

**ANALYSIS OF ROADSIDE AIR POLLUTION IN  
WESTERN PROVINCE OF SRI LANKA**

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Thesis/Dissertation submitted in partial fulfillment of the requirements for the degree  
Master of Engineering

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The undersigned hereby certify that I have read and recommended the thesis for acceptance in partial fulfilment of the requirements for the M.Eng in Highway & Traffic Engineering.

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Date: 25<sup>th</sup> February 2025

Dr. Loshaka Perera

## **DEDICATION**

This dissertation is dedicated to my loving parents, my wife, my siblings and my friends for their endless love, support, and encouragement during this journey.

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## ABSTRACT

Air pollution is now one of the largest issues in the world that is leading to climate change, global warming, more frequent weather extremities, and respiratory related fatalities. Vehicle exhaust is one of the primary causes of air pollution and it emits CO<sub>2</sub>, NO<sub>2</sub>, SO<sub>2</sub>, and Particulate Matter (PM) among other air pollutants. Even though some of these targets and standards are being established by the World Health Organization (WHO) to limit the concentration levels of such toxic pollutants globally, no such clear system is yet visible to achieve such targets in Sri Lanka.

As a starting point, the objective of this research is to analyze the level of roadside air pollutants in the Western Province of Sri Lanka and to identify the annual variation of roadside air quality parameters. Followed by the development of a model to understand the correlation between road traffic and roadside emissions with the intention of proposing mitigation measures to control air pollution.

Air quality data from 40 fixed locations from 2013 to 2018 were collected and spatial analysis was carried out. NO<sub>2</sub> and SO<sub>2</sub> concentrations are analyzed using Arc GIS software and heat maps were generated visualizing the spatial distribution of pollutant concentration in the Western Province of Sri Lanka to identify critical locations with low air quality. Based on the spatial analysis results, it was observed that most of the urban areas have very high concentration levels of NO<sub>2</sub> and SO<sub>2</sub> which exceed more than twice the standard concentration level (WHO Air Quality Guideline-2005) during the period of measurements. It was also observed that from the year 2013 to 2017 there was a gradual decrease in NO<sub>2</sub>, and SO<sub>2</sub> levels in the Western province although, in the year 2018, there was a sudden increase in NO<sub>2</sub> and SO<sub>2</sub> concentration levels.

In addition, roadside air quality data was collected in conjunction with traffic data from 2022 to 2024 at eight selected locations to identify the distribution of pollutants away from the road and up to about 75m distance from the road edge. Based on the results of additional locations it is clear that NO<sub>2</sub>, PM<sub>2.5</sub>, and PM<sub>10</sub> show a positive correlation with traffic data while CO<sub>2</sub> shows some deviation during daytime at some locations.

Keywords: vehicle emissions, air pollution, spatial distribution, air quality

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## LIST OF ABBREVIATIONS

Abbreviation	Description
PCU	Passenger Car Unit
NBRO	National Building Research Organization
VET	Vehicle Emission Testing
ESSD	Environmental Studies & Services Division
CO <sub>2</sub>	Carbon Dioxide
NO <sub>2</sub>	Nitrogen Dioxide
PM <sub>2.5</sub>	Particulate Matter that is 2.5 microns or less in diameter
PM <sub>10</sub>	Particulate Matter 10 micrometers or less in diameter
SO <sub>2</sub>	Sulfur Dioxide
WP	Western Province



# 1 INTRODUCTION

## 1.1 Background

Air pollution has become a significant environmental and public health issue on a global scale, with urban areas experiencing the most severe consequences resulting from swift industrial growth, urban expansion, and rising levels of vehicular traffic (K Arshad et al, 2024). Research conducted internationally has shown that vehicle emissions are one of the main factors in the deterioration of urban air quality and affect the health and environment of millions of people (Guttikunda & Goel, 2018; Smith et al., 2019). Among them are pollutants like CO<sub>2</sub>, NO<sub>2</sub>, PM<sub>2.5</sub>, PM<sub>10</sub> and SO<sub>2</sub> which are highly concentrated in areas with a high level of traffic and, according to the World Health Organization, 2022, are very often implicated in a wide variety of respiratory and heart conditions. These contaminants, frequently emitted from automobile exhaust systems, have a direct impact on human health, in addition to exacerbating wider environmental issues including acid rain and climate change (Chen & Kan, 2020).

The health effects of air pollution are significant: particulate matter, such as PM<sub>2.5</sub>, has the capacity to penetrate into the lungs and circulatory system deeply, causing respiratory problems and increasing the risk of cardiovascular disease. Simultaneously, NO<sub>2</sub> and CO<sub>2</sub> gases have been related to chronic respiratory issues and negative environmental impacts in recent times (Pope & Dockery, 2017). Research indicates that regions characterized by severe traffic congestion encounter worsened air quality issues, which may affect the quality of life and economic productivity of urban inhabitants (Kumar et al., 2021).

It was pointed out in previous studies that the disastrous level of air pollution in major cities worldwide. During the peak period in New Delhi, PM<sub>2.5</sub> concentrations frequently reach above 140 µg/m<sup>3</sup>; in contrast, the WHO annual average threshold recommendation is up to 5 µg/m<sup>3</sup> only (Guttikunda & Goel, 2013; WHO, 2021). In Beijing, similar trends can be seen, with high industrial emissions and seasonal smog events that make the PM<sub>2.5</sub> levels mostly exceed 40 µg/m<sup>3</sup> annually (Chen et al., 2020). On the other hand, cities like Tokyo have comparatively lower PM<sub>2.5</sub> levels, averaging about 15 µg/m<sup>3</sup> annually due to very strict vehicular emission standards (Nakajima et al., 2018).

Apart from particulate matter, the heavy flow of vehicular traffic in urban cities usually records NO<sub>2</sub> concentrations beyond the accepted WHO guideline of 10 µg/m<sup>3</sup>. For instance, Mexico City recorded annual NO<sub>2</sub> at an average of 30 µg/m<sup>3</sup>, with lots of contribution to air quality degradation (Molina et al., 2019). Similarly, Lagos presents NO<sub>2</sub>, and CO<sub>2</sub> emissions generated by intense traffic flow and industrial activity, further deteriorating health in an already susceptible population (Olawoyin et al., 2020). These findings give further evidence of the urgent need for air quality monitoring at the local scale and for mitigation measures accordingly.

The air pollution problems faced by Sri Lanka reflect those seen globally, with urban centres such as Colombo and the Western Province facing significant air quality challenges due to rapid urbanization and unprecedented increases in vehicle numbers. The demographic and economic structure of the country has gradually shifted towards an urban orientation, leading to an increase in vehicle ownership and, consequently, increased emissions from the transport sector (Central Environmental Authority, 2021). It is recognized that automobiles are significant contributors to urban pollution, in particular regarding the concentration of CO<sub>2</sub>, NO<sub>2</sub>, and particulate matter (Perera et al., 2017). Such pollutants have given rise to pressing environmental health problems, with a resulting increase in respiratory illnesses among the urban population and threatened ecosystems within the city environment (Health Ministry of Sri Lanka, 2019).

The Western Province, which accommodates about a third of Sri Lanka's population, is faced with these challenges. With substantial traffic congestion and a lack of public transport infrastructure, primary roads are sources of heavy emissions (Transport Ministry of Sri Lanka, 2022). Moreover, despite the efforts by Sri Lanka to reduce emissions through the Vehicle Emission Testing program and the promotion of electric and hybrid vehicles, these measures have not yet fully alleviated the growing crisis of urban air quality. The absence of real-time and spatially representative air quality data hinders further policy development beyond this, as policymakers lack the basic information needed to take effective action against urban air pollution (Central Environmental Authority, 2020).

## **1.2 Problem statement**

Despite the increasing awareness of air pollution in Sri Lanka, there is a severe deficiency in terms of real-time and localized information, particularly in urban roadside environments where vehicle emissions are usually high. Current research typically provides broad assessments of urban air quality without accounting for variations in pollution levels within specific hot spots, such as heavily trafficked roadways. Without specific data on pollutant concentrations, especially CO<sub>2</sub>, NO<sub>2</sub>, PM<sub>2.5</sub>, and PM<sub>10</sub>, at variable distances from major roads, policymakers are severely limited in their ability to develop and implement effective interventions specifically targeted at lowering pollution exposure near major roadways. For example, although research conducted in other areas has revealed significant gradients in pollutant concentrations relative to proximity to roads, analogous studies remain limited within the Sri Lankan framework (Dharmarathne et al., 2019).

The absence of adequate data limits the identification of pollution hotspots and masks the relationship between traffic density, proximity to the road, and levels of pollutant concentration. Understanding these factors is essential in formulating workable air quality management strategies, particularly with the continuous growth of urban populations and an increasing number of vehicles. This study will seek to bridge these gaps by collecting and analyzing air quality data along major urban roads in the Western Province, providing guidance toward policy considerations for improved air quality.

## **1.3 Objectives**

The objectives of the research can be summarized as follows,

1. To determine the levels of concentration of some major pollutants, namely, CO<sub>2</sub>, NO<sub>2</sub>, PM<sub>2.5</sub>, and PM<sub>10</sub> at different roadside sites in the Western Province of Sri Lanka.
2. To analyze the variation in pollutant concentrations with distance from major roads, assessing how pollution levels change at incremental distances.
3. To determine the relation of traffic density and levels of pollutants: to probe how increased vehicular movement affects air quality alongside roads.

#### **1.4 Scope and Limitations of the Study**

The focus of this research will be to focusing on the Western Province of Sri Lanka, placing a special emphasis on major roads or highways, where emissions from vehicles are expected to be highest. This study is incorporated into an already collected data set (secondary data from NBRO) and air quality concentration data collected using sensor units placed at eight (8) sites with regular intervals from the roadside up to 75m from roadside. These datasets will help to determine the spatial distribution patterns of the pollutants and to identify high-risk areas along urban corridors. Although this study gives insight into the concentration levels of air pollution around roadways, it is still constrained by data that has been collected under specific meteorological conditions and at certain times of the day that may impact the level of pollutants. Further, this research is constrained by resources, and therefore the number of monitored sites is limited.

Under this research study, air quality concentration level measurements for NO<sub>2</sub> and SO<sub>2</sub> were carried out at 40 data collection locations covering major cities and urban areas in the Western province of Sri Lanka during the period of 2013 to 2018. All these locations were within three districts, namely, Colombo, Gampaha and Kaluthara. Colombo urban area, especially in the Colombo Municipal council area, data collection was carried out at nineteen (19) locations. Moreover, Gampaha, which is the second highest populated district in the country (Census Department, Sri Lanka, 2012), is located northeast of the capital. Air quality monitoring for NO<sub>2</sub> and SO<sub>2</sub> concentration levels in Gampaha district was also conducted from 2013 to 2018 based on Eleven (11) locations in the region of Gampaha Municipal Council area and surrounding areas. In addition to that, air quality concentration levels monitoring for NO<sub>2</sub> and SO<sub>2</sub> was conducted in Kalutara District, which is located about 40 km south of the capital. The data collection also began in 2013 at five (05) locations within the Kalutara Municipal Council and five (05) Locations in the Horana Urban Council area. This monitoring measures the monthly average exposure levels of NO<sub>2</sub> and SO<sub>2</sub>.

Although data collection was limited to major cities and urban areas, literature suggests that urban and suburban areas typically exhibit higher pollutant concentrations due to

more significant sources, such as vehicular emissions, industrial activities, and higher population densities (MDPI, 2023; Camfil, 2023) and such regions often serve as hubs for implementing mitigation strategies, with policies such as clean technologies, traffic regulations, and green buffers providing scalable and transferable models for broader regions (Clarity.io, 2023; PMC, 2021). Therefore, the model developed in this study is applicable island-wide although the data used is limited to the Western Province of Sri Lanka.

This dissertation consists of five individual chapters. Chapter 1 explains the meaning of air pollution, specifying its spatial variation and possible impact brought about by different air pollutants and also emphasizing why it is necessary to do research of this type. Chapter 2 will cover an exhaustive review of the literature with regard to local as well as foreign research carried out. Chapter 3 will address the research methodology used in the study. Data collection procedures as well as data preparation processes to be adopted are also covered in the chapter. It also gives the problem statement of research and addresses how the problems identified in the study were solved. Chapter 4 will demonstrate the data analysis process of the collected data, and interpolation is primarily carried out in this chapter. Finally, Chapter 5 will validate the concepts of the researcher from the collected data and implementations, research outputs summary, and discussion on results applicability. This chapter will also reflect on the future scope and research limitations.

## **1.5 Chapter Summary**

Besides the research methodology and restrictions, this chapter entails the background, problem statement, and aims of the study. It is remarked that the background of the research explains the nature of the subject under investigation whereas the problem statement indicates the relevance of the study to the roadside air pollution in Sri Lanka.

## 2 LITERATURE REVIEW

### 2.1 Overview of Air Pollution at Roadsides

Roadside air pollution is a major environmental and public health concern, driven predominantly by vehicular emissions. With the growing number of vehicles on roads worldwide, emissions of harmful pollutants such as nitrogen dioxides (NO<sub>2</sub>), carbon monoxide (CO), sulfur dioxide (SO<sub>2</sub>), and particulate matter (PM<sub>10</sub> and PM<sub>2.5</sub>) have increased, particularly in urban areas with heavy traffic. These pollutants originate mainly from vehicle exhaust, tyre and brake wear, and road dust suspension (Amato et al., 2014; Minguillon et al., 2012; Weiss et al., 2011).

Below are the four primary sources of air pollutants, sources and the potential impacts.

- **Nitrogen Dioxides (NO<sub>2</sub>):** Generated mainly from combustion engines, NO<sub>2</sub> contributes to ground-level ozone and can exacerbate respiratory issues.
- **Carbon Dioxide (CO<sub>2</sub>):** Produced by complete combustion in engines, CO<sub>2</sub> is especially dangerous in confined spaces and high-traffic zones, posing significant health risks.
- **Particulate Matter (PM<sub>10</sub> and PM<sub>2.5</sub>):** Particles released from exhaust, tyre and brake wear, and road dust are suspended in the air and can penetrate deep into the lungs, contributing to respiratory and cardiovascular diseases.
- **Sulfur Dioxide (SO<sub>2</sub>):** Though less common in modern engines, SO<sub>2</sub> is emitted from some diesel engines and older vehicles, contributing to respiratory issues and acid rain.

Pollutants tend to be concentrated within 50-100 meters of roadways, an area often referred to as the "roadside effect zone" (Gaillard et al., 2016; Xu et al., 2015). Levels of NO<sub>2</sub> and PM<sub>2.5</sub> are especially high within this range, particularly during peak traffic hours when emissions are at their highest (EPA, 2015; PMC, 2016). The concentration of these pollutants decreases with distance from the road, but the rate of dispersion depends on factors such as:

**Traffic Volume and Composition:** Higher volumes of traffic, especially with a significant proportion of heavy and fuel-inefficient vehicles, lead to greater emissions and

more severe roadside pollution. Traffic levels fluctuate throughout the day, typically peaking during rush hours, leading to higher concentrations of pollutants. Heavy-duty vehicles, like trucks and buses, contribute more pollutants per unit of time compared to light-duty vehicles. Data from Chinese research institutions indicate that when vehicle speeds decline from 50 km/h to 20 km/h during congestion, emissions such as CO and hydrocarbons can surge by approximately 50% (Liang et al., 2023).

A study focusing on the Boston corridor illustrates those concentrations of pollutants such as black carbon (BC), nitrogen oxides (NO<sub>x</sub>), and ultrafine particles (UFP) show strong spatial gradients, with higher levels observed close to highways and rapid decreases as distance from the highway increases. Factors such as highway design and nearby structures influence these gradients (Hagler et al., 2012; Finn et al., 2010).

**Meteorological Conditions:** Wind speed and direction, temperature, and humidity all influence how pollutants disperse. For instance, strong winds can dilute pollutants, while calm conditions lead to higher concentrations near the road. The pre-monsoon season typically sees high temperatures and low humidity, promoting photochemical reactions that lead to higher ozone formation (Chowdhury et al., 2020). In contrast, post-monsoon conditions are marked by cooler temperatures and higher humidity, which reduce PM<sub>2.5</sub> levels (Guttikunda & Jawahar, 2012). In post-monsoon periods, cooler temperatures and reduced sunlight limit photochemical reactions, leading to lower ground-level ozone formation. However, residual secondary pollutants from the pre-monsoon phase may persist, albeit at lower concentrations (Venkataraman et al., 2014).

**Topography and Urban Structures:** Features such as hills, buildings, and vegetation can trap pollutants close to roads, especially in urban “street canyons” where airflow is restricted. For instance, pollutants may settle in low-lying areas, while urban canyons in cities create wind shadows that trap pollutants, resulting in elevated levels in pedestrian zones and residential areas (Zhou & Levy, 2007).

Prolonged exposure to roadside air pollution is associated with adverse health effects, including respiratory and cardiovascular diseases, particularly among vulnerable groups such as children, the elderly, and those with pre-existing health conditions. Additionally,

pollutants like NO<sub>2</sub> and PM contribute to broader environmental issues, such as acid rain and ecosystem damage (Gaillard et al., 2016; Xu et al., 2015).

## **2.2 Pollutant Concentration Near Roads**

Pollutant concentrations are generally highest within a short range of high-traffic roads, creating a "roadside effect zone" that poses elevated health risks (Zhang et al., 2019; Rojas et al., 2020). Studies consistently report that the concentration of pollutants such as NO<sub>2</sub> and PM<sub>2.5</sub> is markedly higher within 50-100 meters from busy roadways, especially during peak traffic hours (Karner, Eisinger, & Niemeier, 2010). For example, Bowker et al. (2007) observed that pollutant levels can remain elevated within this range due to dense traffic and frequent stops, a common characteristic of urban environments with high congestion. Zhu et al. (2002) further highlighted that ultrafine particle concentrations decrease rapidly beyond this roadside zone, indicating a strong gradient in pollutant levels that significantly affects local air quality.

Research by Zhou and Levy (2007) provides a meta-analysis of mobile source air pollution, emphasizing that pollutant concentration decreases with distance from the roadway. However, the rate of dispersion is not uniform; it is affected by wind speed and direction, as well as local infrastructure such as buildings and trees, which may either block or trap pollutants (Zhou & Levy, 2007). Bowker et al. (2007) found that sound walls, vegetation, and urban structures can disrupt dispersion patterns, leading to hotspots where pollutants are trapped or deflected depending on wind direction and obstacle placement. As a result, it can be concluded that the dispersion of pollutants, particularly NO<sub>2</sub> and PM<sub>2.5</sub>, is distance-dependent and influenced by several external factors.

The spatial extent of pollutants also varies between urban and rural settings. In urban areas, dense infrastructure and high traffic density often extend pollution's reach far beyond the roadside zone, with concentrations remaining high across broader areas (Karner, Eisinger, & Niemeier, 2010). Studies such as Vardoulakis et al. (2003) have shown that in street canyons or densely built urban areas, pollutants may become trapped and linger due to limited airflow and obstruction by tall buildings. In contrast, rural areas with lower traffic density and open landscapes experience quicker pollutant dissipation.

Nevertheless, rural roadside pollution can still affect air quality and environmental health, as pollutants disperse and accumulate across broader but less densely populated zones.

Understanding the spatial distribution of air pollutants near roads is critical for assessing the environmental and health impacts of vehicular emissions. Traffic-related pollutants, including nitrogen oxides (NO<sub>x</sub>), sulfur dioxide (SO<sub>2</sub>), carbon monoxide (CO), and particulate matter (PM<sub>2.5</sub> and PM<sub>10</sub>), tend to accumulate near roads and disperse with increasing distance (Zhu et al., 2002; Mu et al., 2018). However, factors such as traffic volume, road design, weather, topography significantly, and meteorological conditions affect this distribution pattern.

Numerous studies have quantified the exponential decline of pollutants like NO<sub>2</sub> and PM<sub>2.5</sub> with increasing distance from roadways (Health Effects Institute, 2013; Zhang et al., 2020; Eisinger et al., 2021). Health Effects Institute (2013) conducted a critical review of the health effects of traffic-related air pollution, underlining its concentration near high-traffic areas and its association with respiratory and cardiovascular diseases. Zhang et al. (2020) investigated the exponential decline in the concentration of some pollutants, such as NO<sub>2</sub> and PM<sub>2.5</sub>, with increased distance from roadways, with a large decline within 200 meters from the traffic corridors. Dispersion of pollutants in Eisinger et al. (2021) was investigated where a close investigation of large-scale traffic volume influence, including confirmation of larger concentrations at distances close to the roads that are seen to have reduced concentration with distance was done.

PM<sub>2.5</sub> and PM<sub>10</sub> can go deep inside the respiratory system, even down to the lungs and further into the blood, serious health effects have been associated with both types of particulate matter. Long-term exposure to high levels of particulate matter has been associated with various adverse health outcomes, such as respiratory and cardiovascular diseases, exacerbation of asthma, and even premature mortality (Health Effects Institute, 2020).

Mukherjee et al. (2018) synthesized findings showing elevated concentrations of NO<sub>2</sub> close to major roadways, which taper off exponentially beyond 150 meters. Li et al. (2017) found similar trends in urban settings, where NO<sub>2</sub> levels decreased sharply with distance, providing evidence of traffic's impact on local air quality. Gong et al. (2019)

also reported that PM concentrations were significantly higher at roadside locations compared to background levels, underscoring the direct influence of traffic emissions on pollutant levels near busy roads.

Further to the above factors, temporal variations in roadside air quality are influenced by diurnal, seasonal, and episodic factors (Yang et al., 2020) as well. Diurnal patterns in air quality typically reflect traffic volumes, with peak concentrations occurring during morning and evening rush hours (Zheng et al., 2018). As traffic volumes fluctuate throughout the day, concentrations of pollutants such as nitrogen dioxide (NO<sub>2</sub>) and particulate matter (PM) exhibit significant variation. Seasonal changes in air quality are driven by meteorological conditions, such as temperature and humidity, as well as seasonal patterns in vehicle usage (Zhao et al., 2021). For instance, colder months often see higher pollutant levels due to increased vehicle idling and heating demands, whereas warmer months may result in elevated ground-level ozone due to sunlight-driven photochemical reactions. Episodic events, such as wildfires and industrial emissions, can impact roadside air quality, contributing to short-term spikes in pollutant levels (Huang et al., 2019). These events can overshadow typical diurnal and seasonal trends, leading to temporary increases in specific pollutants.

Understanding these variations is essential for assessing air quality and public health impacts, especially in an urban context associated with various land use types and roadside establishments (eg. Schools, offices, etc.)

### **2.3 Traffic-Related Air Pollution (TRAP) Concentrations**

Temporal variability in TRAP concentrations near roadways is influenced by factors such as traffic volume, pollutant type, and the presence of physical structures. Traffic volume patterns, often peaking during rush hours, lead to fluctuations in pollutant concentrations (Levy et al., 2013). Concentrations of pollutants like elemental carbon (EC), nitrogen oxides (NO<sub>x</sub>), and ultrafine particles (UFP) show steep declines within distances of 150–650 meters from roadways, demonstrating sharp concentration gradients near high-traffic areas (Karner et al., 2010; Pattinson et al., 2014).

The spatial distribution of TRAP is affected by structural factors such as street canyons and barriers, which can trap pollutants near roadways. This results in elevated levels in enclosed spaces while reducing downwind dispersion (Hagler et al., 2012). Urban settings with noise barriers, elevated roadways, and vegetation buffers alter both the spatial and temporal dynamics of pollutants, potentially lowering concentrations near the road while increasing them on the road itself (Vardoulakis et al., 2003).

## **2.4 Current Air Quality Guideline**

The World Health Organization (WHO) provides air quality guidelines to protect public health and wellbeing. WHO published the air quality guideline in 2005 and updated it in 2021. The recommended guideline values for various pollutants, including sulfur dioxide (SO<sub>2</sub>), nitrogen dioxide (NO<sub>2</sub>), particulate matter (PM<sub>2.5</sub> and PM<sub>10</sub>), and carbon dioxide (CO<sub>2</sub>) as indicated below.

### **WHO Air Quality Guideline 2005**

Sulphur Dioxide (SO<sub>2</sub>):

- Short-term exposure (24 hours): 20 µg/m<sup>3</sup> (micrograms per cubic meter)
- Long-term exposure (annual): Not specifically established, as short-term exposure guidelines are deemed critical.

Nitrogen Dioxide (NO<sub>2</sub>):

- Short-term exposure (1 hour): 200 µg/m<sup>3</sup>
- Long-term exposure (annual): 40 µg/m<sup>3</sup>

### **WHO Air Quality Guideline 2021**

The WHO 2021 Air Quality Guidelines (AQG) recommend limits for SO<sub>2</sub>, NO<sub>2</sub>, PM<sub>2.5</sub>, and PM<sub>10</sub> to protect public health. Interim targets are set to facilitate progress, emphasizing the need for significant reductions in air pollution levels globally. While presenting its interim targets within the 2021 AQGs, WHO did not impose a stringent, universally applicable timeline for attaining these targets. Although this may be so, emphasis on progressiveness and phase-oriented operations suggests that the attainment of such targets by countries should form a component of long-term air quality improvement programs. Precisely when a country can achieve this target will, however,

depend upon a number of issues like its economic capabilities, technological advancements, and localized air quality conditions.

The Table 2-1 presented WHO Air Quality Guideline (2021) recommended air quality concentration levels. The annual mean concentration refers to the average level of pollutants like PM<sub>2.5</sub> over a year, reflecting long-term exposure and its impact on chronic health issues like respiratory and cardiovascular diseases. The 24-hour mean concentration measures pollutant levels over a 24-hour period, assessing short-term exposure that can cause acute health effects like asthma attacks.

Table 2-1: WHO Air Quality Guidelines Recommended Target Concentration Levels  
2021

Pollutant	Averaging time	Interim target				AQG level
		1	2	3	4	
PM <sub>2.5</sub> µg/m <sup>3</sup>	Annual	35	25	15	10	5
	24-hour	75	50	37.5	25	15
PM <sub>10</sub> , µg/m <sup>3</sup>	Annual	70	50	30	20	15
	24-hour	150	100	75	50	45
O <sub>3</sub> µg/m <sup>3</sup>	Peak season	100	70	—	—	60
	8-hour	160	120	—	—	100
NO <sub>2</sub> µg/m <sup>3</sup>	Annual	40	30	20	10	10
	24-hour	120	50	—	—	25
SO <sub>2</sub> µg/m <sup>3</sup>	24-hour	125	50	—	—	40
CO mg/m <sup>3</sup>	24-hour	7	—	—	—	4

WHO Air Quality Guideline (2021)

The Table 2-2 presented Sri Lankan Air Quality Guideline air quality concentration levels. The National Environmental Act, No. 47 of 1980, established the air quality guideline for Sri Lanka and it was amended in 2008 to enhance environmental protection measures in Sri Lanka. Key amendments included stricter regulations on environmental quality standards and increased penalties for violations. The amended air pollutant concentration levels are as follows.

Table 2-2: Air Quality Guideline National Environmental Act, No. 47 of 1980 -  
Amendment 2008

<b>Pollutant</b>	<b>Averaging Time</b>	<b>Maximum Permissible Level (<math>\mu\text{g}/\text{m}^3</math>)</b>	<b>Maximum Permissible Level (ppm)</b>	<b>Method of Measurement</b>
Particulate Matter - Aerodynamic diameter is less than 10 $\mu\text{m}$ in size ( $\text{PM}_{10}$ )	Annual	50	—	Hi-volume sampling and Gravimetric or Beta Attenuation
	24 hrs.	100	—	
Particulate Matter - Aerodynamic diameter is less than 2.5 $\mu\text{m}$ in size ( $\text{PM}_{2.5}$ )	Annual	25	—	Hi-volume sampling and Gravimetric or Beta Attenuation
	24 hrs.	50	—	
Nitrogen Dioxide ( $\text{NO}_2$ )	24 hrs.	100	0.05	Colorimetric using saltzman Method or equivalent Gas phase chemiluminescence
	8 hrs.	150	0.08	
	1 hr.	250	0.13	
Sulphur Dioxide ( $\text{SO}_2$ )	24 hrs.	80	0.03	Pararosaniline Method or equivalent Pulse Fluorescent
	8 hrs.	120	0.05	
	1 hr.	200	0.08	

National Environmental Act, No. 47 of 1980 – (Amendment 2008)

WHO Air Quality Guidelines 2021 and Sri Lankan Air Quality Guidelines - National Environmental Act, No. 47 of 1980 - Amended 2008, have recommended different levels for the key air pollutants. WHO's recommended levels, on the other hand, are more strict: for instance,  $\text{PM}_{2.5}$  should have an annual mean of 5  $\mu\text{g}/\text{m}^3$  and a 24-hour mean of 15  $\mu\text{g}/\text{m}^3$ , while the annual mean of  $\text{PM}_{10}$  is recommended at 15  $\mu\text{g}/\text{m}^3$ , with  $\text{NO}_2$  recommended to have an annual mean not over 10  $\mu\text{g}/\text{m}^3$ . At the same time, the standards of Sri Lanka allow for higher values:  $\text{PM}_{10}$  at 100  $\mu\text{g}/\text{m}^3$  for the 24-hour mean,  $\text{NO}_2$ 's at 40  $\mu\text{g}/\text{m}^3$  as an annual mean, and  $\text{SO}_2$  at 80  $\mu\text{g}/\text{m}^3$  for the 24-hour average. WHO focuses on more stringent health-based thresholds, while the guidelines of Sri Lanka take into consideration national conditions with a slightly higher tolerance level for pollutants.

There is no WHO guideline recommended value for  $\text{CO}_2$  concentration levels. But it highlights that indoor  $\text{CO}_2$  levels exceeding concentration levels of 1000 ( $\mu\text{g}/\text{m}^3$ )

recognized as threshold indicating poor ventilation. Therefore, this concentration level has used it as the standard concentration levels for CO<sub>2</sub> in this research study. (ASHRAE Standard 62.1-2019, Indoor Air Quality Guidelines (IAQG))

This chapter selected the most suitable literature that can be useful to the study and organized it according to the correct order. The next part of the study is mainly related to the methodology and the analysis of the study.

### **3 METHODOLOGY**

The methodology is split into two parts the data collection and analysis of a secondary data set from the NBRO from the year 2013 to 2018 and a primary data set collection using a sensor unit from year 2022 to 2024 followed by analysis.

#### **3.1 Secondary data from NBRO permanent stations**

##### **3.1.1 Sampling Locations**

Air quality concentration monitoring is being carried out at a number of locations in the major cities in the Western Province of Sri Lanka, namely at Kalutara, Gampaha, Horana and Colombo accounting for 40 centres in total.

There are 19 permanent air quality monitoring centres established within Colombo City as shown in *Figure 3-1* along with 11 centres in Gampaha as shown in *Figure 3-2* and 10 centres in Kaluthara District having 5 centres in Kaluthara and 5 centres in Horana as shown in *Figure 3-3*. Majority of the data collection stations are located closer to roads. Altogether, data from 40 data collection stations were received as secondary data consisting of monthly average SO<sub>2</sub> and NO<sub>2</sub> concentration data. Details of the data collection are attached in Annex 1.

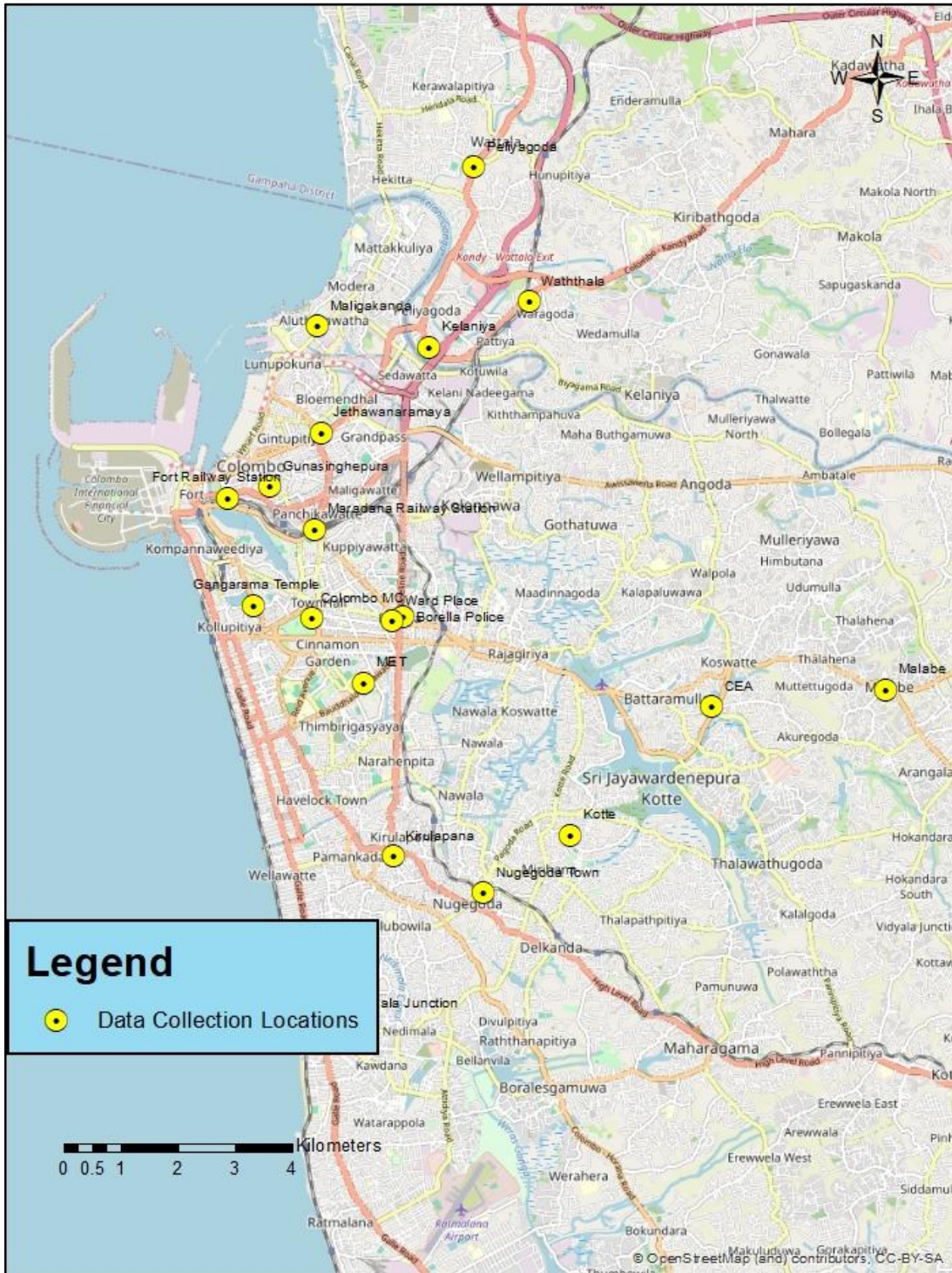


Figure 3-1: Data Collection location at Colombo

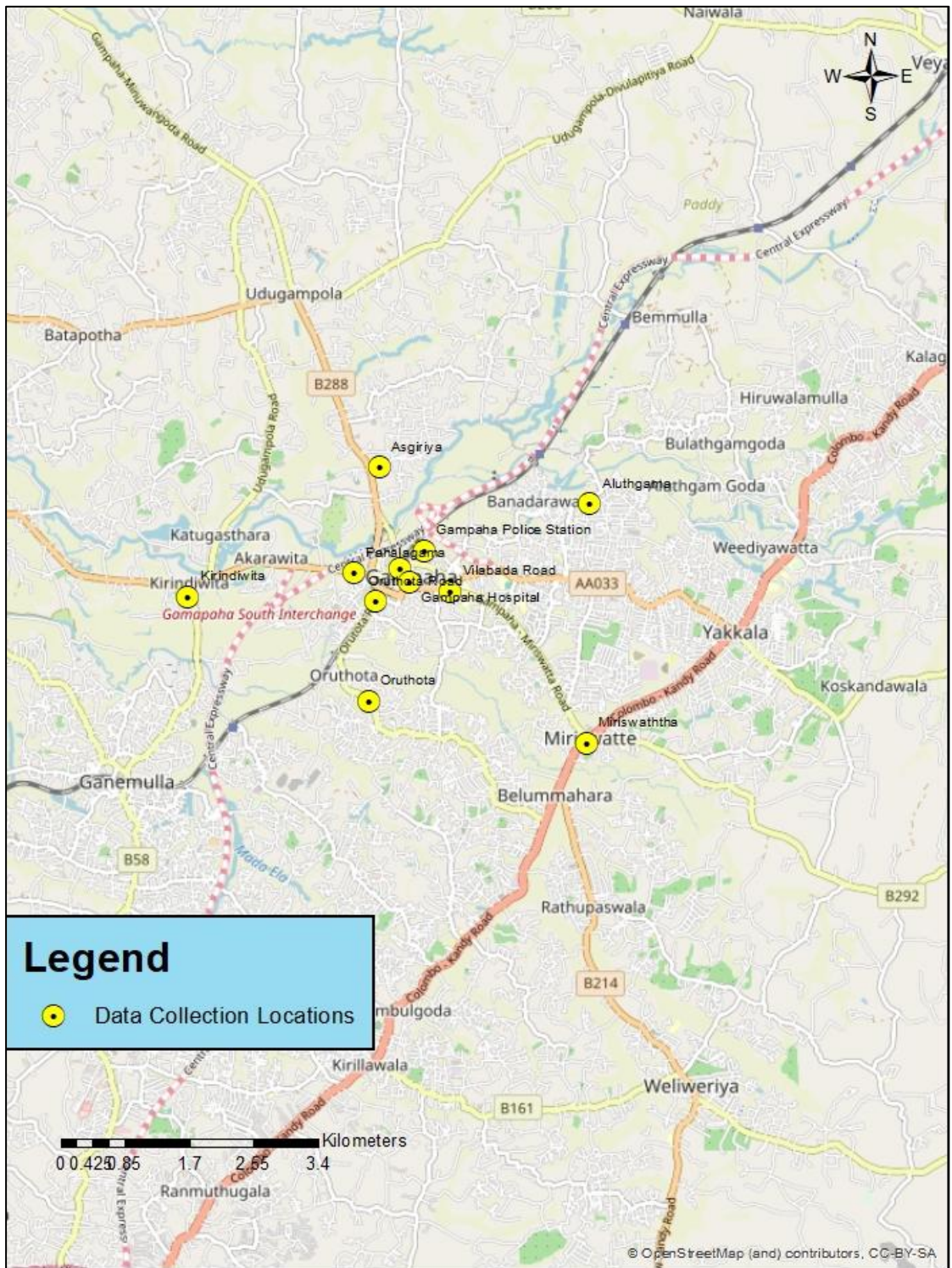


Figure 3-2: Data Collection location at Gampaha urban area

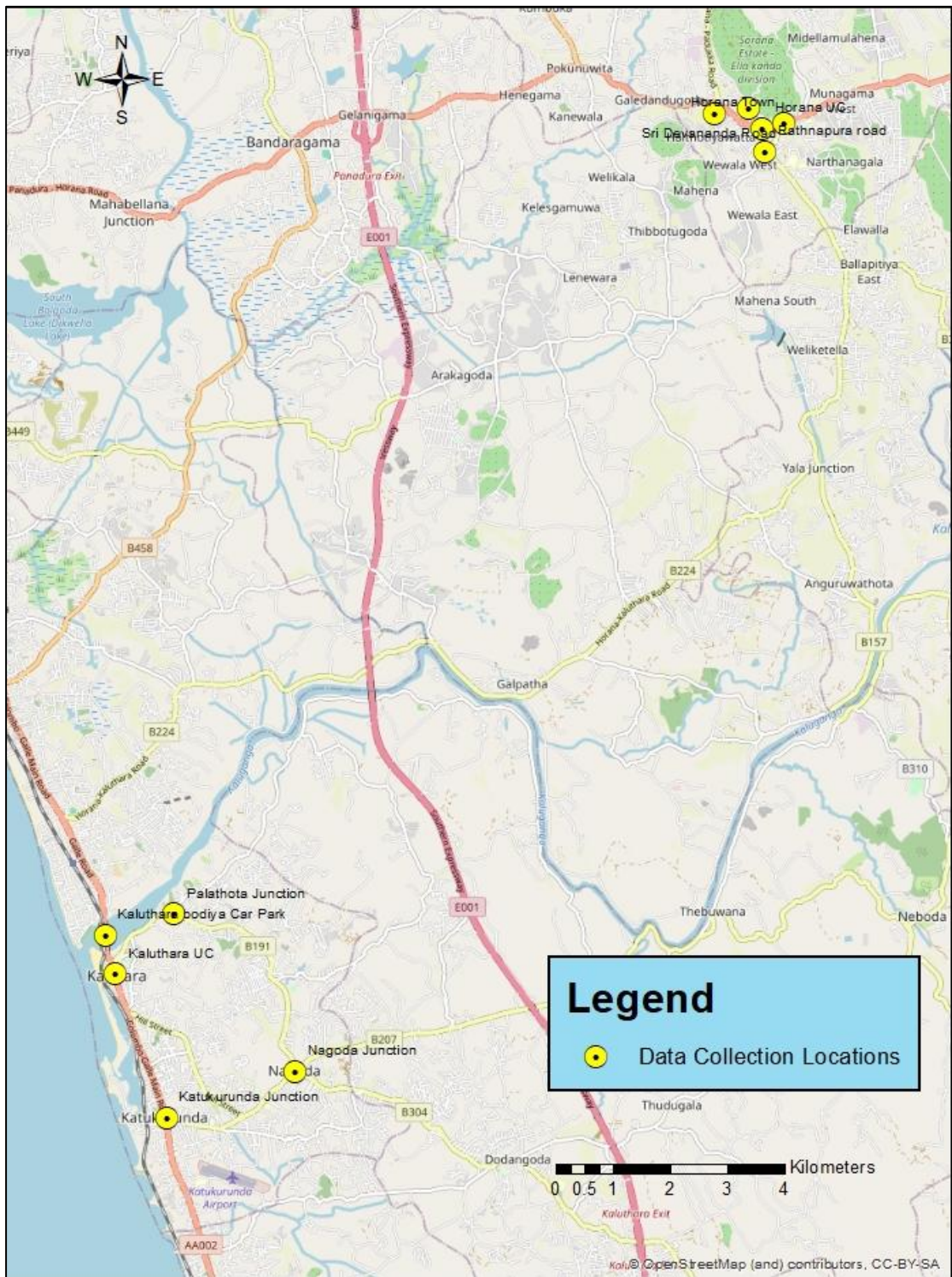


Figure 3-3: Sample location at Kalutara & Horana urban area

### 3.1.2 Sampling Method, Analysis and Validation

Data collection was done using passive sampling techniques which is also termed as a low-cost and simple means of acquiring air quality data. Using the technique, the mean monthly exposure levels of sulfur dioxide (SO<sub>2</sub>) and nitrogen dioxide (NO<sub>2</sub>) were continuously recorded across all the sampling stations. The passive sampling device was placed in an open field, at a distance of at least three meters from a building and three meters above ground level to prevent interference. The passive samples were placed at chosen sampling sites in the 1st week of every month and the samplers were left exposed for a month for SO<sub>2</sub> and NO<sub>2</sub> uptake. A photograph of the passive sampler installed is shown in *Figure 3-4*.



*Figure 3-4: Passive samplers installed at Kalutara Municipal council*

The passive sampling technique is mainly used to evaluate long-term air quality concentration levels at different locations at comparatively low cost and with high data resolution. *Figure 3-5* shows the individual components of the data collection apparatus. The main disadvantage of this method is that every month the apparatus needs to be placed at a selected location and collect the apparatus back after the specified time (1 month) period. Passive sampling technique is used to collect monthly average levels of

exposure of Sulfur Dioxide (SO<sub>2</sub>) and Nitrogen Dioxide (NO<sub>2</sub>). With the use of these passive samplers in strategic locations encompassing pollution hotspots, detailed and cost-effective information related to the level of concentrations of Sulfur Dioxide (SO<sub>2</sub>) and Nitrogen Dioxide (NO<sub>2</sub>) can be obtained, thus facilitating extensive assessment of air quality distribution over a specific area of interest.

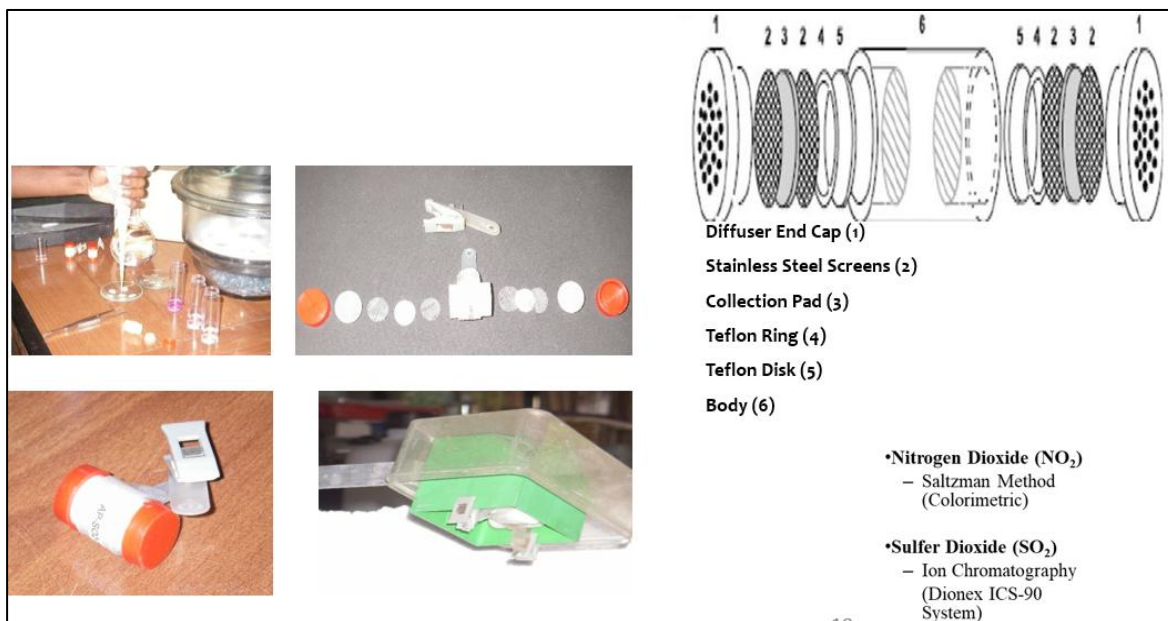


Figure 3-5: Data collection Apparatus

Analytical techniques listed in Table 3-1 below have been used to examine the collected passive sampling data at the NBRO laboratory in order to find the monthly average concentration levels of pollutants.

Table 3-1: Sampling and analytical methods for SO<sub>2</sub> & NO<sub>2</sub> data collection

Parameter	Sampling & Analytical Method	Instrumentation
SO <sub>2</sub>	Passive Sampling method & Ion Chromatographic (IC) Method	DIONX ICS-90 Ion Chromatograph (NBRO developed “Ogawa” type Passive sampler and wind shield)
NO <sub>2</sub>	Passive Sampling method & Saltzman method (Colorimetric)	UV/VIS Spectrophotometer (NBRO developed “Ogawa” type Passive sampler and wind shield)

The Environment Studies and Services Division (ESSD) laboratory of NBRO is an ISO 17025 accredited laboratory; all instruments and lab equipment were calibrated and

maintained as per the standard. Further, all methodologies were reviewed and standardized as part of the process. As a result, the data validation process was completed using fixed monitoring location data.

### **3.1.3 Analysis of Air Quality Data Using GIS Software**

Spatial distribution analysis of nitrogen dioxide (NO<sub>2</sub>) and sulfur dioxide (SO<sub>2</sub>) concentration levels is initiated by acquiring and preparing secondary datasets from the National Building Research Organization (NBRO). Datasets are imported and brought into ArcMap 10.3, a Geographic Information System (GIS) software, where fundamental maps and geographical layers are combined for contextualization. GIS tools are utilized to conduct spatial distribution analysis to define the concentration levels of NO<sub>2</sub> and SO<sub>2</sub>.

The methodology enables a comprehensive exploration of SO<sub>2</sub> and NO<sub>2</sub> pollution, providing valuable insights for air quality management and policy formulation. Organizing geographical data related to atmospheric pollutants is crucial for this process. When analyzing air quality concentrations through Arc GIS, data on SO<sub>2</sub> and NO<sub>2</sub> concentrations along with spatial information like base maps and monitoring site coordinates were given as input. To be compatible with GIS, this data has been geo-referenced and transformed into required file formats of “shapefiles” by importing collected data through CSV files containing latitude and longitude coordinates.

Once the data is prepared, it is imported into ArcGIS software along with the base map and layers that display air quality concentrations. Visualizing GIS maps is essential for creating heat maps that highlight pollution hotspots and for producing maps that use various colours to represent pollutant levels. To analyse pollutant levels at sampled locations Inverse Distance Weighted (IDW) interpolation method was considered out of the available options such as Trend, Spline with Barriers, Kriging etc., considering its unique principle of analysis and interpolation based on the inverse distance weighting between sample locations. Focusing on the western province ensures a clear boundary for the IDW spatial analysis.

The collected data from 40 different locations covering the Western province of Sri Lanka is analyzed using Arc GIS software using special analysis tools. The analysis is carried out for available data from 2013 to 2018 yearly. The individual air quality

concentration maps were generated for SO<sub>2</sub> and NO<sub>2</sub> on a yearly basis representing areas covered under the following concentration ranges.

- ▶ Within the WHO limit (NO<sub>2</sub> concentration < 40 µg/m<sup>3</sup>)
- ▶ High (40 µg/m<sup>3</sup> < NO<sub>2</sub> concentration < 80 µg/m<sup>3</sup>)
- ▶ Extremely high (NO<sub>2</sub> concentration > 80 µg/m<sup>3</sup>)

The generated maps showing pollution concentrations are categorized according to WHO air quality guidelines, and the area represented by each concentration level is extracted from each map to understand the evolving impact of air pollutants over time. Ultimately, the combination of these maps and analytical insights provides a comprehensive view of the current conditions pertaining to air quality, enabling a thorough examination, graphical representation of spatial trends in air quality concentration and identification of pollution hotspots which can eventually facilitate the development of effective mitigation strategies and policy interventions.

For estimating the spatial extent of every category of pollution, concentration maps were re-analyzed using area calculation tools in ArcGIS software. Comparing year difference maps, trends have been found and compared for air quality variation over time in Western Province of Sri Lanka. Accordingly, an output table is prepared for the area of land covered under each SO<sub>2</sub> and NO<sub>2</sub> concentration with each concentration level range.

### **3.2 Selection of the study area and Data Collection Procedure for Primary Data Collection using Sensor Unit**

Primary data collection refers to the process of gathering new, original data directly from the source or field for a specific research study. Primary data collection involves measuring air pollution concentrations of Nitrogen Dioxide (NO<sub>2</sub>), Carbon Dioxide (CO<sub>2</sub>), PM<sub>2.5</sub>, and PM<sub>10</sub> directly at specific locations using compact instruments equipped with sensors for measuring each pollutant concentration.

The study focused on four key pollutants PM<sub>2.5</sub>, PM<sub>10</sub>, NO<sub>2</sub>, and CO<sub>2</sub>, which are commonly associated with vehicular emissions and have significant impacts on air quality and public health. These pollutants were chosen due to their relevance in environmental and regulatory standards, as well as their widespread occurrence in urban and roadside areas.

While other factors such as wind speed, temperature, climate, and traffic density can influence pollutant levels, their exclusion was due to practical limitations. Incorporating these additional variables would have required extra resources, including additional measurement equipment and data sources, which were not available within the study period. For example, measuring wind speed and temperature would necessitate meteorological instruments, and traffic density data would require real-time monitoring systems that were not feasible within the study's time frame.

Despite these exclusions, the chosen parameters were sufficient to provide valuable insights into roadside air quality, and future research could benefit from including these additional factors to offer a more comprehensive understanding of the dynamics influencing pollution levels.

The sites chosen for primary data collection were sited along the National Highways constituting A-Class and B-Class roads, vital corridors of vehicular movement that represent ordinary roadside pollution levels. These roads are selected with the idea that they serve key routes of the transport network and are likely to show an enhanced concentration of pollutants from traffic emissions. The other governing considerations included were easy access and safe locations for placement of instruments, which would thus guarantee the safety of the study area during data collection. The presence of a continuous electricity supply at these sites was also a critical factor, as reliable power is essential for the operation of the monitoring equipment throughout the study period.

### **3.2.1 Mixed Traffic Conditions**

To ensure a thorough investigation of the microenvironment of air pollution, it is necessary to select sites that exhibit a wide range of traffic conditions, including busy, medium and calm traffic states. In addition, after capturing data from these different traffic environments, the study seeks to examine air quality changes or the difference in pollution levels for varying vehicular densities. This manner of research makes it possible to see non-obvious correlations within highly disaggregated levels of a traffic scenario.

### **3.2.2 Proximity to Major Highways**

The study is about areas with national highways which are also notable for A-Class and B-Class roads in Sri Lanka. These areas are important in assessing the effect of fuel combustion on air pollution, especially in urban centres which are usually characterized by high traffic incidences and consequent high pollution levels. Their locations are chosen in such a way because the research aims to analyze the influence traffic volumes have on worsening the air quality and to indicate critical areas requiring immediate remedies or control measures.

### **3.2.3 Geographic Focus on the Western Province**

The research discussed in this section is concentrated within the Western Province of Sri Lanka, which is highly urbanized and industrialized. By focusing on this geographical focal point, the problems of air quality discrepancy with the disaggregation in traffic intensity levels can be tackled more effectively. This also facilitates a more detailed examination of the environmental problems of this region and contributes to the temptation for the development of strategies relevant to air quality in practically suitable regions.

### **3.2.4 Safety Concerns of the Air Quality Monitoring Device**

The air quality monitoring device employed in this study is a compact unit which is able to capture, process and transmit air quality information in real-time. The equipment belongs to the National Building Research Organization (NBRO), and it was required to take necessary precautions in order to ensure safety. This equipment, once positioned in a location, shall not be dislocated until the data collection is confirmed by NBRO. Once the data collection is satisfactory at a particular location, the device shall be moved to another place. It is essential to make sure that the instrument is placed in a safe location so that it will not face any weather obstruction, like rain which can affect its performance and functionality, and also not be exposed to vandalism.

### **3.2.5 Access to Power Supply**

The efficient operation of the air monitoring station on the device is another aspect that should be factored in. This is because an acoustic modem needs a stable 230V power supply which made the selection of the facilities for data collection quite a challenging task. In Sri Lanka, tensions within the power and energy sector were triggered by the economic crisis (2022-2023) which led to load shedding; these power cuts lasted for one to two hours each time and sometimes more frequently than two times in a day. In those locations in which incessant power outages exceeded two hours, they were not selected for data collection. The data therefore was transformed retarded more persistent with less error.

### **3.2.6 Limitations of Fuel Supply to the Country**

Between the months of March 2022 and October 2022, Sri Lanka experienced an acute fuel crisis as a result of the state's various economic challenges. Such problems prevented any progress in terms of data collection. As a result, the problem of fuel shortages went beyond transport facilities but rather inhibited a more 'hands-on' approach to research, meaning that no data was collected in this period of crucial significance.

### **3.2.7 Signal quality in mobile networks**

Mobile air pollution monitoring devices require network communication (internet connection) for transmission of data to the main server hence it is very important to have a good signal level at the point of installation. For successful data collection, areas with good network coverage were identified. This point is very important as if the signal quality is low a situation may arise wherein data loss or delays in publishing may occur, affecting the standard of the study as well as wasting time and effort.

### **3.2.8 Data Collection locations**

Considering all the above facts, it was decided to collect data from eight (08) locations in the Western province of Sri Lanka. The locations selected for data collection to cover the national road network, including 'A class' national highways and 'B class' national roads. The data collection locations are marked on the map below. The Table 3-2

summarize the details of data collection locations and the *Figure 3-6* shows the data collection location map.

Table 3-2: Details of data collection locations

<b>Site No.</b>	<b>Data Collection Location</b>	<b>Road Name Number</b>	<b>Posted Speed (km/h)</b>	<b>Total Number of Lanes</b>	<b>Lane width</b>
1	Nilpanagoda	Ekala Kotadeniyawa Road (B-111)	70	2	3.3m
2	Miriswatta	Colombo Kandy Road (A-01)	50	4	3.7m
3	Yatiana	Katunayake Veyangoda Road (B-208)	70	2	3.5m
4	Kadirana	Baseline Road Negombo (B-597)	70	2	3.7m
5	Minuwangoda	Katunayake Veyangoda Road (B-208)	50	2	3.5m
6	Kadawatha	Colombo Kandy Road (A-01)	50	4	3.7m
7	Veyangoda	Katunayake Veyangoda Road (B-208)	70	2	3.5m
8	Ekala	Ekala Kotadeniyawa Road (B-111)	70	2	3.3m

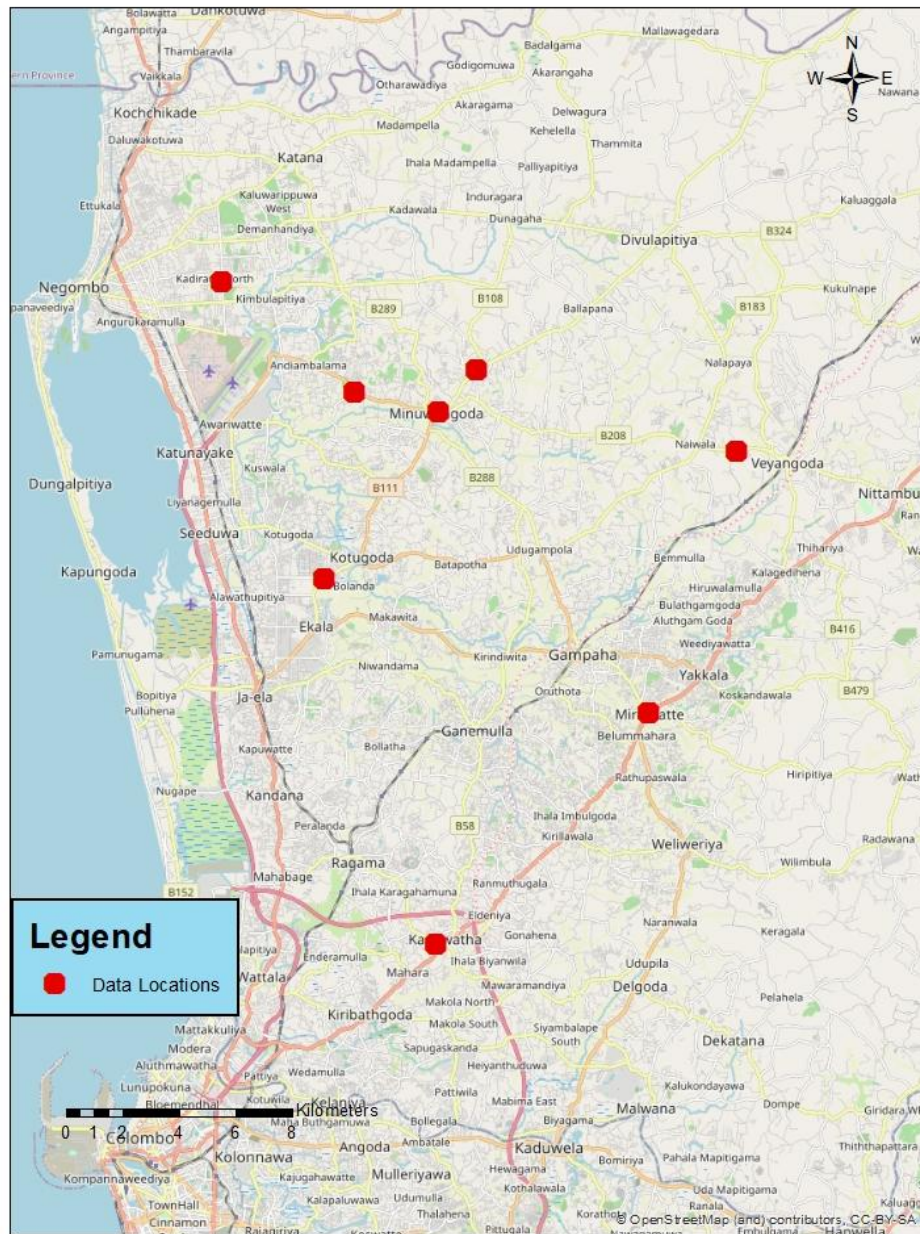


Figure 3-6: Data collection Locations Using Sensor Unit

### 3.3 Details of the monitoring equipment and data collection procedures

This section discusses the methodology used for the collection of the data, which was conducted using a sophisticated air quality measuring device. This device comprehensively augmented the measurements of common air pollutants such as Nitrogen Dioxide (NO<sub>2</sub>), Carbon Dioxide (CO<sub>2</sub>), PM<sub>2.5</sub>, and PM<sub>10</sub>. These pollutants are

especially harmful in the assessment of air quality, especially in an urban area that has significant air pollution.

Notably, a component within the equipment was designed to enable real-time data transfer to a central server using a cellular data service. This is a noteworthy feature in the equipment which allows users to access the data freely and provides the opportunity to monitor variations in air quality over time influenced by the admissibility of the traffic and other environmental quality aspects in the study areas.

The Table 3-3 outlines the measurable ranges for each pollutant detected by the sensors that are installed in the instrument. The measurable ranges of sensors are well within the typical values in Sri Lankan conditions.

Table 3-3: Measurable Range of Sensors

<b>Number</b>	<b>Air Pollutant</b>	<b>Measurable Range</b>
1	NO <sub>2</sub> - Nitrogen Dioxide	0.05 – 100 ppm
2	CO <sub>2</sub> - Carbon Dioxide	400 - 5000 ppm
3	PM <sub>2.5</sub> - Particulate Matter	0 – 500 µg/m <sup>3</sup>
4	PM <sub>10</sub> - Particulate Matter	0 – 500 µg/m <sup>3</sup>

The locations for instrument installation within each site were chosen based on the availability of a secure place for the equipment. The instrument was set up at the roadside and then at 25m, 50m, and 75m from the roadside, thereby allowing the observation of concentrations of pollutants at varying distances away from the roadside. As discussed in the literature review, these distances are common in the dispersion pattern of roadside pollution. However, the selection of installation points was constrained by the availability of safe, secure locations for the instrument.

Due to the fact that direct access to the data collection server was not given, it took a considerable amount of time (from 2-3 days) to receive data from every data collection point. Further, only one instrument was available for the study so that the duration of data collection was stretched. With the combination of these effects, data collection could only move forward with respect to one side of the road at each study site.

The data collection process involved the measurement of PM<sub>2.5</sub>, PM<sub>10</sub>, CO<sub>2</sub>, and NO<sub>2</sub> levels at selected locations. First, the instrument was installed at the roadside (0 m from the road edge) and after collecting the data for one day the instrument was moved to 25

m from the roadside. Similarly, 50 m and 75 m from the roadside data were collected at selected locations. The instrument was installed at safe locations which were not affected by rain or vandalism. However, data collection at some points was not possible and was omitted due to difficulties associated with the safety of the equipment, non-availability of power sources, etc. The data collected was systematically stored in a cloud space for analysis, allowing for comparisons of air quality spatially.

Conjuncture to air quality measurements, traffic data was collected using video recording equipment, a CCTV or handheld video camera, strategically placed at the data collection site. This method enables to capture of accurate traffic counts, which is a key ingredient to develop valuable insights into the relationship between vehicular movement and air quality levels. The recorded footage was subsequently analyzed to determine traffic volume patterns during the monitoring periods. From the video files, traffic volumes were manually counted for 15 mins from each hour to calculate the hourly volumes. This approach is helpful in determining the volume of traffic within a certain time period of traffic survey. The traffic count was limited to 13 hours per day from 6.00 AM to 7.00 PM. The hourly PCU count with heavy vehicle percentage for each site is attached in annex 2.

### **3.4 Consistency in Instrumentation**

To ensure data reliability, a single air quality monitoring instrument was utilized across all data collection sites. This decision mitigated the risk of instrumental variability that could arise from using multiple devices, which may have differing calibration, sensitivity, or measurement accuracy. Utilizing a consistent instrument allows for a more coherent analysis of the data collected, facilitating comparisons between different locations and traffic conditions.

However, commitment to a single instrument required significant time and effort in the setup process. Each location necessitated careful calibration, verification, and ongoing supervision and maintenance (as required), to ensure the accuracy of measurements over the study period.

### **3.4.1 Data Collection and Validation Process**

The data collected at each monitoring location was retrieved from the National Building Research Organization (NBRO) server and delivered in text format for straightforward handling. Each data file recorded air quality metrics at 10-second intervals, providing a detailed temporal snapshot of pollutant concentrations. This high-frequency sampling is crucial for capturing short-term variations in air quality, particularly in response to fluctuations in traffic flow.

After receiving the data files, they were imported into Microsoft Excel for further analysis. The use of Excel facilitated the organization and manipulation of the data, allowing for efficient examination of the dataset's integrity. A critical step in this process involved validating the quality of the data to identify any outliers that could distort the results.

During the quality check, it became apparent that a significant portion of the CO<sub>2</sub> data included individual outlier points that exceeded the measurable limits of the sensor. These outliers were likely the result of sensor calibration issues or transient environmental factors. To maintain the overall quality and reliability of the dataset, these erroneous points were systematically removed. They were replaced with interpolated values calculated from adjacent data points, ensuring that the dataset remained robust and reflective of true air quality conditions.

This careful approach to data validation not only enhances the reliability of the findings but also ensures that the conclusions drawn regarding air quality trends are based on accurate and high-quality data. By addressing these outliers proactively, the integrity of the analysis is upheld, allowing for meaningful insights into the relationship between traffic patterns and air quality.

### **3.5 Regression Analysis**

Linear regression is a simple and well-known statistical technique that is easy to interpret: From direct sight, it gives how pollutant concentration varies concerning proximity from the roadside. It is mainly useful to understand very clearly how the variables relate to each other (Liu et al., 2019).

With the slim dataset and localized measurements along the roadside, linear regression was a feasible method. In environmental studies, linear regression is widely employed when the sample size is fairly small, and no intricate interactions are foreseen between other factors under consideration (Zhang et al., 2021). Linear regression serves again as a vital starting point to uncover trends. Considering that, the overarching assumption was that pollutant concentrations would decrease as one moved away from the road; the present methodology was so perfect for confirming this hypothesis before moving into more complicated models.

The other alternative considered was multiple regression, which could include additional variables such as wind speed, temperature, and traffic density, among others. Unfortunately, due to practical limitations the study did not collect sufficient data regarding these variables, while the sample size was too small to reliably employ multiple regression. Without enough data, using this model could induce overfitting, which means it would not generalize very well in other contexts.

Another possible alternative was non-linear regression, which would have been valid under more complex dependencies between distance and pollutant concentration. However, initial data exploration showed a linear tendency, and any non-linear regression would not apply to this study since it involves more sophisticated techniques in model fitting.

Moreover, data collection took much longer than expected primarily due to logistical problems such as having only one instrument for data collection and limited access to the server for data collection. As such, regression analysis was restricted to linear regression alone since it was not possible to conduct further explorations due to time limitations.

Therefore, this study chooses a linear regression model to evaluate the relationship between pollutant concentrations and distances from the roadside. This decision is made based on considerations of the model's simplicity, interpretability, and nature of the data collected.

### **3.5.1 Survey Domain and Data Collection**

This study was carried out focusing on National Roads (A class and B class roads) located in Gampaha District, Western Province of Sri Lanka, which is an audited area of urbanization with certain features such as high traffic density. The main emphasis was to find out the relationship between air quality parameter concentration with the distance measured from the roadside and the relationship between traffic and air quality parameter concentration. For this study, particulate matter (PM<sub>2.5</sub> and PM<sub>10</sub>), carbon dioxide (CO<sub>2</sub>), and nitrogen dioxide (NO<sub>2</sub>) were identified as key pollutants that significantly impact air quality and pose risks to human health and the environment.

From 2022 October to February 2024, data was collected for eight (08) locations under this study. Data was collected over a 24-hour period from strategically positioned safe monitoring stations located at 0 m (roadside), 25m from the roadside, 50m from the roadside, and 75m from the roadside. Data collection is done using a compact sensor instrument capable of measuring concentrations of particulate matter (PM<sub>2.5</sub> and PM<sub>10</sub>), carbon dioxide (CO<sub>2</sub>), and nitrogen dioxide (NO<sub>2</sub>). Air quality measurements were obtained from each station every 10 seconds which resulted in a broader database that can instantly display varying contaminant levels exacerbated by traffic congestion and prevailing climatic conditions.

### **3.5.2 Organizing the Data**

After all the available data had been collected, the original set was reconstructed into clear parameters for orderly analysis by the use of an Excel worksheet. The data was organized into columns for each, and every measured parameter categorized with measured distance from the roadside:

All readings were scrutinized for accuracy, and any inconsistencies or inaccuracies were eliminated by data correction methodologies. This kept the accuracy and reliability of the data set in place for the purposes of further analysis. It was carried out exploratory data analysis using scatter plots to visualize relationships between traffic count and concentration levels of each air quality parameter.

### 3.5.3 Statistical Analysis

The research implemented linear regression in the statistical analysis. The aim of the regression analysis, which was incorporated in the Microsoft Office 365 Excel Analysis tool regression analysis, was to associate and find out the relationship between PM<sub>2.5</sub>, PM<sub>10</sub>, CO<sub>2</sub>, and NO<sub>2</sub> at different distances from the roadside and the relationship with the air quality concentration with the traffic count.

Separate regression analyses were performed for each pollutant, permitting thereby a deeper exploration of the relationships between the air pollution concentrations of PM<sub>2.5</sub>, PM<sub>10</sub>, CO<sub>2</sub>, and NO<sub>2</sub> at different distances from the roadside. The independent variable (X) considered in all equations is the air quality at the roadside (0m) for the individual pollutants. The concentrations of the other data locations, (excluding roadside data location) of 25m, 50m and 75 m from the side of the road, were considered as the dependent variables. The stability of regression models was determined by the following criteria.

- R-squared values were calculated to provide insight into how much the dependent variable can be explained by the independent variable.
- F-statistics and its p-values provide the extent of the relationship between the dependent and independent variables in each model as well as the model's goodness of fit.
- The coefficients of each independent variable were examined to find out how they influence the quality of air around the roadside. This is very informative if one needs to know how to change levels of pollutants.

As a summary, regression analysis was conducted considering the roadside concentration level of each pollutant as an independent variable and consequently air quality concentration levels at 25m from the roadside, 50m from the roadside, and 75m from the roadside as the dependent variable. The same analysis was carried out for PM<sub>2.5</sub>, PM<sub>10</sub>, CO<sub>2</sub> and NO<sub>2</sub>.

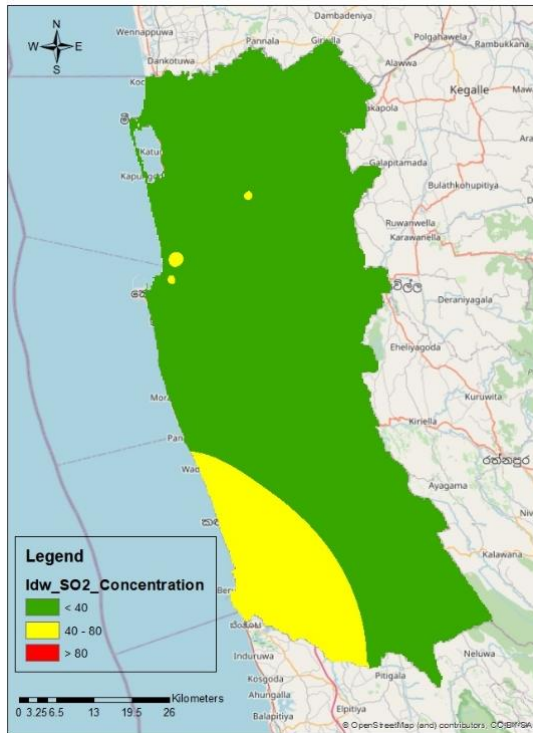
### **3.6 Chapter Summary**

This chapter explains the approach to data collection, which includes site selection instrument installation procedure, and data analysis method. According to the methodology, secondary data from 40 locations were used for GIS analysis and primary data collected from eight locations using sensor units were used for identifying the air quality parameter concentration distribution at roadsides.

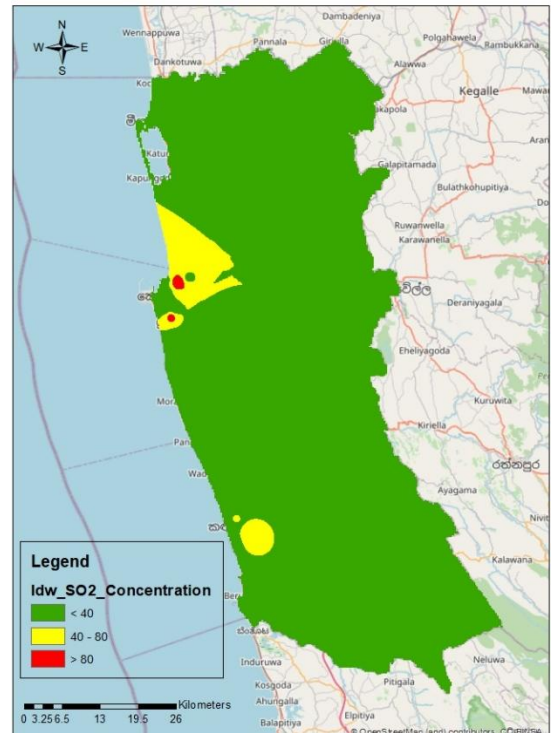
## 4 DATA ANALYSIS AND RESULTS

### 4.1 Analysis of Secondary Data Set

SO<sub>2</sub> concentration distribution maps were generated as discussed in the methodology section 3.1.5 and presented in *Figure 4-1* to *Figure 4-6* below.



*Figure 4-1: SO<sub>2</sub> Concentration level distribution in WP-2013*



*Figure 4-2: SO<sub>2</sub> Concentration level distribution in WP-2014*

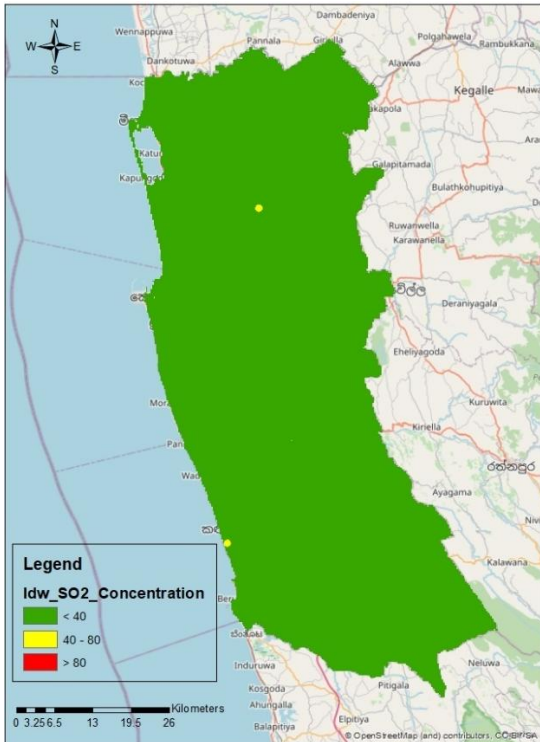


Figure 4-3: SO<sub>2</sub> Concentration level distribution in WP-2015

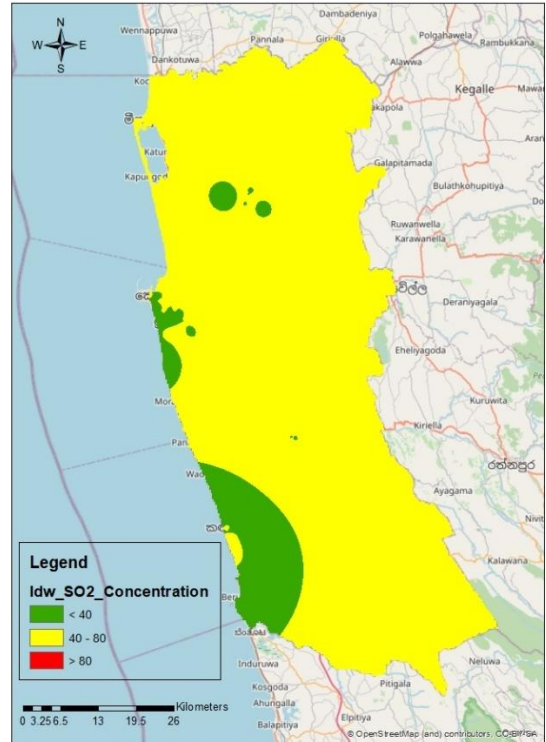


Figure 4-4: SO<sub>2</sub> Concentration level distribution in WP-2016

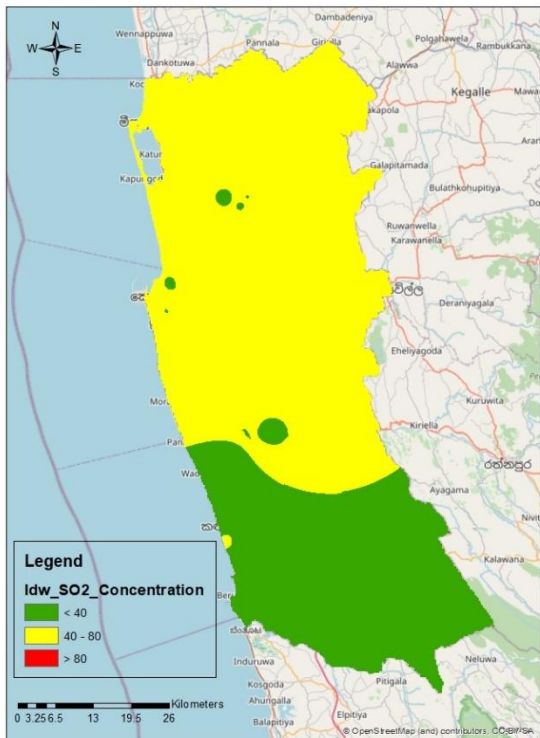


Figure 4-5: SO<sub>2</sub> Concentration level distribution in WP-2017

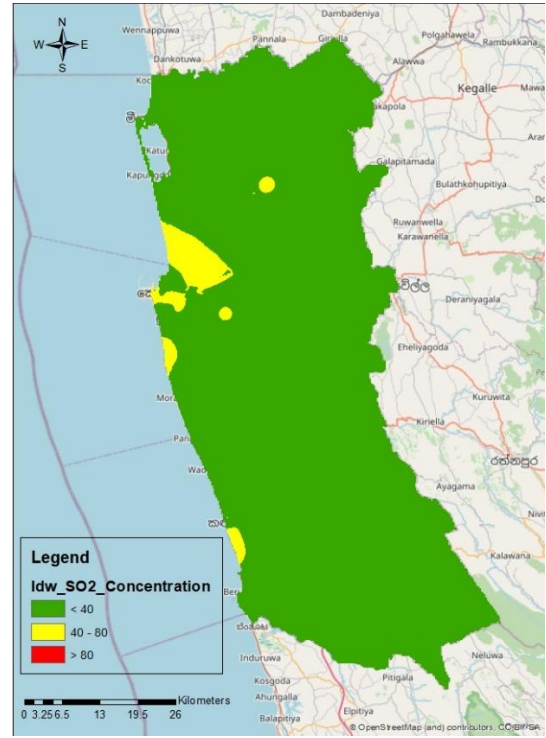
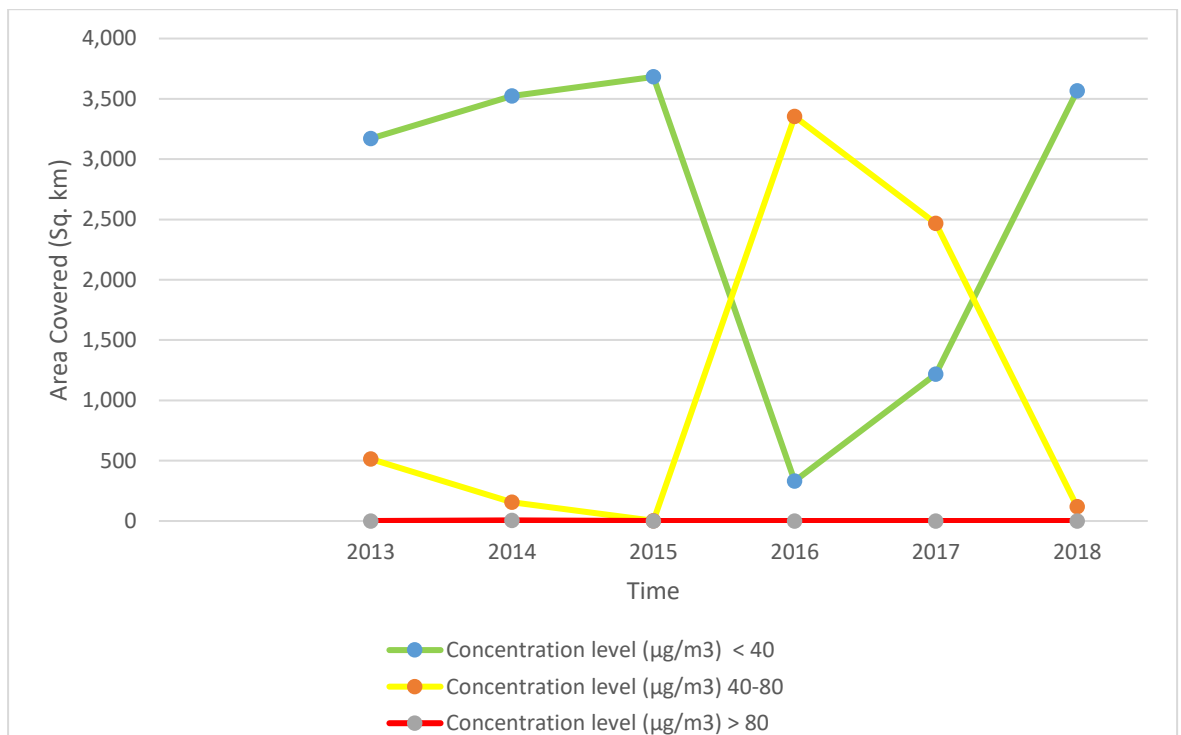


Figure 4-6: SO<sub>2</sub> Concentration level distribution in WP-2018

SO<sub>2</sub> concentration area less than 40 ppm is demarcated in green, between 40 ppm to 80 ppm in yellow and greater than 80 ppm in red. Under these levels of concentration, spatial distribution data were reanalyzed and the land area covered by each concentration level was taken as output and depicted in Table 4-1. The tabulated data was presented as a scatter plot in the graph presented in *Figure 4-7*.

Table 4-1: Area covered with each SO<sub>2</sub> concentration level

SO <sub>2</sub>	Land area covered under SO <sub>2</sub> concentration in each year (km <sup>2</sup> )					
Concentration level (µg/m <sup>3</sup> )	2013	2014	2015	2016	2017	2018
< 40	3,170	3,523	3,682	331	1,216	3,567
40-80	514	156	2	3,353	2,468	117
> 80	-	5	-	-	-	-



*Figure 4-7: Area Covered in each SO<sub>2</sub> concentration level*

It was clear that from 2013 to 2015 there was a clear reduction in area covered with SO<sub>2</sub> concentration between 40 µg/m<sup>3</sup> to 80 µg/m<sup>3</sup> yearly. However, there was a sudden increase in the area covered with SO<sub>2</sub> concentration between 40 µg/m<sup>3</sup> to 80 µg/m<sup>3</sup> in the years 2016 and 2017. However, in 2018 the area covered with SO<sub>2</sub> concentration between 40 µg/m<sup>3</sup> to 80 µg/m<sup>3</sup> again shows a clear decrease.

The highlighted areas in yellow and red have questionable air quality, especially with regard to the more stringent WHO 24-hour guideline of 40 µg/m<sup>3</sup>. The fact that this threshold is regularly exceeded in the years observed points to significant potential health risks, especially for vulnerable people living and working in this area. The increase in 2016-2017 suggests a slack that occurred in compliance with the air quality standards or an increase in the sources of emission, which needs an in-depth investigation.

Where the targets of the National Environmental Act-Sri Lanka might have been a rather relaxing standard of 80 µg/m<sup>3</sup> depending on the implementation period, fluctuating SO<sub>2</sub> gives reason for more stringent controls in terms of emission and the creation of awareness among the public. The decrease in 2018 may reveal the positive response towards corrective measures taken to improve the conditions. However, the need for sustained compliance with WHO standards needs to be stressed since the values exceeded above indicate severe air quality and associated health repercussions.

Similarly, NO<sub>2</sub> Concentration distribution maps generated as discussed in the methodology section 3.1.5 are presented in *Figure 4-8* to *Figure 4-13*.

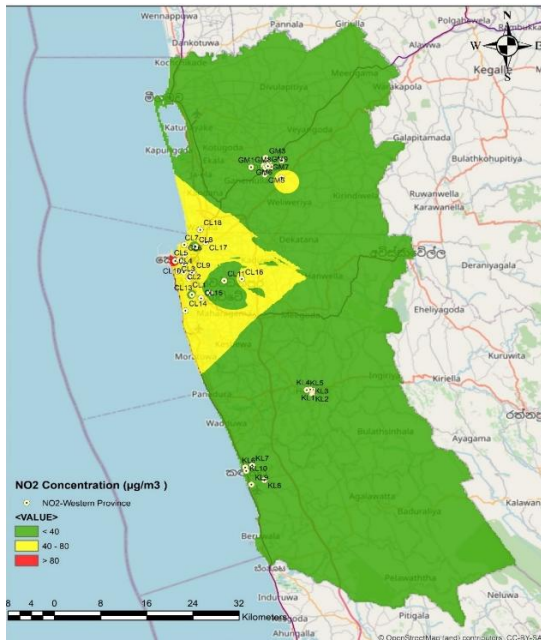


Figure 4-8: NO<sub>2</sub> Concentration level distribution in WP-2013

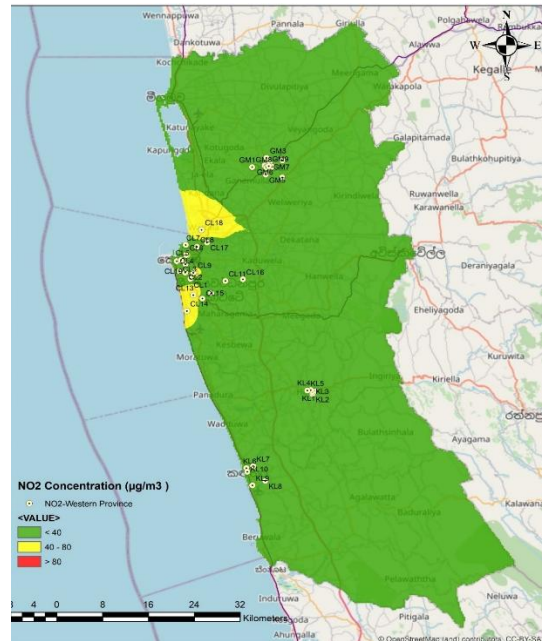


Figure 4-9: NO<sub>2</sub> Concentration level distribution in WP-2014

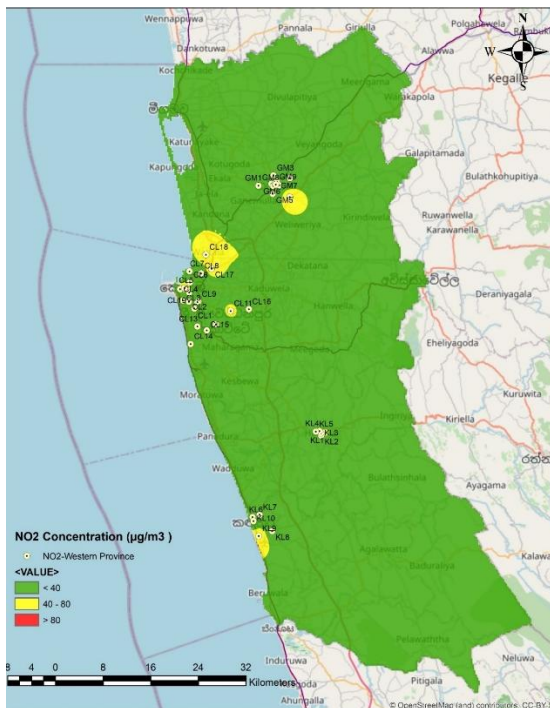


Figure 4-10: NO<sub>2</sub> Concentration level distribution in WP-2015

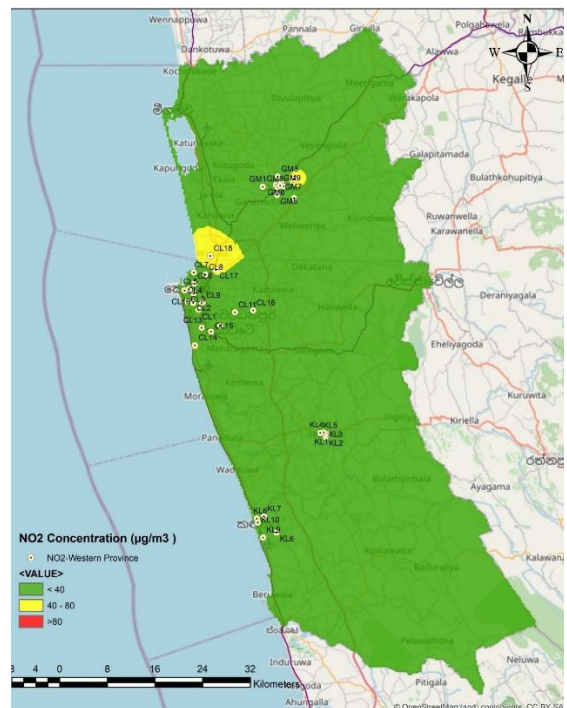


Figure 4-11: NO<sub>2</sub> Concentration level distribution in WP-2016

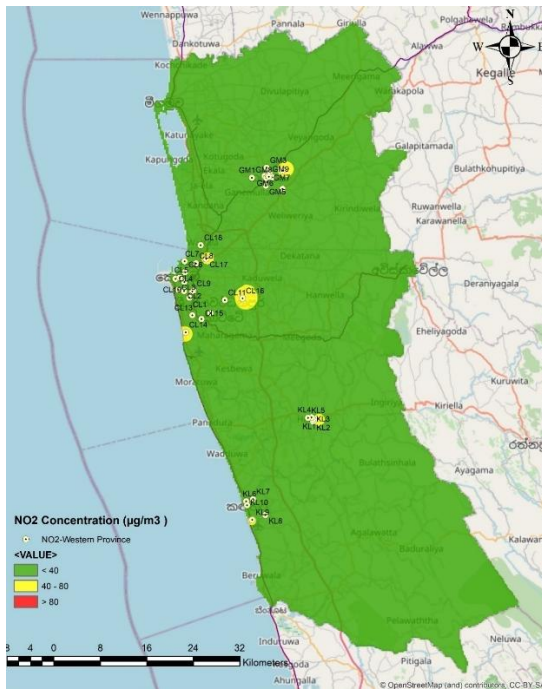


Figure 4-12: NO<sub>2</sub> Concentration level distribution in WP-2017

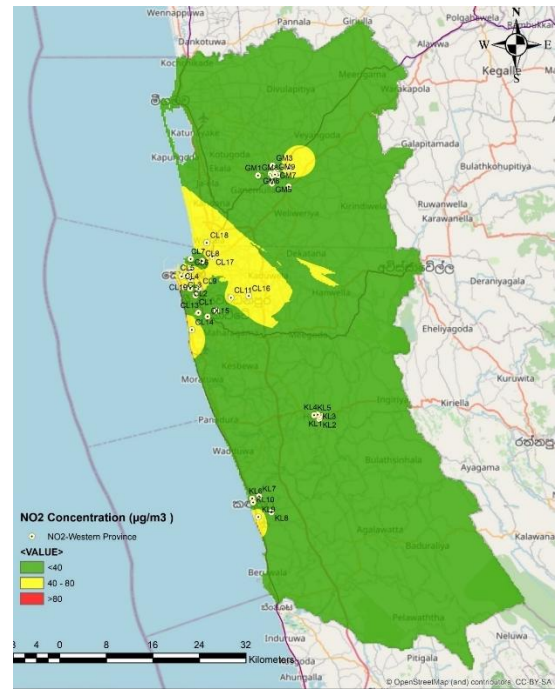


Figure 4-13: NO<sub>2</sub> Concentration level distribution in WP-2018

NO<sub>2</sub> concentration area less than 40 ppm is demarcated in green, between 40 ppm to 80 ppm in yellow and greater than 80 ppm in red. Under these levels of concentration, spatial distribution data were reanalyzed and the land area covered by each concentration level was taken as output and depicted in Table 4-2. The tabulated data was presented as a scatter plot in the graph presented in Figure 4-14.

Table 4-2: Area covered with each NO<sub>2</sub> concentration level

NO <sub>2</sub> Concentration level (µg/m <sup>3</sup> )	Land area covered under NO <sub>2</sub> concentration in each year (km <sup>2</sup> )					
	2013	2014	2015	2016	2017	2018
< 40	3329	3599	3616	3632	3652	3439
40-80	353	85	69	53	32	245
> 80	2	-	-	-	-	-

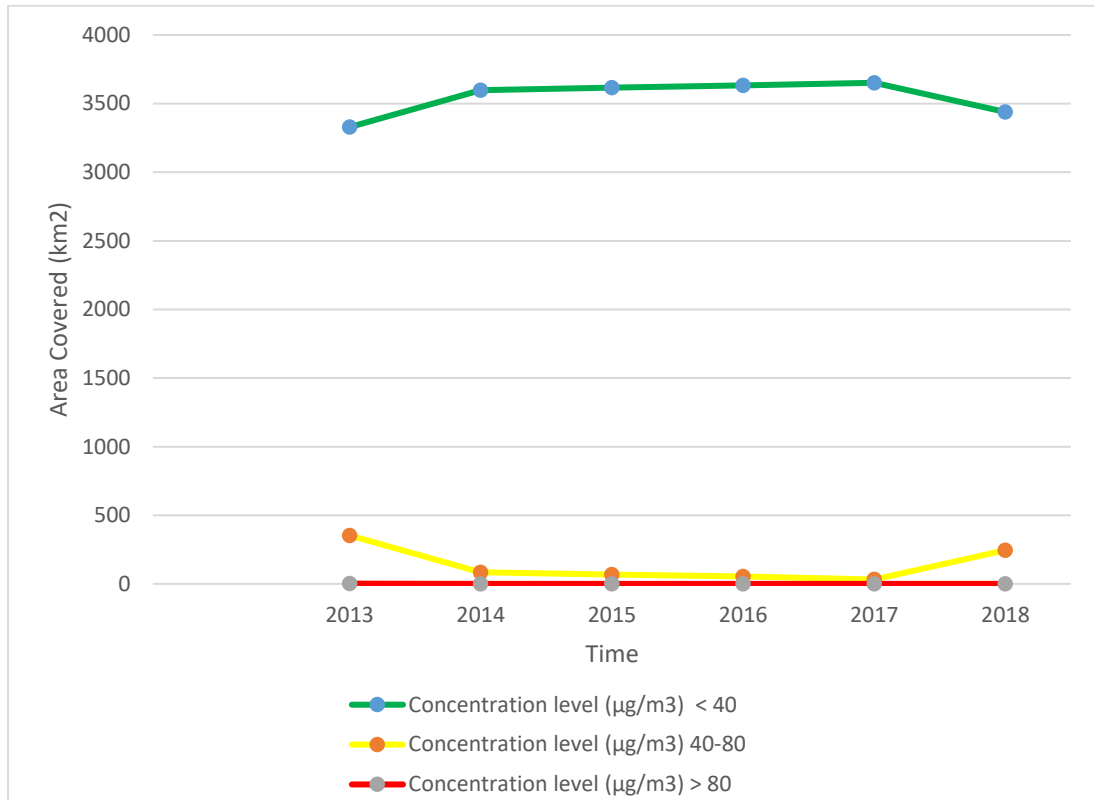


Figure 4-14: Area Covered in each NO<sub>2</sub> Concentration level

It was clear that from 2013 to 2017 there was a clear reduction in area covered with NO<sub>2</sub> concentration between 40  $\mu\text{g}/\text{m}^3$  to 80  $\mu\text{g}/\text{m}^3$  yearly. However, during the year 2018, there was a sudden increase in area covered with NO<sub>2</sub> concentration between 40  $\mu\text{g}/\text{m}^3$  to 80  $\mu\text{g}/\text{m}^3$ .

While it was observed that in some places NO<sub>2</sub> concentrations increased during 2018, this trend is a matter of concern as these concentrations fall within ranges of 40-80  $\mu\text{g}/\text{m}^3$ , which lies within the WHO interim target 1 values of 120  $\mu\text{g}/\text{m}^3$ . Although it is far above the interim target 2 value of 50  $\mu\text{g}/\text{m}^3$  and the final limit of the guideline value of 25  $\mu\text{g}/\text{m}^3$ . These high concentrations result in adverse health effects, with particular significance in urban areas because of the heavy flow of traffic as highlighted in the literature review. This in turn indicates that present-day transport-related pollution significantly deteriorates air quality and might be hazardous to public health where NO<sub>2</sub> concentration levels exceed guideline limits.

This underlines the need for stricter measures and policies in terms of NO<sub>2</sub> levels since the latter consistently exceeds the WHO standards on air quality and thus calls for further mitigating actions with respect to the adverse effects of roadside air pollution.

The levels of concentration still indicate the challenge of maintaining acceptable air quality, when compared with the Sri Lanka National Environmental Act guidelines that adopt different permissible limits of 100 µg/m<sup>3</sup>. This decrease from 2013 to 2017 would indicate some improvements in controls of emissions, while the spike in 2018 underlines that regulatory measures should be strengthened and consistently taken to meet not only SL standards but also WHO standards for healthier air quality outcomes.

The government continuously implemented policies starting from 2008 aiming improvement of air quality in Sri Lanka. Following are the main policy implementations on the island,

1. Banning of Two Stroke Tree Wheelers

- ▶ To prohibit the import of three-wheelers powered by two- Stroke petrol engines with effect from January 2008
- ▶ Suspension of import of the full engine by January 2011
- ▶ Engine block and cylinder head by January 2013 in order to avoid local assembly of two stroke engines

2. Implementation of vehicle emission testing programme

- ▶ In June 2008 the programme started in the western province as a pilot project
- ▶ By June 2013 the programme was implemented island wide

3. Provision of cleaner fuel for vehicles in parallel with Euro Standards

- ▶ 10ppm Sulphur diesel was provided island wide replacing 500 ppm Sulphur diesel from July 2014

The above major policy changes are positively affecting the air quality improvement on the island when considered in the results of this study conducted in urban and suburban areas of the Western Province of Sri Lanka. However, only considering this air quality

concentration level reduction over the years it is not possible to strongly conclude this is the exact reason for the reduction of SO<sub>2</sub> and NO<sub>2</sub> concentration levels. Moreover, other factors such as wind effect, temperature, and other pollutant sources may also cause some effect on this reduction. Therefore, data collection is required, along with traffic count data for a better understanding of air quality concentration levels.

Graphical representation of results using GIS technologies has led to better understanding, as well as in-depth representation with greater details of the spatial distribution of air quality concentration. The GIS generated maps are clearly displaying areas with predefined concentration levels of NO<sub>2</sub> and SO<sub>2</sub> inside of the area of study. GIS analyzed output maps reveal pollution hotspots and enable to clearly identify those areas and implement further actions that may be required to gather additional information relevant to those areas with higher pollution levels to provide adequate solutions to make the contaminant level lower. For example, it was clear that the Colombo urban area and Gampaha urban area had a considerably high air quality concentration level throughout the period. It is suggested to implement monitoring locations at close intervals in order to clearly identify corridors and provide specific countermeasures accordingly.

Moreover, by having continuous monitoring of air quality concentration levels, it can identify pollution hotspots as identified in the above maps (from Figure 4-1 to Figure 4-13). Therefore, it is clear that the proposed methodology is capable of clearly identifying pollution hotspots so that policy makers can implement mitigation measures in order to reduce the concentration levels of pollutants. The following policies may be implemented to reduce the concentration levels of pollutants.

1. Implementation of pollution charging zones where the air pollution levels high in order to reduce unnecessary traffic.
2. Ban on high-emission vehicles in pollution hotspots
3. Identify the main reasons for high air quality concentration (whether traffic congestion, high percentage of heavy vehicles etc... and provide alternative methods such as traffic diversion and heavy vehicle bans during peak hours.

Apart from this, the result of this GIS analysis could be applied to measure the area influenced by each level of concentration of the pollutants and could be used in measuring the magnitude of the consultant distribution and its yearly fluctuation. The

results of GIS analysis of Western Province Sri Lanka are given in an organized manner on a yearly basis. Through the examination of changes in the spatial distribution of SO<sub>2</sub> and NO<sub>2</sub> concentration levels, policymakers can determine regions where air quality has improved or worsened, thus allowing them to set priorities for their interventions and deal with issues surrounding policy design and the imposition or removal of control measures.

Continuous monitoring of air quality even after the implementation of mitigation measures will help to evaluate the effectiveness of implemented measures and will provide a clear path to further improvement.

## **4.2 Analysis using Primary Data**

### **4.2.1 Graphical Representation**

Time series plots were generated considering each pollutant concentration and traffic volume for each data collected location. Concentration levels for each pollutant are marked in the primary axis and traffic volumes are marked in the secondary axis. Further, the WHO air quality guideline standard interim target 1 values for each pollutant is also marked in order to have a better understanding of the air quality of the particular location.

#### **Time series plots of Collected Data (Sensor Unit)**

From *Figure 4-15* to *Figure 4-47* represents the collected data using a sensor unit with traffic volume scatter plot.

#### 4.2.2 PM<sub>2.5</sub> Concentration Time Series plot with Traffic volume

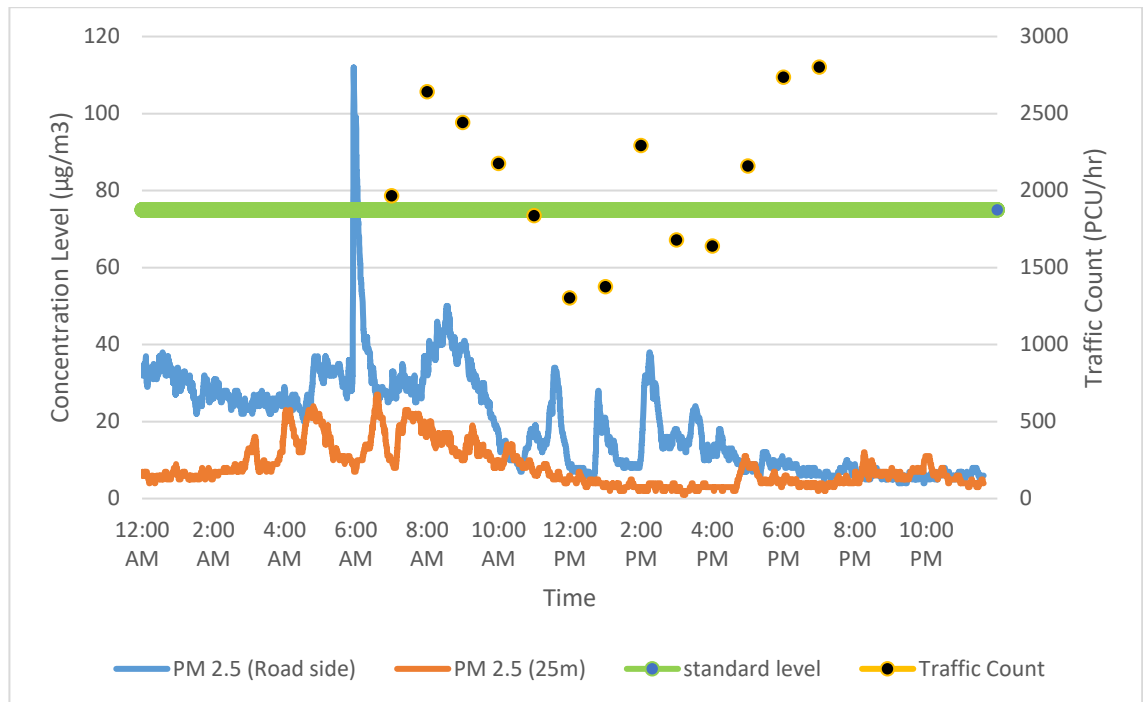


Figure 4-15: PM<sub>2.5</sub> Concentration at Ekala Kotadeniyawa Road – Nilpanagoda (Site-1)

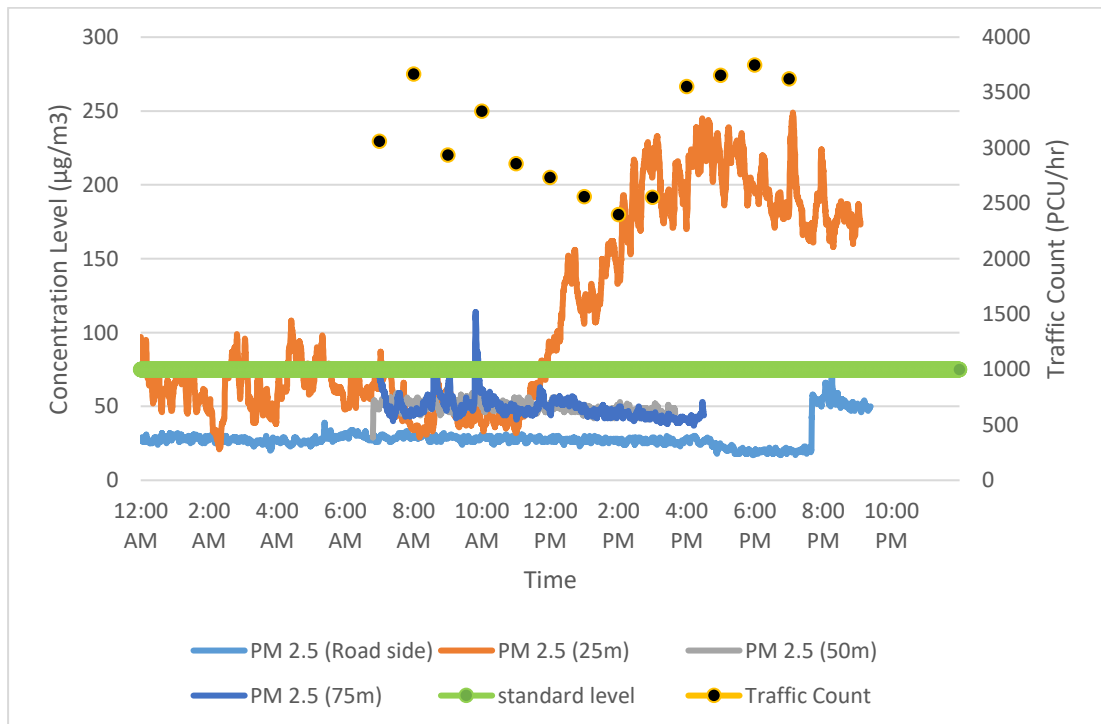


Figure 4-16: PM<sub>2.5</sub> Concentration at Colombo Kandy Road – Miriswatta (Site-2)

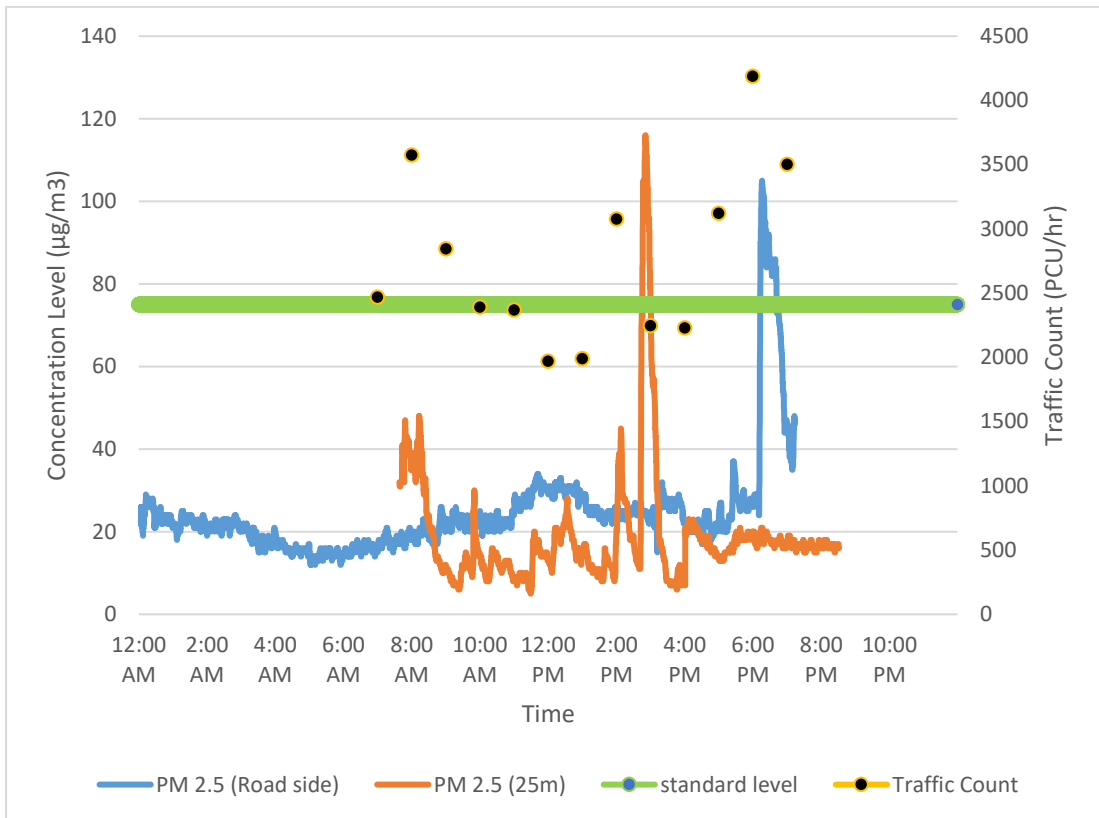


Figure 4-17: PM<sub>2.5</sub> Concentration at Katunayake Veyangoda Road- Yatiyana (Site-3)

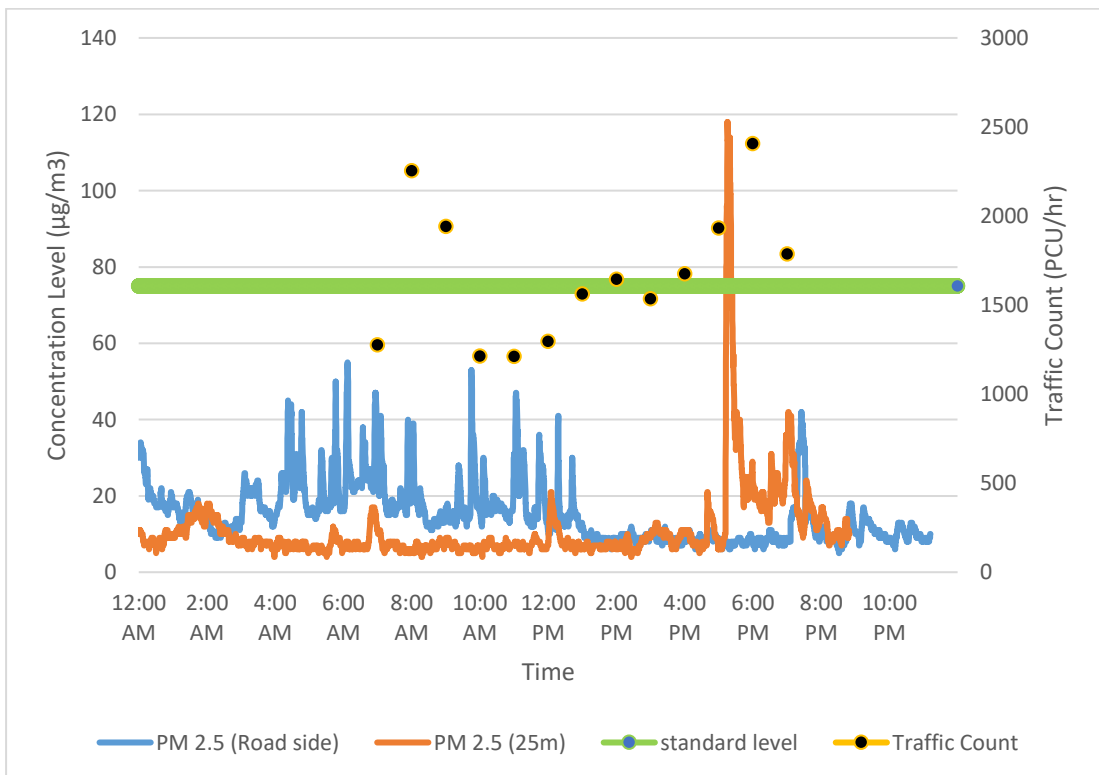


Figure 4-18: PM<sub>2.5</sub> Concentration at Kandawala Katunayake Road – Kadirana (Site-4)

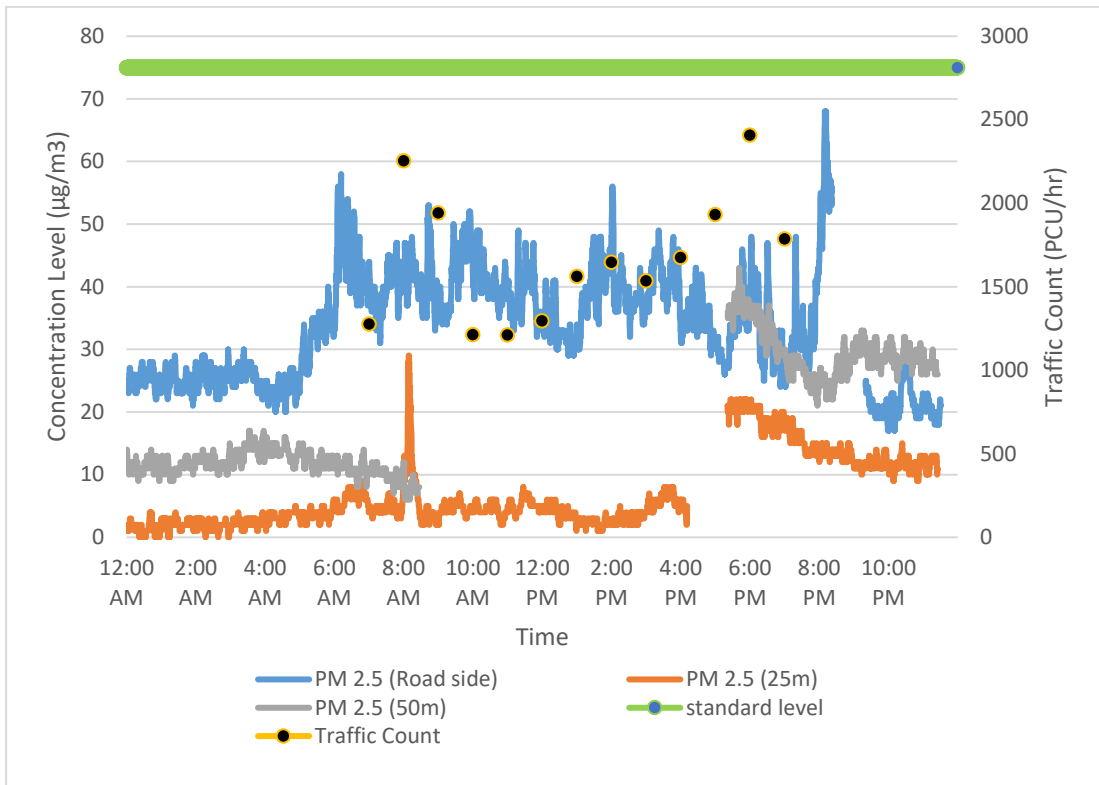


Figure 4-19: PM<sub>2.5</sub> Concentration at Katunayake Veyangoda Road- Minuwangoda (Site-5)

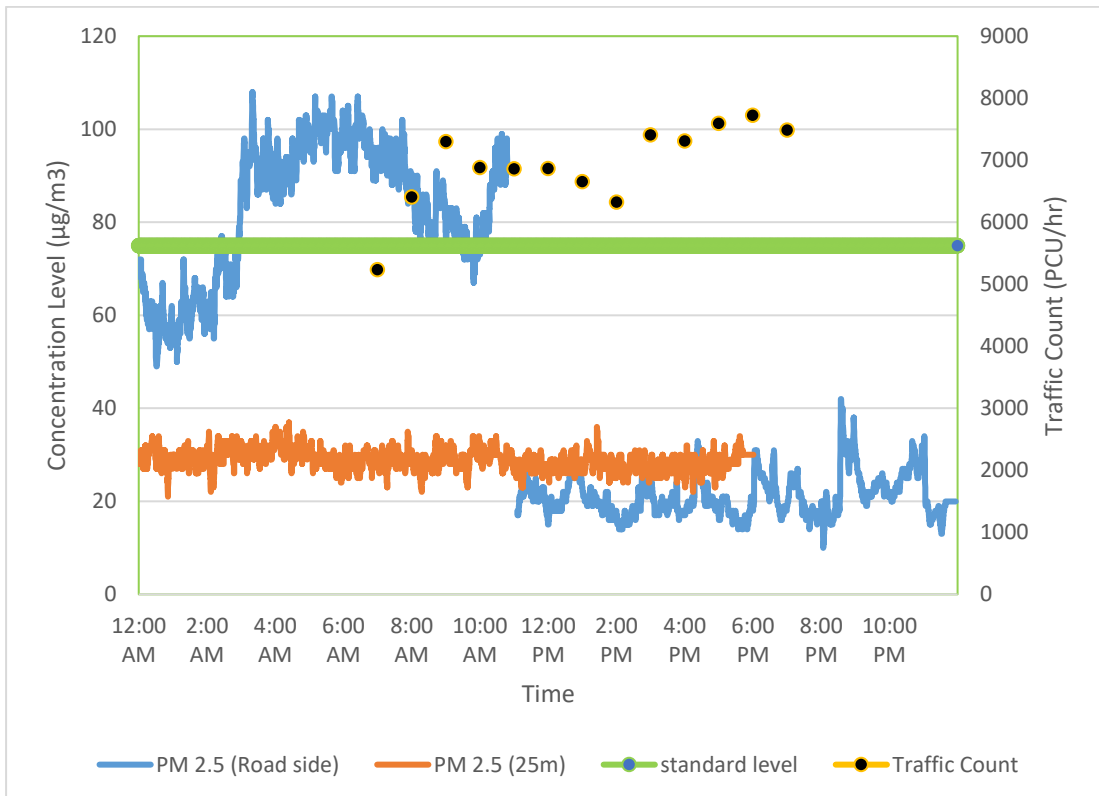


Figure 4-20: PM<sub>2.5</sub> Concentration at Colombo Kandy Road – Kadawatha (Site-6)

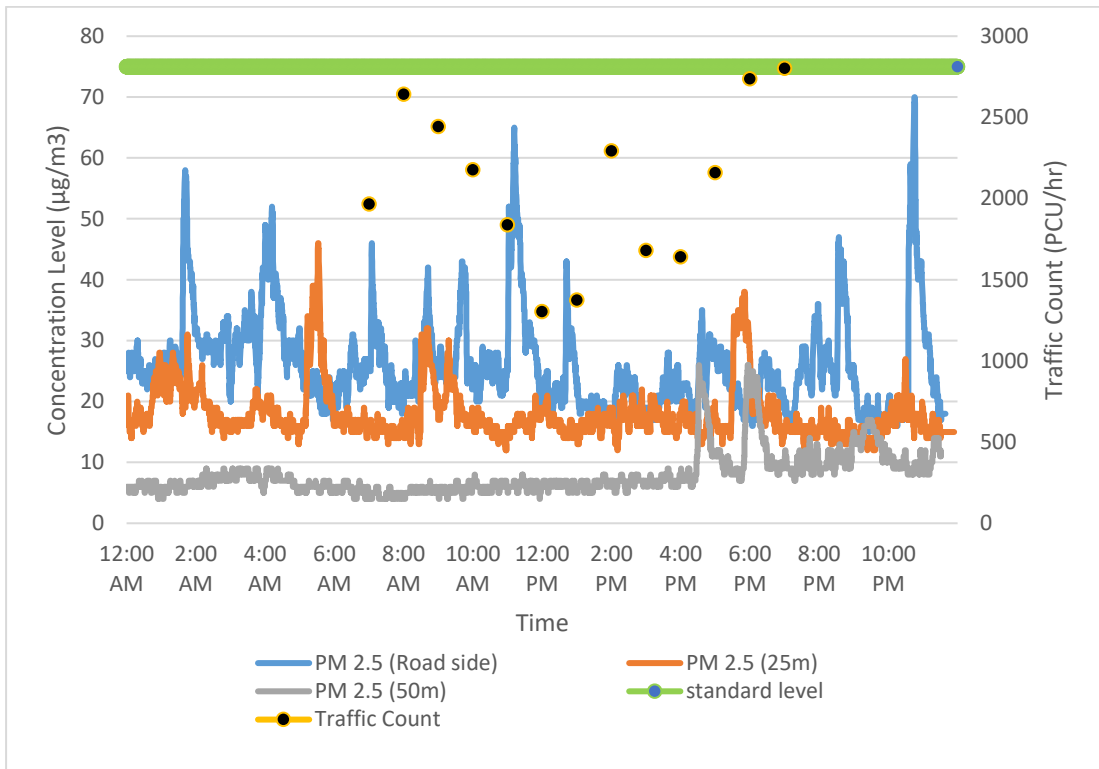


Figure 4-21: PM<sub>2.5</sub> Concentration at Katunayake Veyangoda Road – Veyangoda (Site-7)

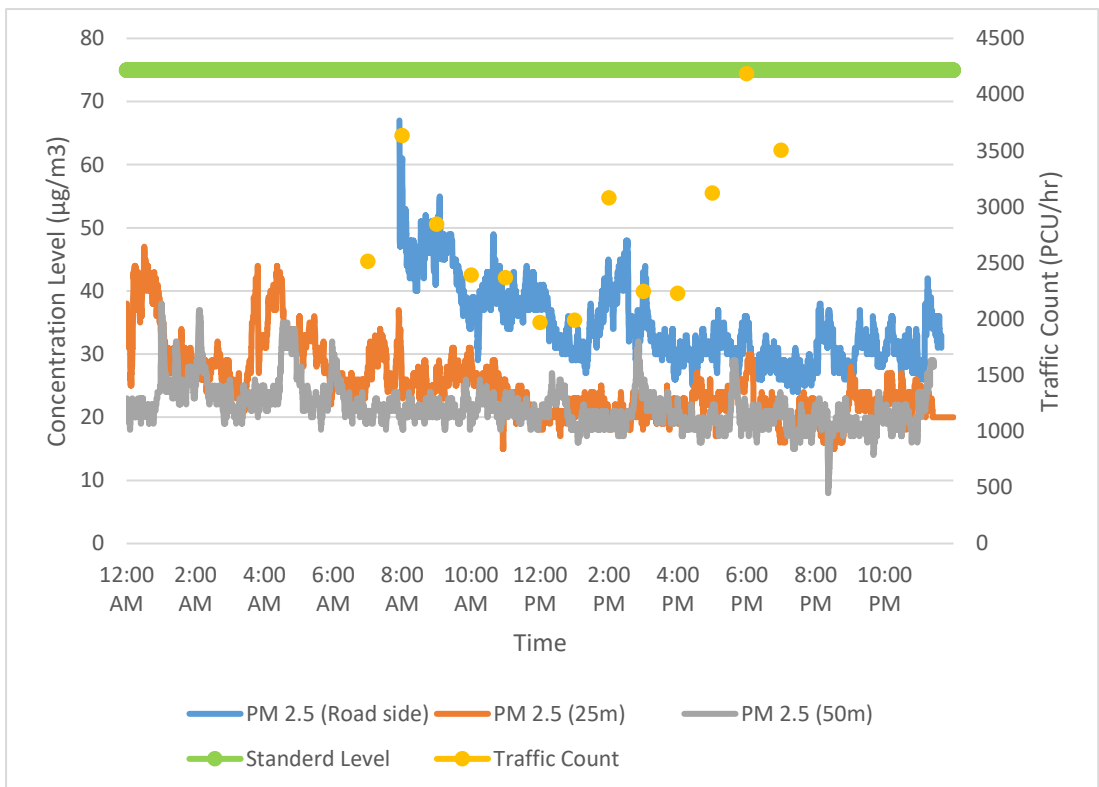


Figure 4-22: PM<sub>2.5</sub> Concentration at Ekala Kotadeniyawa Road – Ekala (Site-8)

## **Detailed Discussion on PM<sub>2.5</sub> Concentration Trends Across Sites:**

### **Ekala Kotadeniyawa Road (Site 1 and Site 8):**

The morning and evening peaks are well-defined in both sites, which fall in typical commuter hours. The aforementioned patterns imply that the source of increased PM<sub>2.5</sub> concentration is highly likely to be vehicular traffic.

At Site 8, the concentration appears to be slightly less volatile than at Site 1, possibly due to the lower volume of heavy traffic in the latter.

### **Colombo Kandy Road (Site 6 and Site 2):**

These sites show very high concentrations of PM<sub>2.5</sub>, especially in the morning and evening hours. The spikes here are substantially higher than those observed at more rural sites, reflective of the intense vehicular emissions along major arterial roads. The Site 6 area, being more urban, could also experience more complex pollutant sources, such as buses and trucks contributing to the fine particulate pollution.

There was a power cut during the roadside data collection at site 6 followed by a rain event. Therefore, there is a discontinuity of data from 10.45 AM to 11.05 AM. It was clear that after the rain event, there was a clear reduction in PM<sub>2.5</sub> concentration level.

There are several studies conducted related to PM<sub>2.5</sub> concentration change due to rain events. Those studies suggested that PM can decrease by up to 58% during rainfall, 43% with post-rain concentrations lower than pre-rain levels (AAQR, 2023). Moreover, it highlighted this effect in Beijing, noting significant PM<sub>2.5</sub> removal during rain events (Xie et al., 2017). Additionally, a 21% reduction in PM<sub>2.5</sub> within an hour of rain was reported in study conducted in Japan (RMETS, 2023). Factors like initial PM levels and rainfall intensity enhance removal efficiency, while high humidity with light rain can cause a wet growth effect, temporarily increasing PM concentrations (Wiley, 2020).

It was observed that in site 2, roadside PM<sub>2.5</sub> concentration is comparatively less than in the other locations. This could be possible due to climatic conditions such as wind, temperature and moisture condition of air. Moreover, the roadside data collection location was surrounded by trees which might have impacted the reduction in PM<sub>2.5</sub> concentration. It was also observed that the 25m reading significantly increased during the afternoon of

the day. This was quite an unexpected observation, and significant differences in climatic conditions or traffic conditions were not observed during the day. Therefore, this rise may be caused due to an internal issue of the sensor unit.

**Katunayaka Veyangoda Road (Site 3, Site 5, and Site 7):**

In Site 3 and Site 7, the concentrations of PM<sub>2.5</sub> are generally lower, with slight spikes at different times of the day. Such patterns suggest moderate pollution, possibly from road dust. The differences between these sites might relate to underlying topography which might trap pollution during stagnant atmospheric conditions.

**Baseline Road (Site 4):**

Site 4 indicates more irregular peaks of concentration, with some sharp increases during specific periods that might be due to local industrial emissions, construction activities or traffic congestion events. Site 4 is located near an apartment construction project location and there are frequent construction vehicle movements throughout the day. Furthermore, the Colombo International Airport and Katunayake BOI zone are also located in close proximities (approximately 3km and 5km respectively). While this site is not as consistently high in PM<sub>2.5</sub> levels as urban ones, it still exhibits noticeable fluctuations likely driven by localized traffic.

Across sites, morning peaks are likely tied to rush hour traffic and colder weather conditions that can trap pollutants near the ground. Some midday dips when traffic is lower, and higher atmospheric dispersion due to sunlight and heating of air serve to dilute particulate concentrations.

Sites closer to industrial zones, like Site 6 or Site 4, show noticeable fluctuations, possibly due to industrial emissions playing a major role during random times of the day.

### 4.2.3 PM<sub>10</sub> Concentration Time Series plot with Traffic volume

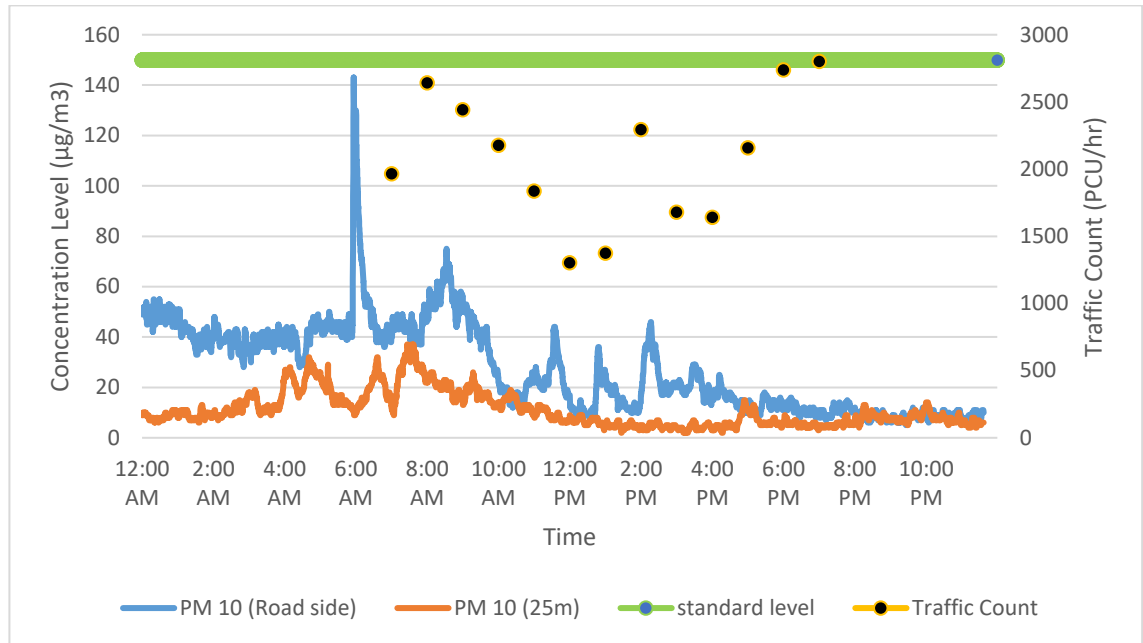


Figure 4-23: PM<sub>10</sub> Concentration at Ekala Kotadeniyawa Road – Nilpanagoda (Site-1)

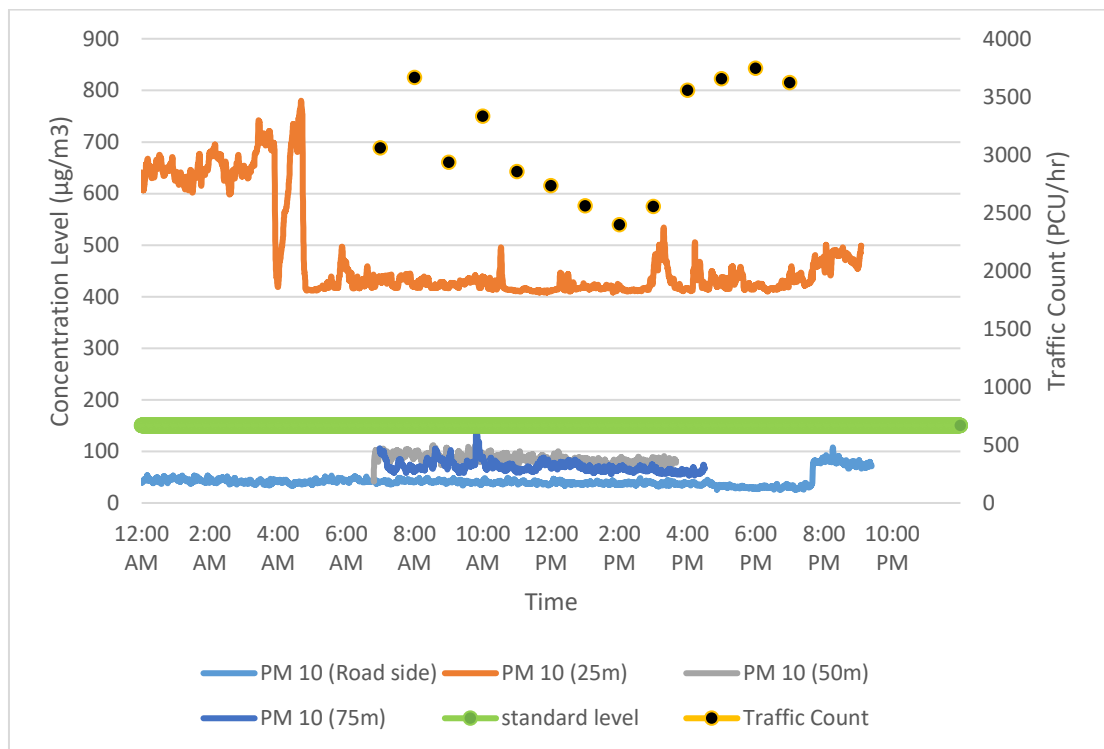


Figure 4-24: PM<sub>10</sub> Concentration at Colombo Kandy Road – Miriswatta (Site-2)

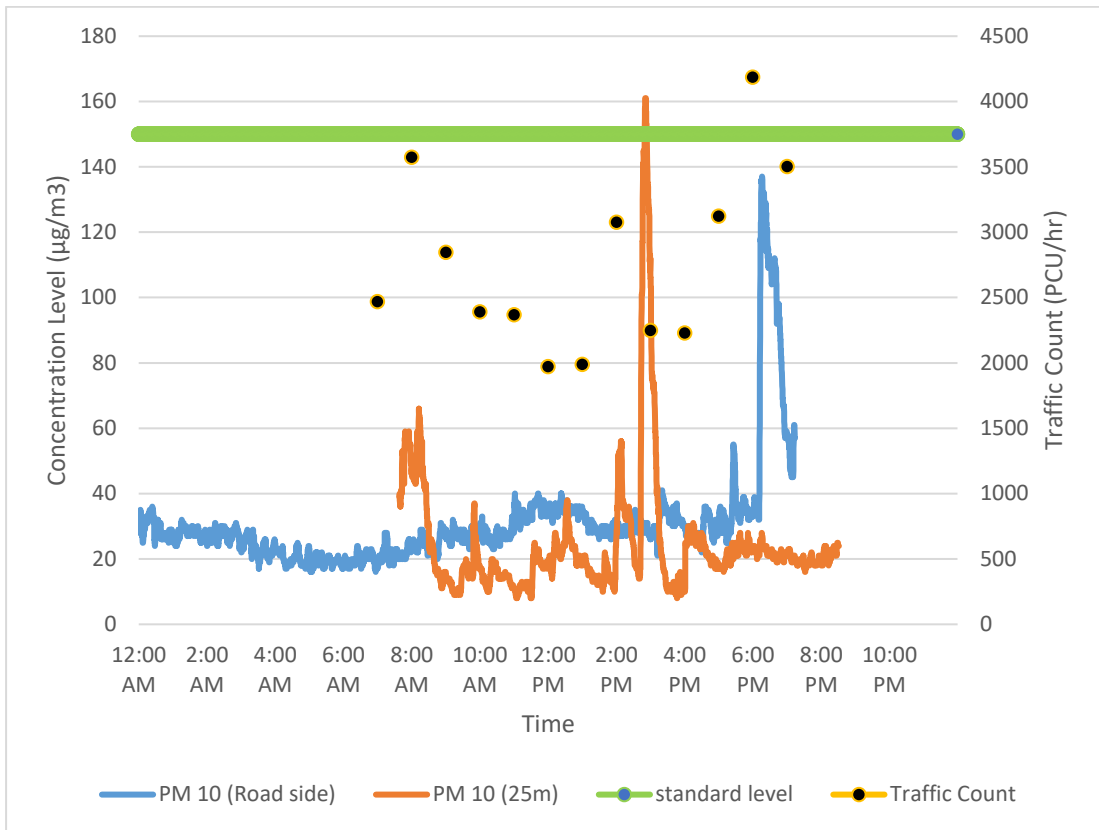


Figure 4-25: PM<sub>10</sub> Concentration at Katunayake Veyangoda Road- Yatiyana (Site-3)

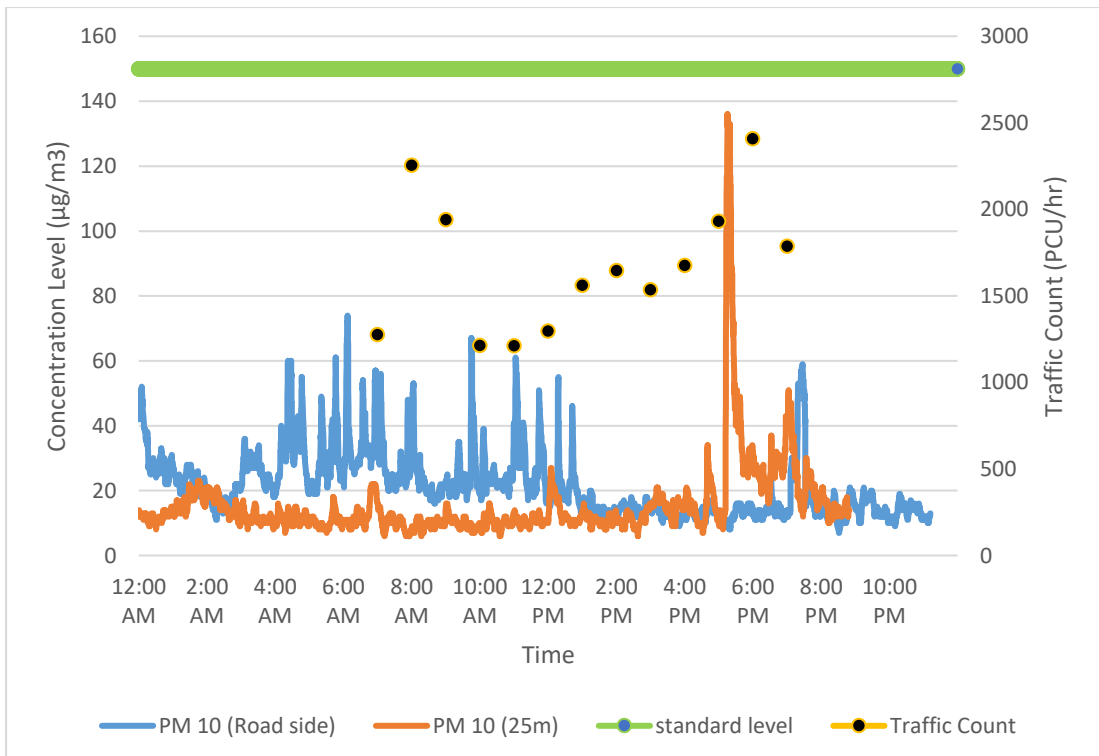


Figure 4-26: PM<sub>10</sub> Concentration at Kandawala Katunayake Road – Kadirana (Site-4)

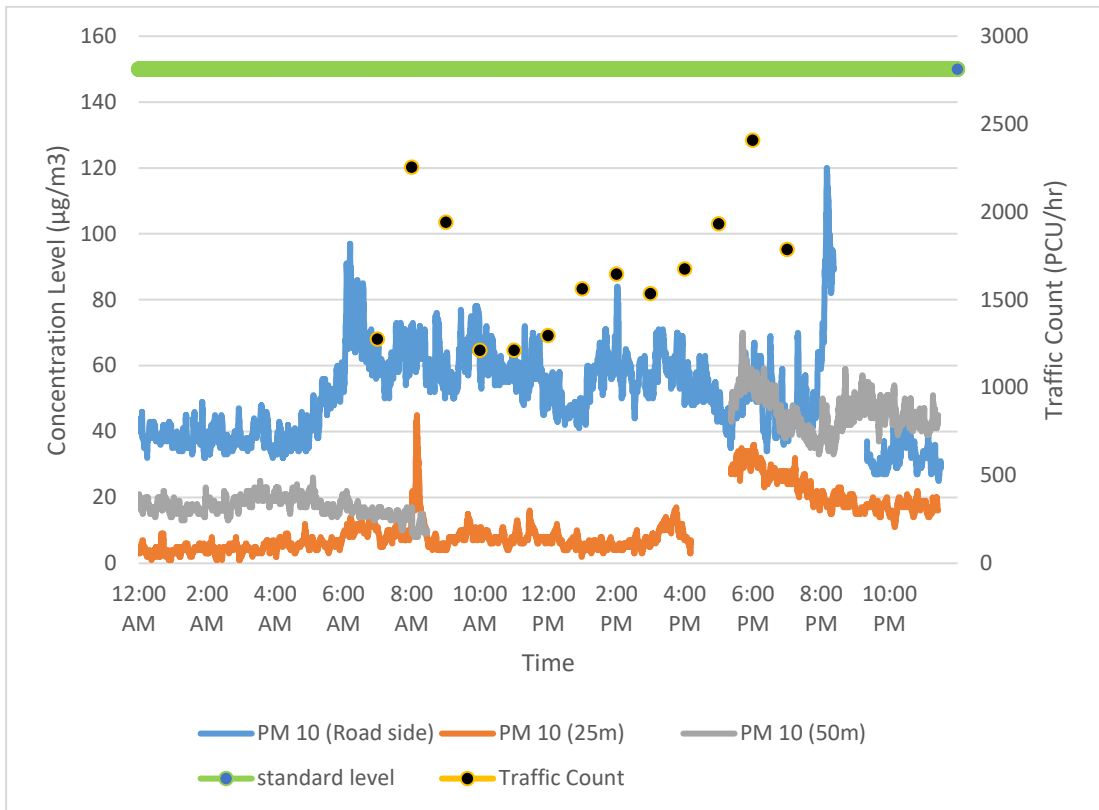


Figure 4-27: PM<sub>10</sub> Concentration at Katunayake Veyangoda Road - Minuwangoda (Site-5)

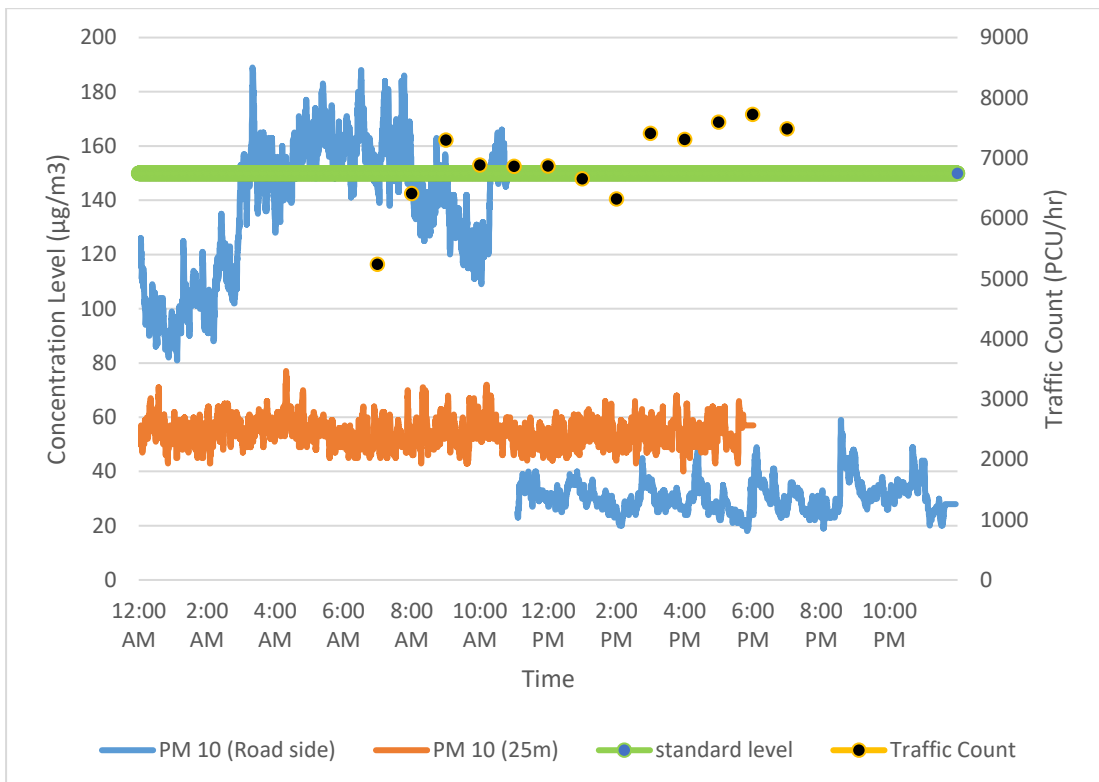


Figure 4-28: PM<sub>10</sub> Concentration at Colombo Kandy Road – Kadawatha (Site-6)

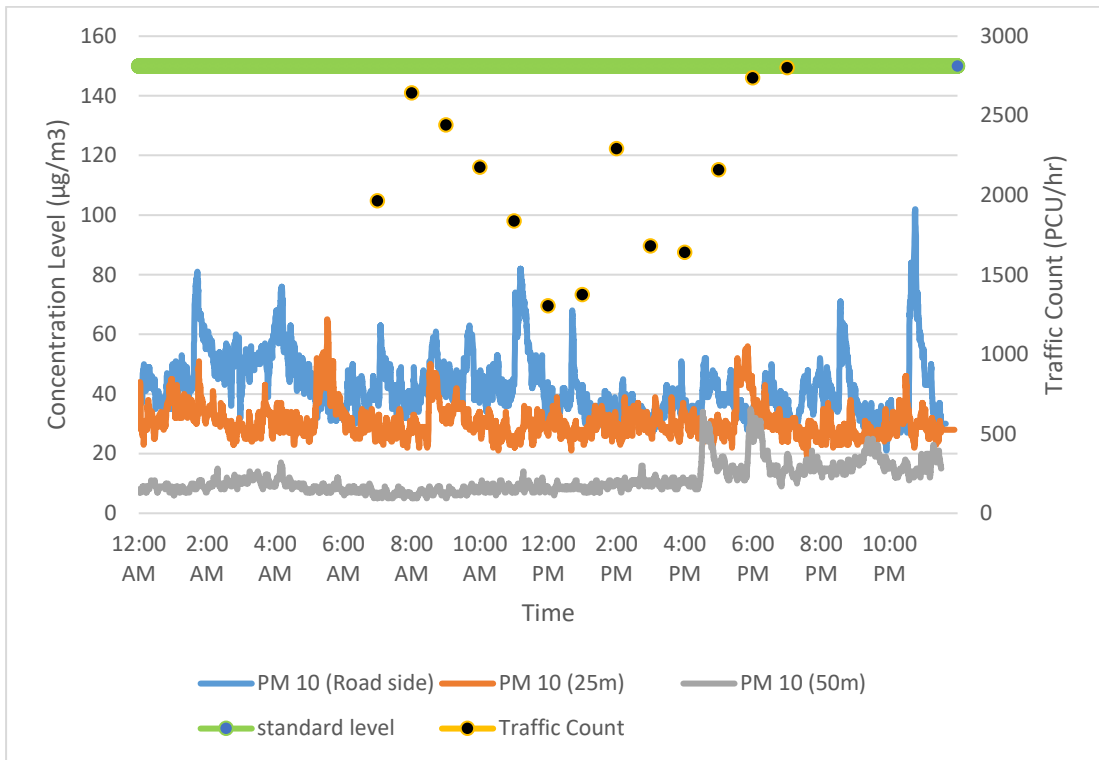


Figure 4-29: PM<sub>10</sub> Concentration at Katunayake Veyangoda Road – Veyangoda (Site-7)

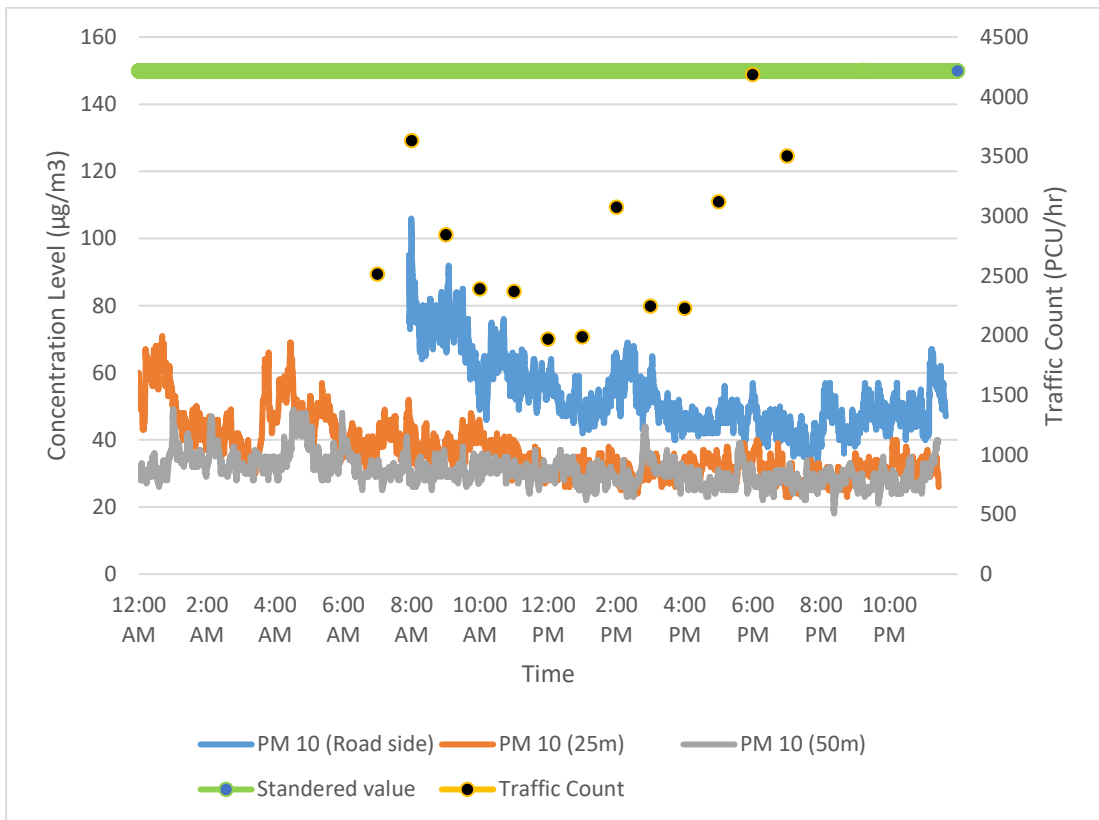


Figure 4-30: PM<sub>10</sub> Concentration at Ekala Kotadeniyawa Road – Ekala (Site-8)

### **Detailed Discussion on PM<sub>10</sub> Concentration:**

#### **Ekala Kotadeniyawa Road (Site 1 and Site 8):**

The pattern of PM<sub>10</sub> concentration is similar to the pattern of PM<sub>2.5</sub>, but it had a higher overall level. Such a higher magnitude of pollution from a combination of traffic emissions because traffic emits coarse fraction particles in addition to finer ones resuspension of road dust is likely responsible for this. The increase on the Site 1 plot is sharper than the Site 8 plot and probably reflects the degradation of roads to give rise to surface emission of particulate matter.

#### **Colombo Kandy Road (Site 6 and Site 2):**

This location consistently shows high PM<sub>10</sub> values. These sites probably see pollution from both combustion sources, namely vehicle emissions, and non-combustion sources like dust from unpaved roads and construction debris on major city roads. The cumulative effect is reflected in the consistently higher PM<sub>10</sub> readings observed throughout the day. Similar to the PM<sub>2.5</sub> concentration levels at site 6 there is a discontinuity of data collection due to power outage and rain occurred. After the rain event it was observed that huge reduction in PM<sub>10</sub> concentration levels similar to PM<sub>2.5</sub> concentration level. Previous studies suggest that significant reduction of PM<sub>10</sub> concentrations can be observed through wet deposition, with raindrops intercepting and removing airborne particulate matter. Poupkou et al. (2021) reported that for heavy precipitation episodes with intensities greater than 7.5 mm/h, the removal efficiency of PM<sub>10</sub> was more than 68%. Zhao et al. (2015) also noted that large-scale precipitation without wind had successfully lowered PM<sub>10</sub> in Beijing.

#### **Katunayake Veyangoda Road (Site 3, Site 5, and Site 7):**

Lower PM<sub>10</sub> concentrations suggest minimal traffic and construction activity in these relatively quieter areas. However, Site 3, a bit more rural, still sees occasional spikes, likely linked to occasional winds transporting dust from adjacent areas.

#### **Baseline Road (Site 4):**

Irregular spikes in PM<sub>10</sub> levels may reflect activities like construction or localized traffic congestion. Interestingly, Site 4 might exhibit more dust-related emissions than other urban areas, as there is potentially less infrastructure to control dust, particularly in drier months.

#### 4.2.4 CO<sub>2</sub> Concentration Time Series plot with Traffic volume

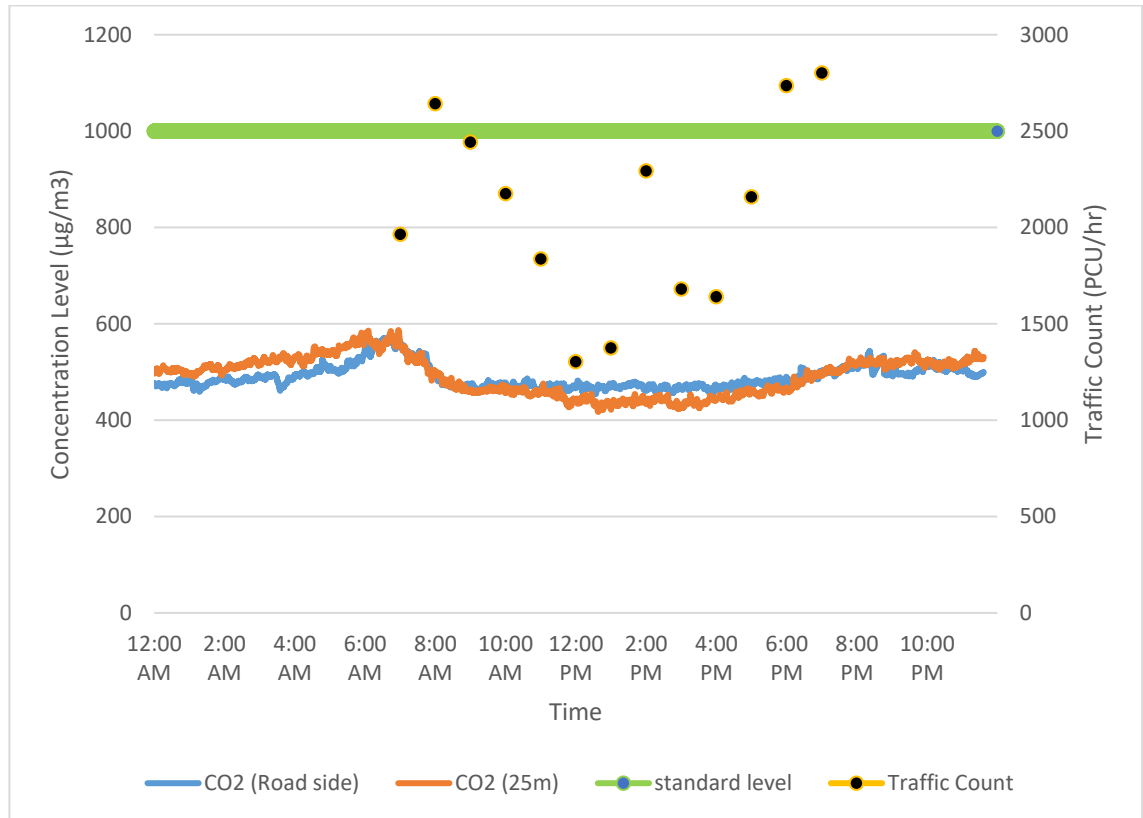


Figure 4-31: CO<sub>2</sub> Concentration at Ekala Kotadeniyawa Road – Nilpanagoda (Site-1)

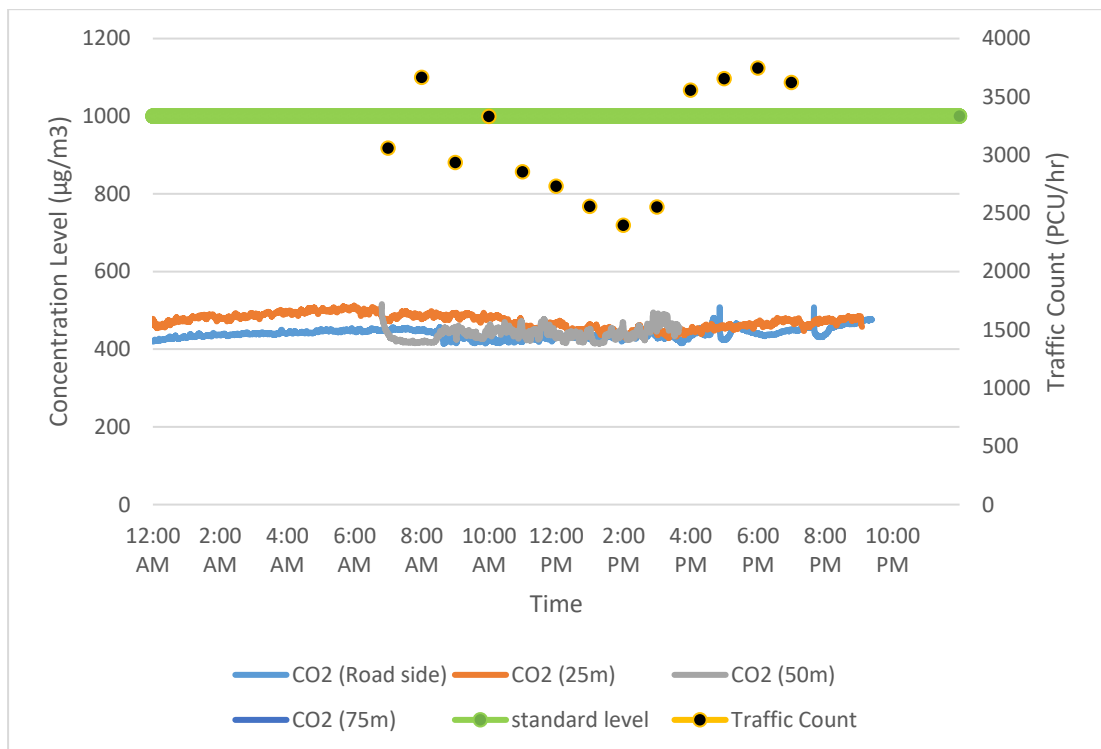


Figure 4-32: CO<sub>2</sub> Concentration at Colombo Kandy Road – Miriswatta (Site-2)

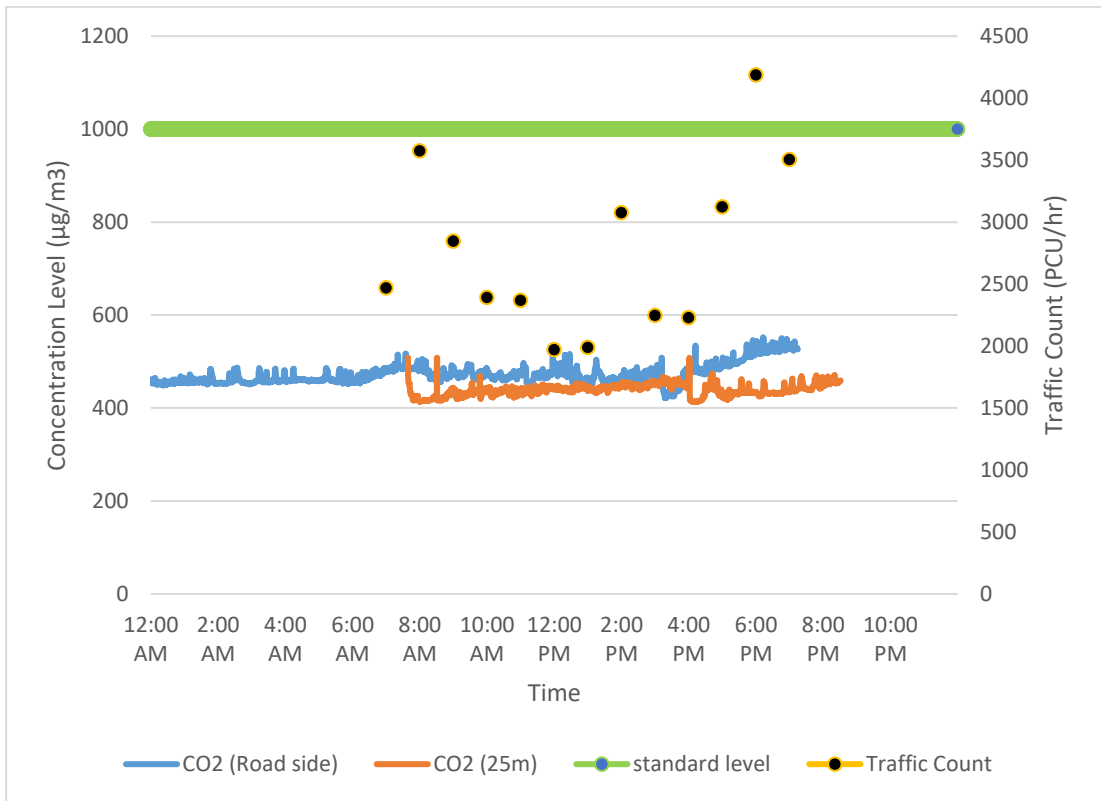


Figure 4-33: CO<sub>2</sub> Concentration at Katunayake Veyangoda Road- Yatiyana (Site-3)

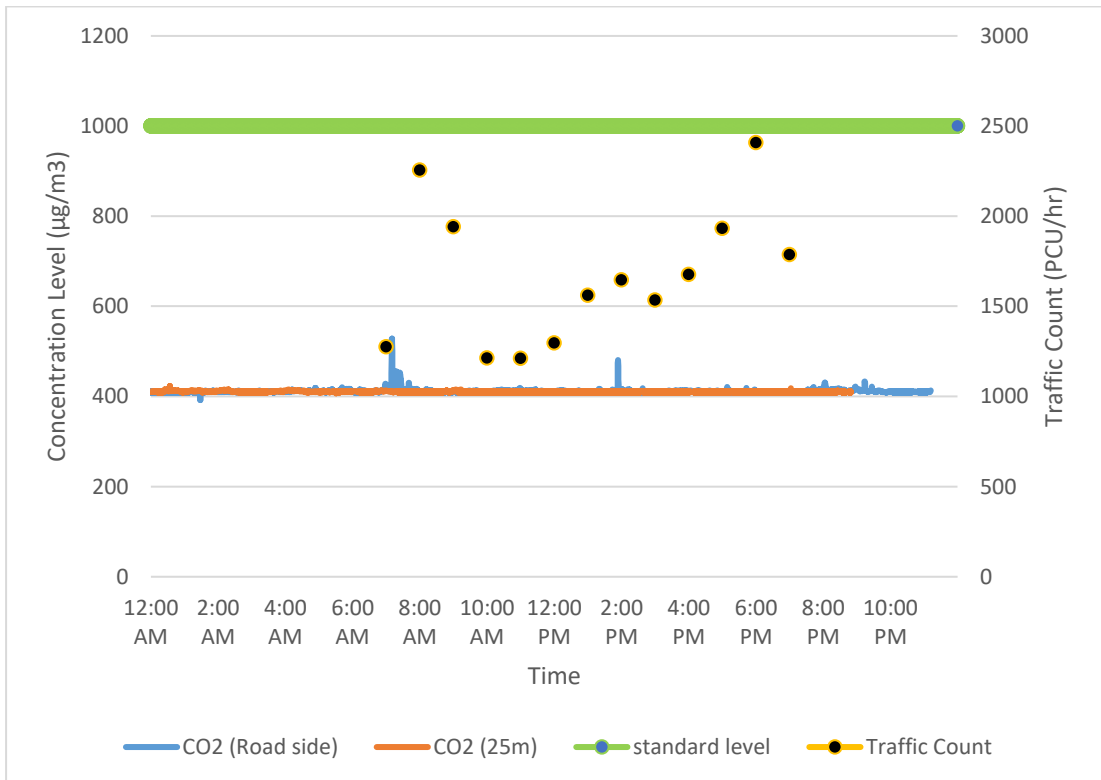


Figure 4-34: CO<sub>2</sub> Concentration at Kandawala Katunayake Road – Kadirana (Site-4)

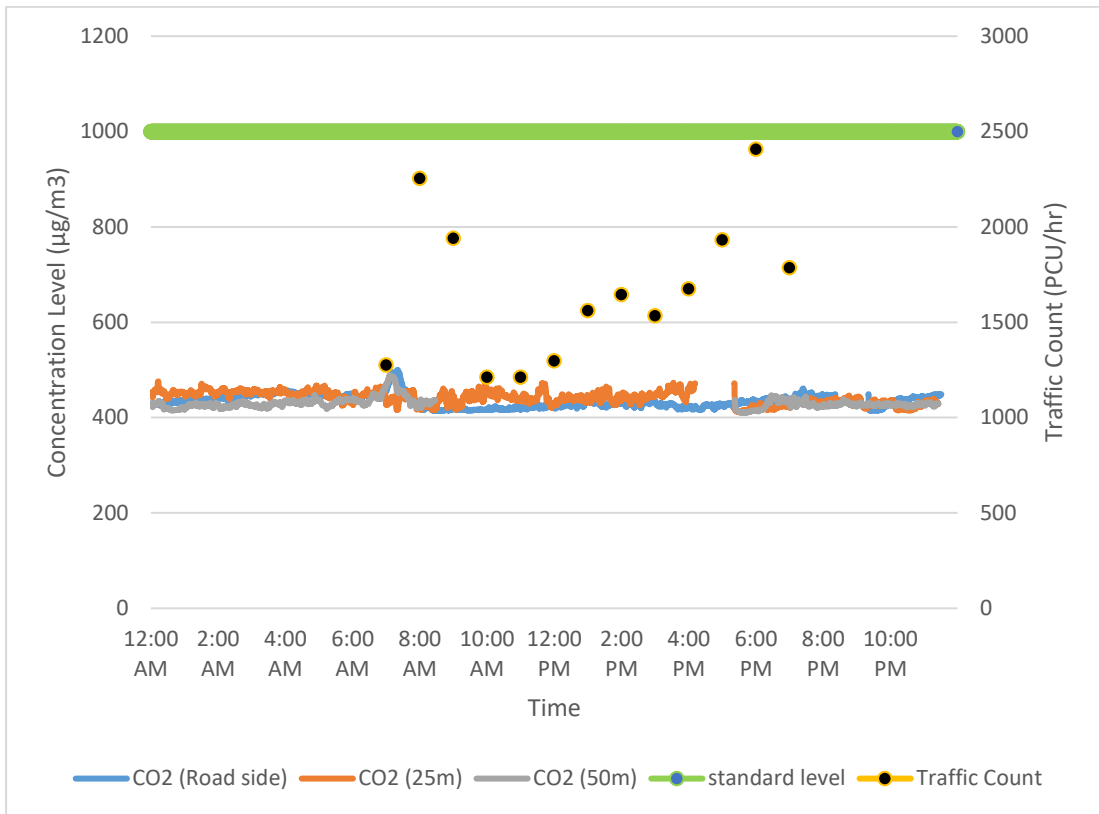


Figure 4-35: CO<sub>2</sub> Concentration at Katunayake Veyangoda Road - Minuwangoda (Site-5)

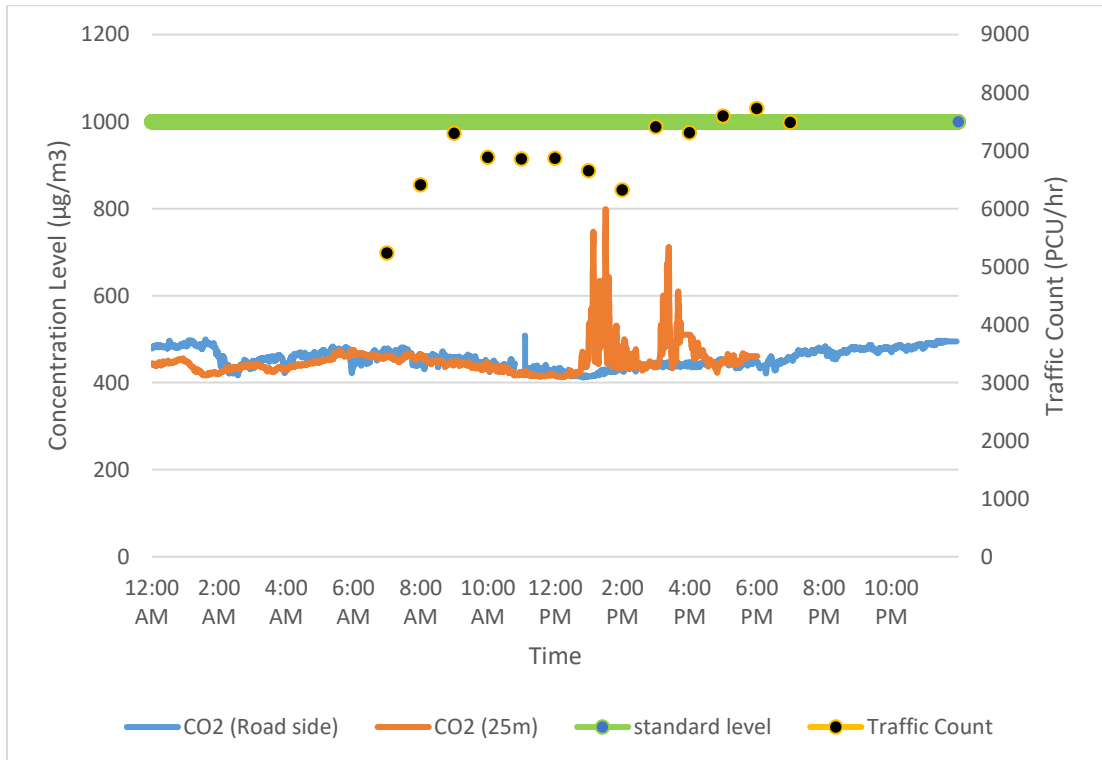


Figure 4-36: CO<sub>2</sub> Concentration at Colombo Kandy Road - Kadawatha (Site-6)

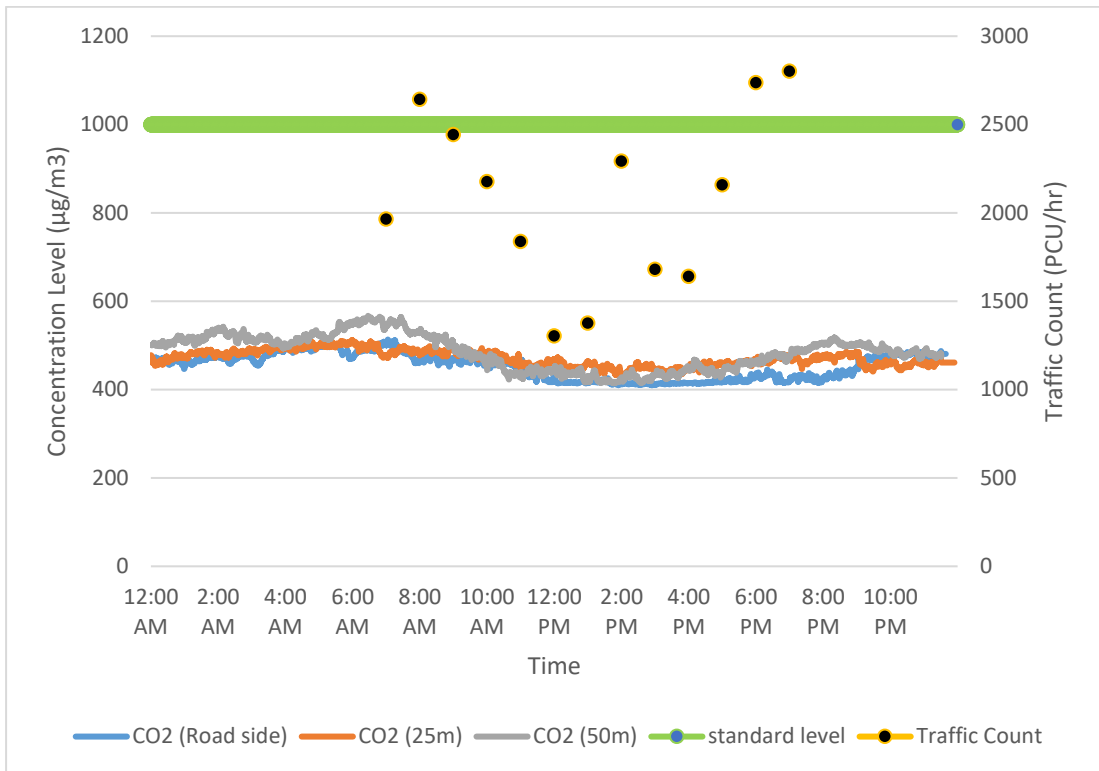


Figure 4-37: CO<sub>2</sub> Concentration at Katunayake Veyangoda Road – Veyangoda (Site-7)

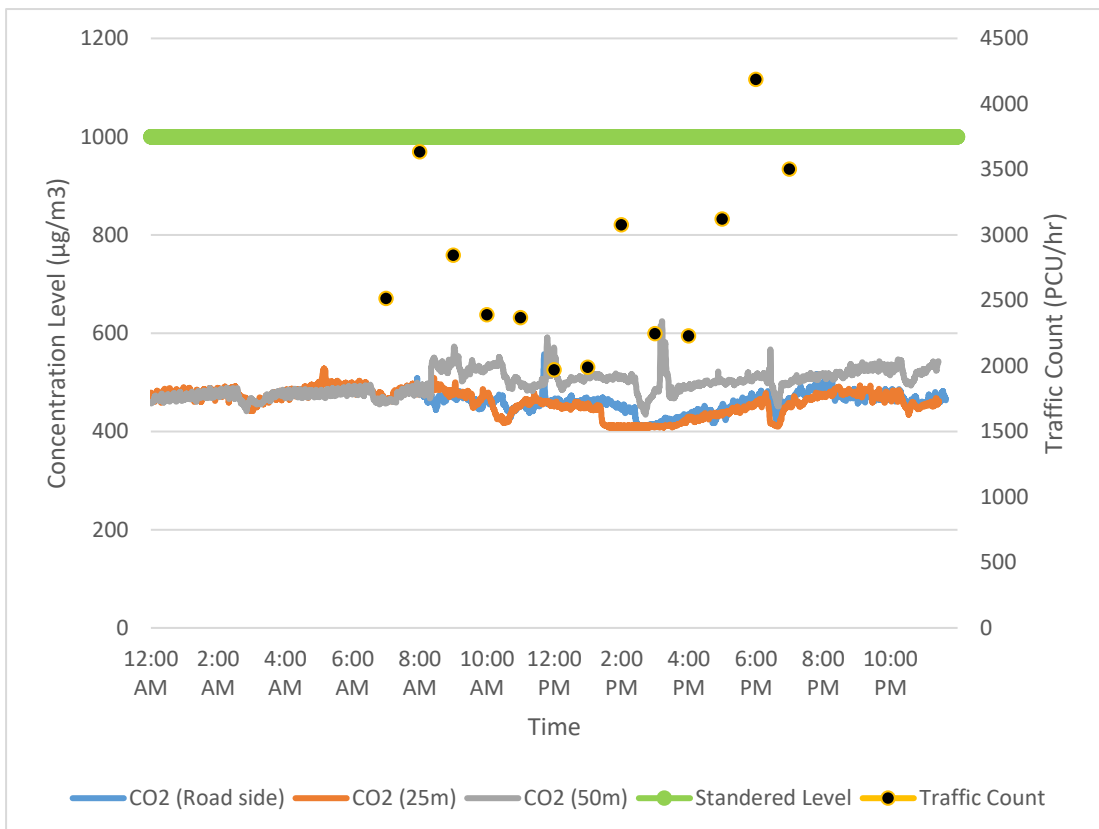


Figure 4-38: CO<sub>2</sub> Concentration at Ekala Kotadeniyawa Road – Ekala (Site-8)

## **Discussion in Detail on CO<sub>2</sub> Concentration:**

### **Ekala Kotadeniyawa Road (Site 1 and Site 8):**

PM<sub>2.5</sub> and CO<sub>2</sub> show similar peak patterns, further solidifying the hypothesis that vehicular traffic emissions are a dominant contributor to CO<sub>2</sub> levels. Site 1 sees sharper fluctuations, which might indicate vehicle idling during rush hours.

### **Colombo Kandy Road (Site 6 and Site 2):**

At Site 6, higher CO<sub>2</sub> levels during peak hours suggest higher traffic volume and congestion, with emissions primarily from cars and heavy trucks. The Site 2 site also shows elevated CO<sub>2</sub> levels, likely because of the high traffic and vehicular density.

### **Katunayake Veyangoda Road (Site 3, Site 5, and Site 7):**

The lower concentration of CO<sub>2</sub> across these locations shows lighter vehicular activities, further proving that CO<sub>2</sub> concentration is directly proportional to traffic volume. Site 3 and Site 1 are semi-rural areas with less vehicle emissions.

### **Baseline Road (Site 4):**

Moderate CO<sub>2</sub> peaks at certain times could suggest localized bursts in traffic or heavy vehicles or even just idling vehicles emitting disproportionate CO<sub>2</sub> during peak or traffic-jam times.

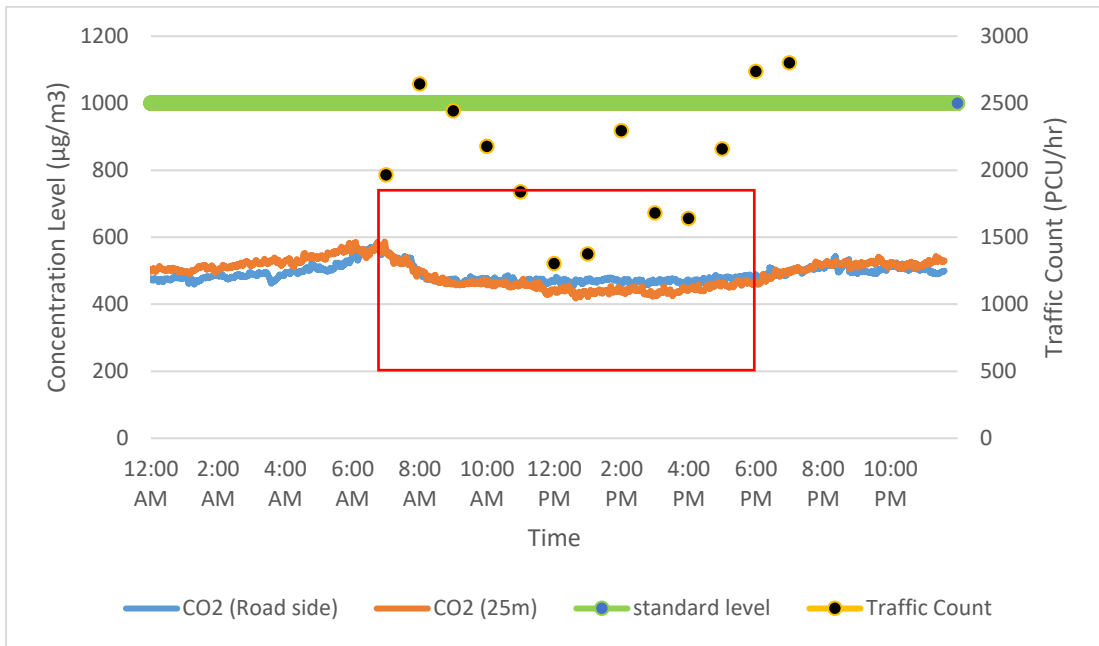


Figure 4-39: CO<sub>2</sub> Concentration at Ekala Kotadeniyawa Road – Nilpanagoda

In addition to the above observations, as clearly marked and illustrated in *Figure 4-39*. Site 1 (*Figure 4-31*), Site 2 (*Figure 4-32*) and Site 7 (*Figure 4-37*) show an unexpected CO<sub>2</sub> concentration reduction in morning peak time while the traffic counts are increasing. This effect could be due to many reasons including wind patterns, fluctuations in vehicular emissions as well as due to photosynthesis effect of nearby vegetation cover. Therefore, this is a good observation which should be carefully investigated in further detail.

#### 4.2.5 NO<sub>2</sub> Concentration Time Series plot with Traffic volume

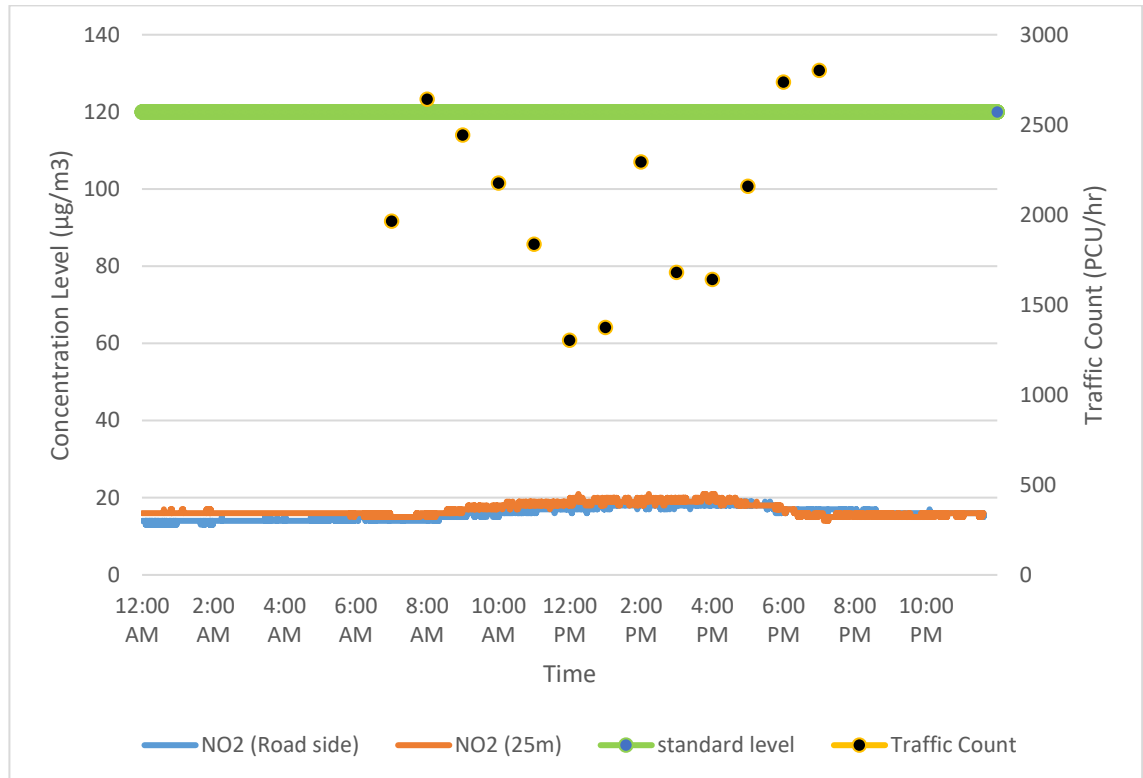


Figure 4-40: NO<sub>2</sub> Concentration at Ekala Kotadeniyawa Road – Nilpanagoda (Site-1)

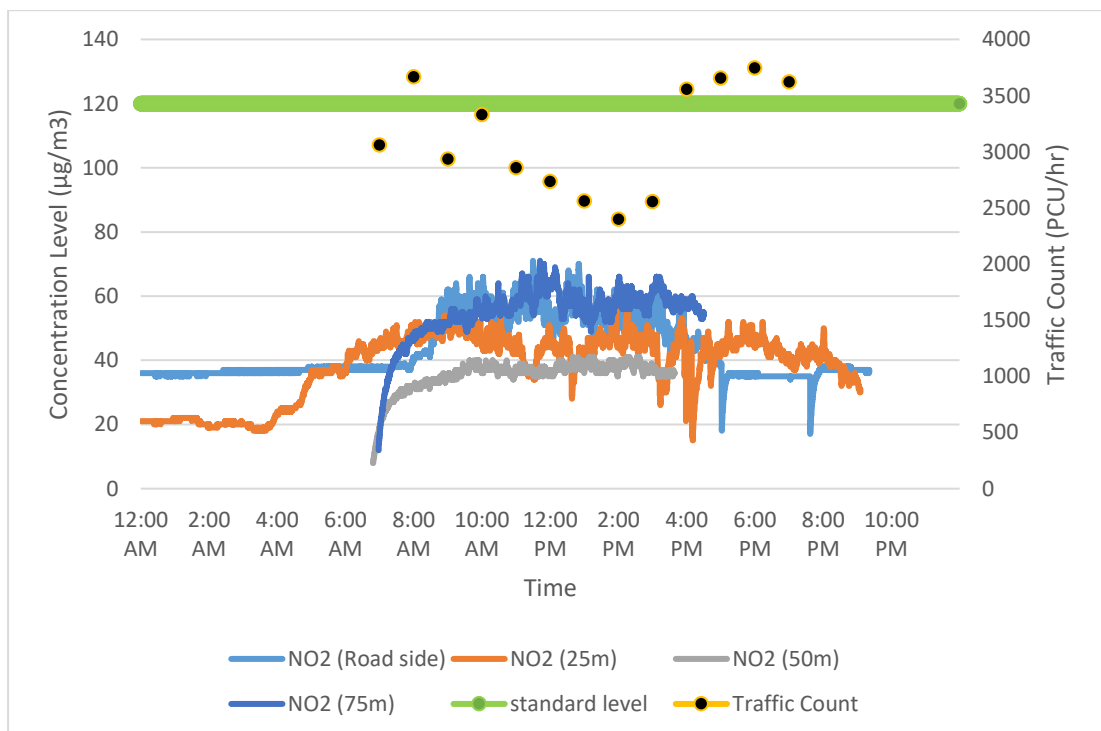


Figure 4-41: NO<sub>2</sub> Concentration at Colombo Kandy Road – Miriswatta (Site-2)

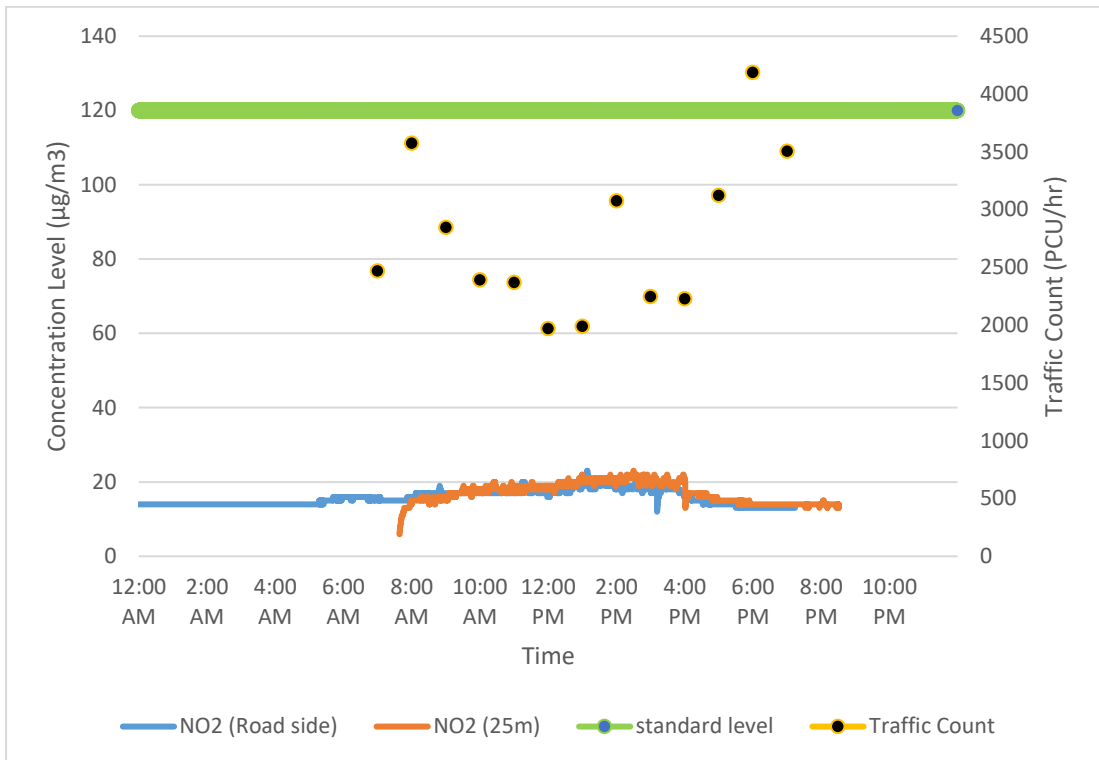


Figure 4-42: NO<sub>2</sub> Concentration at Katunayake Veyangoda Road- Yatiyana (Site-3)

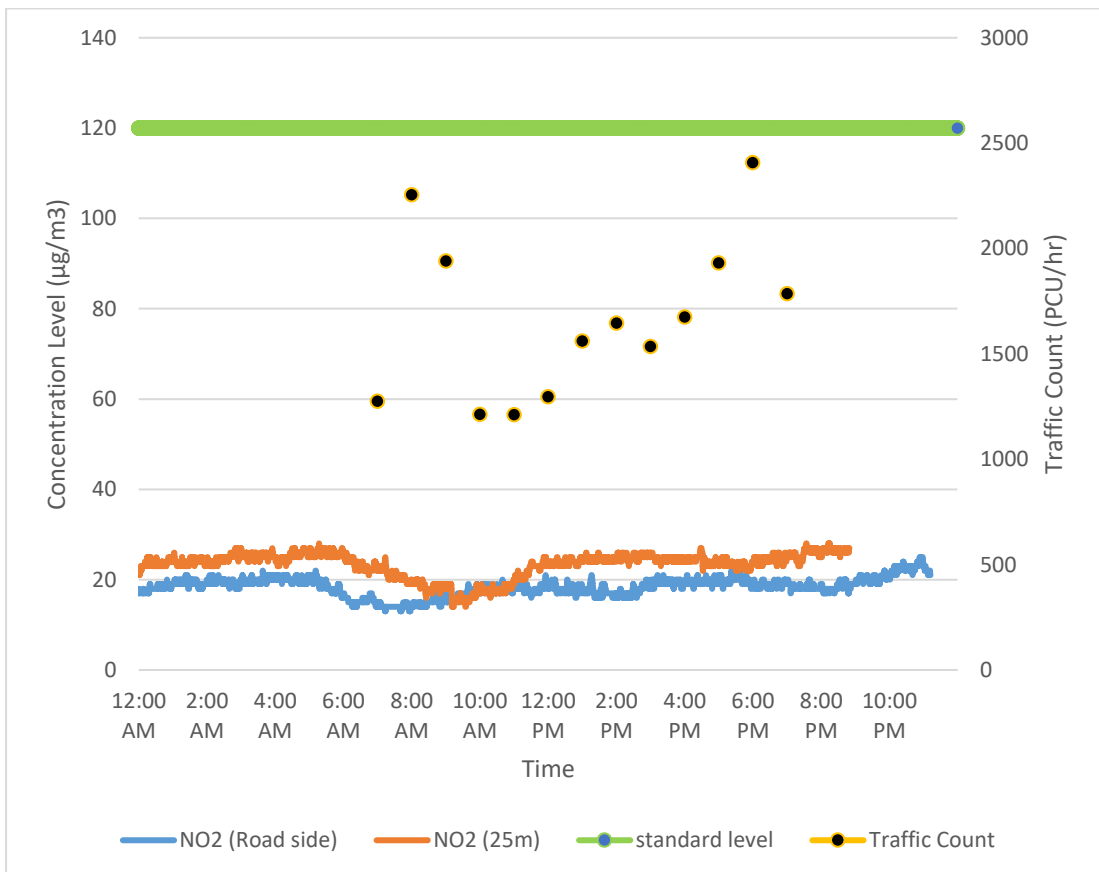


Figure 4-43: NO<sub>2</sub> Concentration at Kandawala Katunayake Road – Kadirana (Site-4)

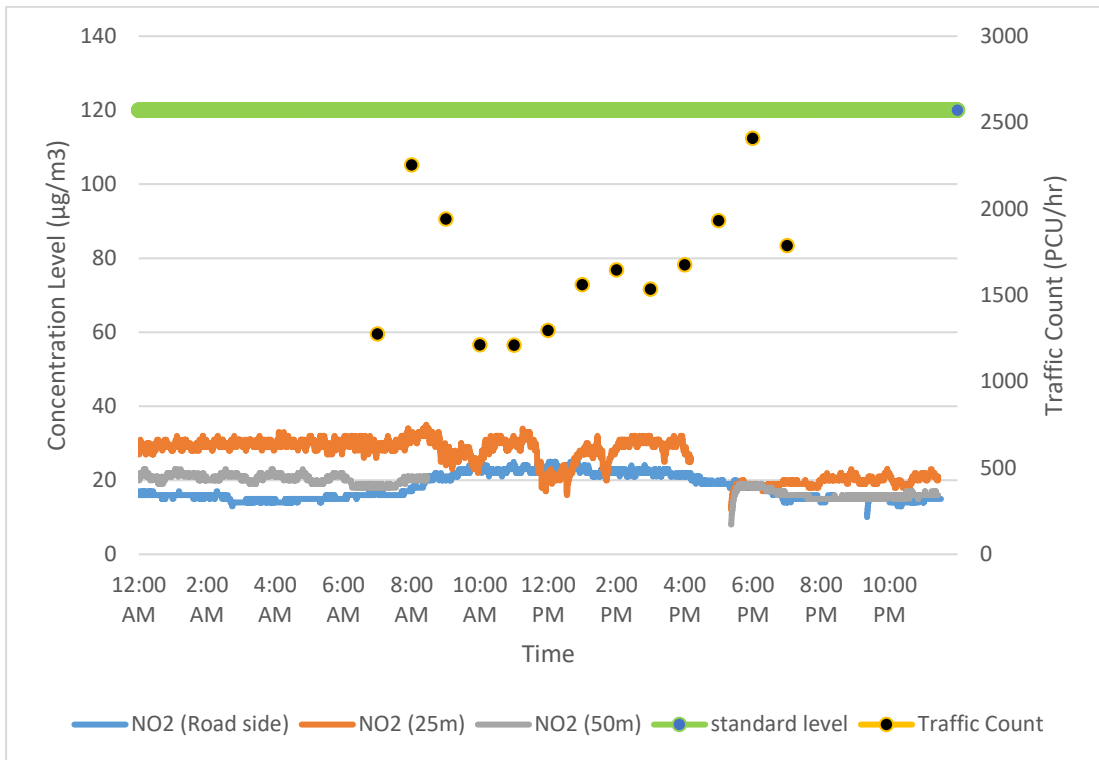


Figure 4-44: NO<sub>2</sub> Concentration at Katunayake Veyangoda Road- Minuwangoda (Site-5)

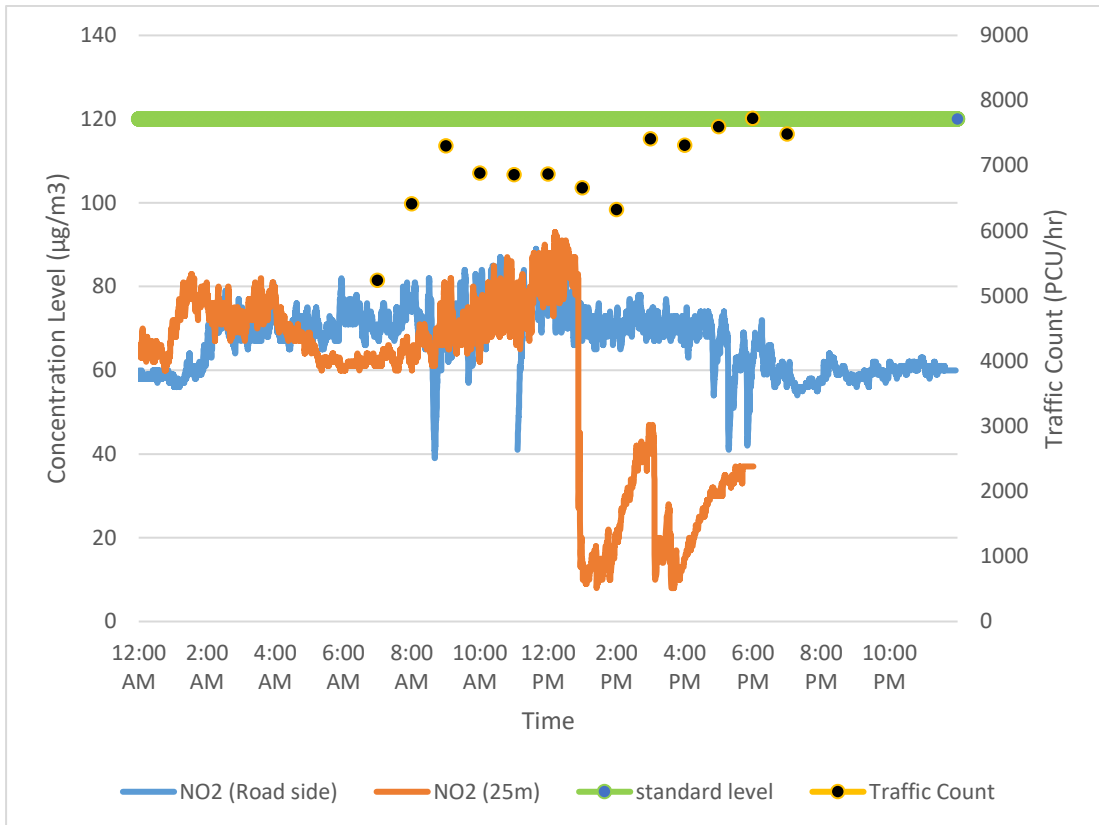


Figure 4-45: NO<sub>2</sub> Concentration at Colombo Kandy Road – Kadawatha (Site-6)

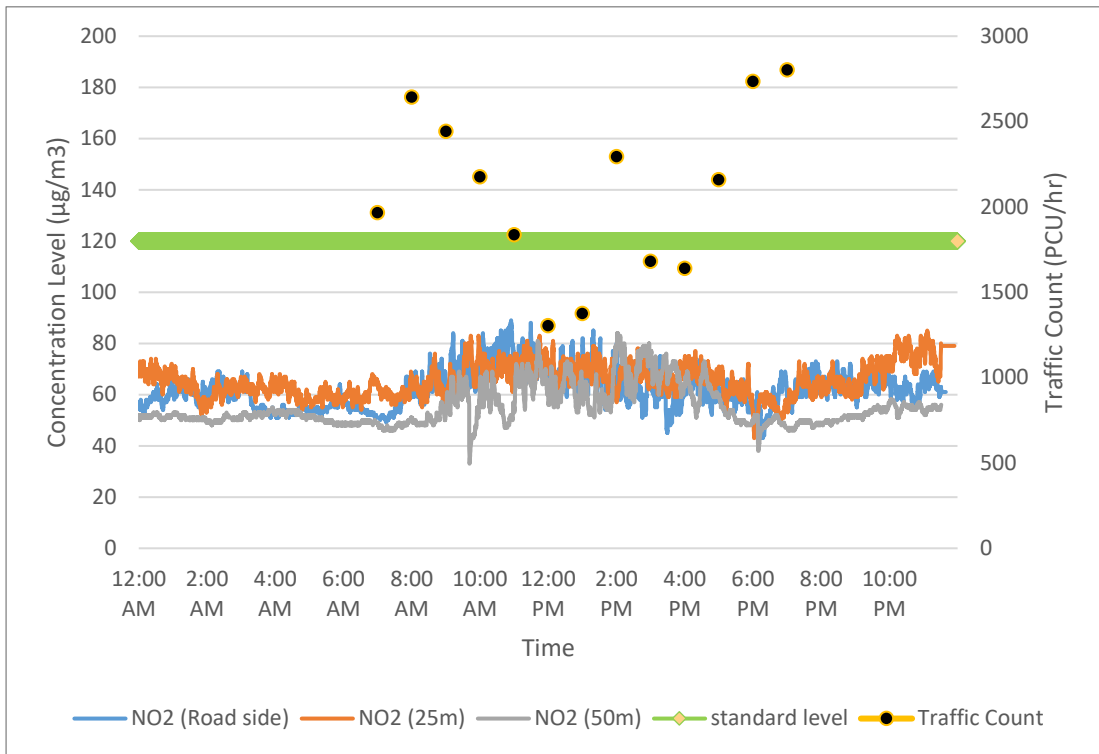


Figure 4-46- NO<sub>2</sub>: Concentration at Katunayake Veyangoda Road – Veyangoda (Site-7)

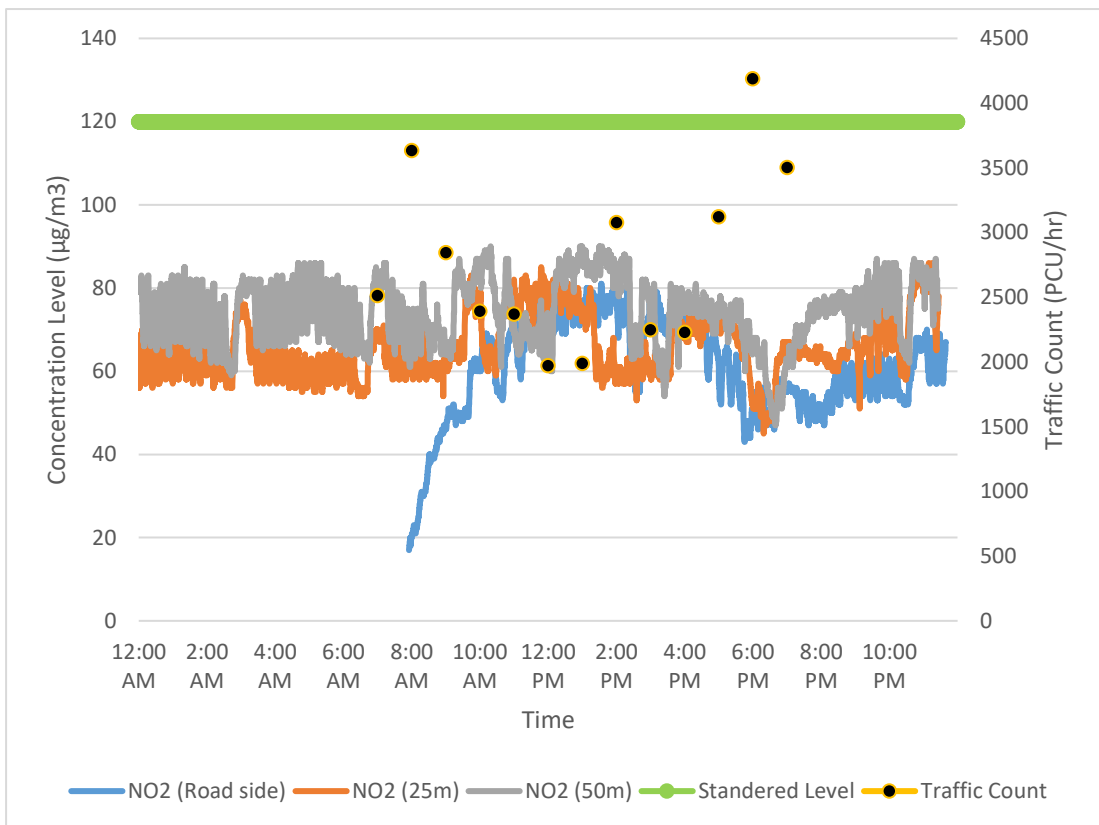


Figure 4-47: NO<sub>2</sub> Concentration at Ekala Kotadeniyawa Road – Ekala (Site-8)

## **NO<sub>2</sub> Concentration Detailed Discussion:**

### **Ekala Kotadeniyawa Road (Site 1 and Site 8):**

NO<sub>2</sub> peaks are directly related to vehicle emissions, specifically from diesel-powered vehicles that emit more NO<sub>2</sub> (EEA, 2019). Peaks appear when there is congestion, especially during rush hours.

### **Colombo Kandy Road (Site 6 and Site 2):**

NO<sub>2</sub> concentration at Site 6 is comparatively high due to the site being highly surrounded by vehicular emissions from trucks and buses. Peaks are showing a trend similar to the traffic flow, and it is prominent in the case of the rush-hour periods.

### **Katunayake Veyangoda Road (Site 3, Site 5, and Site 7):**

Site 3, despite showing overall low levels, may still experience periodic spikes in NO<sub>2</sub> due to local traffic emissions, though much less pronounced than in Site 6.

Site 7 remains relatively sited with much lower changes in NO<sub>2</sub> concentration.

### **Baseline Road (Site 4):**

NO<sub>2</sub> levels in Site 4, although lower compared to urban sites, also show sharp increases occasionally, which could similarly be explained by construction, industrial or vehicular emissions during rush hours or local pollution.

The collected data was then analyzed using liner regression considering distance from road and traffic in order to find out the correlation between pollution concentration levels changes with distance from the roadside as well as the correlation between pollutant concentration and traffic count

## **4.2.6 Results from Regression Analysis**

Regression analysis was conducted to quantify the variation of pollutant concentration with distance from the roadside to aid in the evaluation of dispersion patterns and factors affecting air quality variations. The summary of the results obtained from regression analysis is discussed here. The same analysis was carried out for each pollutant (PM<sub>2.5</sub>, PM<sub>10</sub>, CO<sub>2</sub> and NO<sub>2</sub>) separately. The summary of regression analysis was presented in

Table 4-3, Table 4-4, Table 4-5, and Table 4-6. Regression analysis results for 25m from roadside air quality data.

- **PM<sub>2.5</sub>**

Table 4-3: PM<sub>2.5</sub> Concentration Regression Analysis results

Statistic	Nilpanagoda (Site-1)	Miriswatta (Site-2)	Yatiyana (Site-3)	Kadirana (Site-4)	Minuwangoda Town (Site-5)	Kadawatha (Site-6)	Veyangoda (Site-7)	Ekala (Site -8)
R Square	0.24	0.01	0.00	0.05	0.01	0.12	0.00	0.15
F Statistics	2641.14	44.24	15.64	426.29	69.63	878.96	22.78	953.56
P-value	0	3.10E-11	7.78E-05	3.68E-92	8.27E-17	2.93E-181	1.86E-06	1.89E-193

The R-squared values for site 1, site 8, and site 6 are 23.7%, 14.6%, and 11.9%, respectively, showing the models have a medium explanatory power. The F-statistics at these locations show that the models are statistically significant. All locations record statistically significant p-values, with site 1 recording a p-value of 0.

- **PM<sub>10</sub>**

Table 4-4: PM<sub>10</sub> Concentration Regression Analysis results

Statistic	Nilpanagoda (Site-1)	Miriswatta (Site-2)	Yatiyana (Site-3)	Kadirana (Site-4)	Minuwangoda Town (Site-5)	Kadawatha (Site-6)	Veyangoda (Site-7)	Ekala (Site -8)
R Square	0.31	0.00	0.01	0.06	0.02	0.01	0.00	0.28
F Statistics	3795.29	8.44	28.74	448.07	155.90	66.12	20.93	2216.07
P-value	0	3.70E-03	8.72E-08	1.23E-96	1.83E-35	5.04E-16	4.85E-06	0

While site 8 and site 1 have relatively high explanatory power with R-squared values of 28.4% and 30.9%, respectively, site 6, site 3, site 7, and site 2 show a low value. The F-statistics are very high for site 8 and site 1, while the sites of locations 5 and 6 have a moderate significance. The p-values for all locations were below the significant level, but site 8 and site 1 showed stronger results.

- CO<sub>2</sub>

Table 4-5: CO<sub>2</sub> Concentration Regression Analysis results

Statistic	Nilpanagoda (Site-1)	Miriswatta (Site-2)	Yatiana (Site-3)	Kadirana (Site-4)	Minuwangoda Town (Site-5)	Kadawatha (Site-6)	Veyangoda (Site-7)	Ekala (Site -8)
R Square	0.62	0.06	0.06	0.00	0.00	0.01	0.79	0.53
F Statistics	14158.13	469.67	272.22	0.05	36.71	90.86	23748.36	6393.77
P-value	0	4.18E-101	2.71E-59	8.17E-01	1.43E-09	2.13E-21	0	0

Site 7, site 1, and site 8 have very high R-squared values: 79%, 62%, and 53%, respectively, showing an excellent predictive power. Other sites show lower R-square values. The very high F-values of the mentioned locations prove model significance in site 4, where the model is not significant. P-values for site 7, site 1, and site 8 are 0, proving strong statistical relations, whereas the p-value for site 4 is nonsignificant, at 0.8172.

- NO<sub>2</sub>

Table 4-6 – NO<sub>2</sub>: Concentration Regression Analysis results

Statistic	Nilpanagoda (Site-1)	Miriswatta (Site-2)	Yatiana (Site-3)	Kadirana (Site-4)	Minuwangoda Town (Site-5)	Kadawatha (Site-6)	Veyangoda (Site-7)	Ekala (Site -8)
R Square	0.49	0.21	0.64	0.21	0.02	0.00	0.26	0.13
F Statistics	8064.47	2059.02	7541.45	1957.97	164.03	10.80	2231.51	832.53
P-value	0	0	0	0	3.31E-37	1.00E-03	0	9.15E-171

Site 3 and site 1 have a high R-squared, which means that the model explains most of the variance. Site 2 and site 4 have a moderate value, while site 8 and site 6 have a rather weaker explanatory power. Very high F-values confirm the significance of the model at site 3 and site 1, while the model is also significant at site 2, site 4, and site 7. P-values of 0 for most locations, including site 3 and site 1, confirm highly significant relationships, while site 6 has slightly weaker significance.

## **Relationship between Pollutant concentration and Distance from Roadside**

### **R-Squared Values**

For PM<sub>2.5</sub>, the moderate explanatory power is seen in site 1 (23.7%), site 8 (14.6%), and site 6 (11.9%). In the case of PM<sub>10</sub>, site 1 (30.9%) and site 8 (28.4%) show the strongest R-squared values, respectively, while other sites have limited predictive power due to unmodelled factors. For CO<sub>2</sub>, site 7 (79%), site 1 (62%), and site 8 (53%) have high R-squared values, indicating strong predictability, while other locations lack sufficient explanatory power. NO<sub>2</sub> models show high R-squared values at site 3 and site 1, while moderate values at site 2 and site 4, and weak values at site 8 and site 6 reflect variability due to location-specific factors like topography and traffic intensity.

### **F-Statistics**

The F-statistics for PM<sub>2.5</sub> are significant in the case of site 1, site 8, and site 6. This affirms roadside concentration as a predictor. In the case of PM<sub>10</sub>, very high F-values at site 1 and site 8 indicate the reliability of these models. In addition, it shows moderate significance at site 5 and site 6. The exceptionally high F-values for CO<sub>2</sub> at site 7, site 1, and site 8 confirm that the relationships among predictors are strong, while site 4 remains an exception with insignificant values. Strong F-values across site 3, site 1, and other sites point to robust model reliability; weaker results are observed at site 6.

### **P-values**

For PM<sub>2.5</sub>, the p-values of all sites are very low; site 1 has a perfect zero (0), confirming statistically significant relationships at all locations. Similarly, the PM<sub>10</sub> models have low p-values across the board, with very strong results at site 1 and site 8, while other sites show slightly weaker significance. For CO<sub>2</sub>, p-values of zero (0) at site 7, site 1, and site 8 signify strong statistical correlations, while site 4's non-significant p-value indicates ineffectiveness. Correspondingly, NO<sub>2</sub> p-values are zero (0) at most sites, such as site 3 and site 1, which confirm strong relationships, whereas site 6 has marginally weaker significance.

Overall, the regression models show clear variations in predictive power and significance across the pollutants and sites. The best predictive ability is that of CO<sub>2</sub>, with its R-squared values running up to 79% in site 7, 62% in site 1, and 53% in site 8, hence showing strong correlations and good model reliability in such locations. Similarly, levels of PM<sub>10</sub> exhibit moderate to good predictability at site 8 at 28.4%, and site 1 at 30.9%, while other sites show very poor predictive powers. While PM<sub>2.5</sub> and NO<sub>2</sub> have a strong significance with low p-values and high F-values, there is considerable variation across sites, with key predictors in locations such as site 1 and site 3. The statistical reliability of the models is supported by the consistently low p-values for most pollutants, hence confirming meaningful relationships despite site-specific variability. On the contrary, site 4 underperformed noticeably in the case of CO<sub>2</sub> predictions, with a very low R-squared and a high p-value of 0.8172, which shows local complexities due to unmeasured influencing factors. Overall, the findings emphasize that pollutant behaviour in certain locations including site 1 and site 7, where roadside concentration levels can predict ambient pollutant levels effectively at various distances.

#### 4.2.6.1 Traffic and Roadside Concentration Levels

Regression analysis was conducted using Microsoft Excel 365, considering Traffic volume as the independent variable and consequently air quality concentration level at the roadside as the dependent variable. The same analysis was carried out for PM<sub>2.5</sub>, PM<sub>10</sub>, CO<sub>2</sub> and NO<sub>2</sub>. The summarized tables for regression analysis results are presented in bellow tables from Table 4-7, Table 4-8, Table 4-9, and Table 4-10.

- **PM<sub>2.5</sub>**

Table 4-7: PM<sub>2.5</sub> Concentration with traffic count Regression Analysis results

Statistic	Nilpanagoda (Site-1)	Miriswatta (Site-2)	Yatiyana (Site-3)	Kadirana (Site-4)	Minuwangoda Town (Site-5)	Kadawatha (Site-6)	Veyangoda (Site-7)	Ekala (Site -8)
R Square	0.02	0.02	0.28	0.12	0.04	0.41	0.00	0.00
F Statistics	110.06	117.04	1841.31	659.64	191.04	3492.81	14.74	2.86
P-value	1.74E-25	5.55E-27	0	8.13E-137	1.12E-42	0	1.20E-04	9.08E-02

- **PM<sub>10</sub>**

Table 4-8: PM<sub>10</sub> Concentration with traffic count Regression Analysis results

Statistic	Nilpanagoda (Site-1)	Miriswatta (Site-2)	Yatiyana (Site-3)	Kadirana (Site-4)	Minuwangoda Town (Site-5)	Kadawatha (Site-6)	Veyangoda (Site-7)	Ekala (Site -8)
R Square	0.03	0.00	0.30	0.09	0.04	0.42	0.00	0.00
F Statistics	136.24	21.71	2009.69	515.32	213.54	3668.99	12.17	0.02
P-value	4.44E-31	3.26E-06	0	1.06E-108	2.14E-47	0	5.00E-04	8.98E-01

- **CO<sub>2</sub>**

Table 4-9: CO<sub>2</sub> Concentration with traffic count Regression Analysis results

Statistic	Nilpanagoda (Site-1)	Miriswatta (Site-2)	Yatiyana (Site-3)	Kadirana (Site-4)	Minuwangoda Town (Site-5)	Kadawatha (Site-6)	Veyangoda (Site-7)	Ekala (Site -8)
R Square	0.02	0.11	0.39	0.12	0.03	0.04	0.00	0.07
F Statistics	110.06	617.45	3039.03	659.64	150.62	228.64	14.74	319.23
P-value	1.74E-25	1.13E-128	0	8.13E-137	3.88E-34	1.5E-50	1.20E-04	5.90E-69

- **NO<sub>2</sub>**

Table 4-10: NO<sub>2</sub> Concentration Regression Analysis results

Statistic	Nilpanagoda (Site-1)	Miriswatta (Site-2)	Yatiyana (Site-3)	Kadirana (Site-4)	Minuwangoda Town (Site-5)	Kadawatha (Site-6)	Veyangoda (Site-7)	Ekala (Site -8)
R Square	0.11	0.38	0.31	0.02	0.07	0.13	0.01	0.51
F Statistics	626.13	3065.26	2117.64	91.94	382.19	721.94	49.44	4562.58
P-value	2.36E-130	0	0	1.36E-21	4.28E-82	9.87E-149	2.31E-12	0

### R-squared Values

These R-squared values reflect the proportion of the variance in the dependent variable, pollutant concentrations explained by the model. For PM<sub>2.5</sub>, site-6 has the best relationship, with an R<sup>2</sup> value of 0.41, explaining about 41% of the variation in PM<sub>2.5</sub> due

to traffic count. Site-3 also has a fairly good relationship, with an  $R^2$  value of 0.28, while the rest, like site-8 and site-7, are weak.

For  $PM_{10}$ , Site-6, with  $R^2 = 0.42$ , has again the highest relation to traffic, followed by the value of 0.30 for Site-3. Other sites indicate relationships that are weaker; most specifically, site-1 at 0.07 and site-8 at 0.04 are significantly lower.

For  $CO_2$ , site-3 ( $R^2 = 0.39$ ) shows the highest correlation, indicating that traffic significantly affects  $CO_2$  levels. However, most other sites (e.g., site-6, site-1) show very weak relationships, suggesting other contributing factors to  $CO_2$  levels, especially at low  $R^2$  sites like site-6 ( $R^2 = 0.04$ ).

In  $NO_2$ , site-8 has the highest  $R^2$  of 0.51, which represents a very strong relationship between the traffic count and  $NO_2$  along the roadsides. The relationship for site-3 and site-2 is also fairly moderate to strong, having  $R^2$  values of 0.38 and 0.30, respectively. Sites like site-7 and site-1 fall in the category of having a weak relationship with  $R^2$  values of 0.05 and 0.10, respectively.

### **F-statistics**

The F-statistic helps to assess the significance of the regression model in general. For  $PM_{2.5}$ , the cities of site-6, site-3, and site-1 had high F-statistics, reflecting strong predictive models for those locations. Other sites, like site-8 and site-7, show low F-statistics, which can be regarded as weaker models.

For  $PM_{10}$ , as in the case of  $PM_{2.5}$ , site-6 and site-3 have high F-statistics, indicating a strong predictive relationship. Low F-values are found for sites like site-8 and site-7, supporting the relatively poor predictive capability of the models at these sites.

For  $CO_2$ , site-3 has a high F-statistic, indicating strong prediction accuracy, whereas sites such as site-6 and site-1 have very low F-statistics, showing limited predictive power.

For  $NO_2$ , site-8 shows a very high F-statistic further confirming that the strength of the regression model is very good. High values for F-statistics in site-3 and site-2 support the effectiveness of their models, while site-7 and site-1 have low F-statistics, indicating a weak predictive model.

## **P-values**

On the other hand, the p-values show the statistical significance of the independent variables in the models, which is the traffic count. In the case of PM<sub>2.5</sub>, site-6 and site-3 have a p-value of 0, indicating a very significant relation with the traffic count. All the other sites have p-values close to 0, while site 8 is the only site that shows a p-value of 0.06, slightly above the generally accepted significance level of 0.05.

For PM<sub>10</sub>, site-6 and site-3 both record p-values of 0, thereby reinforcing highly significant relationships. Other sites have significant p-values, save for site 8, which has a high value of 0.1, indicating that this model maintains marginal significance.

For CO<sub>2</sub>, most sites, except for site-1 (p = 0.07), have p-values significantly lower than 0.05, confirming strong statistical relationships between traffic count and CO<sub>2</sub> concentrations, with site-3 having the lowest p-value at 0.

For NO<sub>2</sub>, all sites exhibit p-values less than 0.05, indicating highly significant relationships between traffic count and roadside NO<sub>2</sub> levels. Notably, site-8, site-3, and site-2 have extremely low p-values, signifying very strong predictive relationships.

Overall, considering all the above factors, site-6 and site-3 show the most significant relationship between traffic count and pollutant concentration for predicting roadside pollutant concentration, due to their overall high R<sup>2</sup> values with strong F-statistics and significant p-values for all pollutants. In contrast, site-8 had strong relationships for NO<sub>2</sub> but was problematic in terms of PM<sub>2.5</sub> and PM<sub>10</sub>, with sometimes weaker models.

Generally, the trend of CO<sub>2</sub> concentration provides lower R<sup>2</sup> and F-statistic values, proving that this can also not be purely traffic-sourced, especially for sites like site-6 and site-1.

Indeed, most sites show highly significant NO<sub>2</sub> relationships, making NO<sub>2</sub> the pollutant where the relationship with traffic is strongest. The other sites, such as site-7 and site-1, however, had poorer predictive capability, particularly for PM<sub>2.5</sub> and PM<sub>10</sub>, where other environmental factors might be involved.

The above findings show that certain sites, like site-6 and site-3, are suitable only for traffic-related air quality prediction of certain pollutants like PM<sub>10</sub> and NO<sub>2</sub>. However,

regarding CO<sub>2</sub>, the inclusion of other variables is required to achieve better model accuracy.

As a concluding remark, the regression model for NO<sub>2</sub> and PM<sub>10</sub> pollutants exhibited strong relationships between the two variables. For instance, at site-6 and site-3, this is evidenced in the traffic counts that are able to significantly help explain pollutant concentrations, hence possibly serving as useful predictors of air quality levels. It should be quite accurate to predict air quality concentration levels at those sites for these kinds of pollutants, using traffic counts with high R<sup>2</sup> and significant F-statistics.

In contrast, the association for CO<sub>2</sub> is relatively weaker with traffic count, especially at site-6 and site-1. Since the R<sup>2</sup> and F-statistic values are low, it will not be wise to depend only on the traffic count for prediction purposes in case of CO<sub>2</sub> variations without taking into consideration other environmental variables affecting the levels of CO<sub>2</sub>.

### **4.3 Chapter Summary**

This chapter presents the findings of the secondary data set analysis and regression analyses conducted on air pollution concentration levels (PM<sub>2.5</sub>, PM<sub>10</sub>, CO<sub>2</sub>, and NO<sub>2</sub>) in relation to distance from the roadside and traffic counts across various urban locations. Results indicate significant correlations, with R-squared values showing varying degrees of explanatory power. PM<sub>2.5</sub> and PM<sub>10</sub> levels exhibit moderate to strong relationships and CO<sub>2</sub> levels show generally low predictability while NO<sub>2</sub> levels reveal strong relationships. Statistical significance is reinforced by low p-values, highlighting the impact of traffic on air quality.

## **5 CONCLUSIONS, RECOMMENDATIONS AND LIMITATIONS**

This study has provided a comprehensive analysis of air pollution concentrations, specifically focusing on PM<sub>2.5</sub>, PM<sub>10</sub>, CO<sub>2</sub>, and NO<sub>2</sub>, in relation to distance from the roadside and traffic volumes at various urban locations. The findings have significant implications for understanding the dynamics of air quality in urban environments and contribute to the broader discourse on public health and environmental management.

The Site-4 Kadirana shows some irregular spikes in concentration levels, especially in PM and CO<sub>2</sub>. When the surrounding area was investigated it was found that an ongoing apartment construction project is located close to the data collection location. Furthermore, the Colombo International Airport and Katunayake BOI zone are also located in close proximities (approximately 3km and 5km respectively). Therefore, those factors might have influenced the air quality concentration, which is beyond control and leads to poor correlations between traffic and air quality concentrations.

The observed CO<sub>2</sub> concentration level during the morning peak time may be due to the effect of photosynthesis and it was clearly observed at Nipanagoda -Site 1, Miriswatta - Site 2 and Veyangoda - Site 7. This should be carefully investigated since there is a lack of available literature in this area. Since Sri Lanka is a tropical island receiving rainfall throughout the year, the improvement of urban and suburban green areas would be a sustainable and economical way of controlling air quality improvements.

The Ekala location is located close to the industrial area, therefore the emissions from industrial activities as well as from heavy vehicles are more compared to other data collection sites.

### **5.1 Key insights from the study for Future Considerations**

#### **1. Site-Specific Traffic and Pollution Management**

Among the sites, PM<sub>2.5</sub> and PM<sub>10</sub> have a strong correlation of 0.41 and 0.42, respectively, with traffic at site 6 (Kadawatha). The above-mentioned high traffic volume in Kadawatha indicates that providing countermeasures for traffic in Kadawatha is particularly important. Encouraging more public transport in this area by means of providing an incentive for public transport users or any other means could reduce road traffic-related air pollution in the area. Congestion charging during peak hours in traffic

could help mitigate these high volumes of traffic. Switching to cleaner transport like electric and hybrid cars will help to reduce emissions, especially at high-traffic sites like Kadawatha. Furthermore, as incentives, toll-free parking spaces shall be provided to electric and hybrid vehicles while other vehicle tolls shall be increased.

Site-3-Yatiana: Yatiana is showing moderate values for the three kinds of pollutants: PM<sub>2.5</sub>, PM<sub>10</sub>, and CO<sub>2</sub> with R<sup>2</sup> 0.28, 0.30, and 0.39, respectively. Yatiana will similarly be subjected to similar solutions such as traffic management and green infrastructure that are used in Kadawatha. Since the traffic condition is relatively moderate, such measures would likely work even more efficiently.

## **2. Urban and Environmental Planning**

PM<sub>2.5</sub> and PM<sub>10</sub> (site 6 – (Kadawatha), Site 3 – (Yatiana), site 2 – (Miriswatta) and site 5 – (Minuwangoda Town): Since most of the sites already have weak relationships with PM<sub>2.5</sub> and PM<sub>10</sub>, urban planning can ensure the implementation of buffer zones around highly polluted areas such as Kadawatha, Miriswatta and Minuwangoda Town. In addition, green zones or trees with proper vegetation can be introduced to absorb fine particulate matter and improve overall air quality. More pedestrianized zones in urban locations with high correlations of PM levels, especially during peak hours, will further prevent exposure to traffic pollution.

CO<sub>2</sub> site 6 – (Kadawatha) and site 1 – (Nilpanagoda): In general, CO<sub>2</sub> variation at Kadawatha and Nilpanagoda sites shows a moderate to poor correlation with traffic flow, indicating that there is a relationship with traffic. Besides, an increase in urban greenery in these areas can absorb CO<sub>2</sub>, maintaining the natural balance of pollution levels.

## **3. Infrastructure and Public Awareness Programs**

Site-8 (Ekala): Ekala showed the highest relationship with NO<sub>2</sub>, having an R-squared value of 0.51, indicating that traffic is the main source of NO<sub>2</sub> pollution. NO<sub>2</sub> levels in Ekala could be considerably reduced by investing in public transit systems along with a reduction in heavy vehicle emissions. Public awareness for the use of vehicles emitting lower levels of nitrogen oxides and the use of cleaner fuels could reduce NO<sub>2</sub> pollution considerably. Policymakers shall implement euro 3 and euro 4 standards for fuel in order to reduce NO<sub>2</sub> emissions.

General Recommendations across All Sites: Public awareness about the harmful effects of NO<sub>2</sub>, CO<sub>2</sub>, PM<sub>2.5</sub>, and PM<sub>10</sub> will encourage people to take voluntary measures such as driving less avoiding peak hours or using sustainable modes of transportation such as public transportation. Expanding green roofs and introducing more trees into urban areas will improve air quality, especially in places like Kadawatha, Miriswatta and Yatiyana, which show significant relationships between pollution and traffic.

#### **4. Alternatives to Clean Transportation and Policies**

Integration of Electric and Hybrid Vehicles: Focusing on reducing CO<sub>2</sub> emissions by promoting electric vehicles and hybrid cars in cities like Kadawatha, Miriswatta and Minuwangoda, where traffic-related pollution is moderate to high, would directly impact the CO<sub>2</sub> concentration variations in these areas. Since this is the usual condition in all the urban areas same shall be promoted in the whole island in order to achieve overall reduced traffic-related emissions.

Encouragement of Non-Motorized Transport: In areas like Site-7 (Veyangoda), which shows a weak relationship among pollutants, reducing vehicular traffic may not be effective. However, introducing pedestrian lanes, cycling lanes, and electric scooters can alleviate traffic congestion and improve air quality in the long term.

#### **5. Advanced Emissions Control at High Pollution Sites**

Industrial Regulations: In areas such as Site -6 Kadawatha, Site -3 Yatiyana, and Site -4 Kadirana, where PM<sub>2.5</sub> and CO<sub>2</sub> show weak correlations with traffic, other sources of pollution, including industrial emissions, have to be considered. Stringent regulations on pollution control technologies may be laid down to reduce the level of industrial emissions.

Strengthening Vehicle Emissions: In areas with strong associations, such as Site-6 Kadawatha, Site-2 Miriswatta, and Site-8 Ekala, the implementation of strict emissions standards for trucks and buses would greatly cut NO<sub>2</sub> emissions and generally improve air quality.

#### **6. Technologies for Traffic Emission Reduction**

Adoption of Green Traffic Management Systems: In areas like Site-6 Kadawatha and Site-2 Miriswatta, where PM<sub>2.5</sub> and PM<sub>10</sub> show strong associations with traffic, intelligent

traffic systems could ease traffic flow and reduce times of idling, hence reducing emissions.

Promotion of Electric Vehicles and Hybrid Vehicles: Additional investment in electric public transport and cargo-carrying vehicles in high-pollution sites will help reduce PM and NO<sub>2</sub> emissions, especially in areas like Kadawatha, Miriswatta, and Ekala.

## **7. Expansion of Monitoring Programs**

Continuous Air Quality Monitoring: It is necessary to carry out continuous monitoring, especially for pollutants such as NO<sub>2</sub>, PM<sub>2.5</sub>, and PM<sub>10</sub>, in order to detect real-time pollution levels. In cities like Site-6 Kadawatha where high volume of vehicular traffic, and where the correlations with pollutants are high, real-time monitoring systems would be able to monitor the level of pollution and take timely action when levels fluctuate.

## **5.2 Lessons Learned and Study Limitations**

While this research study provides valuable insights into the relationship between air pollutant concentration levels with distance from the roadside, as well as air pollutant concentration with traffic volumes, several limitations must be acknowledged.

- The data collection of this research project was conducted in a limited number of urban and sub-urban locations in Gampaha District, Western province of Sri Lanka covering the national road network (A class roads and B class roads); which may not fully represent the variability of air quality issues in other regions or cities of the country. Air pollution dynamics may vary significantly based on local geography, industrial activities, land use patterns, development activities and traffic patterns.
- Constraints on the data due to the number of instruments accessible. With the use of one instrument, data could therefore be collected at one location per site at a time, restricted in the breadth of measurements that could be taken. For instance, this study considered only one side of the road for each site, thus preventing a thorough comparison of the levels of pollutants on opposite sides of the road. Moreover, due to restricted access to the data collection server, there were delays in data retrieval so that every data

collection point required 2 to 3 days for collection, further reducing the size of the dataset and the scope for intensive analysis.

- The data collection was carried out over a specific time frame for each location depending on the instrument installation location, safety of the instrument, and availability of power connection may not account for seasonal variations or fluctuations in traffic patterns. Further, Air quality can change significantly due to weather conditions, such as rain, humidity, and wind speed, which were not extensively considered in this research study.
- Another noticeable limitation was time constraints regarding data collection. The research was carried out in time constraints, and this constrained both the amount of data collected, and the extent of analysis performed. Because of the time-consuming nature of data collection, combined with constraints on availability of data collection instruments and server access, there was practically a limiting number of sites and measurements that could be worked in. This also reduced the possibility that data could be collected over a longer span to capture temporal variations in pollutant levels.
- Time constraints similarly affected methods of analysis by regression during the study. It was originally considered worthwhile to investigate multiple regression models or, indeed, possibly non-linear regressions in order to embrace the relationships of pollutants with influencing factors. However, due to time restrictions, analysis became limited to somewhat a simpler linear regression model, which was useful but perhaps has not been able to do justice to the full complexity of the factors affecting air quality.
- Traffic counts were collected using videography and were utilized as an independent variable. However, detailed information on vehicle types, ages of the vehicles, and emissions profiles was not collected. Different vehicle types may emit pollutants at varying rates, and without this detailed breakdown, the analysis may oversimplify the relationship between traffic and air quality parameter concentrations.

- In this study, other pollution sources, such as industrial emissions, construction activities, and local vegetation, which can impact air quality are not considered. The influence of these confounding factors could lead to an underestimation or overestimation of the relationships obtained through the analysis.

Despite these numerous limitations, the research offers a foundation for understanding the relationships between air pollutant concentration with distance from the roadside and air pollutant concentration with traffic counts. Future studies addressing these limitations could provide deeper insights and contribute to more effective air quality management strategies for future policy development addressing serious health issues and environmental issues arising due to bad air quality.

### **Suggestions for Future Research**

#### 1. Enhanced Data Collection

For studies in the future, a more comprehensive dataset could be produced using multiple instruments to collect data in more locations within each site, including both sides of the road. In addition, incorporating various environmental parameters such as wind speed, temperature, and traffic density into the data collection efforts would allow for an even better understanding of the factors affecting air quality.

#### 2. Longer Data Collection Period

Comprehensive data collection shall be conducted, to achieve greater chance of capturing seasonal fluctuations in the concentration of pollutants, which vary by air quality depending on the different weather and traffic conditions in each particular month/season of the year. Most importantly, long-term monitoring will support more convincing data as well as limit any potential bias related to short-term variations in air quality.

#### 3. Advanced Regression Models

In further studies, the application of multiple regression could be made to multiple independent variables at once. This will provide insight into how factors such as distance from the road, wind speed, traffic density, and temperature interact in determining the levels of pollutants. Also, non-linear regression or machine learning techniques may be considered, as they could describe very complex relationships between variables.

#### 4. Real-Time Monitoring

The inclusion of real-time monitoring system of pollutants and environmental parameters would ensure increased accuracy of data as well as the possibilities of dynamic data sets being collected. With this, better time resolution could be achieved by capturing fluctuating air quality at different times of day, weekdays, or weekends, monthly or seasonally in a year.

In conclusion, this study has established clear links between air pollution levels and both distance from the roadside and traffic counts across urban and sub-urban locations in the Western Province of Sri Lanka. The findings underscore the urgent need for targeted interventions to mitigate pollution exposure, highlighting the critical role of urban planning and policy in safeguarding public health. By leveraging these insights, cities can move towards cleaner air and healthier environments for their inhabitants.

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## 7 APPENDIX

### 7.1 Annex 1

#### 7.1.1 SO<sub>2</sub> data

Table 7-1-SO<sub>2</sub> data 2013

Location	2013											
	January	February	April	May	June	July	August	September	October	November	December	
MET	25	34	26	47	20	11	24	18	7	26	20	
Colombo MC	40	28	81	14	18	14	26	26	7	25	19	
Gangarama Temple	18	26	37	40	11	19	38	37	4	-	-	
Fort Railway	53	29	54	69	28	27	29	39	22	37	23	
Gunasinghepura	26	21	24	40	28	27	17	33	13	25	11	
Jethawanaramaya	22	29	50	58	16	17	17	23	21	41	12	
Maligakanda	33	30	35	42	21	14	14	37	18	31	-	
Kelaniya	26	27	38	50	11	10	41	24	20	16	22	
Borella Police	19	36	16	34	14	13	34	-	-	30	22	
Ward Place	10	35	40	42	13	14	23	19	23	22	17	
CEA	21	24	35	58	16	11	18	38	16	26	12	
Kotte	24	35	20	31	26	14	19	29	29	28	12	
Kirulapana	15	34	41	37	19	19	18	18	34	36	11	
Dehiwala Junction	25	16	26	49	23	21	23	29	40	29	-	
Nugegoda Town	29	39	56	62	36	28	18	24	38	32	13	
Malabe	18	41	2	19	26	25	19	24	40	38	14	
Peliyagoda	54	41	55	35	17	15	19	28	31	48	15	
Waththala	29	23	45	65	11	13	16	33	25	45	15	
Maradana Railway	61	45	48	73	37	26	24	45	30	38	24	
Kirindiwita	12	42	35	35	25	37	52	27	4	25	17	
Pahalagama	25	50	28	28	45	38	41	30	27	31	19	
Asgiriya	17	27	20	20	28	42	49	26	22	36	17	
Oruthota Road	32	40	25	25	39	42	50	41	16	39	22	
Oruthota	27	37	33	33	29	33	-	29	14	34	-	
Gampaha Railway	10	38	35	35	32	33	22	-	19	32	19	
Gampaha Police	29	53	34	34	31	17	15	34	24	24	12	
Vilabada Road	16	57	21	21	75	22	21	38	7	30	12	
Gampaha Hospital	55	23	38	38	48	19	12	25	14	44	12	
Miriswaththa	39	62	43	43	31	15	14	23	18	28	19	
Aluthgama	31	24	19	19	10	32	22	36	-	11	11	
Horana Town	27	35	22	22	30	29	23	31	27	7	48	
Rathnapura road	11	28	18	18	22	25	18	18	19	15	57	
Horana UC	23	53	15	15	20	22	30	21	26	17	27	
Sri Somananda Road	19	28	17	17	36	25	21	40	24	20	26	
Sri Devananda Road	32	72	18	18	50	20	21	35	16	26	26	
Kaluthara bodiya Car Park	35	46	45	45	68	79	24	16	11	34	45	
Palathota Junction	22	46	51	51	54	86	28	39	18	30	36	
Nagoda Junction	34	60	32	32	45	53	20	42	20	26	58	
Katukurunda Junction	13	32	30	30	35	52	20	13	14	40	58	
Kaluthara UC	31	20	72	72	77	65	28	25	14	20	42	

Table 7-2-SO<sub>2</sub> data 2014

Location	2014											
	January	February	March	April	May	June	July	August	September	October	November	December
MET	20	29	34	20	20	20	21	20	20	19	19	135
Colombo MC	29	26	28	21	21	26	26	20	19	19	18	50
Gangarama Temple	19	14	10	24	24	20	22	24	21	22	21	70
Fort Railway	43	33	39	15	15	36	38	37	33	33	30	240
Gunasinghepura	21	15	11	17	17	27	19	22	21	20	21	190
Jethawanaramaya	12	14	10	20	20	25	13	24	18	21	19	70
Maligakanda	20	0	5	21	21	29	18	22	17	19	20	45
Kelaniya	22	33	38	15	15	20	22	23	17	21	21	170
Borella Police	22	30	36	21	21	23	24	22	20	20	20	190
Ward Place	27	25	33	25	25	22	24	27	21	23	24	75
CEA	22	14	10	15	15	25	21	21	18	19	20	383
Kotte	12	15	11	20	20	15	20	22	19	19	20	154
Kirulapana	31	13	25	-	14	28	27	27	23	24	22	94
Dehiwala Junction	-	16	15	15	15	31	25	24	18	20	18	356
Nugegoda Town	23	19	18	16	16	43	23	23	17	18	18	84
Malabe	24	21	20	15	15	34	30	30	25	24	24	776
Peliyagoda	45	23	28	20	20	26	23	26	21	22	24	280
Waththala	35	19	23	24	24	21	22	24	21	22	23	380
Maradana Railway	44	37	45	35	15	26	25	27	24	23	23	942
Kirindiwita	17	27	36	21	26	30	33	35	28	29	30	130
Pahalagama	19	31	43	19	33	30	31	32	30	29	29	314
Asgiriya	17	27	38	22	28	34	29	44	28	30	29	90
Oruthota Road	22	37	48	18	28	34	31	38	32	31	30	95
Oruthota	-	20	29	-	29	27	28	35	27	27	26	155
Gampaha Railway	19	-	39	32	39	27	31	29	30	29	29	165
Gampaha Police	12	19	16	16	16	14	21	20	16	17	18	289
Vilabada Road	12	19	20	18	20	18	19	19	18	18	19	80
Gampaha Hospital	12	19	16	16	16	16	18	17	16	17	16	90
Miriswaththa	19	30	42	19	42	12	21	32	28	29	30	169
Aluthgama	14	16	18	16	18	26	28	35	17	19	20	205
Horana Town	45	41	39	38	28	35	31	32	30	29	30	25
Rathnapura road	49	31	33	37	27	26	24	21	21	20	22	36
Horana UC	32	20	28	27	27	23	22	24	20	22	24	53
Sri Somananda Road	32	28	33	30	26	41	35	24	25	26	28	147
Sri Devananda Road	24	15	24	25	26	27	25	27	26	27	27	72
Kaluthara bodiya Car Park	50	39	33	32	20	23	16	20	18	18	19	112
Palathota Junction	47	45	38	33	14	29	16	16	15	16	16	147
Nagoda Junction	66	64	47	41	18	18	10	15	15	17	18	289
Katukurunda Junction	65	67	52	45	22	18	21	24	22	23	23	94
Kaluthara UC	50	49	40	36	24	22	15	20	18	19	21	460

Table 7-3-SO<sub>2</sub> data 2015

Location	2015											
	January	February	March	April	May	June	July	August	September	October	November	December
MET	26	25	25	17	23	19	15	15	17	15	32	37
Colombo MC	50	45	34	18	15	14	11	10	11	12	14	16
Gangarama Temple	34	33	20	21	14	13	6	13	13	11	15	17
Fort Railway	42	39	40	35	25	24	19	17	25	22	43	50
Gunasinghepura	35	32	22	22	19	17	15	20	15	14	42	48
Jethawanaramaya	49	45	33	9	10	6	16	27	26	18	35	40
Maligakanda	35	32	25	27	27	26	15	21	24	20	21	24
Kelaniya	43	40	22	19	14	15	14	19	22	23	52	59
Borella Police	49	45	35	22	23	21	17	20	24	19	36	41
Ward Place	35	34	23	19	14	13	7	13	18	13	36	42
CEA	27	24	21	17	15	14	12	9	12	11	29	33
Kotte	21	19	19	13	15	15	11	11	13	13	29	34
Kirulapana	34	33	27	20	28	21	9	10	16	11	16	18
Dehiwala Junction	38	34	16	18	14	10	19	25	22	17	24	27
Nugegoda Town	43	36	49	25	18	15	22	13	19	15	36	41
Malabe	38	37	35	30	37	30	18	20	21	16	39	45
Peliyagoda	35	33	33	30	51	46	22	12	14	12	31	35
Waththala	46	45	37	33	35	35	20	33	37	29	42	48
Maradana Railway	50	46	58	44	34	31	26	30	26	25	52	60
Kirindiwita	20	16	12	11	9	9	8	9	18	10	17	19
Pahalagama	24	23	21	19	8	7	16	17	32	22	8	10
Asgiriya	14	14	13	11	18	17	9	14	26	11	17	19
Oruthota Road	36	35	34	26	11	11	18	11	22	18	35	40
Oruthota	27	26	23	23	14	13	14	12	22	15	22	26
Gampaha Railway	37	35	30	28	25	22	23	23	42	25	35	40
Gampaha Police	24	28	27	26	31	25	20	18	37	22	31	35
Vilabada Road	12	12	12	13	12	10	10	12	21	6	7	8
Gampaha Hospital	37	33	30	26	21	17	22	23	46	23	36	42
Miriswaththa	50	46	40	48	42	36	15	14	23	39	14	16
Aluthgama	19	17	14	13	12	10	7	34	25	11	55	63
Horana Town	52	47	34	31	34	33	29	24	26	13	62	71
Rathnapura road	41	37	28	25	22	18	18	13	19	12	40	46
Horana UC	16	14	11	14	10	9	6	8	8	6	16	18
Sri Somananda Road	21	18	10	12	12	11	14	8	10	6	25	29
Sri Devananda Road	12	12	7	7	6	5	4	4	6	3	38	44
Kaluthara bodiya Car Park	29	25	18	18	17	14	11	18	14	11	21	24
Palathota Junction	21	20	16	14	13	12	9	19	10	6	23	26
Nagoda Junction	23	18	18	16	28	25	8	16	13	7	22	26
Katukurunda Junction	44	41	31	28	24	21	17	34	24	14	38	44
Kaluthara UC	50	43	43	30	13	11	16	29	22	13	46	52

Table 7-4-SO<sub>2</sub> data 2016

Location	2016											
	January	February	March	April	May	June	July	August	September	October	November	December
MET	30	48	51	54	47	25	30	25	26	90	31	62
Colombo MC	45	38	56	45	43	45	49	50	54	72	32	46
Gangarama Temple	36	50	65	64	47	31	22	29	21	97	42	97
Fort Railway	67	82	72	69	70	34	25	35	40	88	65	61
Gunasinghepura	44	61	71	60	52	23	61	37	32	71	30	73
Jethawanaramaya	32	57	55	52	42	28	46	47	45	89	26	76
Maligakanda	27	32	59	45	64	20	44	30	29	67	35	52
Kelaniya	36	49	59	48	55	35	49	50	68	77	16	51
Borella Police	-	33	56	46	52	-	51	-	36	43	39	-
Ward Place	54	58	52	51	52	26	46	46	32	64	42	56
CEA	41	52	46	43	50	20	35	31	27	58	37	52
Kotte	-	49	36	43	43	43	40	35	25	75	45	64
Kirulapana	38	42	45	54	25	32	27	43	36	80	31	57
Dehiwala Junction	64	64	59	62	40	-	-	-	68	64	25	60
Nugegoda Town	48	51	41	38	43	47	46	43	59	80	27	58
Malabe	32	46	51	53	44	-	70	36	39	68	52	55
Peliyagoda	34	63	63	62	32	59	61	45	55	54	53	50
Watthala	35	79	62	68	32	-	55	50	55	89	49	72
Maradana Railway	87	86	84	74	52	61	69	81	79	57	42	-
Kirindiwita	53	62	61	65	65	38	24	28	27	58	43	53
Pahalagama	35	45	50	54	54	44	27	30	36	39	29	50
Asgiriya	67	62	63	63	39	57	44	22	37	42	32	60
Oruthota Road	48	47	41	45	38	-	24	19	43	27	21	46
Oruthota	19	25	25	31	31	39	59	30	23	30	22	29
Gampaha Railway	42	35	47	40	41	41	53	30	37	51	35	56
Gampaha Police	31	33	31	34	26	20	55	19	22	80	35	47
Vilabada Road	29	42	47	33	38	39	48	26	46	43	32	45
Gampaha Hospital	50	53	58	57	35	42	56	47	59	28	21	52
Miriswaththa	38	36	35	34	73	30	52	41	38	38	27	54
Aluthgama	49	56	55	65	62	49	63	50	77	29	24	46
Horana Town	22	32	49	36	35	24	55	54	47	51	62	56
Rathnapura road	47	46	57	51	53	22	63	61	52	39	29	56
Horana UC	57	40	49	54	52	49	73	74	55	46	45	55
Sri Somananda Road	18	43	51	38	34	34	45	53	56	22	49	58
Sri Devananda Road	21	39	37	40	35	35	40	63	50	31	49	61
Kaluthara bodiya Car Park	30	30	33	36	32	28	35	22	41	47	27	98
Palathota Junction	33	31	36	34	58	46	36	33	53	32	30	31
Nagoda Junction	40	41	40	44	43	28	36	36	29	42	29	32
Katukurunda Junction	57	39	54	59	41	40	63	36	42	49	30	47
Kaluthara UC	64	74	60	76	38	17	44	38	38	47	34	44

Table 7-5-SO<sub>2</sub> data 2017

Location	2017											
	January	February	March	April	May	June	July	August	September	October	November	December
MET	51	55	52	20	53	51	36	32	24	43	40	42
Colombo MC	68	67	62	47	-	48	49	54	51	-	52	49
Gangarama Temple	-	41	44	48	55	33	44	54	37	40	50	50
Fort Railway	72	78	78	73	67	60	71	54	56	53	67	70
Gunasinghepura	60	61	-	40	63	43	33	40	37	54	48	50
Jethawanaramaya	45	55	55	37	48	57	44	-	39	49	51	44
Maligakanda	51	53	44	41	48	49	44	43	35	43	37	38
Kelaniya	52	52	46	43	43	47	40	24	27	44	43	36
Borella Police	-	47	-	49	50	53	57	-	56	53	50	52
Ward Place	47	53	51	35	32	38	33	39	32	40	49	49
CEA	-	47	52	41	50	45	38	48	29	44	50	41
Kotte	-	35	41	54	52	40	37	46	33	46	56	40
Kirulapana	46	44	50	52	58	50	43	38	39	48	43	44
Dehiwala Junction	65	59	63	61	57	64	-	-	39	-	65	53
Nugegoda Town	64	67	64	54	56	46	48	40	43	49	64	51
Malabe	75	56	53	54	60	-	40	47	44	47	48	50
Peliyagoda	53	80	77	73	83	59	66	50	58	50	64	55
Watthala	65	75	76	62	93	-	76	62	50	53	56	60
Maradana Railway	62	91	90	62	84	53	68	61	55	65	64	69
Kirindiwita	40	50	49	40	42	53	64	29	34	36	32	42
Pahalagama	51	59	58	42	36	38	36	55	36	35	33	44
Asgiriya	49	44	42	29	37	38	22	31	30	41	35	49
Oruthota Road	63	53	51	45	58	-	51	58	35	45	45	47
Oruthota	60	57	56	35	45	32	31	46	29	39	49	57
Gampaha Railway	62	67	68	66	66	64	54	46	40	44	53	56
Gampaha Police	72	67	58	56	52	56	48	56	45	46	53	55
Vilabada Road	49	57	45	40	47	33	49	48	33	40	43	46
Gampaha Hospital	58	62	50	37	47	33	41	49	42	47	52	53
Miriswaththa	58	60	55	32	40	33	33	47	36	36	55	49
Aluthgama	77	71	71	69	71	66	68	75	62	65	69	68
Horana Town	45	40	39	45	47	35	50	19	39	47	33	49
Rathnapura road	61	34	46	56	57	46	31	36	41	39	27	47
Horana UC	68	51	42	-	50	47	37	43	-	44	48	52
Sri Somananda Road	51	32	39	56	46	36	32	39	34	41	46	51
Sri Devananda Road	35	32	38	38	26	29	25	27	19	26	28	26
Kaluthara bodiya Car Park	35	43	42	32	45	55	35	24	42	48	32	34
Palathota Junction	37	36	33	39	32	34	27	26	29	34	21	38
Nagoda Junction	47	41	38	35	-	36	24	23	26	44	23	39
Katukurunda Junction	49	44	43	43	35	31	39	23	19	27	26	45
Kaluthara UC	49	48	44	42	49	46	-	38	20	28	24	38

Table 7-6-SO<sub>2</sub> data 2018

Location	2018											
	January	February	March	April	May	June	July	August	September	October	November	December
MET	28	23	42	17	30	31	25	27	31	30	34	31
Colombo MC	46	43	NA	38	33	32	43	24	NA	NA	35	37
Gangarama Temple	18	14	20	29	41	39	36	29	32	33	32	57
Fort Railway	43	47	52	48	45	47	41	61	68	63	67	72
Gunasinghepura	44	40	51	42	43	42	26	24	31	34	24	41
Jethawanaramaya	32	41	47	41	48	45	47	37	39	NA	50	46
Maligakanda	17	12	28	21	35	36	37	34	30	23	26	31
Kelaniya	23	24	30	30	35	34	20	26	32	34	40	30
Borella Police	62	49	54	61	46	44	42	58	65	70	62	50
Ward Place	27	35	32	27	23	27	21	18	25	35	29	NA
CEA	26	39	40	31	29	27	25	16	24	31	40	37
Kotte	11	7	16	12	20	29	19	24	29	32	38	20
Kirulapana	32	42	40	46	30	29	19	20	24	20	20	47
Dehiwala Junction	50	48	51	39	33	37	24	34	40	37	47	44
Nugegoda Town	48	42	34	29	39	30	27	21	29	34	35	25
Malabe	82	51	47	38	53	35	36	32	47	41	52	56
Peliyagoda	NA	NA	64	51	52	49	41	40	46	55	63	53
Waththala	40	47	63	46	43	52	48	42	45	49	62	65
Maradana Railway	85	68	86	48	53	59	73	56	37	38	76	73
Kirindiwita	21	18	19	17	23	20	15	11	14	15	18	21
Pahalagama	31	27	29	34	21	17	20	22	25	28	31	37
Asgiriya	21	18	19	12	11	19	21	29	23	19	29	24
Oruthota Road	34	30	29	30	34	28	35	29	39	29	33	35
Oruthota	25	19	24	20	25	30	26	27	30	24	23	27
Gampaha Railway	52	58	27	29	36	41	37	33	25	21	23	20
Gampaha Police	NA	NA	24	26	31	NA	42	48	42	25	38	34
Vilabada Road	25	21	19	19	24	25	25	11	44	28	26	28
Gampaha Hospital	43	40	47	38	31	27	39	33	41	38	31	24
Miriswaththa	17	14	23	17	18	15	26	20	21	21	14	15
Aluthgama	62	66	51	43	50	61	38	44	42	44	48	52
Horana Town	22	28	53	39	24	24	35	24	29	26	19	28
Rathnapura road	27	32	NA	20	29	45	20	15	15	16	40	42
Horana UC	56	61	55	46	44	42	49	50	43	45	56	49
Sri Somananda Road	13	17	14	12	16	14	12	12	16	16	17	13
Sri Devananda Road	12	12	14	15	12	6	8	7	9	9	13	12
Kaluthara bodiya Car Park	36	29	30	22	23	32	29	21	36	26	41	35
Palathota Junction	27	22	31	19	32	18	18	24	21	23	30	37
Nagoda Junction	NA	NA	24	NA	27	19	18	18	20	32	24	28
Katukurunda Junction	49	39	NA	24	47	25	38	32	41	42	62	70
Kaluthara UC	63	50	53	NA	49	33	30	29	32	35	43	51

## 7.1.2 NO<sub>2</sub> data

Table 7-7-NO<sub>2</sub> data 2013

Location	2013											
	January	February	April	May	June	July	August	September	October	November	December	
MET	57	30	49	24	43	37	18	34	27	82	24	
Colombo MC	80	72	39	14	29	24	14	18	39	42	40	
Gangarama Temple	64	34	58	38	37	31	18	15	29	-	29	
Fort Railway Station	100	140	145	51	47	36	34	34	38	100	37	
Gunasinghepura	23	62	80	42	39	34	-	62	35	36	27	
Jethawanaramaya	80	85	115	10	58	48	49	39	41	73	15	
Maligakanda	21	38	96	34	37	29	41	28	42	29	-	
Kelaniya	50	59	45	24	27	23	22	25	36	38	25	
Borella Police	64	60	92	34	41	33	34	39	41	39	27	
Ward Place	55	57	30	14	16	14	11	17	21	28	29	
CEA	64	52	66	19	15	13	14	13	21	36	17	
Kotte	84	46	34	29	21	18	11	11	9	25	14	
Kirulapana	58	36	59	22	17	33	19	19	30	43	15	
Dehiwala Junction	89	95	50	29	21	29	-	62	7	21	20	
Nugegoda Town	118	75	52	27	25	23	20	19	-	63	11	
Malabe	118	88	109	32	46	44	52	31	42	62	13	
Peliyagoda	58	81	76	35	48	38	36	36	49	14	16	
Waththala	65	75	106	27	27	22	69	-	57	42	34	
Maradana Railway Station	83	154	101	64	45	51	82	96	52	87	44	
Kirindiwita	5	23	25	11	10	8	10	11	14	16	15	
Pahalagama	24	38	13	20	26	21	20	28	-	56	23	
Asgiriya	5	20	26	12	14	10	11	11	14	13	7	
Oruthota Road	49	42	24	13	34	30	27	42	41	41	20	
Oruthota	26	29	13	20	35	28	25	16	24	25	-	
Gampaha Railway	68	64	20	44	33	30	29	-	45	44	49	
Gampaha Police Station	41	48	44	25	23	23	24	27	35	30	33	
Vilabada Road	32	15	24	30	13	10	12	16	13	13	19	
Gampaha Hospital	53	19	11	31	32	27	27	32	41	39	45	
Miriswaththa	32	69	13	47	32	28	74	16	0	17	29	
Aluthgama	17	25	35	17	14	11	25	52	22	30	27	
Horana Town	57	30	41	41	43	35	42	37	69	40	44	
Rathnapura road	21	83	18	18	24	23	34	25	46	37	45	
Horana Urban Council	20	48	19	19	13	14	12	9	18	22	28	
Sri Somananda Road	24	30	18	18	15	11	14	16	30	19	16	
Sri Devananda Road	21	83	20	20	9	10	8	5	10	9	11	
Kaluthara bodiya Car Park	13	57	21	26	23	35	19	15	19	26	18	
Palathota Junction	33	28	23	17	16	33	15	15	16	24	16	
Nagoda Junction	20	55	14	17	18	41	14	31	18	20	20	
Katukurunda Junction	39	96	19	40	35	67	32	31	45	61	35	
Kaluthara UC	51	116	22	35	32	59	28	48	51	55	26	

Table 7-8-NO<sub>2</sub> data 2014

Location	2014											
	January	February	March	April	May	June	July	August	September	October	November	December
MET	28	49	64	37	44	38	41	31	14	26	28	28
Colombo MC	20	35	41	48	29	25	34	36	22	22	50	47
Gangarama Temple	18	34	41	61	37	32	34	-	30	22	34	37
Fort Railway Station	33	64	89	84	48	42	45	25	34	43	53	50
Gunasinghepura	33	65	84	49	40	35	41	64	33	24	25	33
Jethawanaramaya	29	53	70	70	59	51	59	46	28	57	37	35
Maligakanda	60	-	65	-	39	34	43	36	33	28	27	36
Kelaniya	30	55	75	35	28	24	28	-	32	43	33	30
Borella Police	33	63	85	61	42	36	41	43	33	34	33	34
Ward Place	19	35	41	47	16	14	31	22	20	24	23	38
CEA	13	29	32	26	15	13	21	42	-	23	27	26
Kotte	8	18	15	30	22	19	20	-	18	16	51	20
Kirulapana	30	58	80	-	16	14	22	27	24	27	55	41
Dehiwala Junction	70	50	92	47	22	19	33	-	-	34	43	44
Nugegoda Town	22	41	52	18	25	22	27	-	29	34	36	50
Malabe	26	47	61	47	48	41	42	34	33	33	33	53
Peliyagoda	33	59	82	54	49	42	46	40	37	39	33	77
Waththala	28	53	70	30	27	24	28	-	37	43	51	78
Maradana Railway Station	87	153	163	83	46	40	45	56	35	58	67	78
Kirindiwita	10	19	30	24	31	24	26	36	14	13	18	15
Pahalagama	25	47	80	34	-	15	28	49	33	32	28	24
Asgiriya	13	35	56	29	35	29	32	46	14	14	11	10
Oruthota Road	40	77	125	29	37	30	31	53	37	26	29	32
Oruthota	40	39	63	-	43	34	38	54	46	19	21	20
Gampaha Railway	19	35	64	38	46	39	39	60	46	-	-	37
Gampaha Police Station	27	50	84	22	-	31	41	51	28	28	32	24
Vilabada Road	18	38	64	74	82	60	62	81	14	12	13	8
Gampaha Hospital	30	57	92	35	39	30	35	92	33	37	31	29
Miriswaththa	19	35	83	38	40	30	39	111	55	56	65	64
Aluthgama	33	59	61	82	-	20	41	89	17	18	15	11
Horana Town	52	27	76	28	29	36	34	28	26	62	48	39
Rathnapura road	57	29	97	24	26	33	34	39	33	31	32	20
Horana Urban Council	30	15	59	32	32	17	25	60	12	11	17	17
Sri Somananda Road	21	11	34	39	28	13	21	52	-	13	19	13
Sri Devananda Road	23	17	24	37	27	29	31	49	-	9	7	11
Kaluthara bodiya Car Park	87	126	68	27	31	25	28	23	21	17	33	25
Palathota Junction	54	35	73	34	24	32	29	11	17	12	20	26
Nagoda Junction	75	88	47	34	29	17	25	17	18	15	41	16
Katukurunda Junction	51	64	35	41	27	23	25	22	30	33	21	40
Kaluthara UC	108	100	93	31	27	33	31	29	41	40	43	45

Table 7-9-NO<sub>2</sub> data 2015

Location	2015											
	January	February	March	April	May	June	July	August	September	October	November	December
MET	36	34	34	25	30	27	21	20	21	20	41	47
Colombo MC	70	65	48	28	21	19	13	15	13	17	17	19
Gangarama Temple	48	45	30	32	19	17	7	16	19	15	21	24
Fort Railway Station	58	54	57	47	36	32	27	23	36	31	62	71
Gunasinghepura	50	46	34	32	26	23	20	28	21	17	56	64
Jethawanaramaya	68	63	48	10	9	8	23	36	33	26	50	57
Maligakanda	49	46	34	39	39	35	25	30	34	27	32	36
Kelaniya	60	56	34	28	19	17	20	30	35	28	78	89
Borella Police	70	65	49	28	33	30	24	28	35	26	52	59
Ward Place	51	47	32	27	18	16	10	15	23	18	48	55
CEA	40	37	30	23	22	20	14	13	18	14	41	47
Kotte	30	28	26	17	21	19	19	14	18	14	38	44
Kirulapana	50	47	37	29	34	31	13	12	21	17	22	26
Dehiwala Junction	53	50	21	23	20	18	24	36	30	23	38	43
Nugegoda Town	58	54	69	35	24	21	31	19	26	21	51	58
Malabe	56	53	49	41	52	47	25	24	29	23	50	57
Peliyagoda	51	48	45	43	73	66	31	17	22	16	44	51
Waththala	65	60	52	45	48	43	25	45	52	41	50	57
Maradana Railway Station	71	67	82	59	49	44	37	43	38	33	75	86
Kirindiwita	24	22	16	14	12	11	8	12	24	13	21	25
Pahalagama	34	31	29	27	10	9	21	23	46	32	13	15
Asgiriya	17	16	17	15	25	22	12	20	39	14	20	23
Oruthota Road	53	49	46	36	15	13	25	15	31	26	54	62
Oruthota	38	36	28	31	20	18	18	18	35	19	34	39
Gampaha Railway	53	49	43	39	33	29	30	32	63	35	47	54
Gampaha Police Station	42	39	37	35	43	38	27	26	51	28	42	48
Vilabada Road	16	15	14	17	15	13	12	15	30	12	8	9
Gampaha Hospital	50	47	42	35	29	26	29	32	64	37	49	56
Miriswaththa	70	65	56	69	57	51	39	17	33	56	21	24
Aluthgama	25	23	19	18	15	14	12	49	38	18	79	90
Horana Town	75	70	51	43	51	45	38	33	35	20	22	25
Rathnapura road	59	55	40	38	29	26	27	19	28	17	32	37
Horana Urban Council	21	20	14	20	11	10	8	10	12	7	42	48
Sri Somananda Road	29	27	15	16	17	15	17	11	15	9	21	24
Sri Devananda Road	17	15	9	10	7	6	6	5	7	4	14	16
Kaluthara bodiya Car Park	41	38	24	23	23	21	17	26	19	12	35	40
Palathota Junction	30	28	23	20	19	17	12	24	14	9	33	37
Nagoda Junction	32	29	24	21	42	38	12	24	16	10	27	31
Katukurunda Junction	63	59	44	39	34	30	24	47	34	21	55	63
Kaluthara UC	69	64	61	45	18	16	22	42	30	19	66	75

Table 7-10-NO<sub>2</sub> data 2016

Location	2016											
	January	February	March	April	May	June	July	August	September	October	November	December
MET	29	17	28	19	27	19	18	16	29	24	43	29
Colombo MC	35	42	31	25	25	20	17	16	19	24	40	52
Gangarama Temple	36	24	24	20	30	15	14	15	14	18	39	50
Fort Railway Station	51	32	55	29	16	30	45	34	41	41	49	66
Gunasinghepura	29	50	48	34	40	31	28	26	35	32	45	45
Jethawanaramaya	38	44	50	37	24	41	34	30	40	45	40	48
Maligakanda	16	29	32	28	52	33	34	28	41	33	32	29
Kelaniya	36	58	54	33	45	37	43	35	35	45	52	43
Borella Police	-	46	44	34	43	-	53	35	38	40	42	-
Ward Place	31	35	27	23	22	16	15	13	16	22	45	60
CEA	30	33	31	21	25	15	18	14	19	21	35	31
Kotte	-	27	23	24	26	29	27	14	14	6	8	47
Kirulapana	40	29	28	22	28	32	18	16	19	23	42	13
Dehiwala Junction	20	13	54	32	35	-	-	-	43	52	42	48
Nugegoda Town	44	52	42	29	33	30	26	23	26	43	39	52
Malabe	48	36	49	34	35	35	32	29	29	40	43	59
Peliyagoda	39	37	37	24	29	32	34	33	28	38	-	59
Waththala	50	51	53	42	12	-	49	41	53	49	48	60
Maradana Railway Station	65	67	64	51	56	37	55	38	45	59	50	-
Kirindiwita	15	32	18	16	14	11	11	9	14	17	14	24
Pahalagama	41	33	45	33	-	22	31	27	34	38	27	42
Asgiriya	8	11	17	18	12	15	16	14	17	19	14	21
Oruthota Road	32	38	45	37	33	31	36	33	33	38	27	46
Oruthota	21	32	32	22	24	23	17	20	25	29	20	30
Gampaha Railway	32	21	40	38	46	36	37	33	40	40	29	38
Gampaha Police Station	20	30	42	33	32	46	32	23	21	16	12	29
Vilabada Road	18	14	17	16	18	14	15	22	35	18	13	27
Gampaha Hospital	33	71	43	31	22	30	34	23	40	41	29	34
Miriswaththa	15	29	22	18	25	29	55	22	57	54	36	58
Aluthgama	65	28	63	56	68	47	48	42	41	20	15	20
Horana Town	21	19	18	11	12	11	15	17	17	24	18	39
Rathnapura road	44	45	39	28	25	29	35	29	36	18	21	43
Horana Urban Council	54	49	56	55	52	29	48	33	52	39	30	30
Sri Somananda Road	17	20	19	15	16	14	15	12	22	19	19	53
Sri Devananda Road	13	11	11	8	12	10	13	11	22	12	27	58
Kaluthara bodiya Car Park	25	27	26	21	23	23	26	18	21	37	23	32
Palathota Junction	27	22	16	20	12	19	16	13	19	15	16	28
Nagoda Junction	27	26	20	17	16	17	17	13	16	18	12	27
Katukurunda Junction	25	51	41	32	30	35	29	21	28	38	23	42
Kaluthara UC	28	50	41	31	27	30	28	18	26	44	23	45

Table 7-11-NO<sub>2</sub> data 2017

Location	2017											
	January	February	March	April	May	June	July	August	September	October	November	December
MET	39	35	31	26	19	17	17	20	25	27	21	37
Colombo MC	50	43	33	21	28	16	17	14	19	-	19	46
Gangarama Temple	-	48	43	23	-	29	12	15	20	35	25	62
Fort Railway Station	78	-	73	71	61	72	36	39	43	67	61	62
Gunasinghepura	40	42	-	45	43	41	48	49	44	42	41	46
Jethawanaramaya	53	48	64	45	39	33	34	34	36	43	38	36
Maligakanda	26	33	43	38	47	30	32	31	33	25	24	20
Kelaniya	41	38	53	49	38	39	45	31	39	29	27	33
Borella Police	-	50	-	39	42	-	38	46	38	49	44	44
Ward Place	43	-	31	14	16	17	13	14	15	30	28	38
CEA	42	40	34	24	15	21	15	21	21	31	37	35
Kotte	40	46	37	23	11	11	14	12	15	12	15	20
Kirulapana	55	35	31	46	19	25	17	18	33	34	28	53
Dehiwala Junction	47	51	49	45	42	44	43	40	34	37	48	49
Nugegoda Town	60	45	39	30	45	26	21	27	26	35	40	45
Malabe	40	58	48	41	29	34	28	31	27	48	50	53
Peliyagoda	63	54	36	29	52	26	34	47	25	30	41	40
Watthala	78	70	53	43	39	-	31	44	47	63	57	57
Maradana Railway Station	76	86	65	59	56	46	63	60	62	76	83	88
Kirindiwita	34	26	19	17	14	14	11	12	13	16	19	27
Pahalagama	45	44	42	38	-	28	29	34	31	33	38	48
Asgiriya	20	23	14	17	9	17	16	-	27	12	15	-
Oruthota Road	48	49	31	29	37	33	13	37	31	39	39	40
Oruthota	40	46	47	48	27	32	27	25	20	23	27	37
Gampaha Railway	43	46	40	40	39	37	40	37	35	38	39	46
Gampaha Police Station	41	41	38	30	34	32	28	32	28	30	33	33
Vilabada Road	22	27	18	25	20	18	18	17	17	23	24	24
Gampaha Hospital	47	53	42	41	42	37	32	35	29	32	44	44
Miriswaththa	33	23	22	21	22	22	19	20	18	19	27	27
Aluthgama	61	69	67	54	69	57	55	50	50	59	44	48
Horana Town	64	59	56	45	37	43	39	41	41	46	54	67
Rathnapura road	30	31	39	37	33	30	32	31	24	26	22	21
Horana Urban Council	54	68	53	55	50	51	45	47	-	45	48	53
Sri Somananda Road	24	21	21	16	19	16	19	20	26	26	27	29
Sri Devananda Road	10	14	13	11	12	13	8	8	7	11	15	19
Kaluthara bodiya Car Park	41	30	31	26	17	26	27	23	20	30	31	31
Palathota Junction	33	32	26	23	19	18	18	19	15	21	30	37
Nagoda Junction	24	25	20	-	29	16	19	14	15	22	23	25
Katukurunda Junction	56	57	44	47	33	34	20	26	32	41	42	46
Kaluthara UC	52	56	51	45	33	37	-	-	21	41	46	56

Table 7-12-NO<sub>2</sub> data 2018

Location	2018											
	January	February	March	April	May	June	July	August	Septemb	October	Novembe	Decembe
MET	31	22	46	21	33	30	28	30	21	26	37	42
Colombo MC	64	44	NA	39	36	28	NA	26	NA	37	38	51
Gangarama Temple	21	15	14	34	45	36	38	34	23	33	41	69
Fort Railway Station	46	50	74	61	57	56	48	64	73	71	75	75
Gunasinghepura	44	42	56	48	23	32	30	28	34	42	46	47
Jethawanaramaya	35	44	52	47	52	45	48	42	48	NA	55	57
Maligakanda	12	8	37	29	40	40	52	46	33	26	34	36
Kelaniya	28	30	43	40	42	43	30	33	31	32	38	38
Borella Police	71	50	57	52	42	55	53	66	69	73	60	53
Ward Place	29	39	39	32	26	28	24	19	26	26	33	NA
CEA	37	40	42	30	32	26	27	17	20	23	36	43
Kotte	10	7	10	15	22	26	NA	22	33	33	47	25
Kirulapana	44	49	41	30	28	27	19	23	20	29	38	54
Dehiwala Junction	53	49	59	46	41	39	27	38	46	41	50	55
Nugegoda Town	50	41	45	34	36	30	28	26	30	36	43	43
Malabe	80	56	49	41	63	56	33	40	51	47	64	65
Peliyagoda	NA	NA	68	49	52	64	42	50	59	58	62	53
Waththala	40	48	67	51	47	60	50	48	47	57	69	70
Maradana Railway Station	88	61	72	54	59	56	57	61	73	59	75	80
Kirindiwita	19	17	20	19	31	20	12	20	16	16	24	25
Pahalagama	47	42	50	38	27	23	26	25	28	35	35	43
Asgiriya	17	15	21	20	20	15	21	17	24	18	17	15
Oruthota Road	56	51	51	43	36	30	37	31	35	30	30	37
Oruthota	36	32	35	33	29	30	24	24	32	29	30	31
Gampaha Railway	46	42	42	43	39	38	35	34	37	36	41	48
Gampaha Police Station	NA	NA	36	38	36	NA	35	31	39	38	38	33
Vilabada Road	15	13	21	15	19	15	18	15	19	17	13	14
Gampaha Hospital	42	38	54	46	33	28	41	36	44	46	12	14
Miriswaththa	18	17	26	23	22	17	44	18	23	22	17	17
Aluthgama	78	70	63	71	64	78	42	50	59	61	66	75
Horana Town	24	34	57	51	20	23	43	34	34	30	24	30
Rathnapura road	26	37	NA	21	33	40	21	21	16	17	56	59
Horana Urban Council	63	70	56	54	54	44	50	52	50	58	60	51
Sri Somananda Road	19	26	19	13	18	21	14	14	19	17	15	15
Sri Devananda Road	14	15	15	15	11	8	9	7	11	9	14	15
Kaluthara bodiya Car Park	26	27	17	20	17	25	21	20	20	23	36	32
Palathota Junction	21	16	29	16	28	16	14	29	30	22	28	28
Nagoda Junction	26	20	21	NA	15	16	16	16	18	21	10	20
Katukurunda Junction	34	26	NA	27	40	31	29	18	23	35	34	65
Kaluthara UC	31	23	39	34	40	34	33	30	39	24	25	45

## 7.2 Annex 2

### 7.2.1 Traffic Data

Table 7-13 – Traffic Volume data of Nilpanagoda (Site 1)

Nilpanagoda (Site 1)		
Time	Total PCU Kadawatha	Heavy Vehicle %
6:00- 7:00	1966	4.07%
7:00- 8:00	2643	4.59%
8:00- 9:00	2443	7.41%
9:00-10:00	2177	10.20%
10:00-11:00	1838	10.28%
11:00-12:00	1304	13.56%
12:00-13:00	1376	13.11%
13:00-14:00	2294	8.95%
14:00-15:00	1681	10.79%
15:00-16:00	1641	17.81%
16:00-17:00	2160	10.18%
17:00-18:00	2736	7.56%
18:00-19:00	2802	7.03%

Table 7-14 - Traffic Volume data of Miriswatta (Site 2)

Miriswatta (Site 2)		
Time	Total PCU Kadawatha	Heavy Vehicle %
6:00- 7:00	3061	7.70%
7:00- 8:00	3668	6.68%
8:00- 9:00	2935	7.11%
9:00-10:00	3332	7.45%
10:00-11:00	2857	10.01%
11:00-12:00	2734	9.69%
12:00-13:00	2560	10.81%
13:00-14:00	2398	8.31%
14:00-15:00	2555	12.38%
15:00-16:00	3556	12.78%
16:00-17:00	3656	10.55%
17:00-18:00	3746	7.56%
18:00-19:00	3623	5.55%

Table 7-15 - Traffic Volume data of Yatiyana (Site 3)

Yatiyana (Site 3)		
Time	Total PCU Kadawatha	Heavy Vehicle %
6:00- 7:00	2470	5.79%
7:00- 8:00	3574	6.08%
8:00- 9:00	2846	6.97%
9:00-10:00	2392	9.27%
10:00-11:00	2370	11.22%
11:00-12:00	1971	14.63%
12:00-13:00	1990	15.13%
13:00-14:00	3077	11.29%
14:00-15:00	2248	12.07%
15:00-16:00	2229	18.25%
16:00-17:00	3122	11.33%
17:00-18:00	4186	7.52%
18:00-19:00	3504	8.01%

Table 7-16 - Traffic Volume data of Kadirana (Site 4)

Kadirana (Site 4)		
Time	Total PCU Kadawatha	Heavy Vehicle %
6:00- 7:00	1276	6.19%
7:00- 8:00	2255	6.60%
8:00- 9:00	1941	5.93%
9:00-10:00	1213	9.67%
10:00-11:00	1212	10.28%
11:00-12:00	1297	10.89%
12:00-13:00	1562	9.11%
13:00-14:00	1646	8.22%
14:00-15:00	1535	9.37%
15:00-16:00	1676	11.04%
16:00-17:00	1932	9.64%
17:00-18:00	2407	6.11%
18:00-19:00	1787	6.66%

Table 7-17 - Traffic Volume data of Minuwangoda Town (Site 5)

Minuwangoda Town (Site 5)		
Time	Total PCU Kadawatha	Heavy Vehicle %
6:00- 7:00	2470	5.79%
7:00- 8:00	3574	6.08%
8:00- 9:00	2846	6.97%
9:00-10:00	2392	9.27%
10:00-11:00	2370	11.22%
11:00-12:00	1971	14.63%
12:00-13:00	1990	15.13%
13:00-14:00	3077	11.29%
14:00-15:00	2248	12.07%
15:00-16:00	2229	18.25%
16:00-17:00	3122	11.33%
17:00-18:00	4186	7.52%
18:00-19:00	3504	8.01%

Table 7-18 - Traffic Volume data of Kadawatha (Site 6)

Kadawatha (Site 6)		
Time	Total PCU	Heavy Vehicle %
6:00- 7:00	5239	8.10%
7:00- 8:00	6411	7.03%
8:00- 9:00	7302	7.48%
9:00-10:00	6885	7.84%
10:00-11:00	6862	10.54%
11:00-12:00	6869	10.20%
12:00-13:00	6657	11.38%
13:00-14:00	6324	8.75%
14:00-15:00	7412	13.03%
15:00-16:00	7313	13.45%
16:00-17:00	7598	11.10%
17:00-18:00	7724	7.96%
18:00-19:00	7486	5.84%

Table 7-19 - Traffic Volume data of Veyangoda (Site 7)

Veyangoda (Site 7)		
Time	Total PCU	Heavy Vehicle %
6:00- 7:00	1966	4.07%
7:00- 8:00	2643	4.59%
8:00- 9:00	2443	7.41%
9:00-10:00	2177	10.20%
10:00-11:00	1838	10.28%
11:00-12:00	1304	13.56%
12:00-13:00	1376	13.11%
13:00-14:00	2294	8.95%
14:00-15:00	1681	10.79%
15:00-16:00	1641	17.81%
16:00-17:00	2160	10.18%
17:00-18:00	2736	7.56%
18:00-19:00	2802	7.03%

Table 7-20 - Traffic Volume data of Ekala (Site 8)

Ekala (Site 8)		
Time	Total PCU	Heavy Vehicle %
6:00- 7:00	2515	6.19%
7:00- 8:00	3635	6.42%
8:00- 9:00	2846	6.97%
9:00-10:00	2392	9.27%
10:00-11:00	2370	11.22%
11:00-12:00	1971	14.63%
12:00-13:00	1990	15.13%
13:00-14:00	3077	11.29%
14:00-15:00	2248	12.07%
15:00-16:00	2229	18.25%
16:00-17:00	3122	11.33%
17:00-18:00	4186	7.52%
18:00-19:00	3504	8.01%