Final Technical Report

Air Pollution exposure levels to pedestrians and commuters in different locations in city of Colombo

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Background and justification

The city of Colombo has expanded and traffic flow had changed over the past few years with new urban planning concepts while the number of vehicles on the road has markedly increased. With the increase number of vehicles, the congested traffic could be noticed especially in rush hours (Offices and schools starting time periods, offices and schools closing time periods).

Nevertheless, Sri Lanka government has undertaken many actions to reduce and control the outdoor air pollution. Final aim of such activities is to protect the health and improve the quality of life of the people, and prevent the health cost to the government and the individuals. Thus it is important to understand the actual exposure levels to the people. The impact of the series of activities cannot be evaluated if the existing pollution level is not known. Further, air pollution exposure level in the present context is important to plan the future activities.

Although air quality monitoring is conducted in the Colombo Fort this will not adequately represent the personal exposure levels of the pedestrians and the commuters across the city. The personal exposure levels much accurately represent the air that a person is breathing. Thus, the personal exposure level is a better parameter than the ambient air quality level when the health is concern.

Many air pollutants are prevailing in the ambient air. Out of them, Particulate Matter less than 2.5 micrometres in diameter ($PM_{2.5}$) is one of the most hazardous pollutants prevailing in the ambient air. $PM_{2.5}$ can reach up to the lung alveoli (most sensitive and lowest end of the respiratory system, where the air exchange occurs) and penetrated to the blood circulation system of the body. The data available on $PM_{2.5}$ levels in the city of Colombo is scared. PM consists of a mixture of solid and liquid particles suspended in the air. Specific components of PM from different sources are heterogeneous physically and chemically and are likely to have differential health impacts (Grahame and Schlesinger, 2010). Several indicators have been used to describe PM. Particle size (or aerodynamic diameter) is often used to characterize PM as, for example, PM_{10} (particles with a diameter <10 μm) and $PM_{2.5}$ (those with a diameter < 2.5 μm). The most important chemical constituents of PM are sulfate, nitrate, ammonium, other inorganic ions (such as Na+, K+), organic carbon (OC), elemental carbon (EC), crustal material, particle-bound water and heavy metals (WHO, 2006a). The term “black carbon” is more loosely used with varied meanings in different disciplines (Smith et al., 2009). The terms “BC” and “soot” are often used interchangeably despite the fact that they are not synonymous, leading to terminological confusion. For the purpose of this research, we use the following definition of BC: “EC as well as all components in the soot that absorbs light such as some OC fractions (known as brown carbon) that show strong absorption in near-UV region of solar spectrum” (Rehman et al., 2011). Epidemiological studies provide evidence on the association between high levels of PM exposure and adverse health effects (Dherani et al., 2008). However, little research is available on BC, despite the fact that a high proportion of BC particles are < 1μm in aerodynamic diameter, which allows them to penetrate deeply into lungs (USAID, 2010). The few epidemiological studies available to date show positive associations between traffic-related BC and adverse health effects such as increased blood pressure (Wilker et al., 2010), increased acute respiratory inflammation (Lin et al., 2011), lower cognition level (Suglia et al., 2008), and reduced lung function (Suglia et al., 2008). Small aerosols like BC are the third-leading contributor to the burden of disease in South Asia and the fifth-leading cause of mortality in Asia as a whole (USAID, 2010).

Objective

Objective of the proposed study is to assess the personal exposure of PM2.5 at selected junctions and the roads in the city of Colombo.

Brief methodology

Based on available statistics of traffic and a qualitative inquiry with experts, 11 bus routes passes through many junctions of city of Colombo were selected. A research assistant was instructed to walk across the junctions in traffic periods with carry $PM_{2.5}$ monitor and black carbon monitor. Research assistant commute through the public buses for given destinations. He started from the first bus stand up to the terminal bus stand. Other than carrying the air quality monitors, research assistants bring a GPS monitor (Global Positioning System) with them. Another research assistant accompanied the research assistant on long trips for providing the necessary assistance. While he is walking/travelling, he will be requested to bring /wear air quality monitor.

The air quality monitors used in this study are one the most advance monitors available in the market to date which can monitor the real time $PM_{2.5}$ and black carbon. These monitors are easy to handle in field situations, and produces reliable and robust data. Monitoring data were downloaded to the computer at the end of the measurements. Based on the manual time log by the research assistant, air quality data were analysed and only the air quality logs with in the first bus stations to end bus station was calculated. Then the mean of the $PM_{2.5}$ and the BC were calculated for each bus root.

Garmin eTrex legend H was used to take the GPS data; a handheld monitor which can automatically logged the coordinates on move. GPS coordinates were download to the computer through the BaseCamp software. Data were further streamlined with the same software based on the information taken from the data record. These data were further plotted using the google maps for visualization purpose. Based on the data from GPS units, Average time spend for each trip as well as speed of the bus was calculated.

Results

Study completed obtaining the GPS locations of 3278 locations in 13 bus routes and at least 26 towns or junctions where the bus routes are started and ending. The table one gives the list of bus routes and starting and ending towns/junctions, and the PM $_{2.5}$ and BC concentration of the bus routes. Table further shows that total distance of 144 km was monitored in the city of Colombo for the $PM_{2.5}$ and the BC over 802 minutes of commuting.

Table 1: Summary of $PM_{2.5}$ and BC concentration in each bus route

	Start city	**End city**	**$PM_{2.5}$** $\mu g/m^3$	**BC** $\mu g/m^3$	**Total distance**	**Average Speed Km/h**	**Time period (minutes)**
1	Kollupitiya	Kaduwela	143.80	**35.346**	18.2	13	84.35
2	Battaramulla	Dehiwala	145.62	17.644	11.6	8	**86.36**
3	Moratuwa	Colombo Fort	150.36	20.618	16.6	15	66.49
4	Colombo Fort	Narahenpita	184.29	33.990	6.5	8	46.52
5	Narahenpita	Wellawatta	149.45	18.672	4.7	11	25.26
6	Dehiwala	Hettiyawatta	108.38	16.707	18.5	14	79.00
7	Hettiyawatta	Colombo Fort	92.54	10.389	3.4	8	25.00
8	Colombo Fort	Maharagama	74.42	10.384	13.1	10	75.00
14	Maharagama	Moratuwa	94.00	10.527	14	**17**	50.00
10	Kollupitiya	Wellampitiya	127.90	7.342	10.4	9	71.00
11	Angoda	Colombo Fort	176.42	9.092	10.6	10	64.00
12	Colombo Fort	Wellampitiya	245.11	13.573	4.9	**5**	60.00
13	Colombo Fort	Dehiwala	227.63	15.087	11.5	10	70.00
	Total				144		802.98

Highest time period was taken to travel from Battaramulla to dehiwala and the second highest was taken to travel from Kollupitiya to Kaduwela. Highest $PM_{2.5}$ concentration was reported from Colombo Fort – Wellampitiya bus route and the highest BC concentration was reported from Kollupitiya Kaduwella bus route. Highest distance was reported from Dehiwala – Hettiyawatta bus route. Lowest average speed was reported from Colombo Fort Wellampitiya bus route and the highest speed was reported from the Maharagma – Moratuwa bus route.

Table 2 present the descriptive statistics of the $PM_{2.5}$ and BC concentration. Mean value of the $PM_{2.5}$ and the BC were 148 μg/m^3 (Standard Deviation (SD)= 51) and 16.87 μg/m^3 SD = 8.860) respectively.

Table 2: Descriptive statistics of $PM_{2.5}$ and BC concentration

Parameter	PM μg/m^3	BC μg/m^3
Mean	147.68	16.87
N	13	13
Std. Deviation	51	8.860
Minimum	74	7.342
Maximum	245	35.346

Similarly, table 3 gives the summary statistics of the speed, distance and the duration of all the bus routes. Mean speed of the bus routes were 10.6 km/hr while the mean distance was 11.1 km and the mean duration was 62 minutes.

Table 3: Summary statistics of bus speed, travel distance and duration

Parameter	Speed km/hr	Distance (km)	Duration (minutes)
Mean	10.6	11.1	62:01
Number	13	13	13
Std. Deviation	3.33	5.073	20:08
Minimum	5.00	3.40	25:00
Maximum	17.00	18.50	86:36

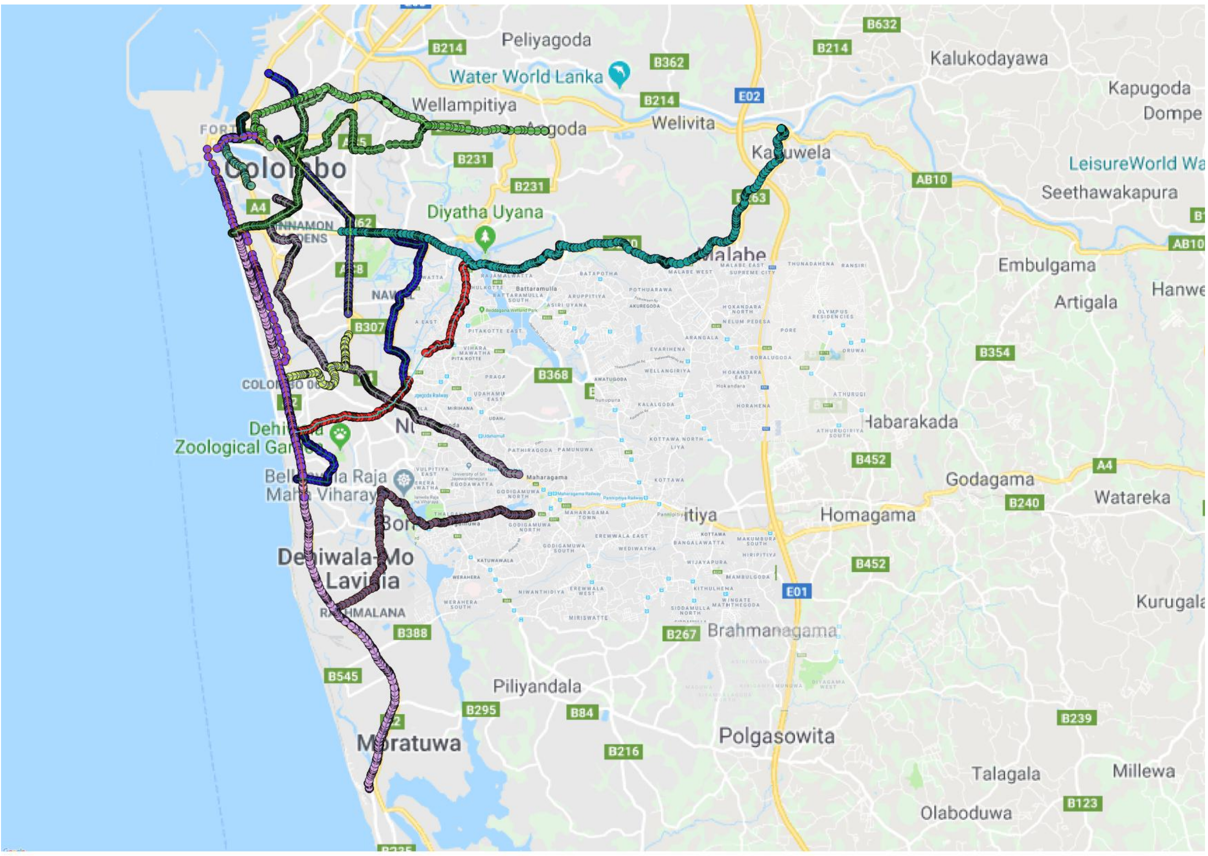

Figure 1: GPS locations of the bus routes and locations of towns/junction pass

After obtaining the GPS locations approximately every 30 seconds to one minute, all of them were exported using the BaseCamp software. After processing the data, all GPS locations were plotted in the google maps as shown in the figure 1. By figure 1, it could be noticed that the bus routes represent the city of Colombo, even penetrating to the suburb. Figure 2 gives a more closer view, showing the GPS coordinates across the bus routes.

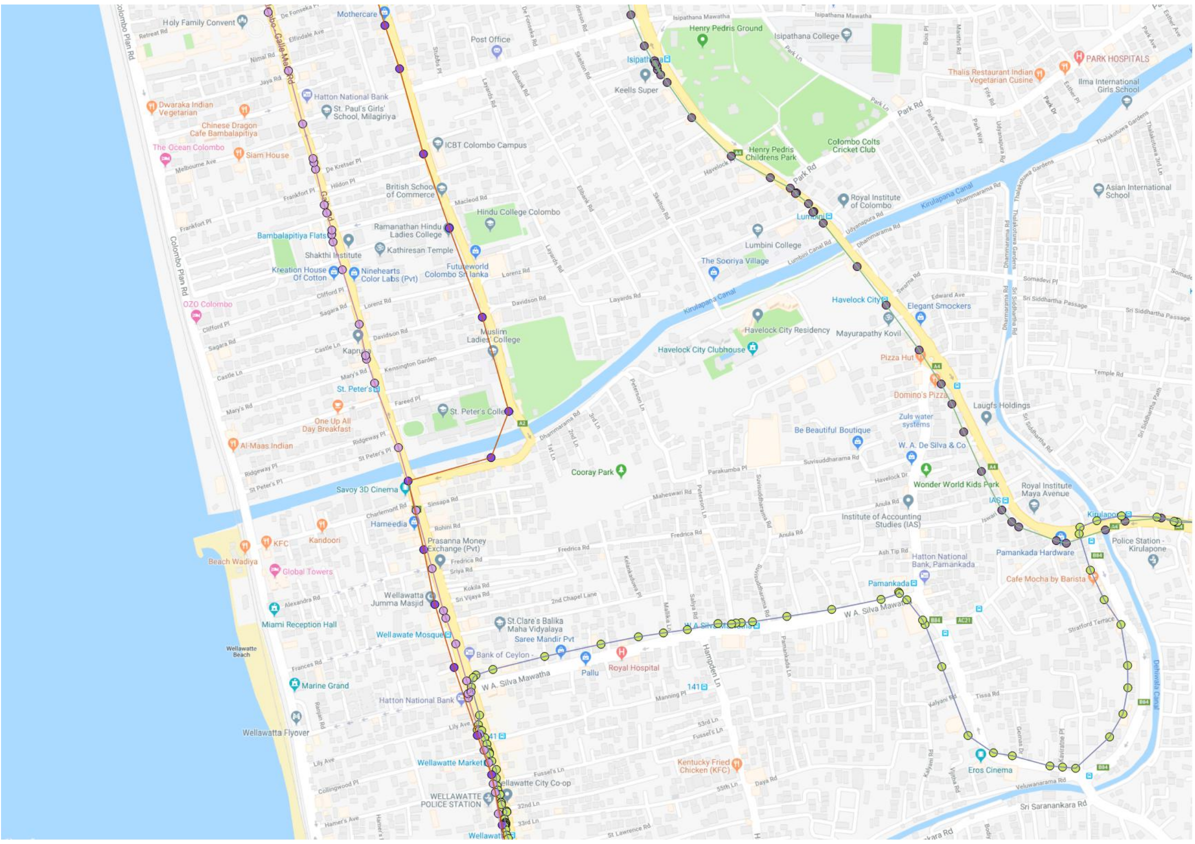

Figure 2: Closer view of the GPS coordinates across the bus routes

Discussion

Although the present study is a small scale simple study with comparatively small budget, it could be noticed that the study resulted vary important information worth for policy decisions in the future.

The study monitored the air quality in 13 bus routes. Since the bus routes are pass over the many sub cities, towns and junctions, all the of them were monitored for $PM_{2.5}$ and BC. Is important to note that this is the first study in Sri Lanka which monitored $PM_{2.5}$ and BC together with obtaining the GPS coordinates. The study reported mean $PM_{2.5}$ concentration of 148 $\mu g/m^3$. This value gives an average estimate of the $PM_{2.5}$ exposed by a passenger commuting across the city using a non-air-conditioned vehicle. It should be noted that the World Health Organization guideline value for the outdoor $PM_{2.5}$ level was 25 $\mu g/m^3$. However, it should be noted that this value is for 24 hours. The increase value of the $PM_{2.5}$ concentration emphasised the importance of further strengthen the regulation of traffic related emission standards in view of protecting the public.

BC concentration do not have an established value so far which limit the comparison. However, the reported values seem a considerable propotion as compared to the studies in other countries. However, BC is considered to be a hazards pollutant in the PM. Evidence are emerging in the international literature about the hazards features of the BC. In addition to the health effects, it is a well-known short-lived greenhouse gas affect the climate change.

Study used the novel methodology with obtaining coordinates while the air quality is monitoring. It gave the opportunity to understand the geographical distribution of bus routes and most polluted bus routes in among the monitored. The distribution shows, the selected bus routes are almost equally distributed across the city of Colombo. Further, the study demonstrates the possibility of using the techniques of GIS for mapping in the low resource context using the free web tools such as Google Earth.

In addition to the route display, obtaining the GPS location was assisted to obtain the distance travel in each route as well as the speed of the bus. It could be noticed that the average bus speed was 10.6 km/hr in the selected bus routes. This reflect the strength of traffic in city of Colombo. It is necessary to get the suitable policy decisions to control the traffic in city of Colombo in view of reducing the time spend on the roads with commuting to passengers' destinations.

Study Limitations

The study is limiting from the several methodological issues. Firstly, the study selected only 13 bus routes in the city of Colombo, although there are many bus routes in Colombo. It was not possible to select all the bus routes as it is logistically impractical. Perhaps the study initially planned only 10 bus routes. However, as the data collection progress, the scientific evaluation noted the importance of obtaining another 3 routes to representatively cover the city of Colombo.

Secondly, the $PM_{2.5}$ levels were monitored by the instrument which uses the light scattering technology. This technique reported the air quality levels slightly higher than the monitoring by the gravimetric technology. Gravimetric technology is considered to be the gold standard method for PM monitoring. However, gravimetric methodology is impractical to monitor the PM levels by minute to minute.

Conclusion

1. Average $PM_{2.5}$ concentration over 803 minutes and 144 km in the city of Colombo was 148 $\mu g/m^3$.
2. Average BC concentration over 803 minutes and 144 km in the city of Colombo was 16.9 $\mu g/m^3$.
3. Propotion of PM: BC was varied based on the bus route. Highest PM levels and the highest BC levels was reported not from the same bus route.
4. Average speed of the selected bus routes was 10.6km/hr.
5. Highest time period was taken to travel from Battaramulla to dehiwala and the second highest was taken to travel from Kollupitiya to Kaduwela among the selected bus routes for the study.
6. Lowest average speed was reported from Colombo Fort Wellampitiya bus route and the highest speed was reported from the Maharagma – Moratuwa bus route among the selected bus routes for the study.

Recommendations

- The study reported the high $PM_{2.5}$ levels as compared to the World Health Organization guideline values. Therefore, it is necessary to further enforces the regulations and reduce the public exposure to the ambient air pollution.
- Speed of commuting in the bus routes are low. This will further increase the inhaled dose of the pollutant and also reduces the productive utilization of the time. Therefore, it is necessary to take necessary actions to reduce the traffic in the city of Colombo, specially for non- air conditioned public transport.
- The study conducted in the limited number of bus routes. It is recommended to expand the similar methodology for other bus routes in Colombo and also replicate in other cities.
- Similar study should be repeated after a stipulated period of time. The findings will be important to assess the outcomes of the mitigation options.

Scientific outcome of the study

- The preliminary findings of the study were presented in an abstract as follow.

  Effects of Indoor Air Pollution on Children Under 5, Ranathunga N. Perera P, Nandasena, Y.L.S., Hettiarachchi, C., Abesiriwardena, N., Sinhababu, R.J., Piyal, T., Seventh National Symposium on Air Quality Management in Sri Lanka 2018, August 16- 17, 2018

- A manuscript will be prepared to submit to an international journal

Budget

Voucher Number	Description	Expenses (RS)
671	Allowance NHDF staff – administrative staff	5500
673	Allowance for data collection and technical resource team	24400
719	Petty cash for miscellaneous expenses such as travelling and foods	11000
78	Petty cash for miscellaneous expenses such as travelling and foods	6870
80	Allowance for data collection and technical resource team	24400
81	Allowance NHDF staff – administrative staff	3500
569	Allowance NHDF staff – administrative staff	3500
570	Allowance for data collection and technical resource team	24400
165	Allowance NHDF staff – administrative staff	3500
166	Allowance for data collection and technical resource team	24400
246	Allowance for data collection and technical resource team	24400
247	Allowance NHDF staff – administrative staff	3500
284	Allowance for data collection and technical resource team	24400
285	Allowance NHDF staff – administrative staff	3500
	Proposed deposit to National Health Development Fund, Ministry of Health (for cost of logistic management)	12730
	Total expenses	**200,000**
	Cash remain from the project	**0**

Acknowledgement

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