE CLASSROOMS CRITERION- FIVE CRITICAL SCHOOLS**

THURSTAN College							
Grade & Class	Min.	Max.	Mean	SD	CV	Status of being selected	Pollution level
3A	0.07	0.81	0.54	0.14229	0.263088	Not selected	2
3B	0.02	0.86	0.5174	0.18158	0.350482	Selected as the most polluted	1
3C	0.03	0.91	0.5792	0.19546	0.337863	Selected as the least polluted	3
4A	0.18	0.9	0.6543	0.1669	0.255719	Selected as the least polluted	3
4B	0.04	0.88	0.6152	0.15068	0.244814	Selected as the most polluted	1
4C	0.06	0.92	0.6327	0.17171	0.271498	Not selected	2
5A	0	0.93	0.5751	0.21561	0.374744	Not selected	2
5B	0.03	0.92	0.5543	0.20369	0.367673	Selected as the most polluted	3
5C	0.02	0.89	0.6161	0.15628	0.254087	Selected as the least polluted	1

NALANDA College							
Grade & Class	Min.	Max.	Mean	SD	CV	Status of being selected	Pollution level
3A	0.07	0.91	0.6455	0.20333	0.315361	Selected as the most polluted	1
3B	0.31	0.94	0.7268	0.14872	0.204198	Not selected	3
3C	0.56	0.94	0.777	0.0874	0.111665	Not selected	4
3D	0.2	0.9	0.6835	0.14283	0.208594	Not selected	2
3E	0.51	0.94	0.8095	0.08161	0.100965	Selected as the least polluted	5
4A	0.03	0.96	0.6877	0.2179	0.317142	Not selected	4
4B	0.32	0.98	0.7618	0.15865	0.208877	Selected as the least polluted	1
4C	0.21	0.94	0.6655	0.18301	0.274893	Selected as the most polluted	5
4D	0.01	0.97	0.7028	0.2566	0.365108	Not selected	2
4E	0.01	0.98	0.6976	0.20875	0.29911	Not selected	3
5A	0.05	0.96	0.5826	0.26245	0.450762	Not selected	3
5B	0.04	0.98	0.5669	0.29497	0.519899	Not selected	2
5C	0.12	0.97	0.6757	0.25243	0.376522	Selected as the least polluted	5
5D	0.05	0.95	0.6736	0.2681	0.397844	Not selected	4
5E	0.04	0.96	0.5354	0.26395	0.493307	Selected as the least polluted	1

MAHINDA College							
Grade & Class	Min.	Max.	Mean	SD	CV	Status of being selected	Pollution level
3A	0.02	0.84	0.3703	0.21590	0.5825192	Not selected	2
3B	0.00	0.92	0.4234	0.22938	0.54211156	Selected as the least polluted	3
3C	0.00	0.84	0.3634	0.21212	0.5835956	Selected as the most polluted	1
4A	0.00	0.87	0.4979	0.21721	0.4366862	Selected as the most polluted	1
4B	0.04	0.90	0.5422	0.21597	0.3978388	Not selected	2
4C	0.00	0.89	0.5834	0.22973	0.3935727	Select as least polluted	3
5A	0.00	0.84	0.5235	0.21046	0.4014065	Not selected	2
5B	0.00	0.76	0.4976	0.18965	0.3807174	Selected as most polluted	1
5C	0.00	0.89	0.5422	0.23798	0.4393097	Selected as least polluted	3

MAHANAMA College							
Grade & Class	Min.	Max.	Mean	SD	CV	Status of being selected	Pollution level
3A	0.313528	0.920443	0.751188	0.120292	0.160136	Not selected	5
3B	0.512119	0.956746	0.795027	0.094298	0.11861	Selected as the least polluted	6
3C	0.230783	0.958538	0.743613	0.144264	0.194005	Not selected	4
3D	0.021747	0.882337	0.500675	0.321763	0.642659	Selected as the most polluted	1
3E	0.331015	0.924581	0.72285	0.120431	0.166605	Not selected	3
3F	0.247986	0.918341	0.717436	0.125266	0.174603	Not selected	2
4A	0.440765	0.987816	0.764921	0.09604	0.125555	Not selected	5
4B	0.374408	0.959683	0.711642	0.117104	0.164555	Selected as the most polluted	1
4C	0.416358	0.954925	0.718016	0.109202	0.152089	Not selected	2
4D	0.026409	0.977168	0.75194	0.188326	0.250454	Not selected	4
4E	0.200475	0.938854	0.785044	0.154722	0.197087	Selected as the least polluted	6
4F	0.360046	0.919753	0.738464	0.141261	0.19129	Not selected	3
5A	0.449202	0.967462	0.769659	0.124765	0.162104	Not selected	5
5B	0.281012	0.919121	0.741741	0.131536	0.177333	Not selected	4

5C	0.439613	0.908591	0.802864	0.085326	0.106276	Selected as least polluted	6
5D	0.072407	0.918124	0.658814	0.182043	0.276319	Selected as most polluted	1
5E	0.226854	0.879359	0.703011	0.124354	0.176888	Not selected	2
5F	0.122881	0.923669	0.707629	0.184831	0.261198	Not selected	3

ISIPATHANA College

Grade & Class	Min.	Max.	Mean	SD	CV	Status of being selected	Pollution level
3A	0.45	0.92	0.7141	0.11541	0.162344	Not selected	6
3B	0.36	0.9	0.6495	0.13951	0.215199	Not selected	4
3C	0.22	0.92	0.6693	0.15567	0.232255	Not selected	5
3D	0.32	0.97	0.7494	0.1462	0.194742	Selected as the least polluted	7
3E	0.02	0.75	0.5459	0.14226	0.260895	Not selected	2
3F	0	0.73	0.4747	0.18459	0.389636	Selected as the most polluted	1
3G	0	0.73	0.5562	0.22345	0.399812	Not selected	3
4A	0.28	0.89	0.6335	0.14051	0.221849	Not selected	5
4B	0.33	0.84	0.6539	0.10761	0.164432	Selected as the least polluted	6
4C	0	0.82	0.6275	0.13983	0.22243	Not selected	4
4D	0.02	0.89	0.6569	0.1684	0.256578	Not selected	7
4E	0	0.77	0.507	0.20424	0.402533	Not selected	2
4F	0.19	0.82	0.5133	0.15985	0.312061	Selected as the most polluted	1
4G	0.01	0.81	0.5405	0.15926	0.29415	Not selected	3
5A	0.25	0.89	0.6243	0.15805	0.253586	Not selected	6
5B	0.07	0.91	0.6626	0.16652	0.251318	Selected as the least polluted	7
5C	0.08	0.8	0.5852	0.16825	0.288036	Not selected	3
5D	0.26	0.83	0.5749	0.10439	0.181835	Not selected	2
5E	0.23	0.7	0.5205	0.10959	0.20953	Selected as the most polluted	1
5F	0.28	0.81	0.5973	0.12761	0.212722	Not selected	4
5G	0.38	0.79	0.6016	0.08335	0.138883	Not selected	5