

1. PROJECT:

Study of Ambient Air Quality in Main Urban Cities in Sri Lanka by using Passive Sampling Air Quality Monitoring Technique

2. BACKGROUND:

Urbanization and increment of traffic flow has deteriorated the quality of air in urban areas in Sri Lanka. Colombo, the commercial capital of Sri Lanka is a foremost victim of the deteriorated air quality. Many researches were conducted and several actions are being taken to control air pollution in urban area in Sri Lanka. The first attempt was taken by “clean air 2000 action plan”, which is proposed several actions to manage ambient air pollution in Sri Lanka and the action plans were renewed time to time. Since the major source of air pollution is vehicular emissions most of the actions recommended were related to control vehicular emission and improve fuel quality. Reduction of sulfur content in diesel and introduction of unleaded petrol were the actions, which was taken in order to improve the fuel quality. Other than that, actions taken in order to control vehicular emission were Vehicular Emission Testing (VET) program, development of road surface and removing road obstructions. Also, introducing cleaner fuel vehicles such as hybrid and electric vehicles to the fleet has also contributed to control air emissions.

Presently, Vehicular Emission Testing program is the major on-going activity in air quality management in Sri Lanka. As one of the activity identified under the VET program is Air Quality Monitoring in urban areas. This program is used to assess the existing levels and analyze air pollution trends and its’ variation and to evaluate the effectiveness of the management activities related to ambient air pollution. The Air Quality Status Monitoring Program under the VET program was started in 2012 at major cities Colombo, Gampaha, Horana, Kaluthara, Rathnapura and Galle in Sri Lanka by using passive sampling air quality monitoring techniques. Then after the program were expanded including other cities such as Kandy, Kurunegala and Anuradhapura.

The continuous air quality monitoring data clearly indicated that above actions have positively contributed to improve ambient air quality in urban areas especially in Colombo. Some findings of the monitoring program show that the SO₂ level in Colombo urban area was also decreased by 7% in 2001 and 15% in 2003 respectively due to the fuel quality improvement by reducing sulfur content in diesel. Also, the ambient SO₂ and particulate matter (PM) levels in ambient air were decreased about 10% – 20% with the implementation of VET program. Significant decrease of air pollutants about 30% - 40% in Colombo was observed from 2009 to 2012 as a result of improvement of road surface, removal of road obstructions and VET program. Also, the results indicate that, introducing of hybrid vehicles has contributed significantly to reduce NO₂ level in ambient air in urban areas. Therefore, the actions taken to manage air pollution at urban areas in Sri Lanka has positively affected to improvement of air quality in urban areas. However, the recent results indicate that increasing trend patterns of air quality in most of urban areas probably to increased vehicle density in urbanized cities and the exposure levels in high traffic areas of each city are comparatively higher than that of surrounding areas.

The ambient air quality monitoring program was therefore continuing from 2012 to 2016 and a monitoring network with 78 sampling points and data base on ambient air quality at above 9 selected major urban areas were developed while studying pollution trends, spatial variations and identifying factors affecting on air quality in each urban area.

3. PROJECT OBJECTIVES OF 2017 PROGRAM

The objective of the 2017 program is to obtain continuous ambient air quality database at above selected major urban areas where the monitoring program has been already implemented monitoring network while further extended with 10 more locations in Puttalam area in 2017 while incorporating PM_{2.5} particulate sampling. The monitoring program was therefore continued in 2017 as well by monitoring ambient Sulfur Dioxide (SO₂) and Nitrogen Dioxide (NO₂) levels on monthly average and PM_{2.5} levels in 24-hour average. It was allocated about Rs. 11,528,000.00 to National Building Research Organization (NBRO) by VET fund to continue the above monitoring program within the year 2017. Out of Rs. 11,528,000.00, about Rs. 4,934,990.00 were used to purchase PM_{2.5} instruments with accessories and the balance was used for the air quality sampling program. Summary of the total budget is given in annexure 1 and project outcome was presented in this report.

4. STUDY METHODOLOGY

4.1 Selection of Sampling Locations

In the year 2017, air quality monitoring was continued at the same monitoring locations selected in urban areas of Colombo, Gampaha, Horana, Kaluthara, Rathnapura, Galle, Kandy, Kurunegala and Anuradhapura. The number of sampling locations in each urban area is given in table 4.1.1 and details of selected sampling locations are presented in relevant sections and maps.

Table 4.1.1: Number of Ambient Air Quality Monitoring Locations in each Urban Area

Urban Area	Number of Sampling Locations						
	2012	2013	2014	2015	2016	2017	
	SO ₂ /NO ₂	SO ₂ /NO ₂	SO ₂ /NO ₂	SO ₂ /NO ₂	SO ₂ /NO ₂	SO ₂ /NO ₂	PM _{2.5}
Colombo	19	19	19	19	19	19	3
Gampaha	11	11	11	11	11	11	2
Kalutara	5	5	5	5	5	5	1
Horana	5	5	5	5	5	5	1
Rathnepura	8	8	8	8	8	8	1
Galle	6	6	6	6	6	6	1
Kandy			10	13	13	13	3
Kurunegala				6	6	6	2
Anuradhapura				5	5	6	1
Puttalam						10	2
	54	54	64	77	78	89	17

4.2 Sampling

The low cost and user-friendly passive sampling technique was used for the collection of monthly average exposure level of Sulfur Dioxide (SO₂) and Nitrogen Dioxide (NO₂). At each selected location, passive sampling apparatus was installed in an open area with the minimum distance of 3 m from the structure and at 3 m height from the ground level. Passive samplers were installed at selected sampling points in 1st week of every month and exposed to the environment for a period of one month.

PM_{2.5} samples were collected by Active Sampling Techniques using “INSTRUMEX” PM_{2.5} air sampler in according to the particulate matter (PM_{2.5}) speciation guidance USEPA as stipulated by the National Ambient Air Quality regulations gazette No. 1562/22- August 15th 2008 stipulated by Ministry of Environment and Natural Resources, Sri Lanka.

4.3 Sample Analysis

Collected passive samples were analyzed after each exposure period using analytical methodologies given in table 4.3.1. The data of each location are presented under results and discussion session.

Table 4.3.1: Description of the analytical methods for each parameter

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

Collected PM_{2.5} samples were analyzed after each sampling period using analytical balance as per the method stipulated in the National Ambient Air Quality regulations gazette No. 1562/22- August 15th 2008 stipulated by Ministry of Environment and Natural Resources, Sri Lanka. The results are presented under results and discussion session.

4.4 Validation of Data

Since the automated ambient air quality monitoring unit at Central Environment Authority (CEA) has some technical problems and only few monitoring programs were conduct, it was unable to carryout parallel sampling programs up to the September 2016. Therefore, no data were compared with automated data. However, the Environment Studies and Services Division (ESSD) laboratory is in the process of taking ISO17025 accreditation, all instruments and laboratory wears were calibrated and all methodologies were updated and standardized. Also, the quality control charts (Figure 1 & 2) and primary standards were used to maintain the accuracy of the results. Therefore, data validations were done through quality control charts.

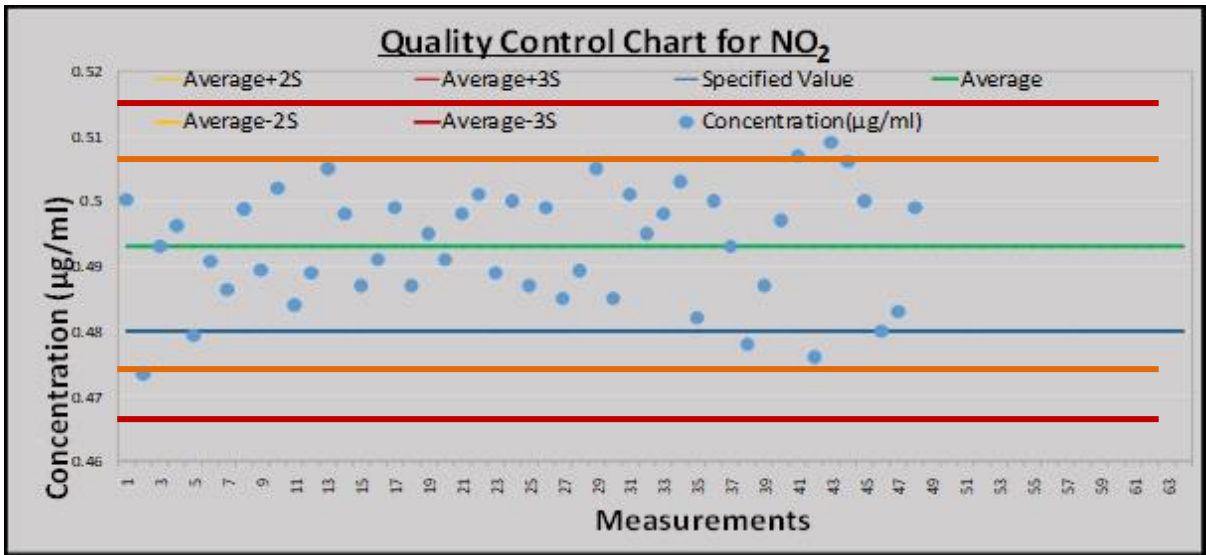


Figure 4.4.1: Quality Control Chart for the determination on NO₂ Concentration

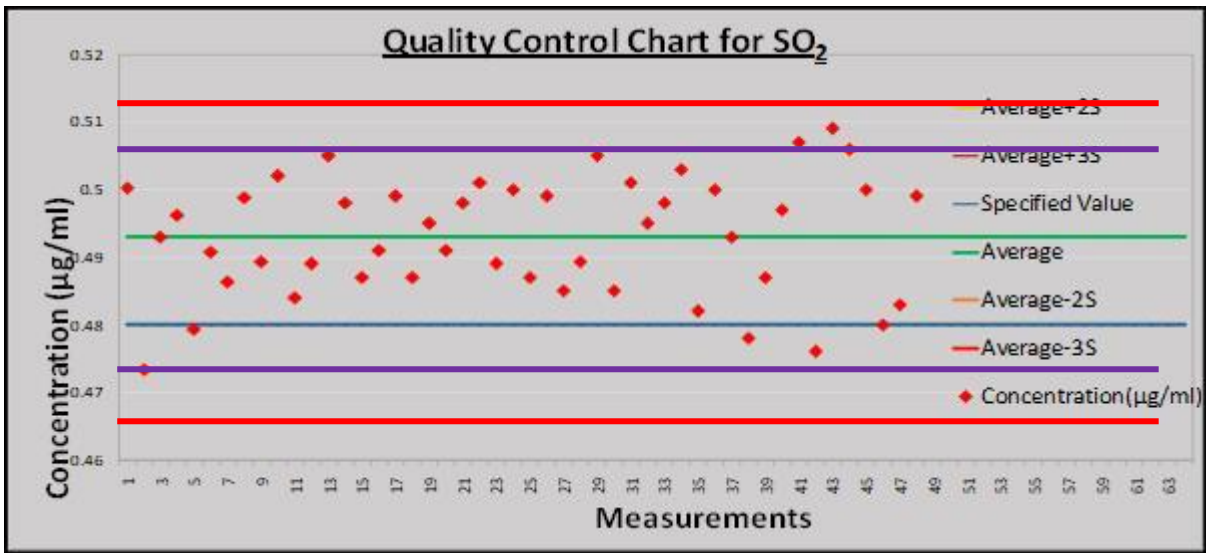


Figure 4.4.2: Quality Control Chart for the determination on SO₂ Concentration

5. REFERENCE GUIDELINE VALUES

According World Health Organization (WHO) guidelines, daily exposure of SO₂ should be less than 20 µg/m³. Therefore, annual exposure also should not exceed above limit. But they have already offers an interim target level 2 as 50 µg/m³ specially for developing countries. The annual exposure of NO₂ should be less than 40 µg/m³.

The National Ambient Air Quality regulations for 24-hour average PM_{2.5} is 0.050 mg/m³ as in the gazette No. 1562/22- August 15th 2008 stipulated by Ministry of Environment and Natural Resources, Sri Lanka

6. AMBIENT AIR QUALITY LEVELS

Measured Air Quality Exposure levels at each selected location in each city during the study period are summarized in following sections.

6.1 AMBIENT AIR QUALITY IN 2017 – AT COLOMBO URBAN AREA

Colombo, the capital city of Western province as well as the commercial capital of Sri Lanka is one of the coastal cities with deteriorated air quality. Several research studies have found that pollution levels in Colombo air is being increased during the last few decades with the increase of vehicle density, industries, domestic and commercial activities in and around the city.

Continuous Air quality exposure levels monitoring with respect to NO₂ and SO₂ in Colombo Urban area was started in 2001 by NBRO at 16 Location within the Colombo Municipal Council and surrounding areas. The monitoring program was then extended to 19 locations with the financial assistant of VET found in 2012 to measure monthly average NO₂ and SO₂ level. The measuring results show that pollutant levels are comparatively high in high traffic congested areas than in surrounding areas. The annual average pollutant levels have exceeded the recommended WHO guideline values for SO₂ and NO₂ within the city. Although, monitoring data from 2012 to 2014 has shown a drop-in air pollution level, the trend appeared to reverse and slightly increase from 2014 to 2017.

Air quality exposure levels measuring activities with respect to NO₂ and SO₂ in Colombo Urban area were continued in 2017 as well under this project. The sample locations description is given in table 6.1.1 and figure 6.1.1 shows the locations map. The table 6.1.2 presents the overview of each location in the Colombo urban area

Table 6.1.1: Selected Sampling Locations in Colombo Urban area

Urban Area	No of Points	Location ID	Location Description
Colombo	19	CL1	Meteorology Department
		CL2	Colombo MC
		CL3	Gangarama Temple
		CL4	Fort Railway Station
		CL5	Gunasinghepura
		CL6	Jethawanaramaya
		CL7	Maligakanda
		CL8	Kelaniya
		CL9	Borella Police Station
		CL10	Ward Place
		CL11	CEA - Battaramulla
		CL12	Kotte - Nagaviharaya
		CL13	Kirulapana
		CL14	Dehiwala Junction
		CL15	Nugegoda Town
		CL16	Malabe Town
		CL17	Peliyagoda
		CL18	Waththala
		CL19	Maradana Railway Station

Sample Location at Colombo Urban Area in 2017

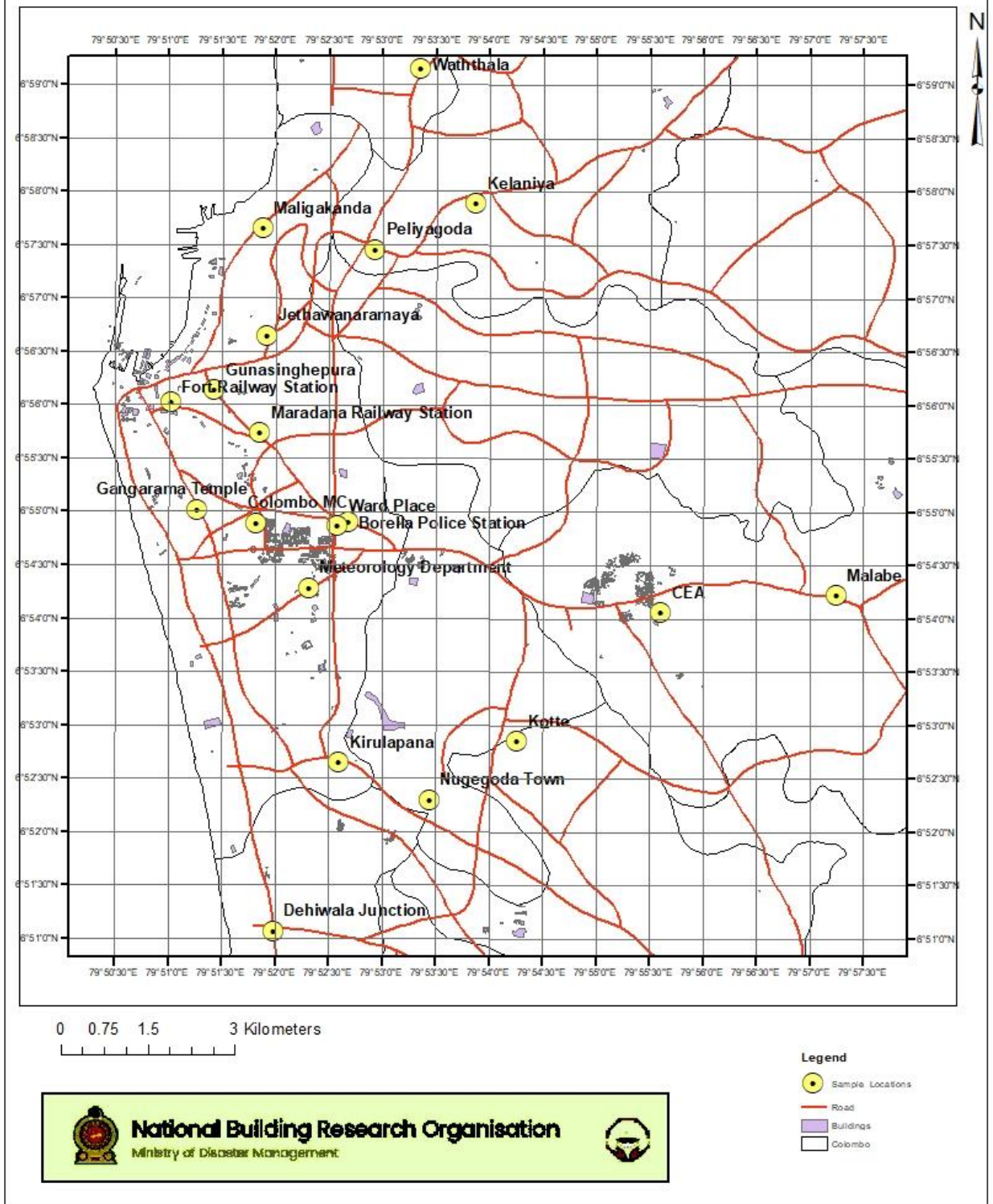


Figure 6.1.1: Sampling Locations Map in Colombo Urban area

Table 6.1.2: Overview of each location in the Colombo urban area



Location No: CL1
Location Name: MET Dept.
GPS Coordinates: 6.9047640N
79.8720660E



Location No: CL2
Location Name: CMC
GPS Coordinates: 6.9149600N
79.8637790E



Location No: CL3
Location Name: Gangarama
GPS Coordinates: 6.9169710N
79.8546200E



Location No: CL4
Location Name: Fort Railway Station
GPS Coordinates: 6.9338590N,
79.8504950E



Location No: CL5
Location Name: Gunasinghepura
GPS Coordinates: 6.9357150N
79.8572660E



Location No: CL6
Location Name: Jethawanarama
GPS Coordinates: 6.9441950N
79.8654000E



Location No: CL7
Location Name: Maligakanda
GPS Coordinates: 6.9609500N
79.8647880E



Location No: CL8
Location Name: Kelaniya
GPS Coordinates: 6.9576730N
79.8822730E



Location No: CL9
Location Name: Borella Police
GPS Coordinates: 6.9151380N
79.8781710E



Location No: CL10
 Location Name: Ward Place
 GPS Coordinates: 6.9145140N
 79.8764890E



Location No: CL11
 Location Name: CEA
 GPS Coordinates: 6.9010090N
 79.9268200E



Location No: CL12
 Location Name: Kotte
 GPS Coordinates: 6.8808680N,
 79.9044440E



Location No: CL13
 Location Name: Kirulapana
 GPS Coordinates: 6.8775390N,
 79.8766020E



Location No: CL14
 Location Name: Dehiwala
 GPS Coordinates: 6.8512390N,
 79.8665100E



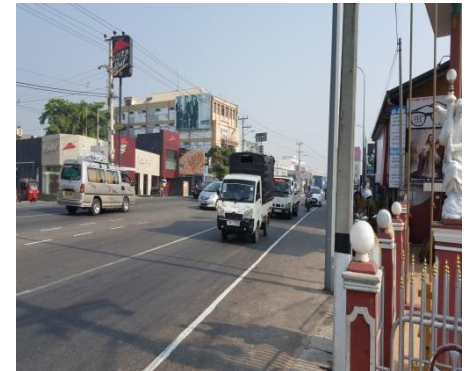
Location No: CL15
 Location Name: Nugegoda
 GPS Coordinates: 6.8717170N,
 79.8907630E



Location No: CL16
 Location Name: Malabe
 GPS Coordinates: 6.9037250N,
 79.9542180E



Location No: CL17
 Location Name: Peliyagoda
 GPS Coordinates: 6.9647960N,
 79.8979760E



Location No: CL18
 Location Name: Wattala
 GPS Coordinates: 6.9860070N,
 79.8893660E



Location No: CL19
 Location Name: Maradana
 GPS Coordinates: 6.9289490N,
 79.8642660E

Monthly average NO₂ and SO₂ exposure levels at each measuring location within Colombo urban area for the year 2017 is summarized in table 6.1.3 and 6.1.4 respectively. However, some of data were missing due to the missing of passive sampler by unavoidable situations such as personal or urban council activities, attacking of monkeys or birds and some climatic conditions such as heavy rain and flood etc. Table 6.1.5 shows that PM_{2.5} concentration of selected sample locations in Colombo in 2017

The figure 6.1.2(a) and 6.1.2(b) presented the variation of NO₂ and SO₂ in each location within the year 2017 in Colombo. It indicates that at the levels are highly subjective to the local wind condition. At most of locations, high exposure levels are recorded in during North-East monsoon period (December – February) compared to South-West monsoon period (May-September). The pattern was changed at some locations depending on the localised wind pattern. Figure 6.1.3 shows that variation of PM_{2.5} concentrations in selected sample locations in Colombo in 2017

Table 6.1.3: Monthly Average Levels of NO₂ at each location in Colombo Urban Area

Site Name	Location Id	NO ₂ Concentration (µg/m ³)											
		Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
MET Department	CL1	39	35	31	26	19	17	17	20	25	27	21	37
CMC	CL2	50	43	33	21	28	16	17	14	19	-	19	46
Gangarama	CL3	-	48	43	23	-	29	12	15	20	35	25	62
Fort	CL4	78	-	73	71	61	72	36	39	43	67	61	62
Gunasinghepura	CL5	40	42	-	45	43	41	48	49	44	42	41	46
Jethawanaramaya	CL6	53	48	64	45	39	33	34	34	36	43	38	36
Maligakanda	CL7	26	33	43	38	47	30	32	31	33	25	24	20
Kelaniya	CL8	41	38	53	49	38	39	45	31	39	29	27	33
Borella PS	CL9	-	50	-	39	42	-	38	46	38	49	44	44
Borella WP	CL10	43	-	31	14	16	17	13	14	15	30	28	38
CEA Battaramulla	CL11	42	40	34	24	15	21	15	21	21	31	37	35
Kotte	CL12	40	46	37	23	11	11	14	12	15	12	15	20
Kirulapana	CL13	55	35	31	46	19	25	17	18	33	34	28	53
Dehiwala	CL14	47	51	49	45	42	44	43	40	34	37	48	49
Nugegoda Town	CL15	60	45	39	30	45	26	21	27	26	35	40	45
Malabe	CL16	40	58	48	41	29	34	28	31	27	48	50	53
Peliyagoda	CL17	63	54	36	29	52	26	34	47	25	30	41	40
Waththala	CL18	78	70	53	43	39	-	31	44	47	63	57	57
Maradana RS	CL19	76	86	65	59	56	46	63	60	62	76	83	88

Table 6.1.4: Monthly Average Levels of SO₂ at each location in Colombo Urban Area

Site Name	Location Id	SO ₂ Concentration($\mu\text{g}/\text{m}^3$)											
		Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
MET Department	CL1	51	55	52	20	53	51	36	32	24	43	40	42
CMC	CL2	68	67	62	47	-	48	49	54	51	-	52	49
Gangarama	CL3	-	41	44	48	55	33	44	54	37	40	50	50
Fort	CL4	72	78	78	73	67	60	71	54	56	53	67	70
Gunasinghepura	CL5	60	61	-	40	63	43	33	40	37	54	48	50
Jethawanaramaya	CL6	45	55	55	37	48	57	44	-	39	49	51	44
Maligakanda	CL7	51	53	44	41	48	49	44	43	35	43	37	38
Kelaniya	CL8	52	52	46	43	43	47	40	24	27	44	43	36
Borella PS	CL9	-	47	-	49	50	53	57	-	56	53	50	52
Borella WP	CL10	47	53	51	35	32	38	33	39	32	40	49	49
CEA Battaramulla	CL11	-	47	52	41	50	45	38	48	29	44	50	41
Kotte	CL12	-	35	41	54	52	40	37	46	33	46	56	40
Kirulapana	CL13	46	44	50	52	58	50	43	38	39	48	43	44
Dehiwala	CL14	65	59	63	61	57	64	-	-	39	-	65	53
Nugegoda Town	CL15	64	67	64	54	56	46	48	40	43	49	64	51
Malabe	CL16	75	56	53	54	60	-	40	47	44	47	48	50
Peliyagoda	CL17	53	80	77	73	83	59	66	50	58	50	64	55
Waththala	CL18	65	75	76	62	93	-	76	62	50	53	56	60
Maradana RS	CL19	62	91	90	62	84	53	68	61	55	65	64	69

Table 6.1.5: 24-hourly Average Levels of PM_{2.5} at Selected location in Colombo Urban Area

Site Name	Location Id	PM _{2.5} ($\mu\text{g}/\text{m}^3$)											
		Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
Borella	CL9	-	-	-	-	-	-	-	-	-	-	52	35
Peliyagoda	CL17	-	-	-	-	-	-	-	-	-	-	33	56
Maradana RS	CL19	-	-	-	-	-	-	-	-	-	-	42	25

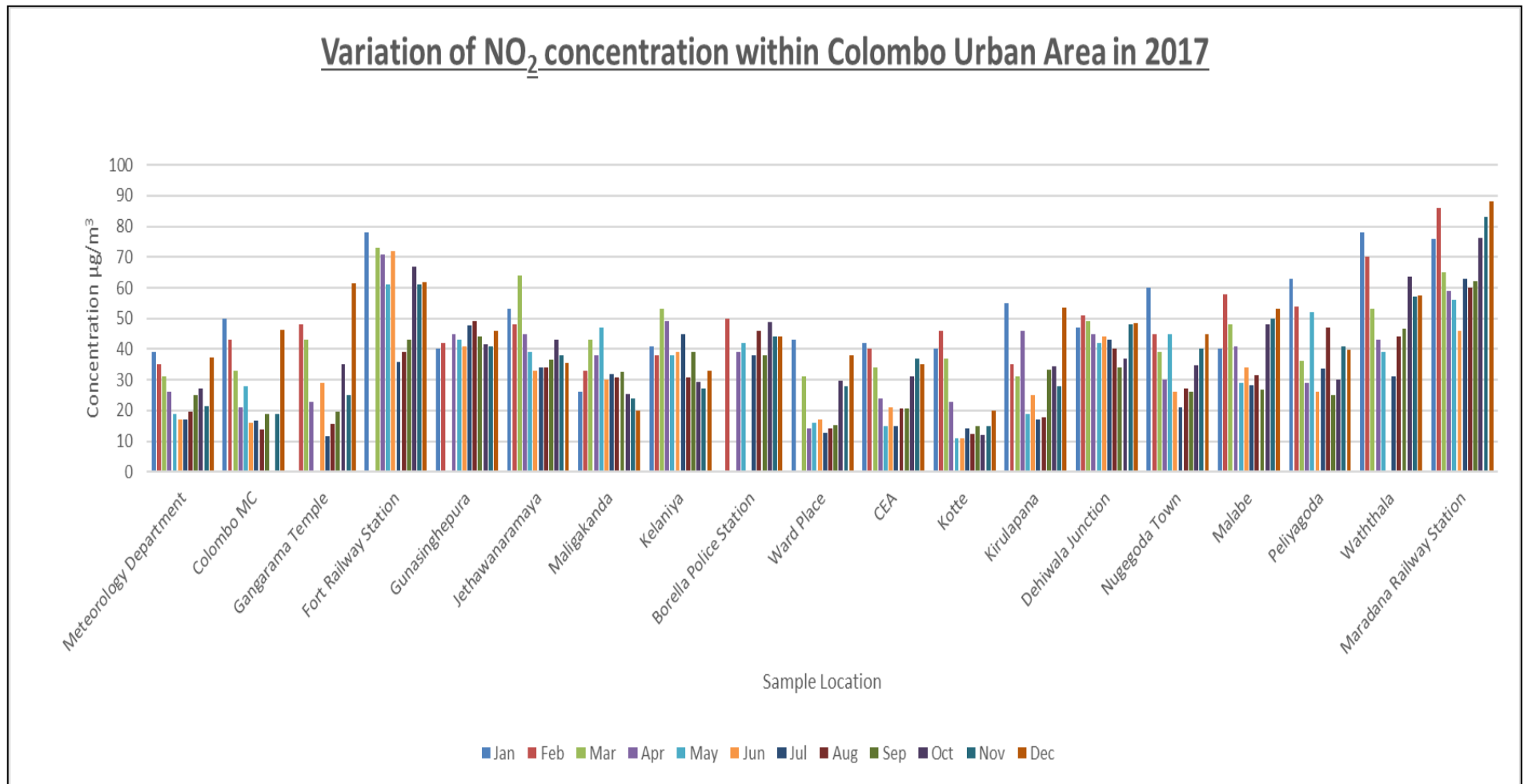


Figure 6.1.2(a): Variation of NO₂ concentration within Colombo Urban Area in 2017

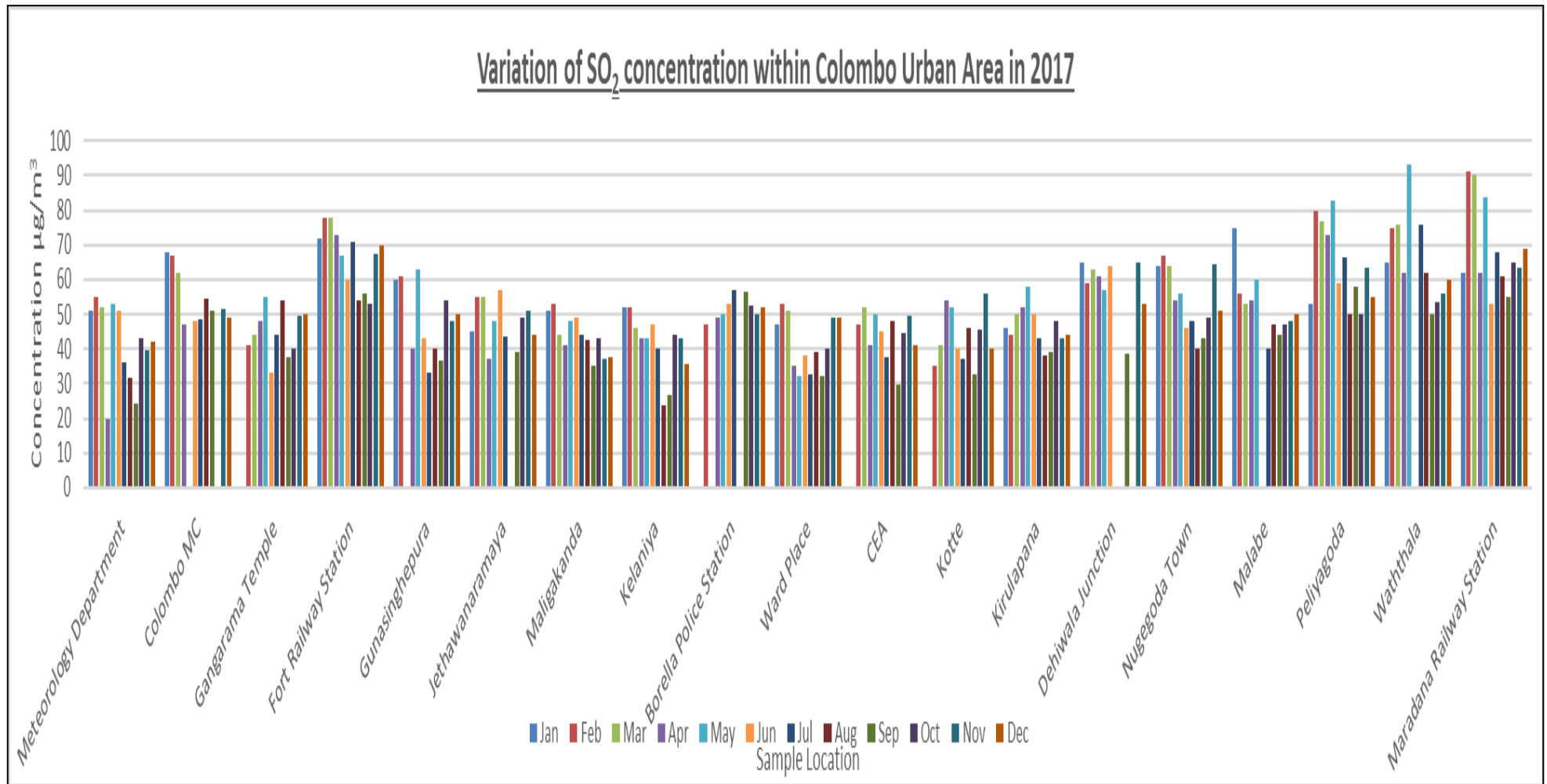


Figure 6.1.2(b): Variation of SO₂ concentration within Colombo Urban Area in 2017

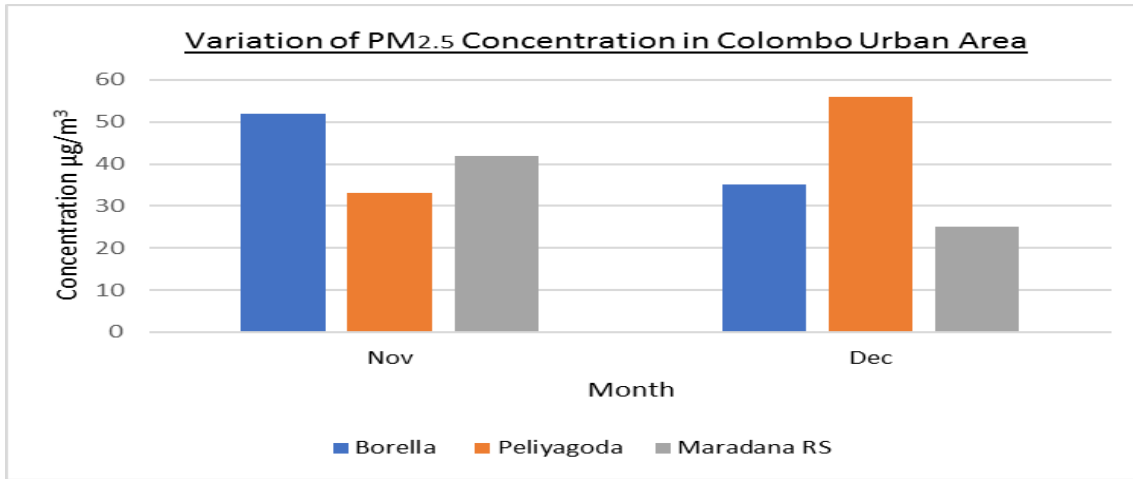


Figure 6.1.3: Variation of PM_{2.5} concentration within Colombo Urban Area

Figure 6.1.4(a) and 6.1.4(b) represent the annual average NO₂ and SO₂ concentration levels at each sampling location in Colombo urban area during the year, 2017. The annual average NO₂ and SO₂ levels in year 2017 within Colombo are in between 21 µg/m³ - 68 µg/m³ and 41 µg/m³ - 69 µg/m³ respectively. The high levels are represented highly urbanised areas with high traffic Maradana (CL19), Fort Railway Station (CL4), Borella (CL9), Malabe (CL16), Peliyagoda (CL17) and Wattala (CL18) where exceeded the annual WHO guideline values for NO₂ and 24 hour WHO guideline values for SO₂. Relatively low levels are at isolated areas with residential and low traffic in Kotte (CL12).

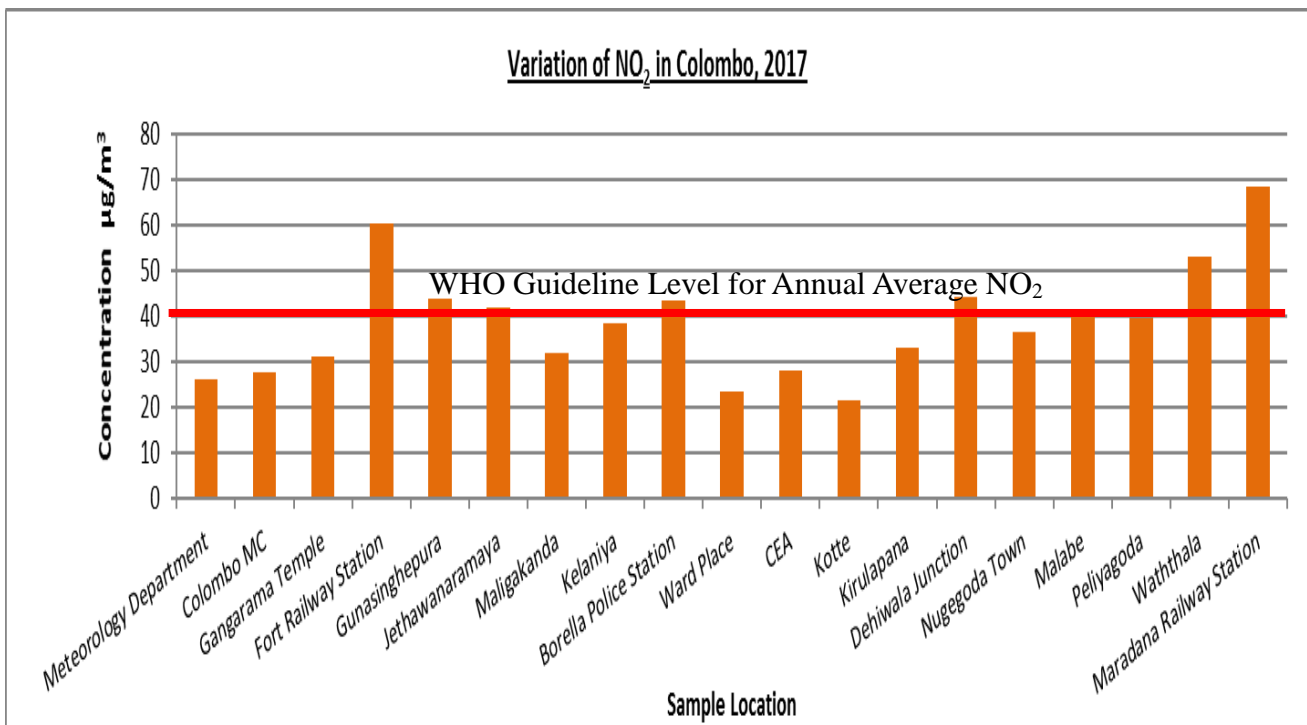


Figure 6.1.4(a): Annual average NO₂ concentration within Colombo Urban Area in 2017

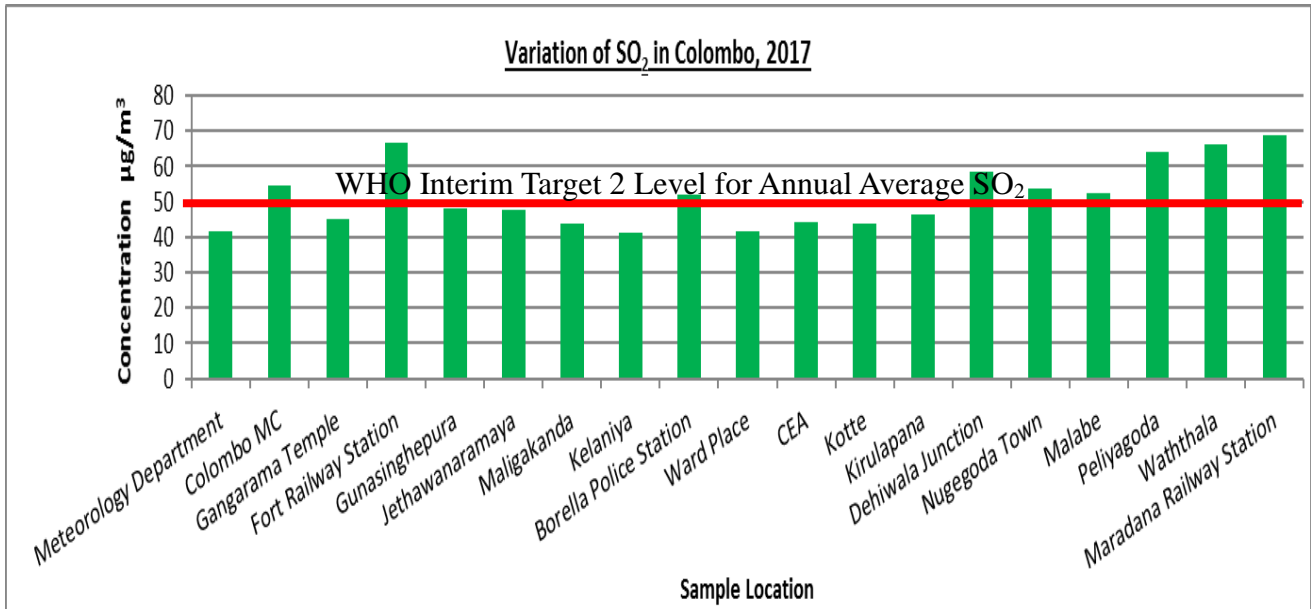


Figure 6.1.4(b): Annual average SO₂ concentration within Colombo Urban Area in 2017

The figure 6.1.5 shows a comparison and trend of both SO₂ and NO₂ exposure in each sample location for six-year time period. Trend of NO₂ exposure has decreased while SO₂ exposure has increase since 2012 in Colombo urban area. Boxplot of NO₂ and SO₂ exposure in each location at Colombo area from 2012 to 2017 are represents in figure 6.1.6(a) and 6.1.6(b). The annual average levels of each pollutant for same period is represents in figure 6.1.7(a) and 6.1.7(b) respectively. Accordingly, the exposure level of NO₂ was in decreasing trend from 2012 to 2015 and slightly get increased 2015 to 2017 while SO₂ exposure has an increasing trend from 2012 to 2017.

These changes of pollutant levels in Colombo urban area should represent the actions implemented to manage air quality in Sri Lanka including, fuel quality improvements, vehicular emission control through VET program, development of road surface and removing road obstructions as well as introducing of cleaner fuel vehicles such as hybrid and electric vehicles to the fleet would also leads to reduces pollution load. Increase of pollutant sources such as increase of vehicular fleet, movement of construction vehicles, construction activities and weaknesses of VET programs could lead to increase the pollutant levels.

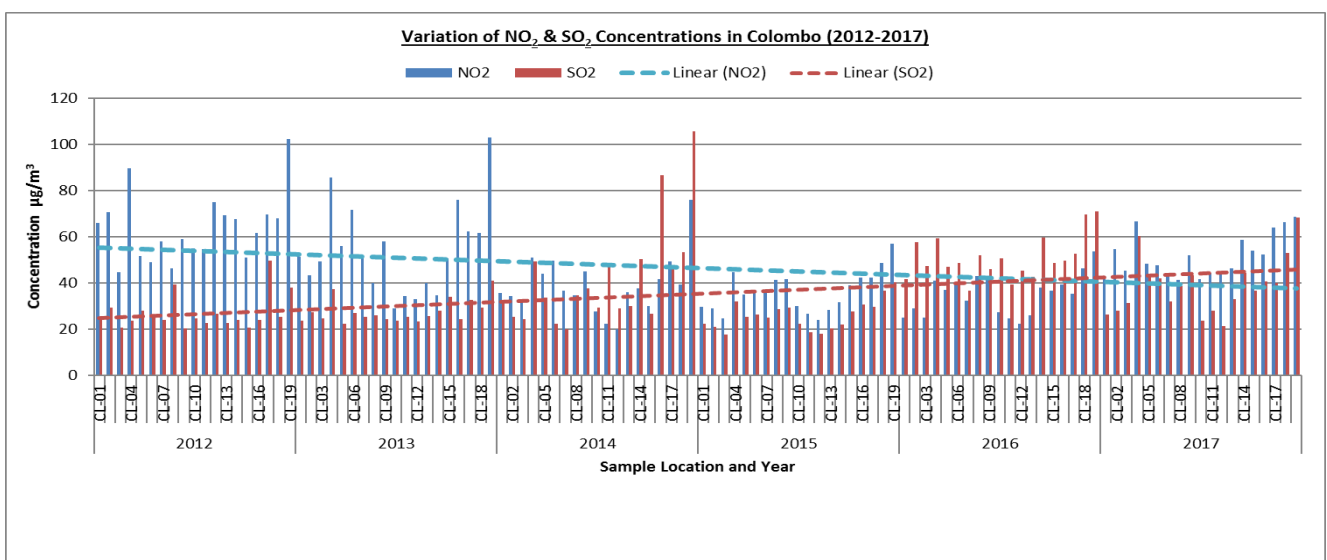


Figure 6.1.5: Average NO₂ and SO₂ variations from 2012-2017

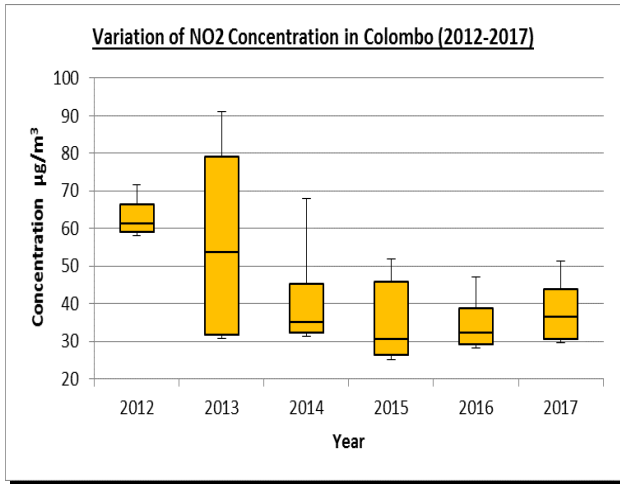


Figure 6.1.6(a): Boxplot of NO₂ Concentration variation in Colombo 2012-2017

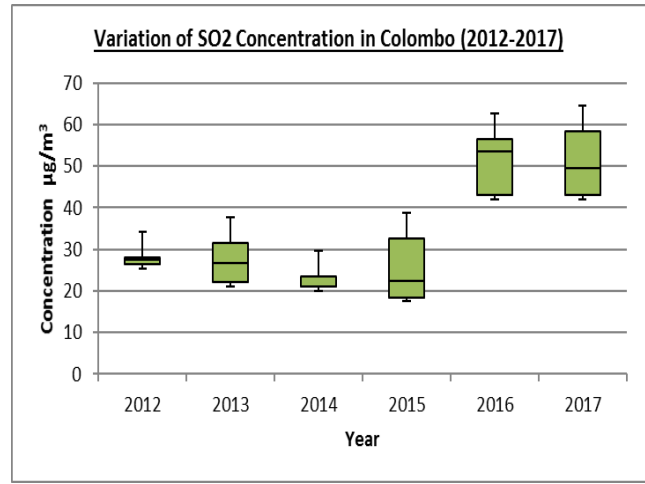


Figure 6.1.6(b): Boxplot of SO₂ Concentration variation in Colombo 2012-2017

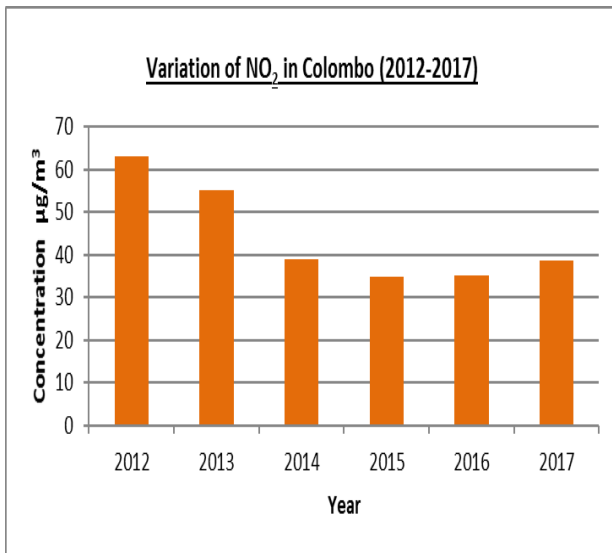


Figure 6.1.7(a): Annual average NO₂ variations from 2012-2017 in Colombo Urban area

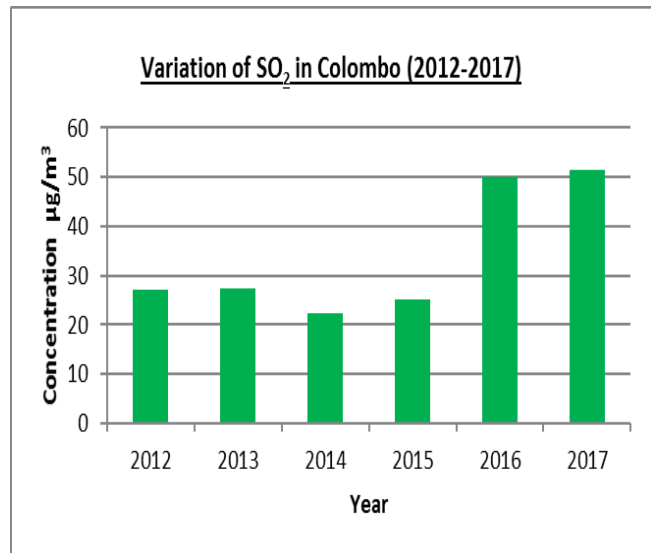
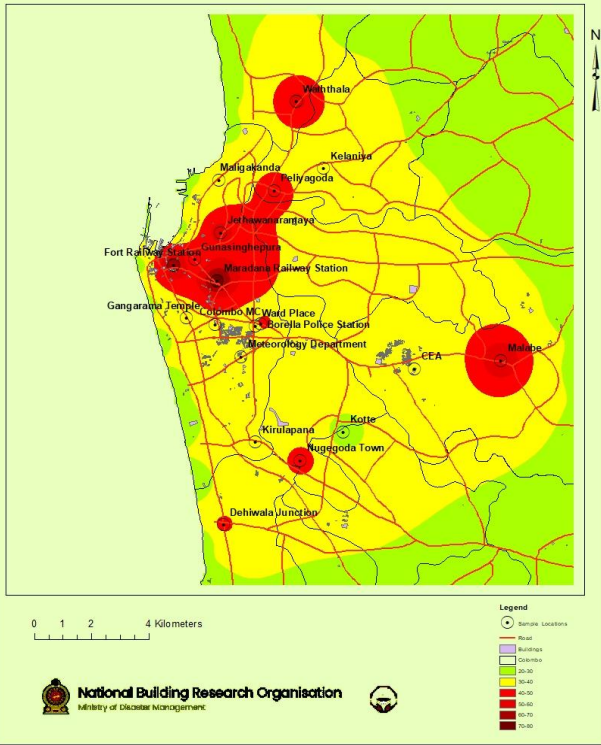


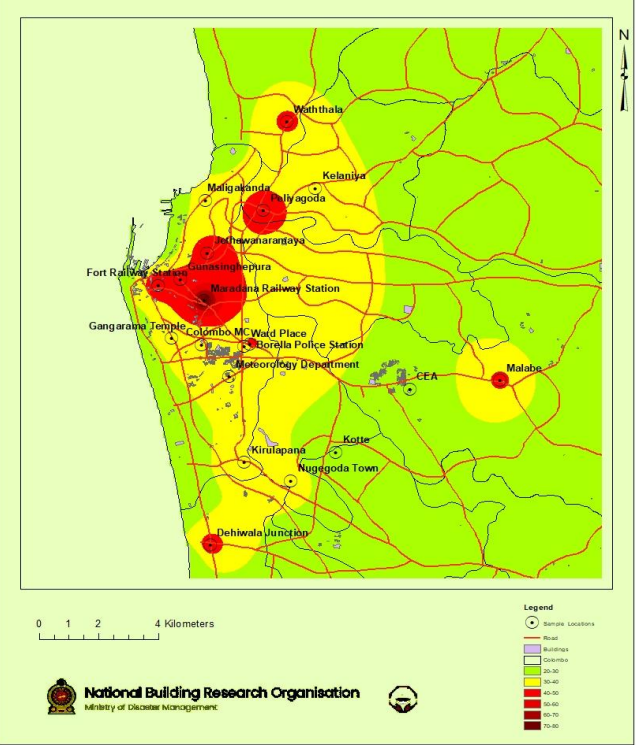
Figure 6.1.7(b): Annual average SO₂ variations from 2012-2017 in Colombo Urban area

Annual geographical variation of NO₂ and SO₂ levels from 2013 to 2017 in Colombo urban city is shown in figure 6.1.8 and figure 6.1.9 respectively. The figures indicate the critical and moderately polluted area in which attention to be made. Also, it indicates that how the extend of the critical area is change from year to year depending on pollution load.

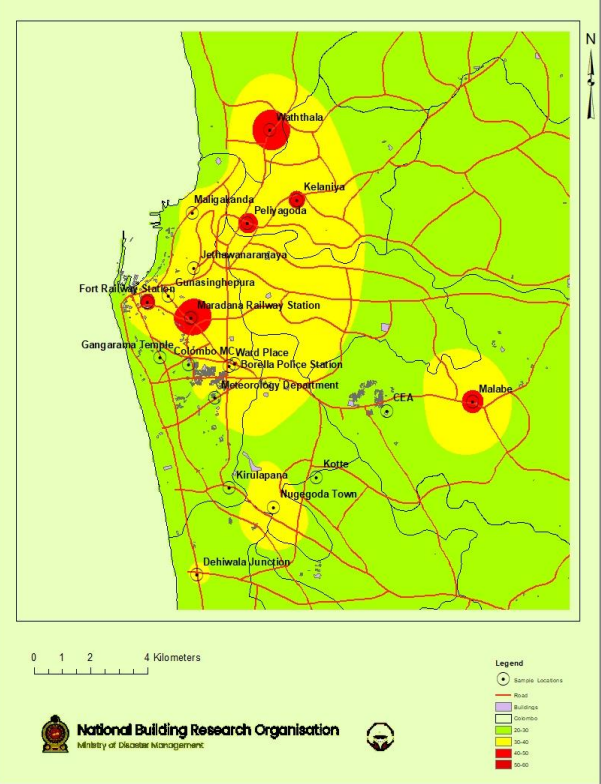
Variation of NO2 Concentration at Colombo Urban Area in 2013



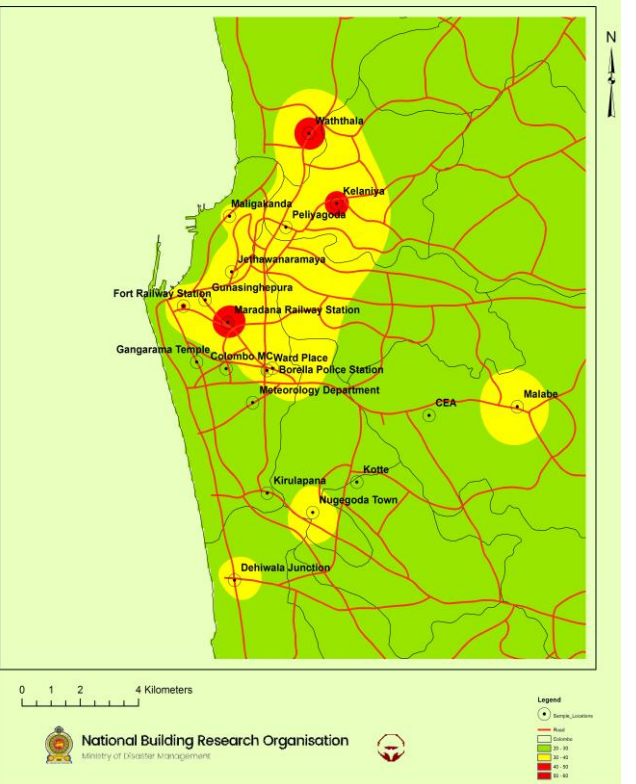
Variation of NO2 Concentration at Colombo Urban Area in 2014



Variation of NO2 Concentration at Colombo Urban Area in 2015



Variation of NO2 Concentration at Colombo Urban Area in 2016



Variation of NO₂ Concentration at Colombo Urban Area in 2017

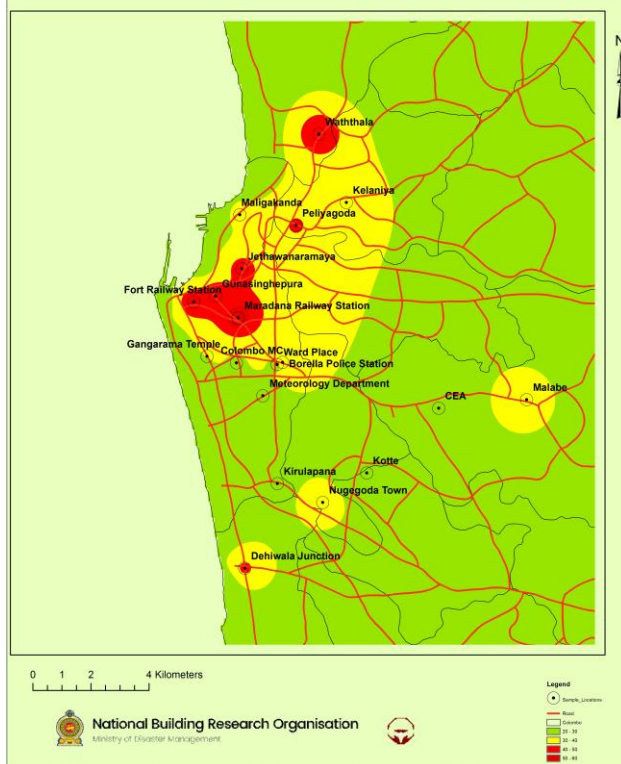
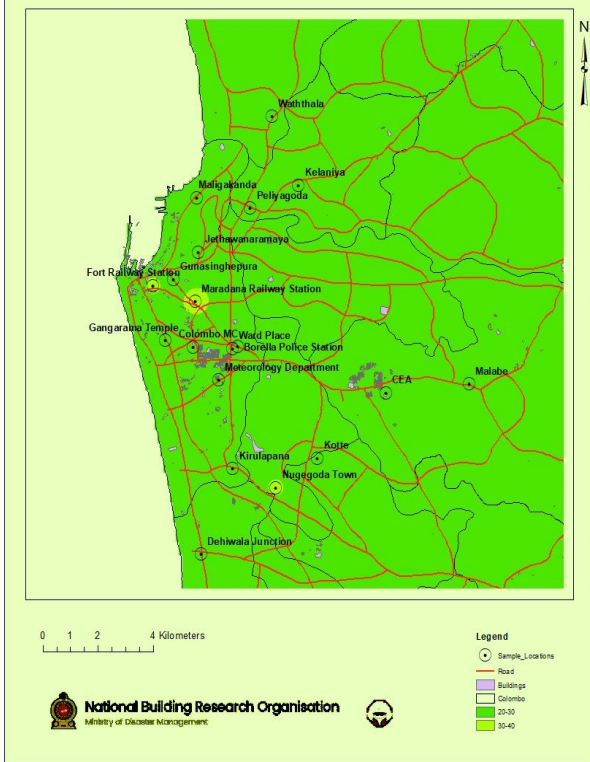
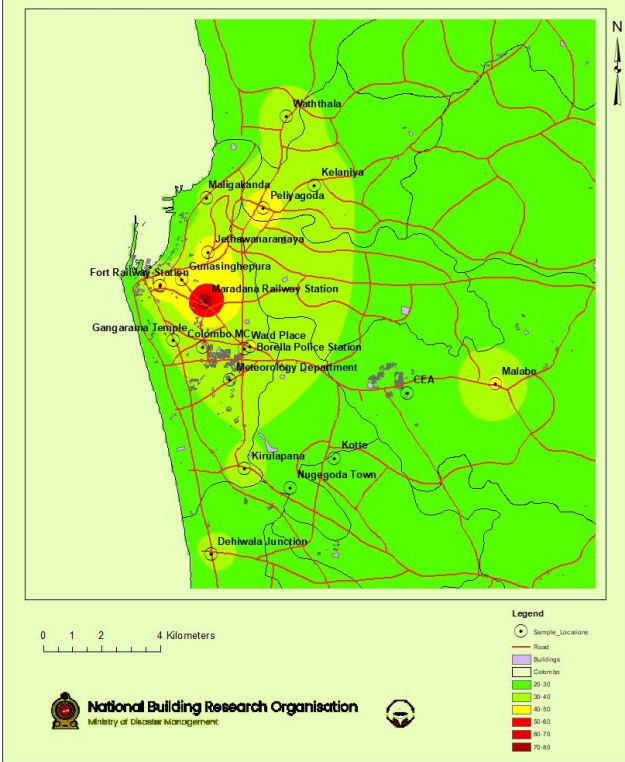


Figure 6.1.8: Variation of NO₂ concentration within Colombo Urban Area from 2013 to 2017

Variation of SO₂ Concentration at Colombo Urban Area in 2013



Variation of SO₂ Concentration at Colombo Urban Area in 2014



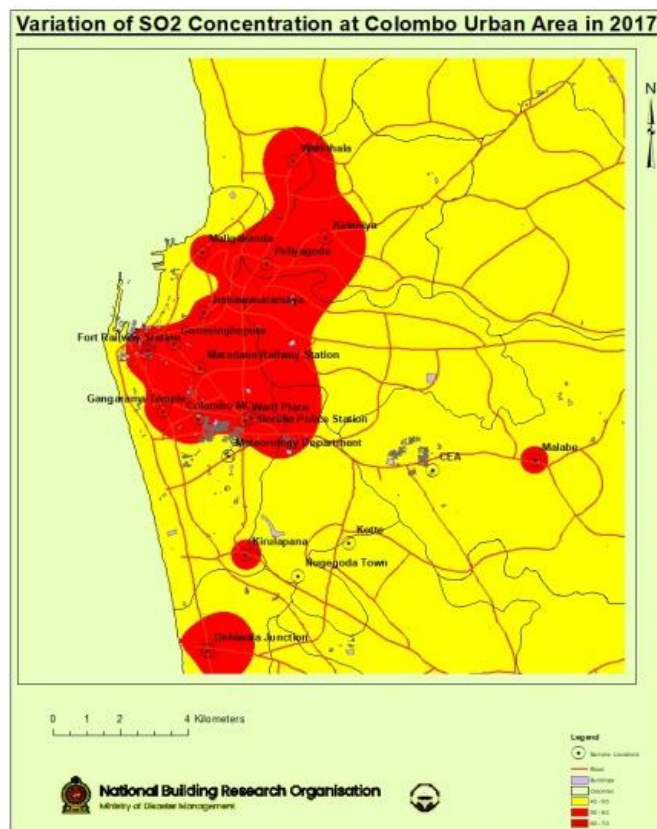
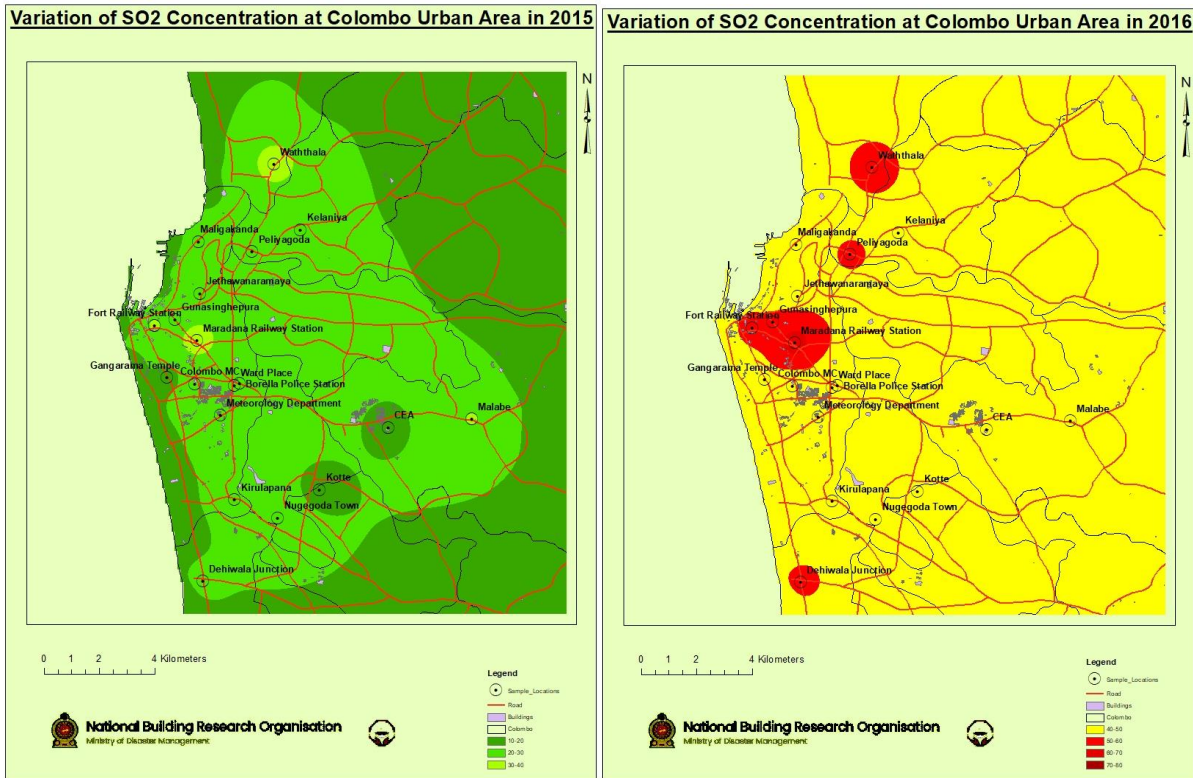


Figure 6.1.9: Variation of SO₂ concentration within Colombo Urban Area from 2013 to 2017

The air pollutant levels are highly subjective to the weather condition of the urban area. Therefore, monsoonal climatic variations of wind direction are highly affected for the dispersion of these pollutants in the urban area. The average levels of SO₂ and NO₂ were therefore analyzed to assess the climatic impact on pollutant dispersion within the Colombo urban and surrounding area.

The figures 6.1.10(a) and 6.1.10(b) respectively shows how pollutants are dispersed in the study area in four different monsoonal patterns which are North-East (NE), Inter-monsoon followed by North-East (InNE) monsoon, South-West (SW) monsoon and Inter-monsoon followed by South-West (InSW) monsoon. According to the analysis, both NO₂ and SO₂ levels shows highest in NE monsoonal and lowest in SW monsoonal season. This could be due to the low dispersion of pollutant during NE monsoon in which make wind shier by prevailing and sea winds. It also clearly indicates that the land extend that has critical pollution levels are also high in NE monsoon period than SW monsoon period. The pollutant levels during NE monsoon exceeded the WHO interim target level 2 of SO₂ exposure level as well as annual average level of NO₂ exposure level. The pollutant levels in InNE monsoon is lower that the NE monsoon but higher than that of SW and InSW periods.

The figure 6.1.11(a) and 6.1.11(b) illustrate monsoonal seasonal variation of NO₂ and SO₂ levels in 2017 in Colombo Urban area. These figures indicate that the levels of both pollutants have increased in NE monsoon compared to other monsoon seasons.

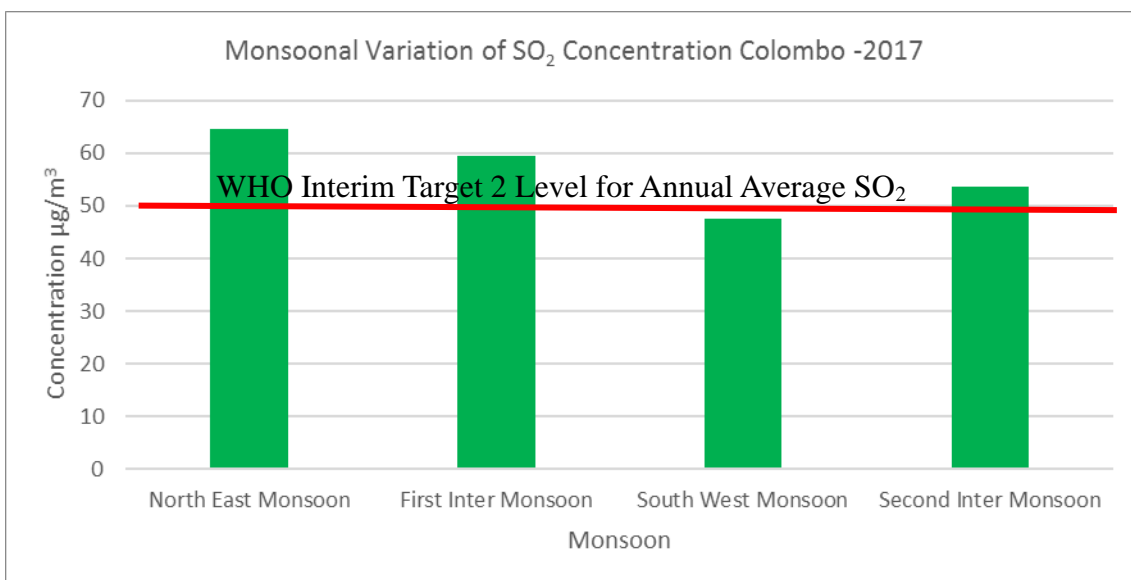


Figure 6.1.10(a): Monsoonal Variation of NO₂ concentration within Colombo Urban Area

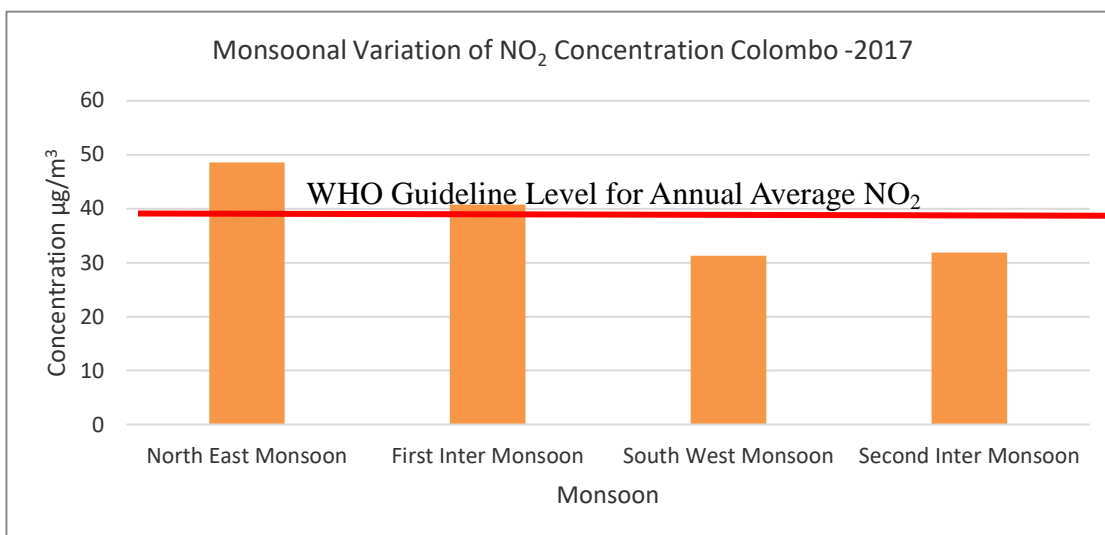
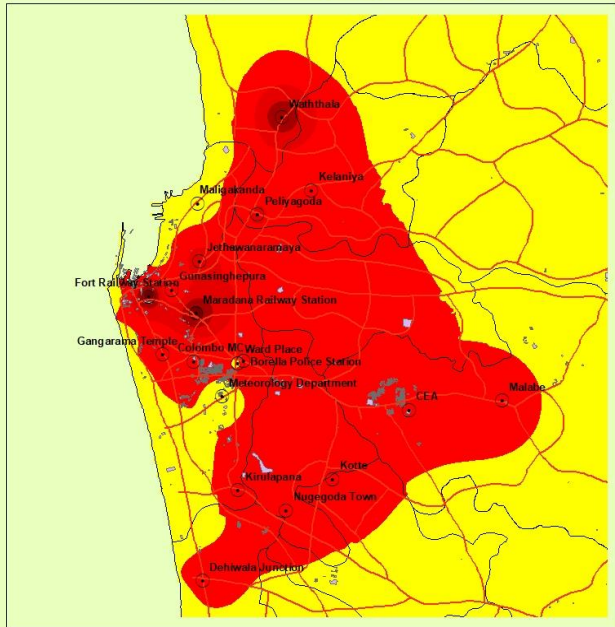


Figure 6.1.10(b): Monsoonal Variation of SO₂ concentration within Colombo Urban Area

Variation of NO₂ Concentration at Colombo Urban Area in North-East Monsoon Season 2017

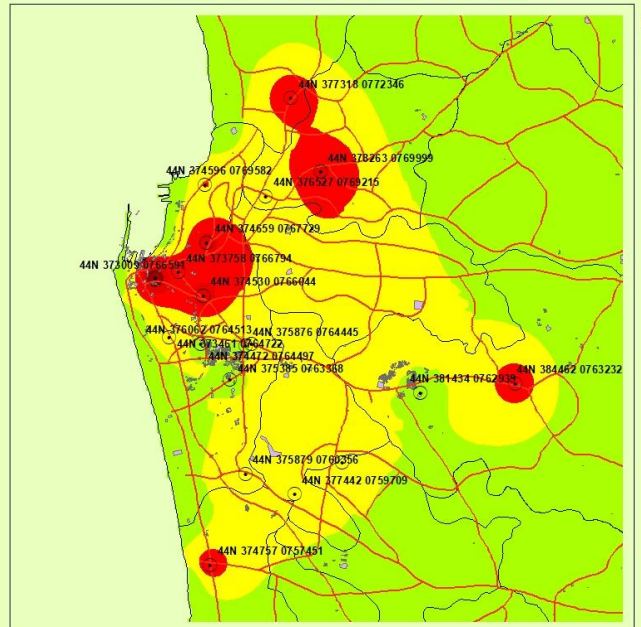


0 1 2 4 Kilometers

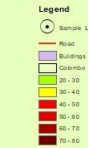


National Building Research Organisation
Ministry of Disaster Management

Variation of NO₂ Concentration at Colombo Urban Area in First Inter Monsoon Season 2017

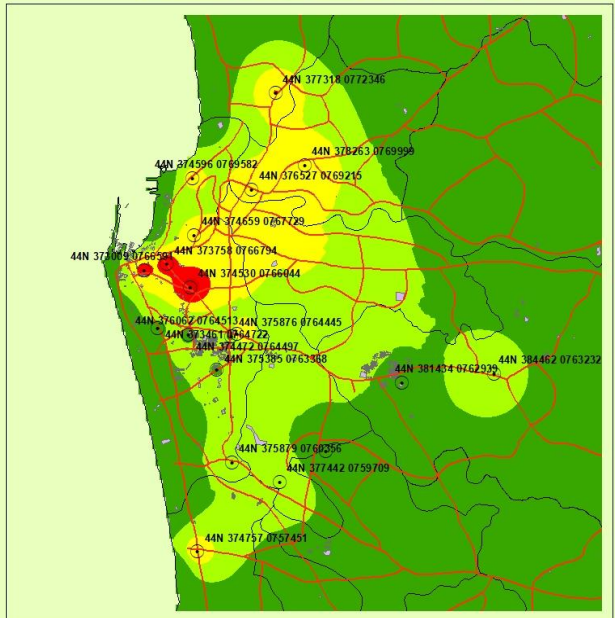


0 1 2 4 Kilometers



National Building Research Organisation
Ministry of Disaster Management

Variation of NO₂ Concentration at Colombo Urban Area in South-West Monsoon Season 2017

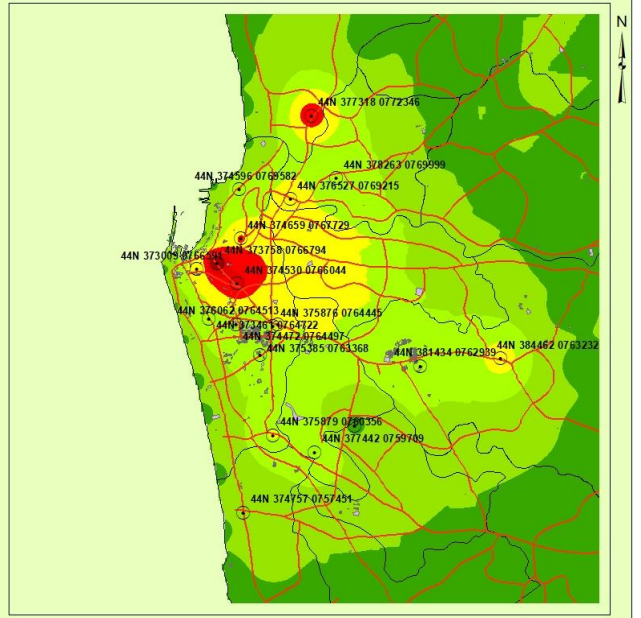


0 1 2 4 Kilometers

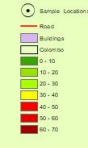


National Building Research Organisation
Ministry of Disaster Management

Variation of NO₂ Concentration at Colombo Urban Area in Second Inter Monsoon Season 2017



0 1.25 2.5 5 Kilometers



National Building Research Organisation
Ministry of Disaster Management

Figure 6.1.11(a): Monsoonal Seasonal Variation of NO₂ Exposure Colombo Urban City in 2017. From left to right it shows North East Monsoonal Season Exposure, First Inter Monsoon Season Exposure, South West Monsoonal Season Exposure and Second Inter Monsoon Season Exposure respectively.

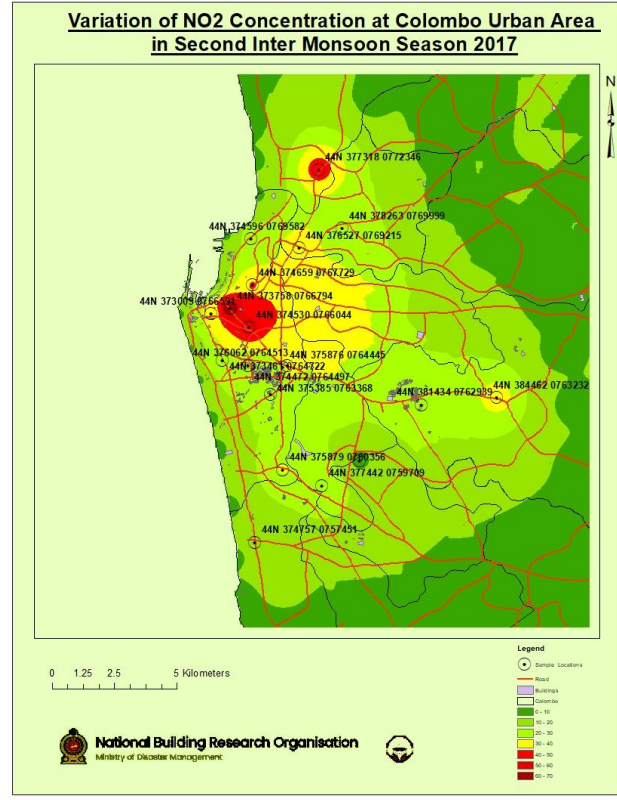
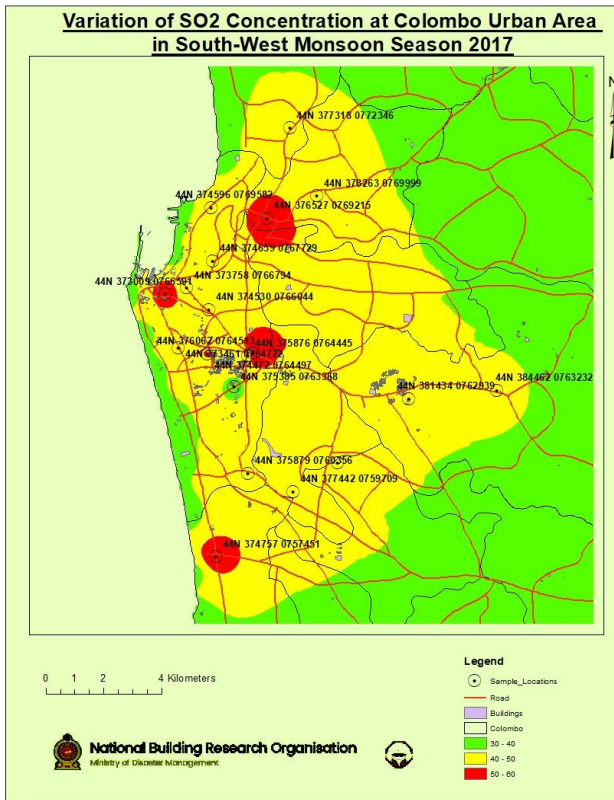
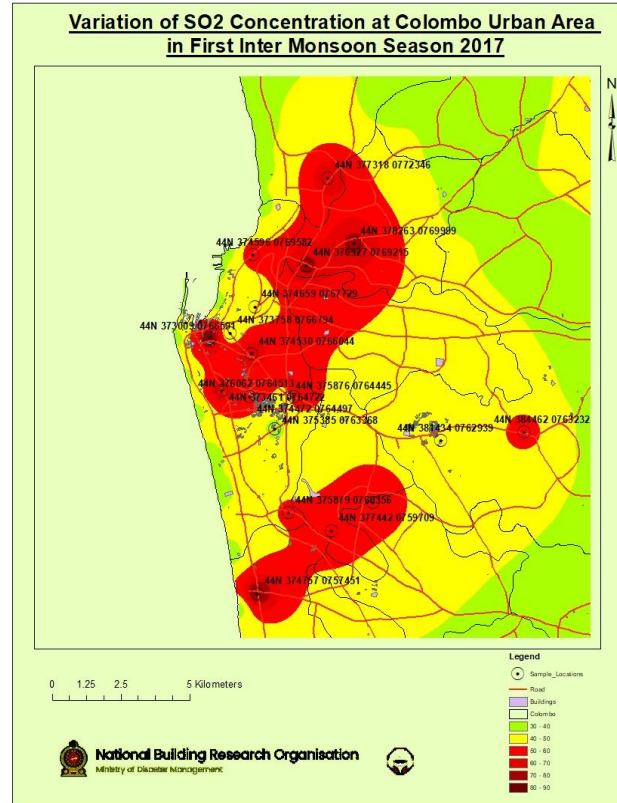
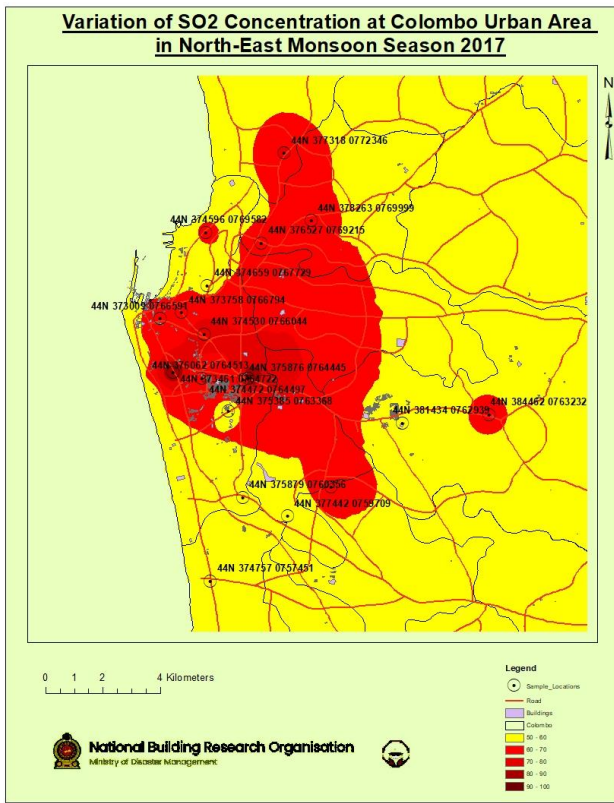


Figure 6.1.11(b): Monsoonal Seasonal Variation of SO₂ Exposure Colombo Urban City in 2017. From left to right it shows North East Monsoonal Season Exposure, First Inter Monsoon Season Exposure, South West Monsoonal Season Exposure and Second Inter Monsoon Season Exposure respectively.

6.2 AMBIENT AIR QUALITY IN 2017 – AT GAMPAHA URBAN AREA

Gampaha is a major city in Gampaha District, Western Province, Sri Lanka. It is situated to the north-east of the capital Colombo. It is the sixth largest urban area in Western Province after Colombo, Negombo, Kalutara, Panadura and Avissawella. Gampaha is also the second largest urban centre in Gampaha district, after Negombo. According to the facts of central index prepared by urban development authority (UDA), Gampaha develops around 95% although the population is less than in Negombo. Gampaha has a land area of 25.8 hectares and is home to the offices of 75 government institutions.

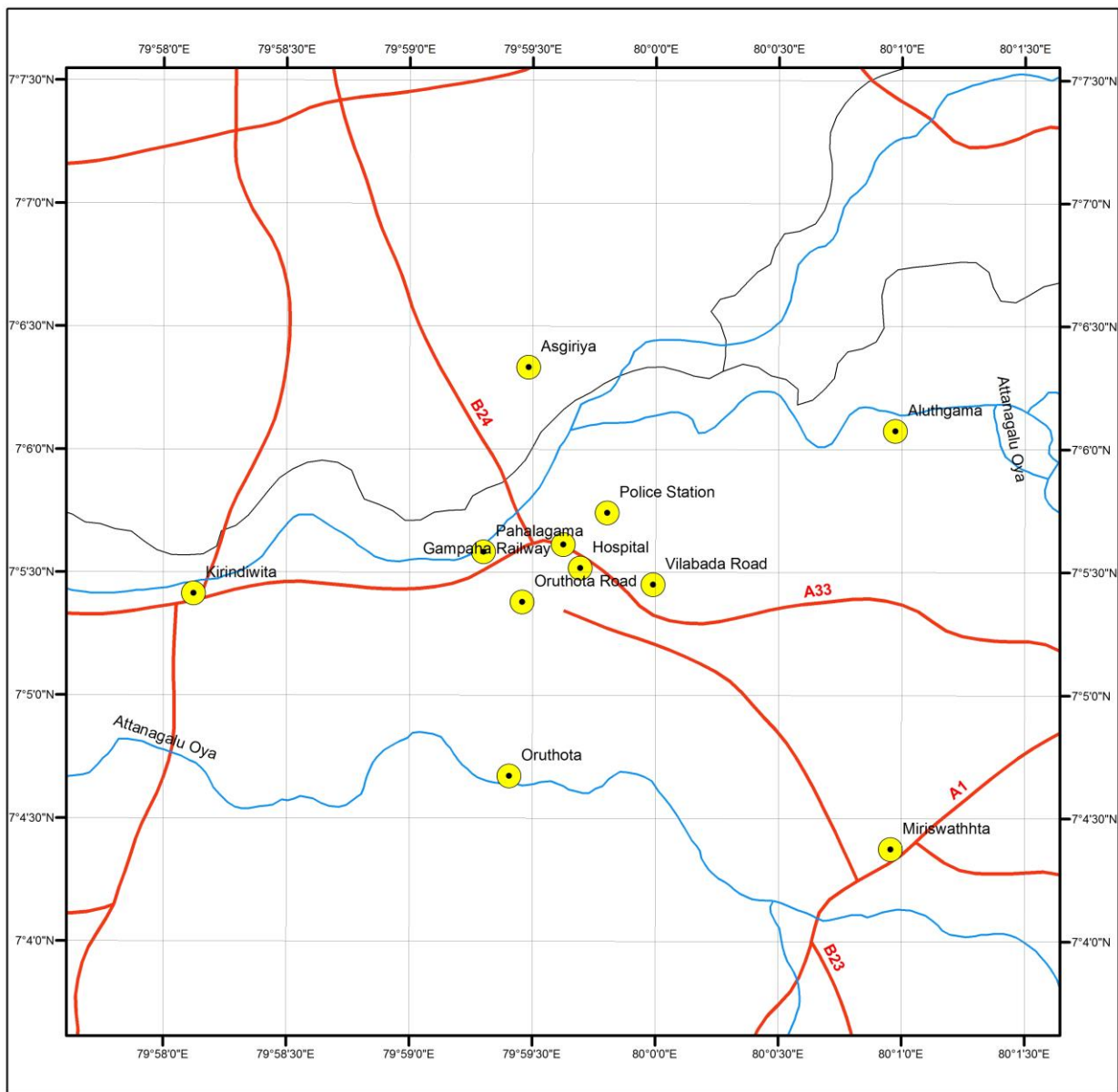
Air quality exposure levels with respect to NO₂ and SO₂ in Gampaha Urban area was started in 2012 at 11 Locations within the Gampaha Municipal Council and surrounding areas with the financial assistant of VET found. The monitoring program was continued in 2017 to measure monthly average NO₂ and SO₂ level. The monthly average NO₂ and SO₂ exposure levels at each measuring location within Gampaha urban area in 2017 is summarised in table 6.2.2 and 6.2.3 respectively.

Air quality exposure levels measuring activities with respect to NO₂ and SO₂ in Gampaha Urban area were continued in 2017 as well under this project. The sample locations description is given in table 6.2 and Figure 6.2 shows the locations map. The Table 6.2.1 presents the overview of each location in the Gampaha urban area.

Table 6.2.1: Selected Sampling Locations in Gampaha Urban area

Urban Area	No of Points	Sampling Location	Location Description
Gampaha	11	GM1	Kirindiwita
		GM2	Pahalagama
		GM3	Asgiriya
		GM4	Oruthota Road
		GM5	Oruthota
		GM6	Gampaha Railway
		GM7	Gampaha Police Station
		GM8	Vilabada Road
		GM9	Gampaha Hospital
		GM10	Aluthgama
		GM11	Miriswaththa

Sample Locations at Gampaha Urban Area



0 0.5 1 2 Kilometers



- Legend**
- Sample Locations
 - Streams
 - Road
 - Gampaha

Figure 6.2.1: Sampling Locations Map in Gampaha Urban area

Table 6.2.2: Overview of each location in the Gampaha urban area



Location No: GM1
Location Name: Kirindiwita
GPS Coordinates: 7.0902160N,
79.9687110E



Location No: GM2
Location Name: Pahalagama
GPS Coordinates: 7.0930380N,
79.9883480E



Location No: GM3
Location Name: Asgiriya
GPS Coordinates: 7.1055420N,
79.9913920E



Location No: GM4
Location Name: Oruthota Rd
GPS Coordinates: 7.0896450N,
79.9909850E



Location No: GM5
Location Name: Oruthota
GPS Coordinates: 7.0778570N,
79.9901070E



Location No: GM6
Location Name: Gampaha R.S
GPS Coordinates: 7.09354260N
79.9937630E



Location No: GM7
Location Name: Gampaha P.S
GPS Coordinates: 7.0956810N,
79.9967340E



Location No: GM8
Location Name: Vilabada Rd
GPS Coordinates: 7.0908370N,
79.9998310E



Location No: GM9
Location Name: Gampaha HP
GPS Coordinates: 7.0919530N,
79.9949050E



Location No: GM10
 Location Name: Miriswatta
 GPS Coordinates: 7.0729160N, 80.0159380E



Location No: GM11
 Location Name: Aluthgama
 GPS Coordinates: 7.1012450N, 80.0162410E

Monthly average NO₂ and SO₂ exposure levels at each measuring location within Gampaha urban area for the year 2017 is summarised in table 6.2.3 and 6.2.4 respectively. However, some of data were missing due to the missing of passive sampler due to unavoidable situations such as personal or urban council activities, attacking of animals or birds and some climatic conditions such as rain and flood etc. Table 6.2.5 shows that PM_{2.5} concentration of selected sample locations in Gampaha in 2017

Table 6.2.3: Monthly Average Exposure Levels of NO₂ at each location in Gampaha Urban Area

Urban Area	Location	NO ₂ Concentration(µg/m ³)											
		Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
Kirindiwita	GM1	34	26	19	17	14	14	11	12	13	16	19	27
Pahalagama	GM2	45	44	42	38	-	28	29	34	31	33	38	48
Asgiriya	GM3	20	23	14	17	9	17	16	-	27	12	15	22
Oruthota Road	GM4	48	49	31	29	37	33	13	37	31	39	39	40
Oruthota	GM5	40	46	47	48	27	32	27	25	20	23	27	37
Gampaha Railway	GM6	43	46	40	40	39	37	40	37	35	38	39	46
Gampaha Police St.	GM7	41	41	38	30	34	32	28	32	28	30	33	33
Vilabada Road	GM8	22	27	18	25	20	18	18	17	17	23	24	24
Gampaha Hospital	GM9	47	53	42	41	42	37	32	35	29	32	37	44
Aluthgama	GM10	33	23	22	21	22	22	19	20	18	19	29	27
Miriswaththa	GM11	61	69	67	54	69	57	55	50	50	59	44	48

Table 6.2.4: Monthly Average Exposure Levels of SO₂ at each location in Gampaha Urban Area

Urban Area	Location	SO ₂ Concentration(µg/m ³)											
		Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
Kirindiwita	GM1	40	50	49	40	42	53	64	29	34	36	32	42
Pahalagama	GM2	51	59	58	42	36	38	36	55	36	35	33	44
Asgiriya	GM3	49	44	42	29	37	38	22	31	30	41	35	49
Oruthota Road	GM4	63	53	51	45	58	-	51	58	35	45	45	47
Oruthota	GM5	60	57	56	35	45	32	31	46	29	39	49	57
Gampaha Railway	GM6	62	67	68	66	66	64	54	46	40	44	53	56
Gampaha Police St.	GM7	72	67	58	56	52	56	48	56	45	46	53	55
Vilabada Road	GM8	49	57	45	40	47	33	49	48	33	40	43	46
Gampaha Hospital	GM9	58	62	50	37	47	33	41	49	42	47	52	53
Aluthgama	GM10	58	60	55	32	40	33	33	47	36	36	55	49
Miriswaththa	GM11	77	71	71	69	71	66	68	75	62	65	69	68

Table 6.2.5: 24 hourly Average Levels of PM_{2.5} at Selected location in Gampaha Urban Area

Site Name	Location Id	PM _{2.5} (µg/m ³)											
		Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
Gmpaha Police Station	GM7	-	-	-	-	-	-	-	-	-	-	40	38

The figure 6.2.2 (a) and 6.2.2 (b) presented the variation of NO₂ and SO₂ in each location within the year 2017 in Gampaha urban area. When considering both NO₂ and SO₂ concentrations it can be seen that the highest pollutant concentrations are at “Miriswaththa” area for every month. Figure 6.2.3 shows that variation of PM_{2.5} concentration in selected sample locations in Gampaha in 2017

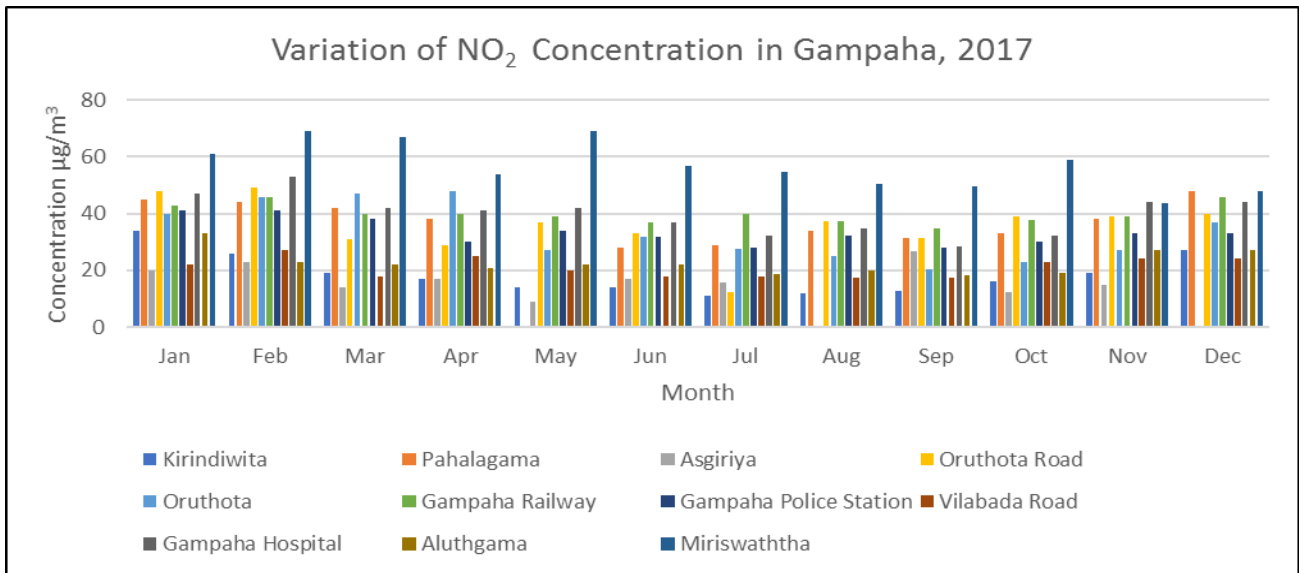


Figure 6.2.2(a): Variation of concentration of NO₂ within Gampaha Urban Area in 2017

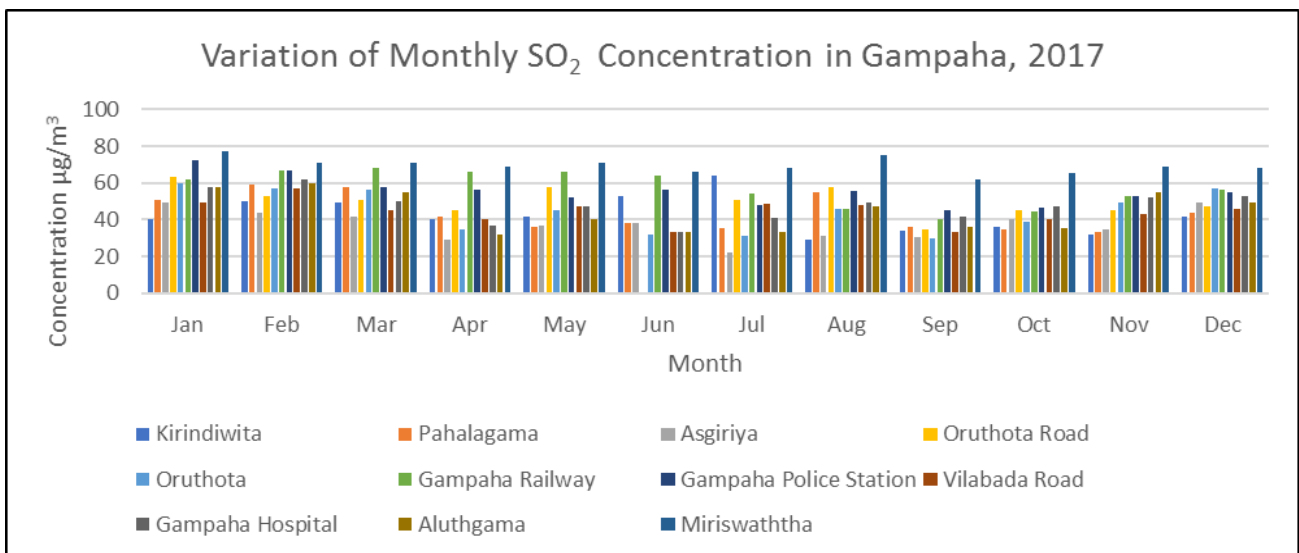


Figure 6.2.2(b): Variation of NO₂ concentration within Gampaha Urban Area in 2017

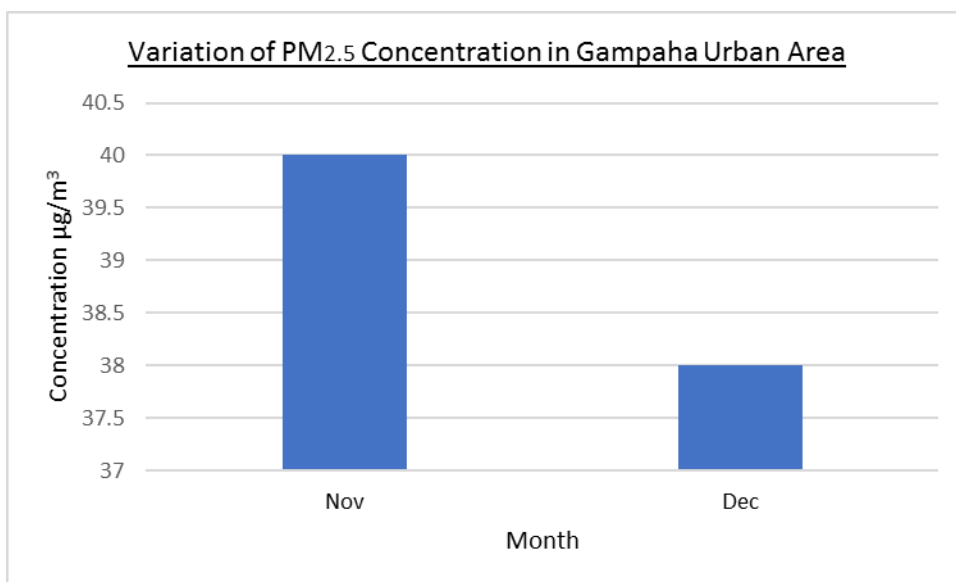


Figure 6.2.3: Variation of PM_{2.5} concentration within Gampaha Urban Area

Figure 6.2.4 and 6.2.5 represent the annual average NO₂ and SO₂ concentration levels at each sampling location in Gampaha urban area during the year 2017. The annual average NO₂ and SO₂ levels in year 2017 are in between 17µg/m³ - 57 µg/m³ and 37 µg/m³ - 69 µg/m³ respectively. The high levels are representing areas with high traffic Miriswatta (GM11), Gampaha Railway Station (GM6), Gampaha Police Station (GM7) and Gampaha Hospital Junction (GM9) where exceeded the annual WHO guideline values for NO₂ and 24 hour WHO guideline values for SO₂. Relatively low levels are recorded at locations away from the urban area such as Kiridivita (GM1) and Vilabada Road (GM8) etc.

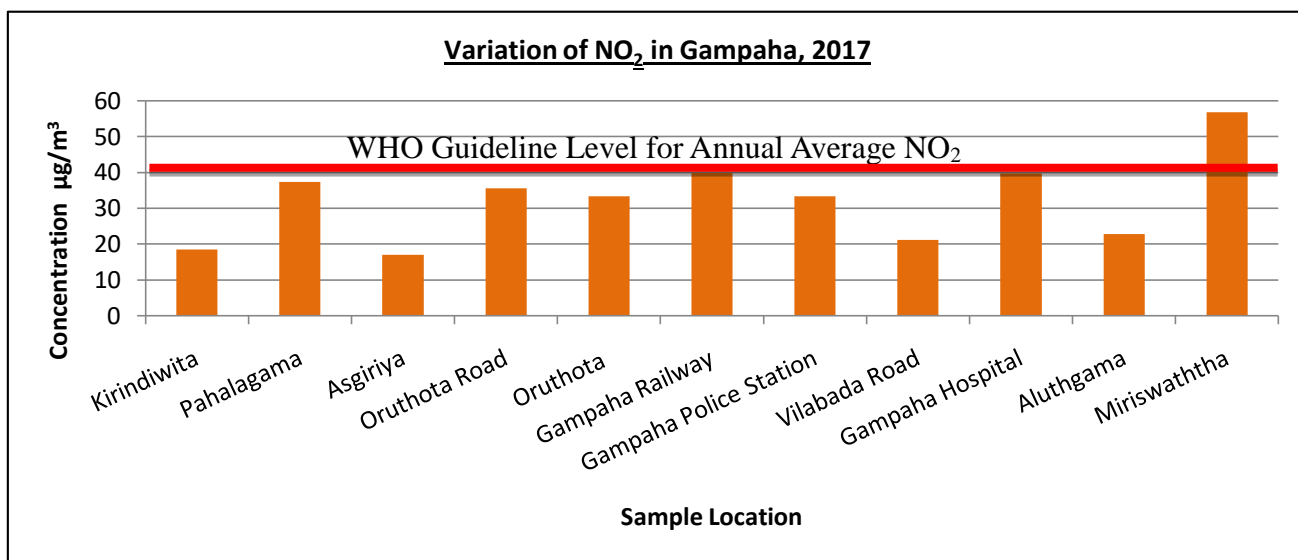


Figure 6.2.4: Annual average NO₂ concentration within Gampaha Urban Area in 2017

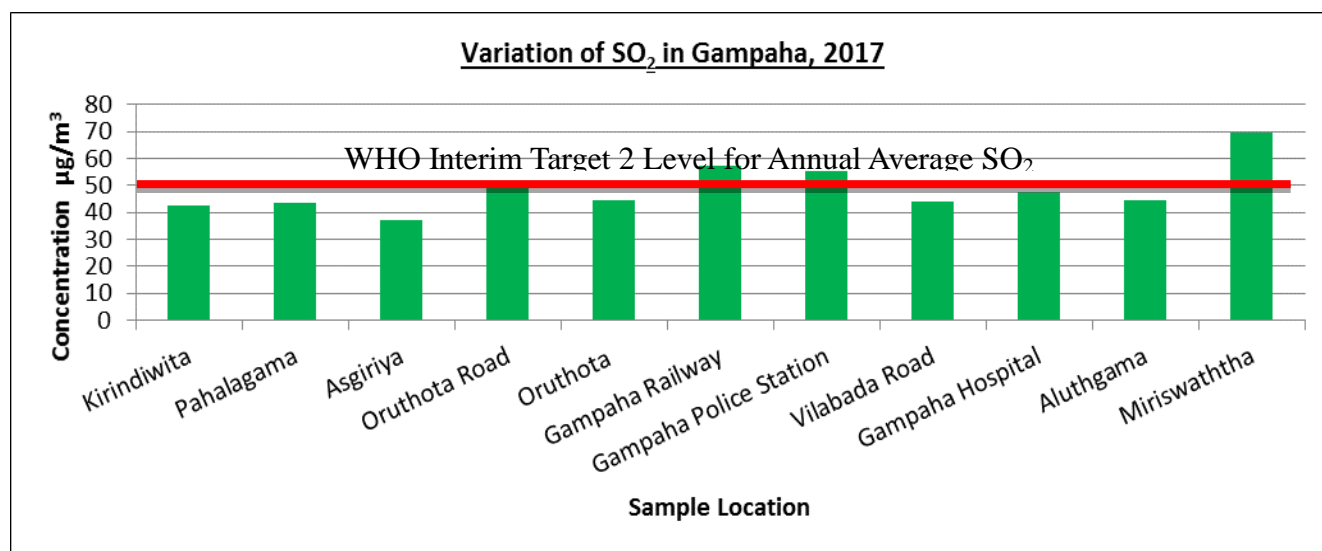


Figure 6.2.5: Annual average SO₂ concentration within Gampaha Urban Area in 2017

Annual average levels of NO₂ and SO₂ in each location at Gampaha area from 2012 to 2017 are represented in figure 6.2.6. Box plot of each pollutant for the same period are given in figure 6.2.7 & 6.2.8 respectively and spatial distribution are show in figure 6.2.9 and 6.2.10 respectively. Accordingly, the exposure levels of NO₂ are in decreasing trend while SO₂ levels are in increasing trend from 2012 to 2017. This reduction of pollutant levels in Gampaha urban area should be due to the actions implemented to manage air quality in Sri Lanka including vehicular emission control through VET program, development of road surface and removing road obstructions etc. as well as introduction of cleaner fuel vehicles such as hybrid and electric vehicles to the fleet etc.

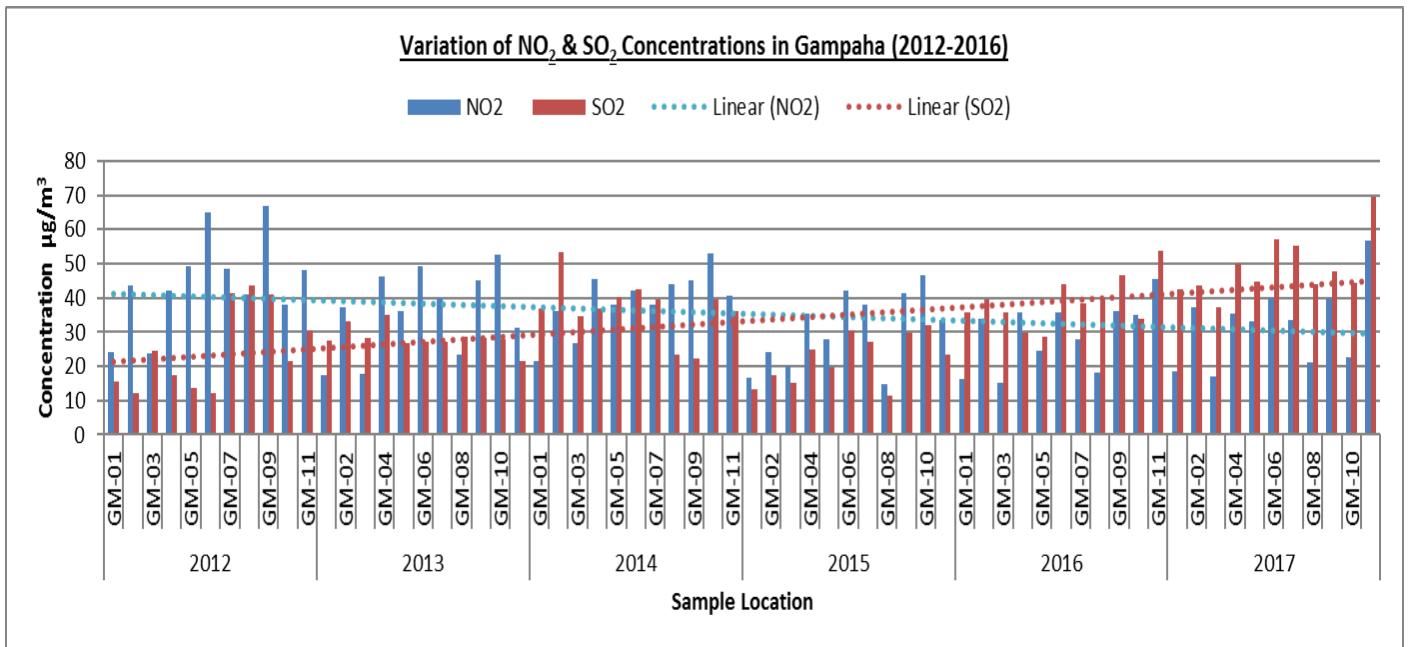


Figure 6.2.6: Average NO₂ and SO₂ variations from 2012-2017

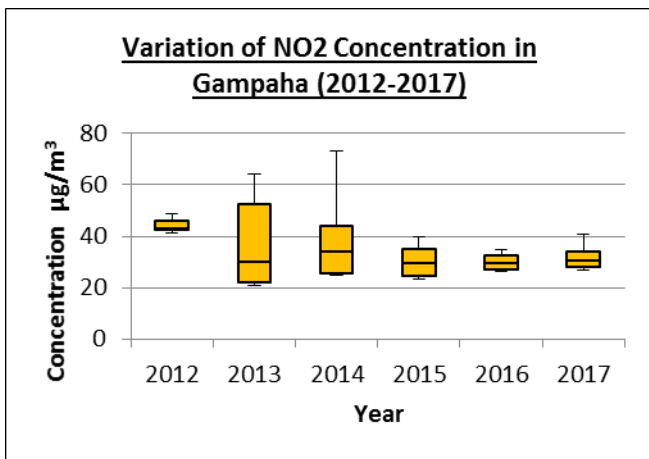


Figure 6.2.7: Boxplot of NO₂ Concentration variation in Gampaha (2012-2017)

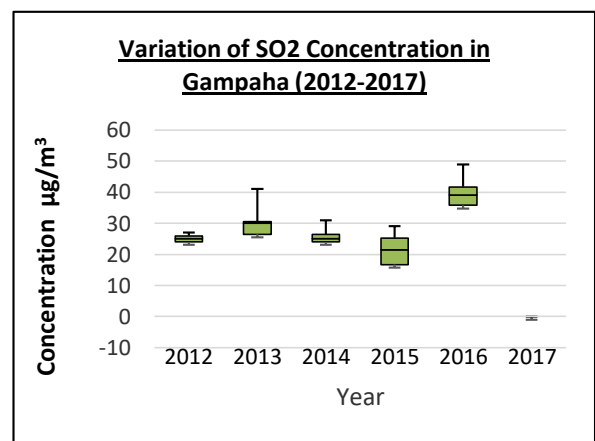


Figure 6.2.8: Boxplot of SO₂ Concentration variation in Gampaha (2012-2017)

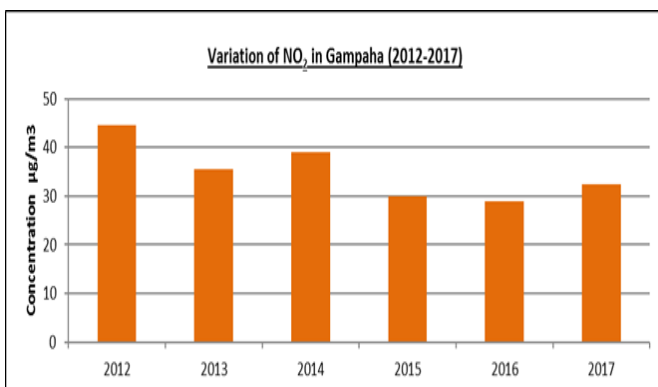


Figure 6.2.9: Annual average NO₂ variations from 2012-2017 in Gampaha Urban area

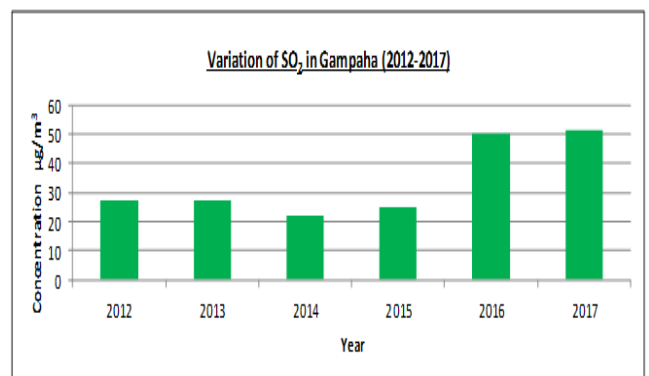
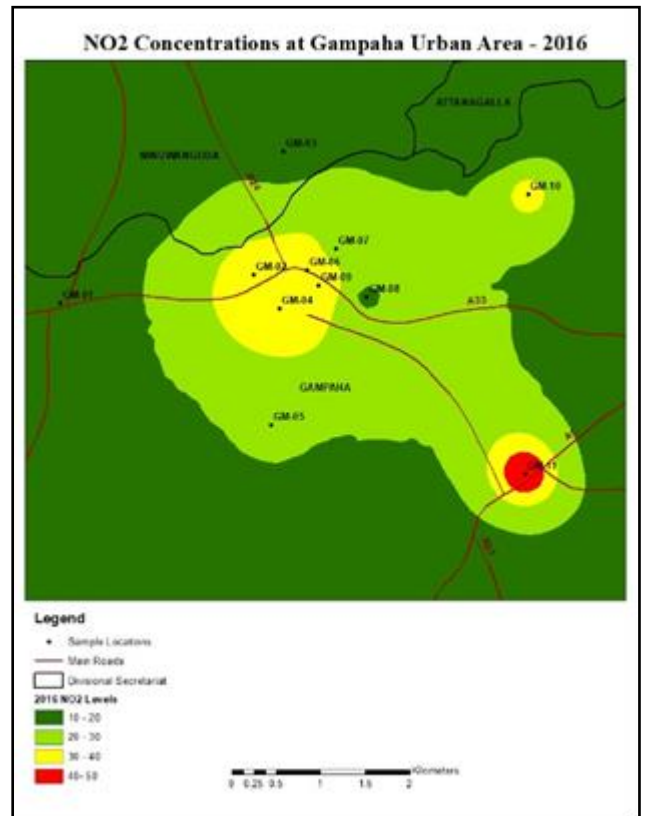
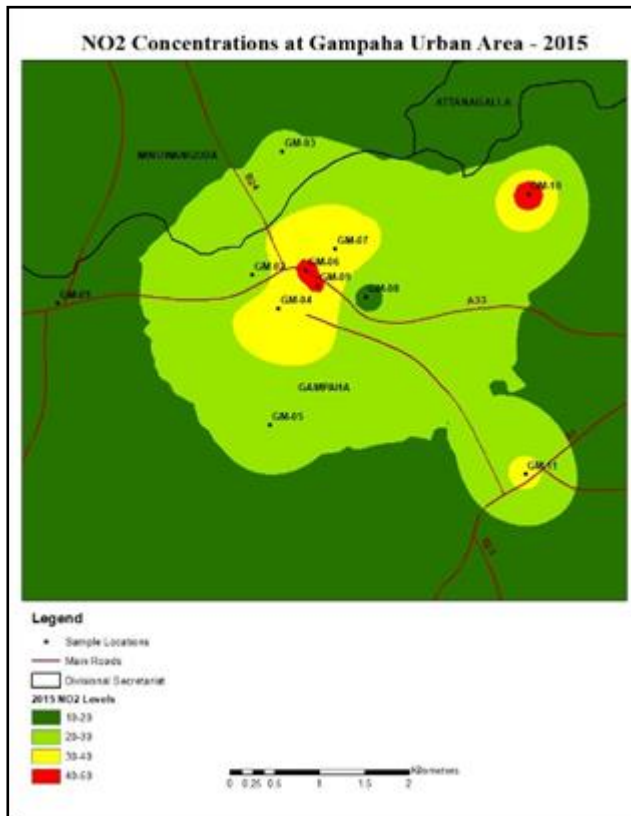
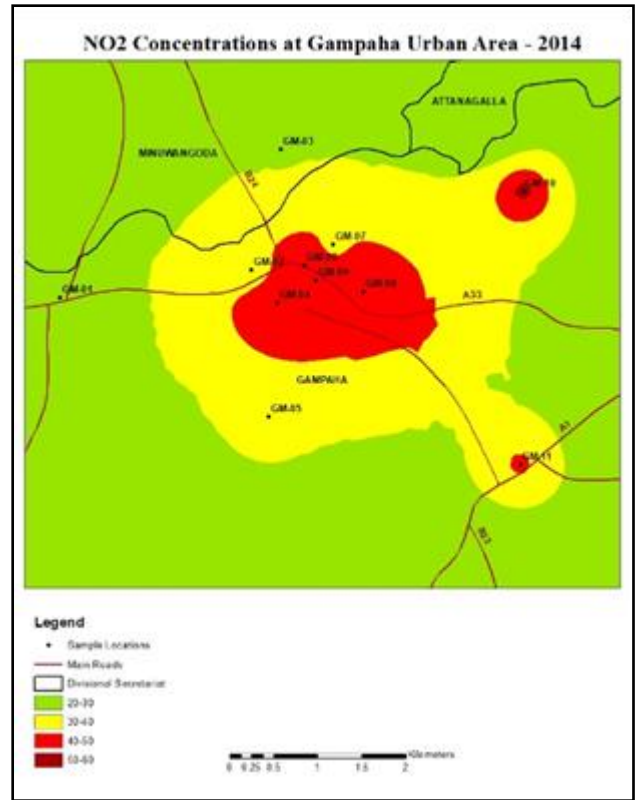
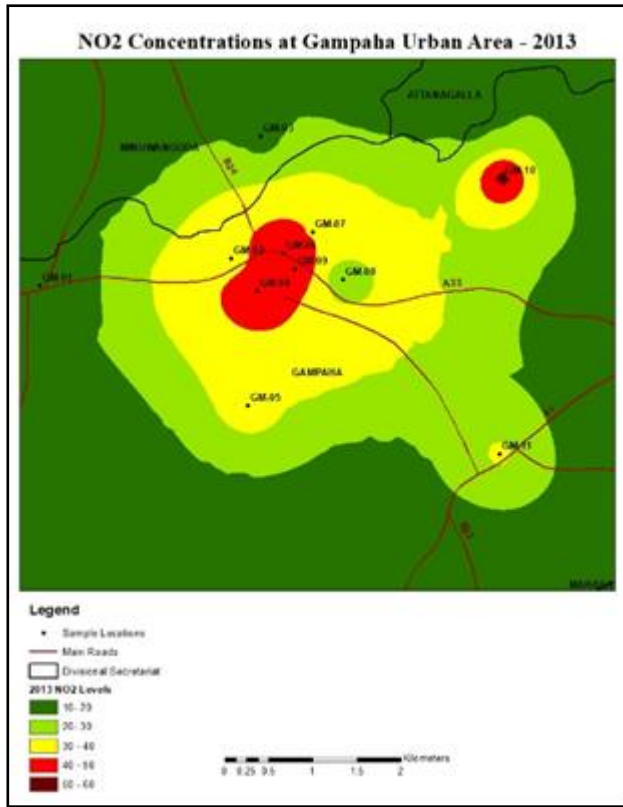


Figure 6.2.10: Annual average SO₂ variations from 2012-2017 in Gampaha Urban area



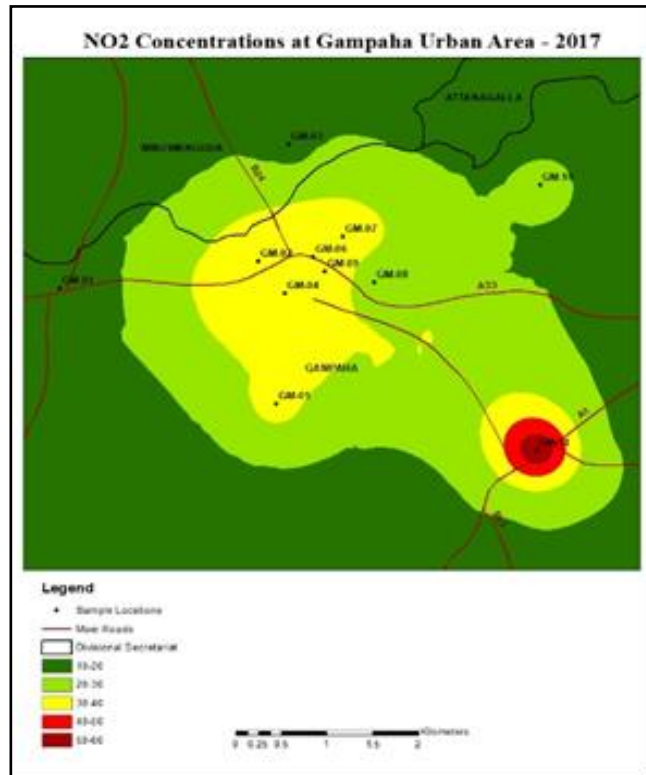
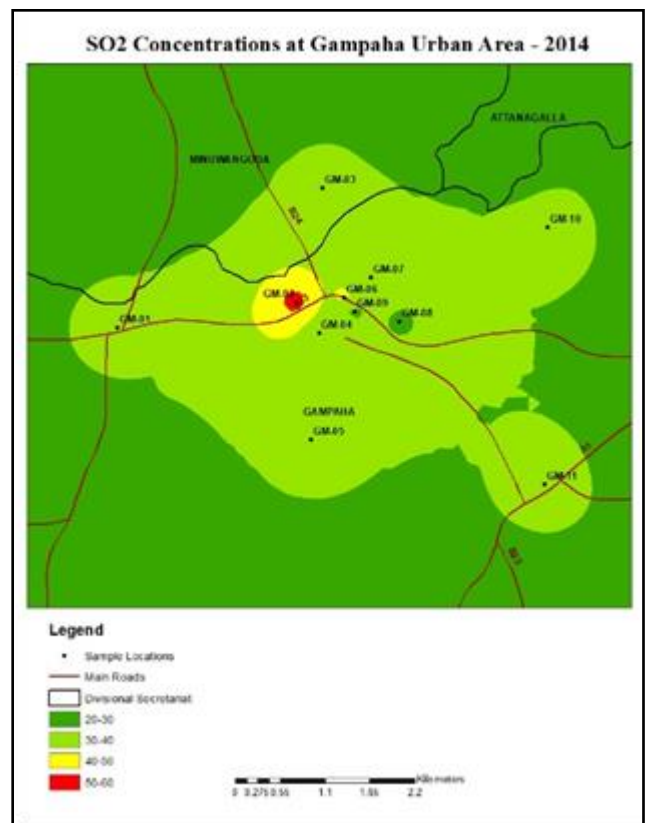
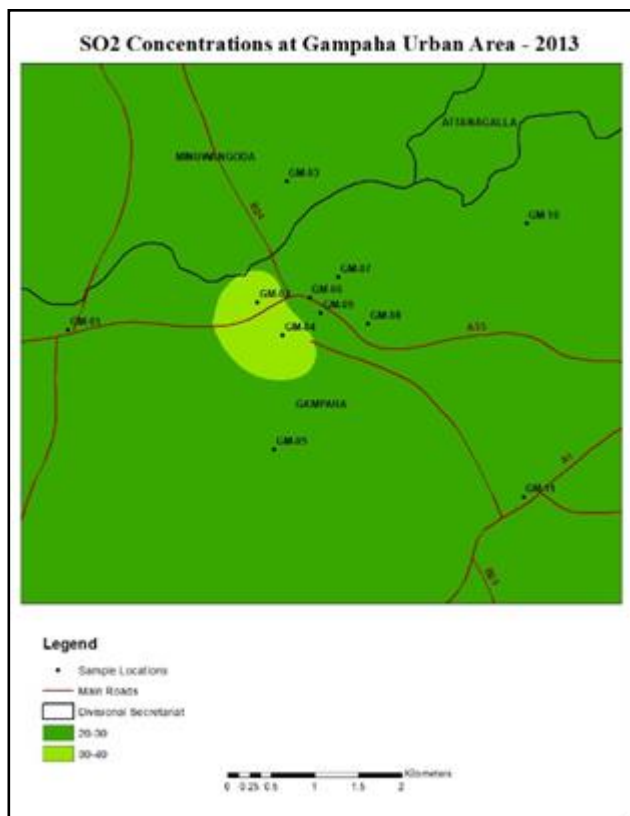


Figure 6.2.11: Variation of NO₂ concentration within Gampaha Urban Area from 2013 to 2017



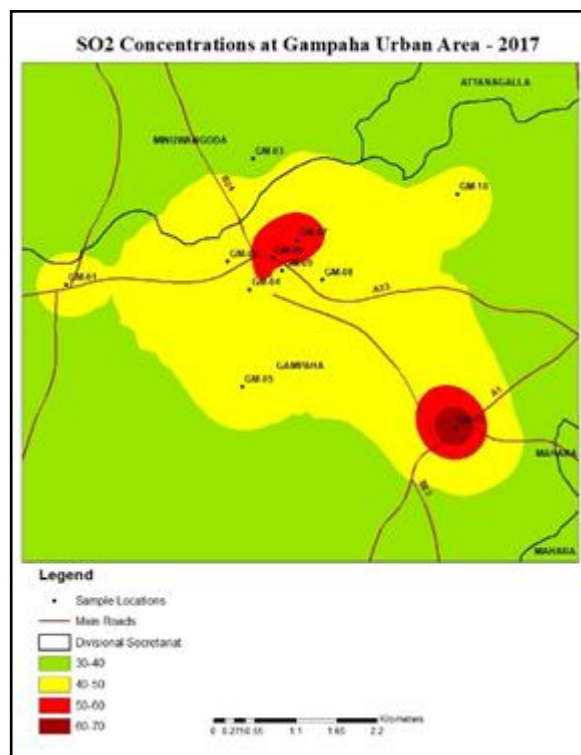
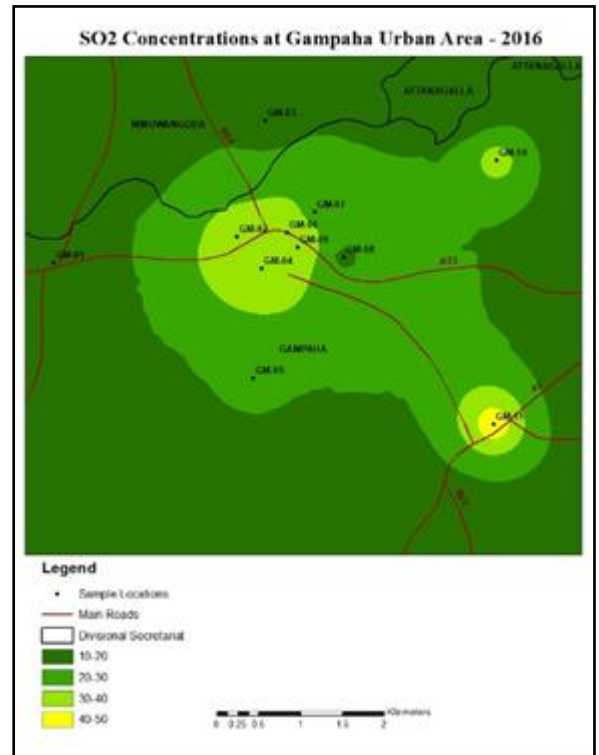
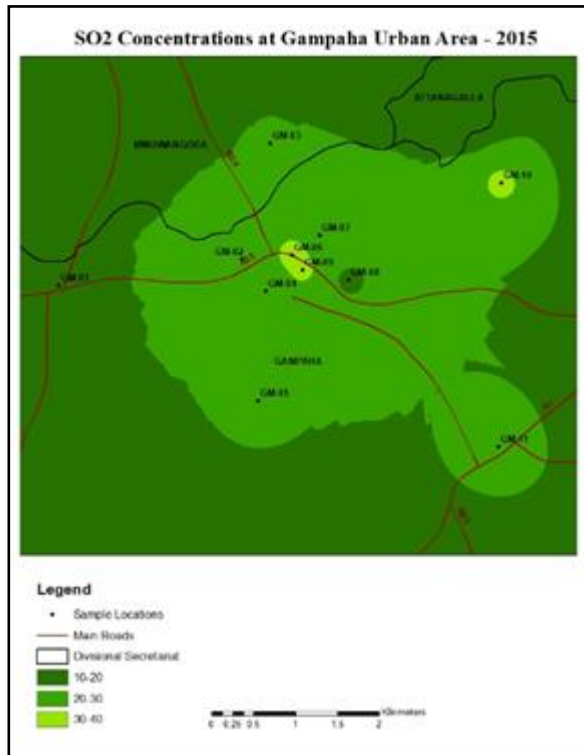


Figure 6.2.12: Variation of SO₂ concentration within Gampaha Urban Area 2013 to 2017

As an island, monsoon variation is highly influence on the dispersion and transport of the pollutants. The average NO₂ and SO₂ levels with respective to the monsoon variations are shown figure 6.2.13 and 6.2.14 respectively. It indicates that at the levels are highly subjective to the local wind condition. Most of locations, high exposure levels are recorded in

during North-East monsoon period (November – February) compared to South-West monsoon period (May-August). The pattern was changed at some locations depending on the localised wind pattern.

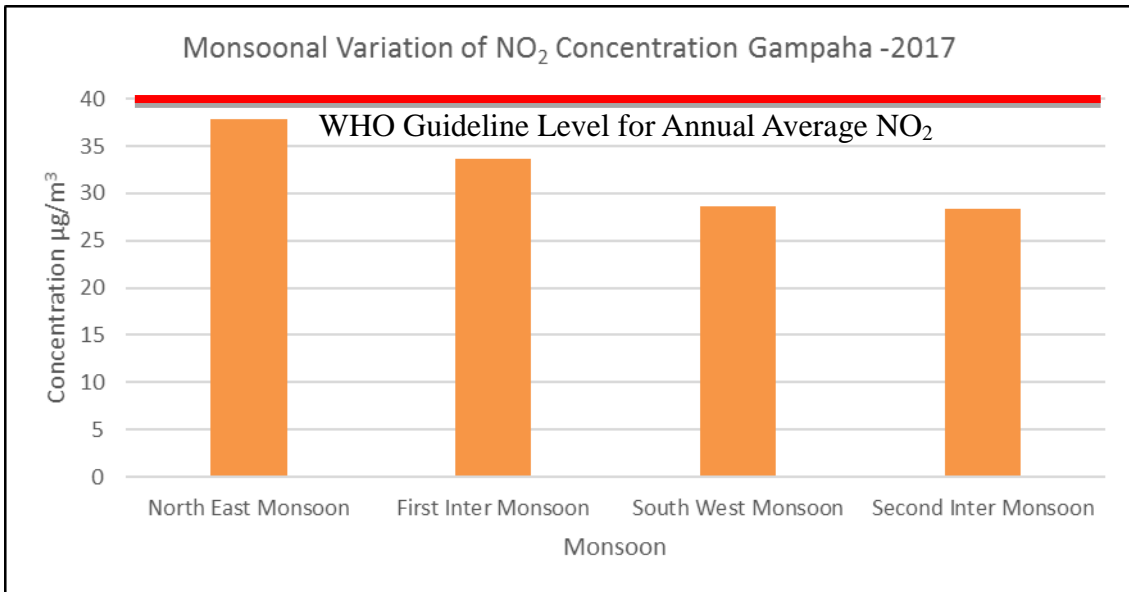


Figure 6.2.13: Variation of NO₂ Concentration due to monsoon seasons at Gampaha urban area in 2017

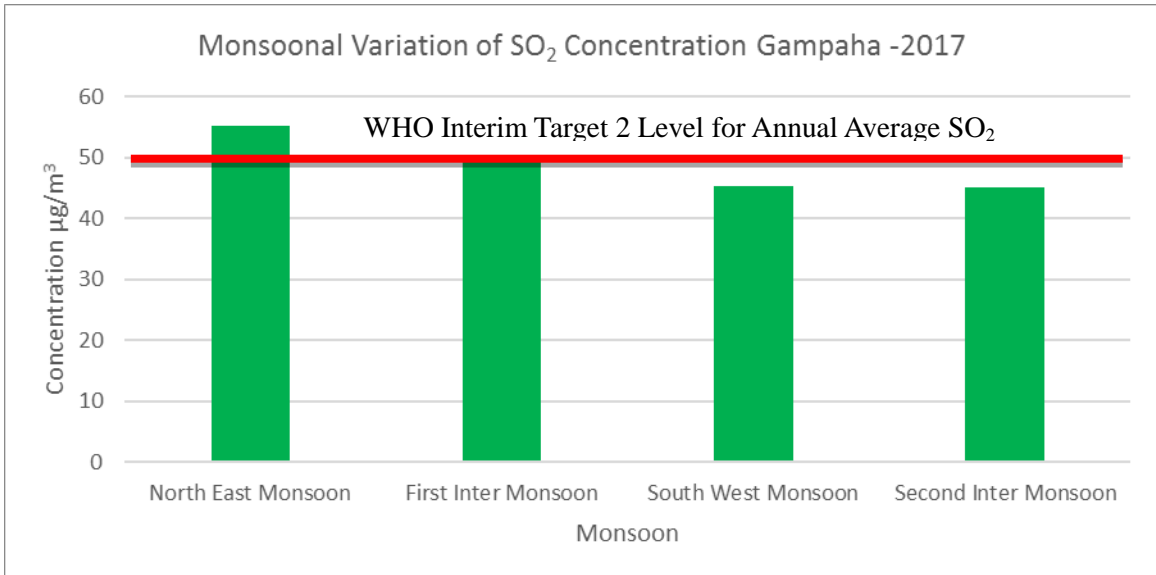
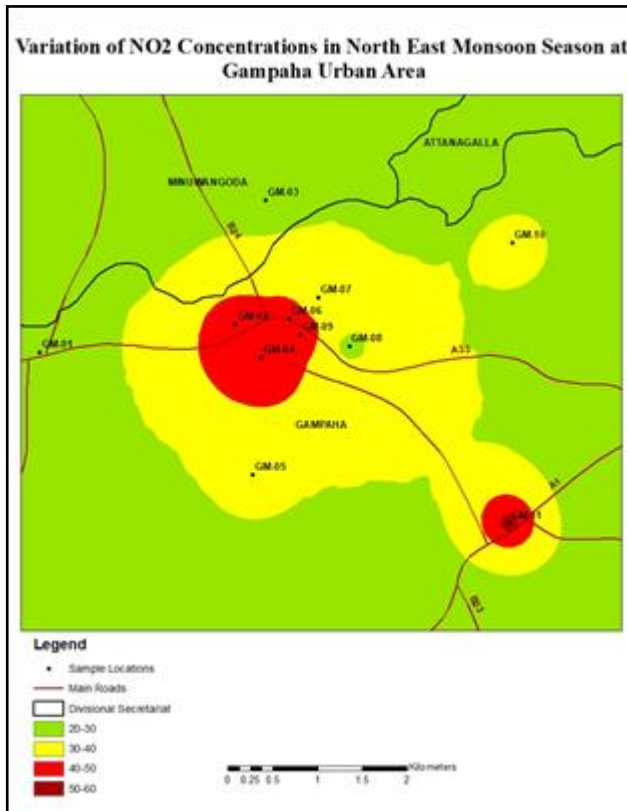
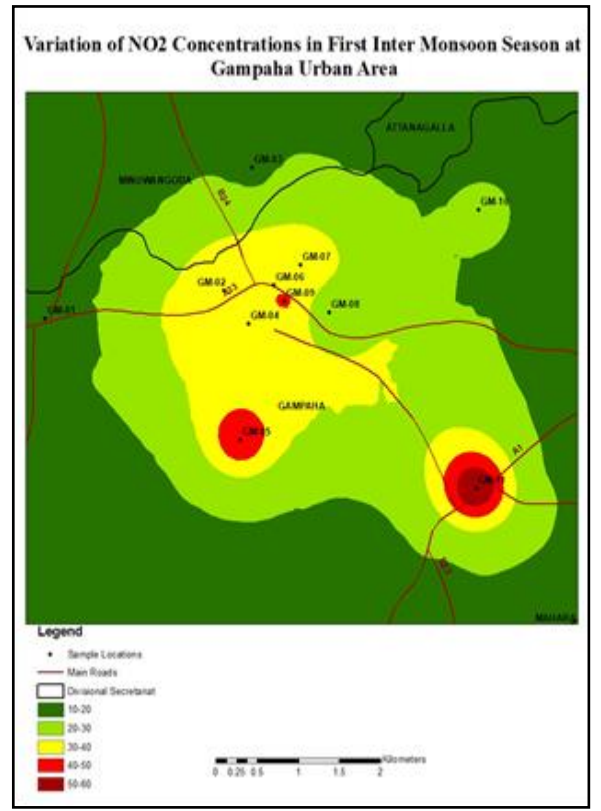


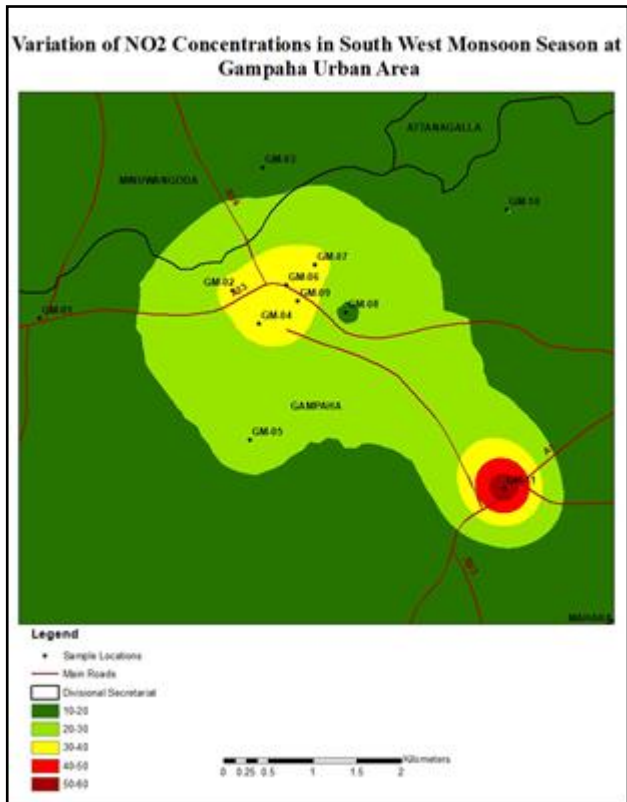
Figure 6.2.14: Variation of SO₂ Concentration due to monsoon seasons at Gampaha urban area in 2017



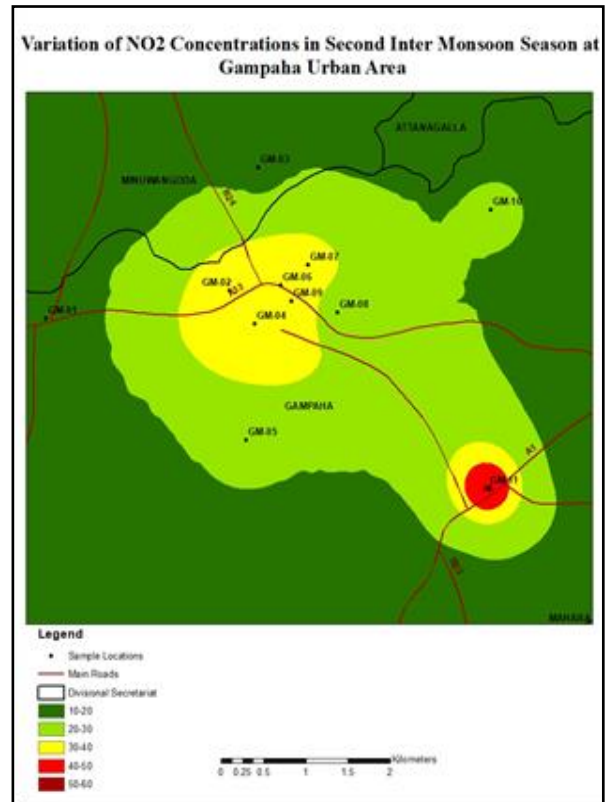
(a)



(b)

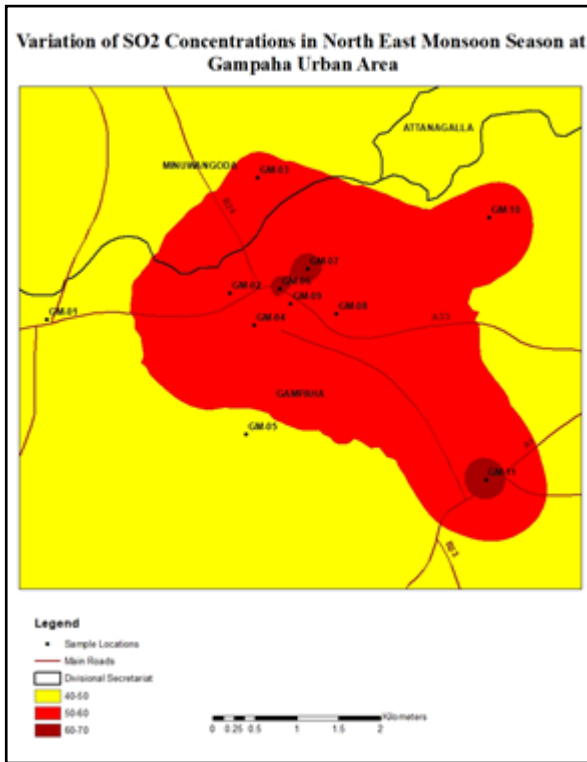


(c)

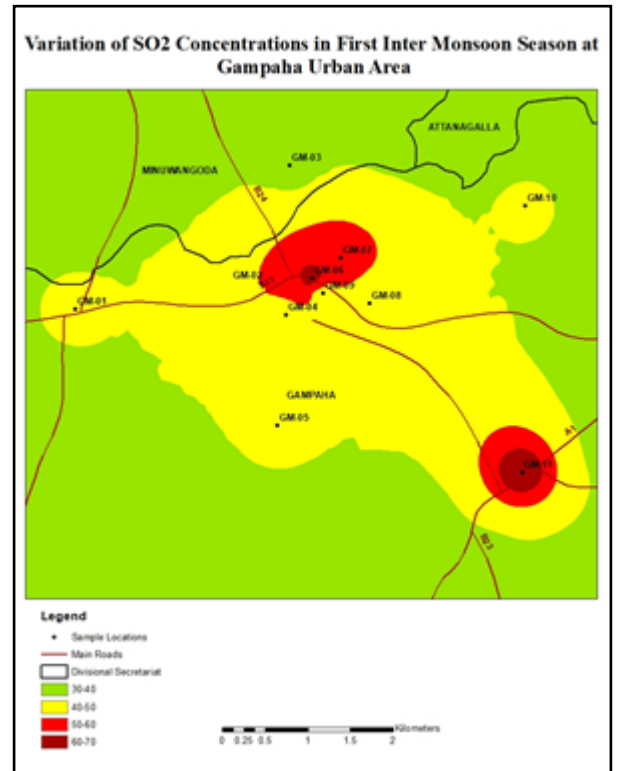


(d)

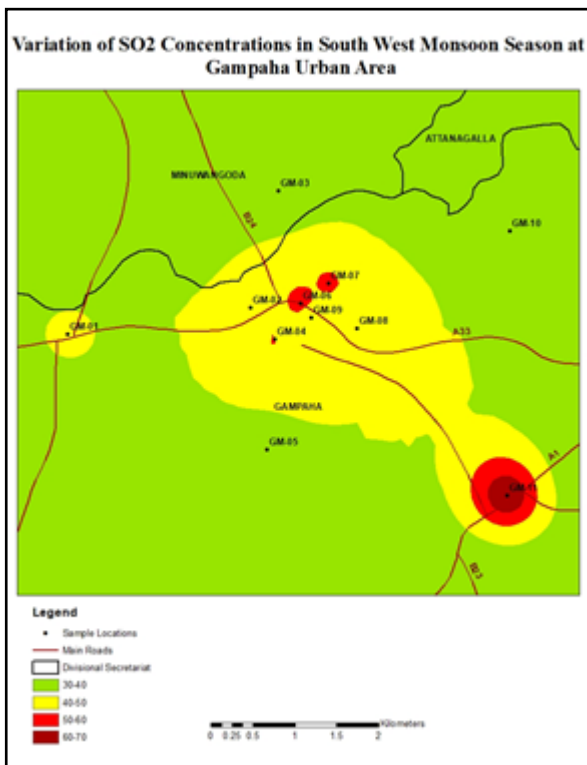
Figure 6.2.15: Variation of NO₂ exposure levels due to monsoon seasons at Gampaha Urban City in 2107. (a)North East Monsoon (b)First Inter Monsoon (c)South West Monsoon (d)Second Inter Monsoon.



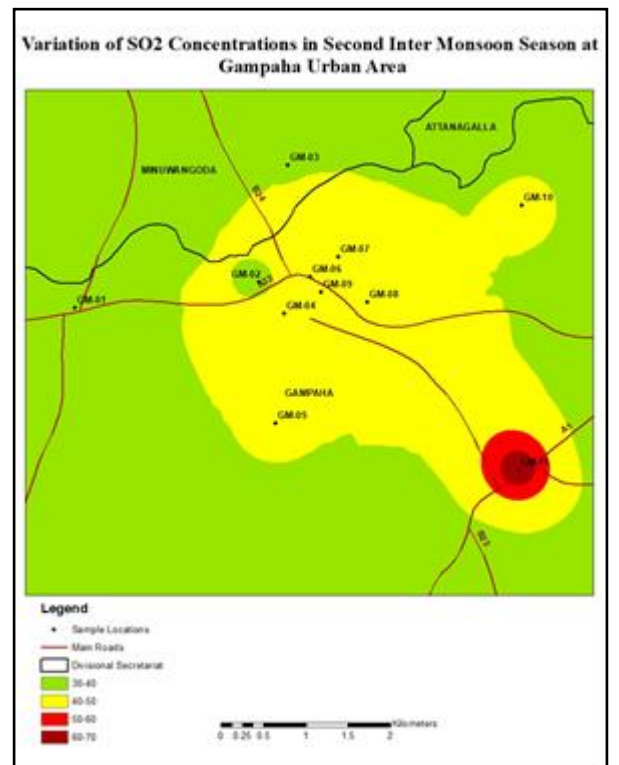
(a)



(b)



(c)



(d)

Figure 6.2.16: Variation of SO₂ exposure levels due to monsoon seasons at Gampaha Urban City in 2107. (a)North East Monsoon (b)First Inter Monsoon (c)South West Monsoon (d)Second Inter Monsoon.

6.3 AMBIENT AIR QUALITY IN 2017 – AT KALUTARA URBAN AREA

Kalutara is the largest city in Kalutara District, Western Province, Sri Lanka. It is also the administrative capital of Kalutara District. It is located approximately 40 km (25 miles) south of the capital Colombo.

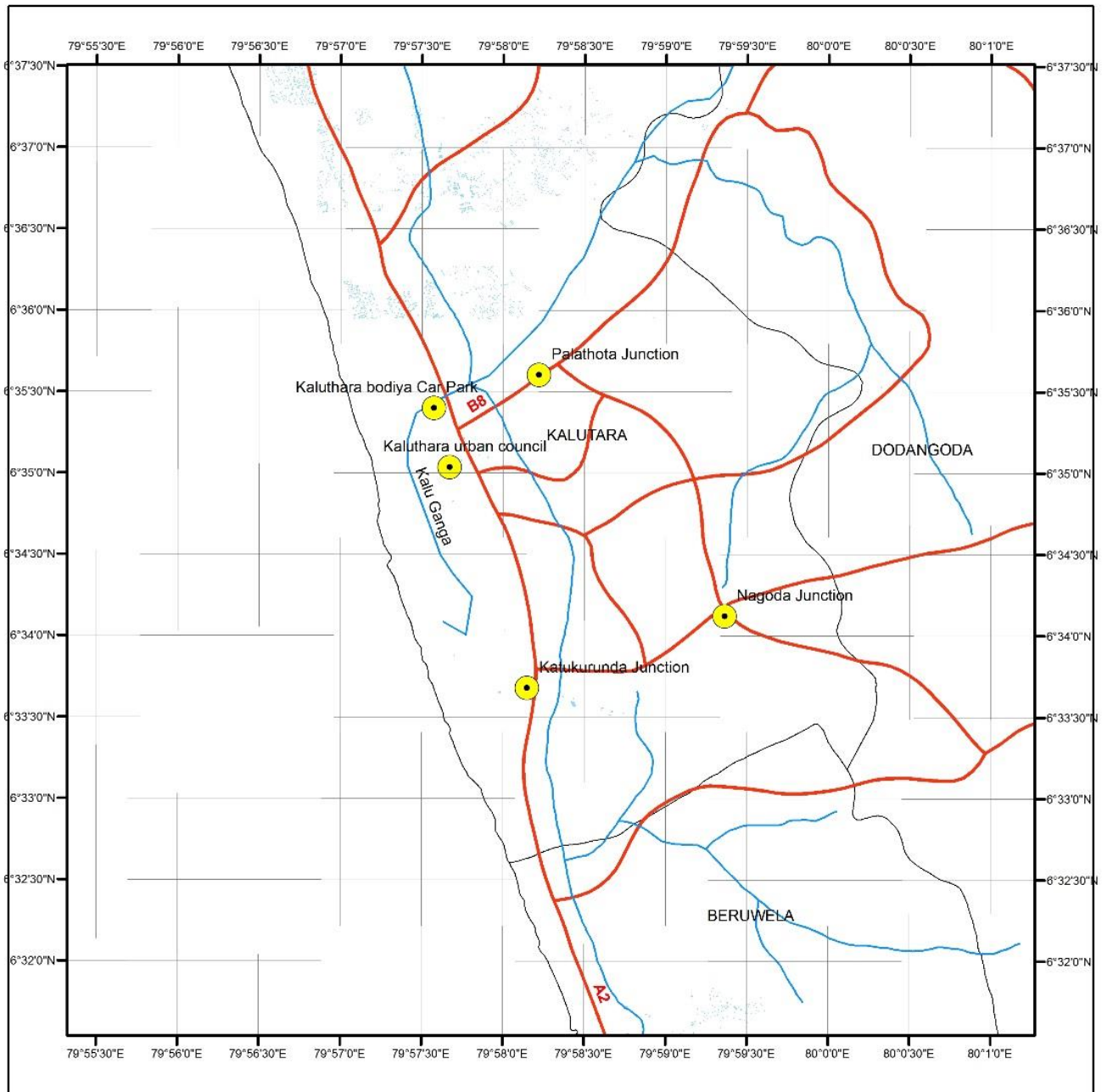
Air quality exposure levels with respect to NO₂ and SO₂ in Kalutara Urban area was started in 2012 at 5 Locations within the Kalutara Municipal Council and surrounding areas with the financial assistant of VET fund. The monitoring program was continued in 2017 to measure monthly average NO₂ and SO₂ level. The monthly average NO₂ and SO₂ exposure levels at each measuring location within Kalutara urban area in 2017 is summarised in table 6.3.3 and 6.3.4 respectively.

Air quality exposure levels measuring activities with respect to NO₂ and SO₂ in Kalutara Urban area were continued in 2016 as well under this project. The sample locations description is given in table 6.3.1 and figure 6.3.2 shows the locations map. The table 6.3.1 presents the overview of each location in the Kalutara urban area.

Table 6.3.1: Selected Sampling Locations in Kalutara Urban area

Urban Area	No of Points	Sampling Location	Location Description
Kalutara	5	KL1	Kaluthara Bodiya Car Park
		KL2	Palathota Junction
		KL3	Nagoda Junction
		KL4	Katukurunda Junction
		KL5	Kaluthara urban council

Sample Locations at Kalutara Urban Area



0 0.75 1.5 3 Kilometers

Legend

- Sample_Locations
- Streams
- Road
- Buildings
- Kalutara



Figure 6.3.1: Sampling Locations Map in Kalutara Urban area

Table 6.3.2: Overview of each location in the Kalutara urban area



Location No: KL1
 Location Name: Kalutara
 Bodhiya Car Park
 GPS Coordinates: 6.5899890N,
 79.9595960E



Location No: KL2
 Location Name: Palathota
 Junction
 GPS Coordinates:
 6.5933790N,
 79.9703360E



Location No: KL3
 Location Name: Nagoda
 Junction
 GPS Coordinates:
 6.5686880N,
 79.9893720E



Location No: KL4
 Location Name: Katukurunda
 Junction
 GPS Coordinates:
 6.5613240N,
 79.9691410E



Location No: KL5
 Location Name: Urban
 Council.
 GPS Coordinates:
 6.5839210N,
 79.9611970E

Monthly average NO₂ and SO₂ exposure levels at each measuring location within Kalutara urban area for the year 2017 is summarised in table 6.3.3 and 6.3.4 respectively. Table 6.3.5 shows that PM_{2.5} concentration of selected sample location in Kalutara in 2017.

Table 6.3.3: Monthly Average Exposure Levels of NO₂ at each location in Kalutara Urban Area

Urban Area	Location	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
Kaluthara Bodiya Car Park	KL1	41	30	31	26	17	26	27	23	20	30	31	31
Palathota Junction	KL2	33	32	26	23	19	18	18	19	15	21	30	37
Nagoda Junction	KL3	24	25	20	-	29	16	19	14	15	22	23	25
Katukurunda Junction	KL4	56	57	44	47	33	34	20	26	32	41	42	46
Kaluthara urban council	KL 5	52	56	51	45	33	37	-	-	21	41	46	56

Table 6.3.4: Monthly Average Exposure Levels of SO₂ at each location in Kalutara Urban Area

Urban Area	Location	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
Kaluthara Bodiya Car Park	KL 1	35	43	42	32	45	55	35	24	42	48	32	34
Palathota Junction	KL 2	37	36	33	39	32	34	27	26	29	34	21	38
Nagoda Junction	KL 3	47	41	38	35	-	36	24	23	26	44	23	39
Katukurunda Junction	KL 4	49	44	43	43	35	31	39	23	19	27	26	45
Kaluthara urban council	KL 5	49	48	44	42	49	46	-	38	20	28	24	38

Table 6.3.5: 24-hourly Average Levels of PM_{2.5} at Selected location in Kalutara Urban Area

City & Site	Location	PM _{2.5} (µg/m ³)											
		Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
Kalutara - Police Station	KL 5	-	-	-	-	-	-	-	-	-	-	32	27

The figure 6.3.2(a) and 6.3.2(b) present the variation of NO₂ and SO₂ in each location within the year 2017 in Kalutara Urban Area. It indicates that at the levels are highly subjective to the wind condition. At most of locations, high exposure levels are recorded in during North-East monsoon period (December – February) compared to South-West monsoon period (May-September). The pattern was changed at some locations depending on the localised wind pattern. Figure 6.3.3 shows that variation of PM_{2.5} concentration in selected sample locations in Kalutara in 2017.

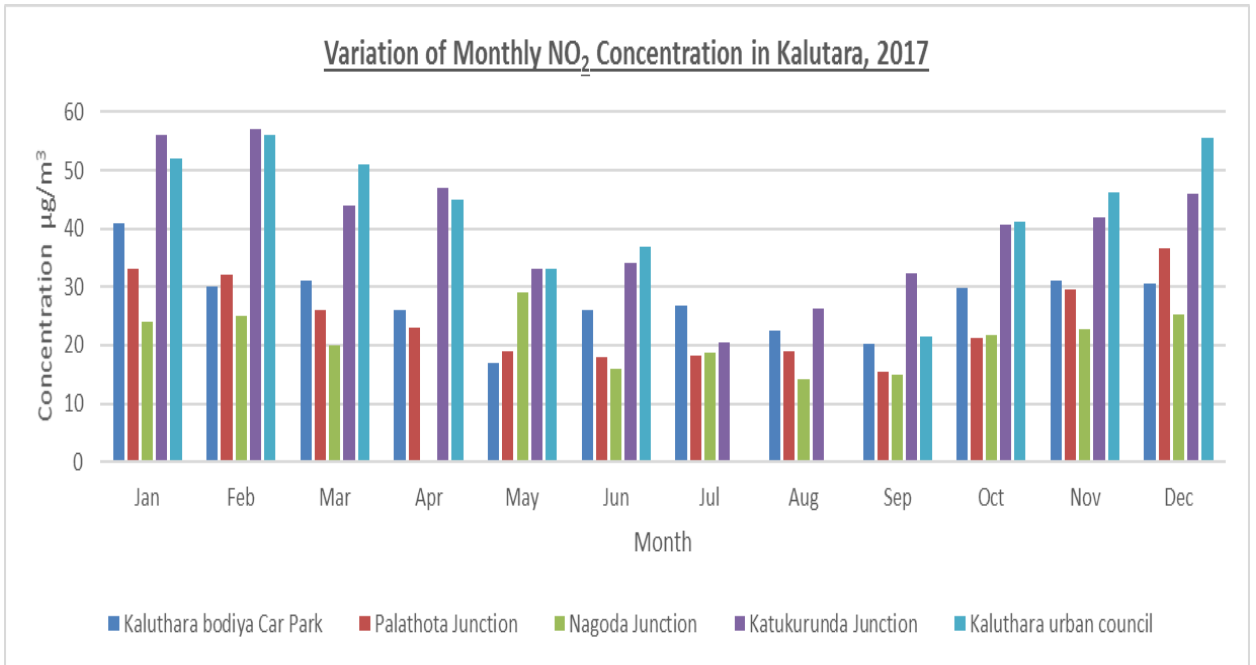


Figure 6.3.2 (a): Variation of NO₂ concentration within Kalutara Urban Area in 2017

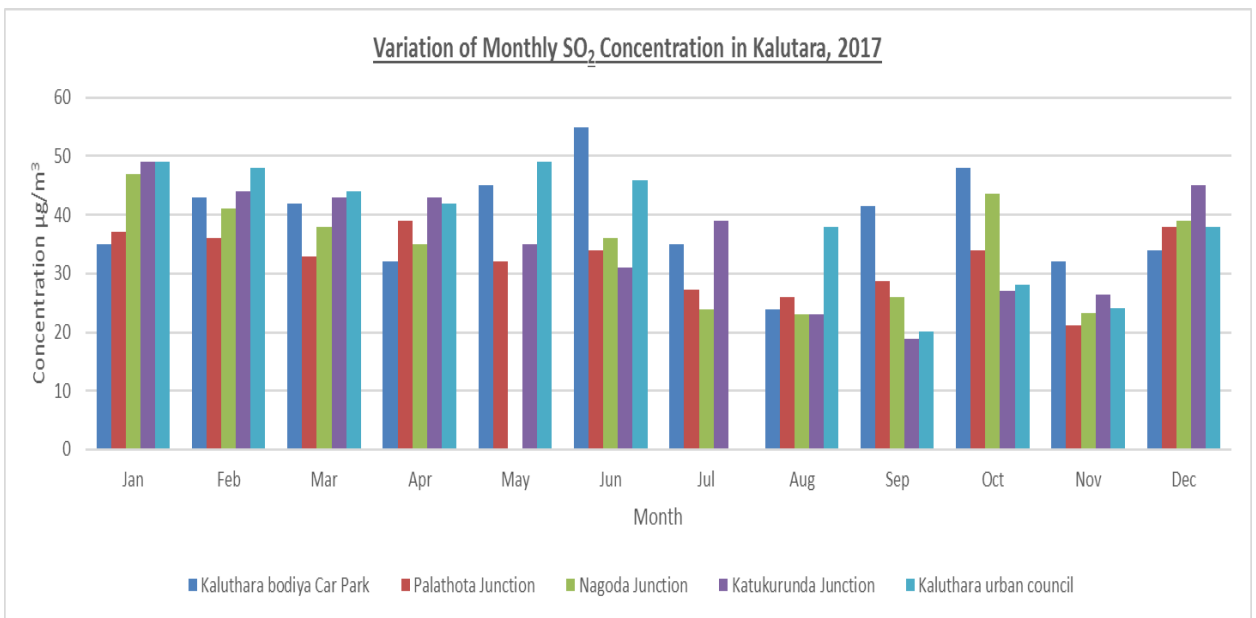


Figure 6.3.2 (b): Variation of SO₂ concentration within Kalutara Urban Area in 2017

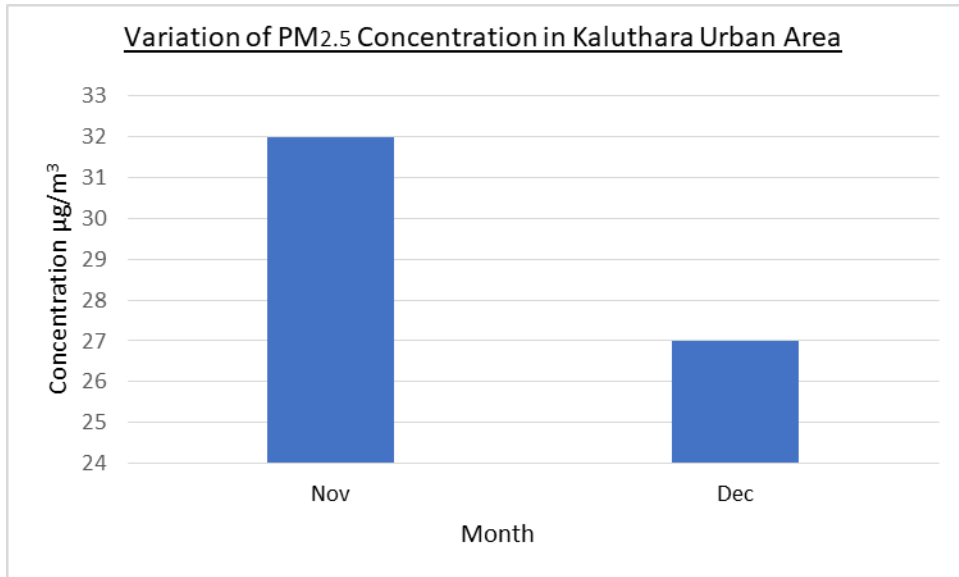


Figure 6.3.3: Variation of PM_{2.5} concentration within Kalutara Urban Area

Figure 6.3.4 and 6.3.5 represent the annual average NO₂ and SO₂ concentration levels at each sampling location in Kalutara urban area during the year, 2017. The annual average NO₂ and SO₂ levels in year 2017 are in between 21 $\mu\text{g}/\text{m}^3$ - 44 $\mu\text{g}/\text{m}^3$ and 32 $\mu\text{g}/\text{m}^3$ - 39 $\mu\text{g}/\text{m}^3$ respectively. The high levels are represented areas with high traffic areas such as Katukurunda Junction (KL4) and Kalutara City area (KL5) where reached or exceeded the annual WHO guideline values for NO₂ and 24 hour WHO guideline values for SO₂. Relatively low levels are recorded at locations away from the urban area such as Palathota Junction (KL2) and Nagoda Junction (KL3) etc.

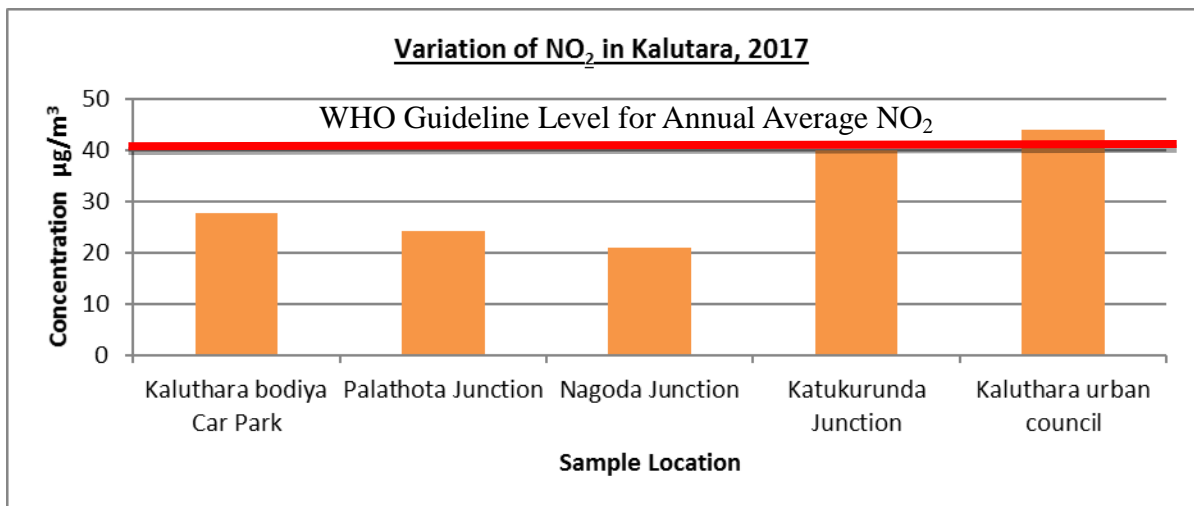


Figure 6.3.4: Annual average NO₂ concentration within Kalutara Urban Area in 2017

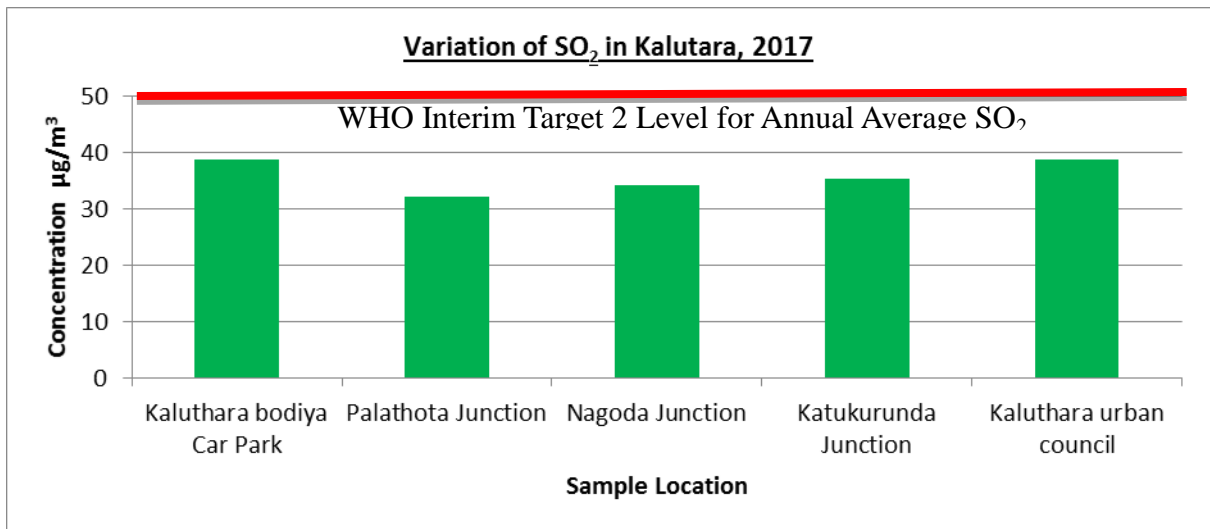


Figure 6.3.5: Annual average SO₂ concentration within Kalutara Urban Area in 2017

Annual average levels of NO₂ and SO₂ in each location at Kalutara area from 2012 to 2017 are represents in figure 6.3.6 and boxplot of each pollutant for the same period are given in figure 6.3.7 and 6.3.8 respectively. Accordingly, the annual exposure levels of NO₂ were in decreasing trend from 2012 to 2016 while 2017 has slight increment than 2016. SO₂ levels were in increasing trend from 2012 to 2016 while 2017 has slight decrement than 2016. This reduction of pollutant levels in Kalurata urban area should be due to the actions implemented to manage air quality in Sri Lanka including vehicular emission control through VET program and development of road surface etc. as well as introduction of cleaner fuel vehicles such as hybrid and electric vehicles to the fleet etc.

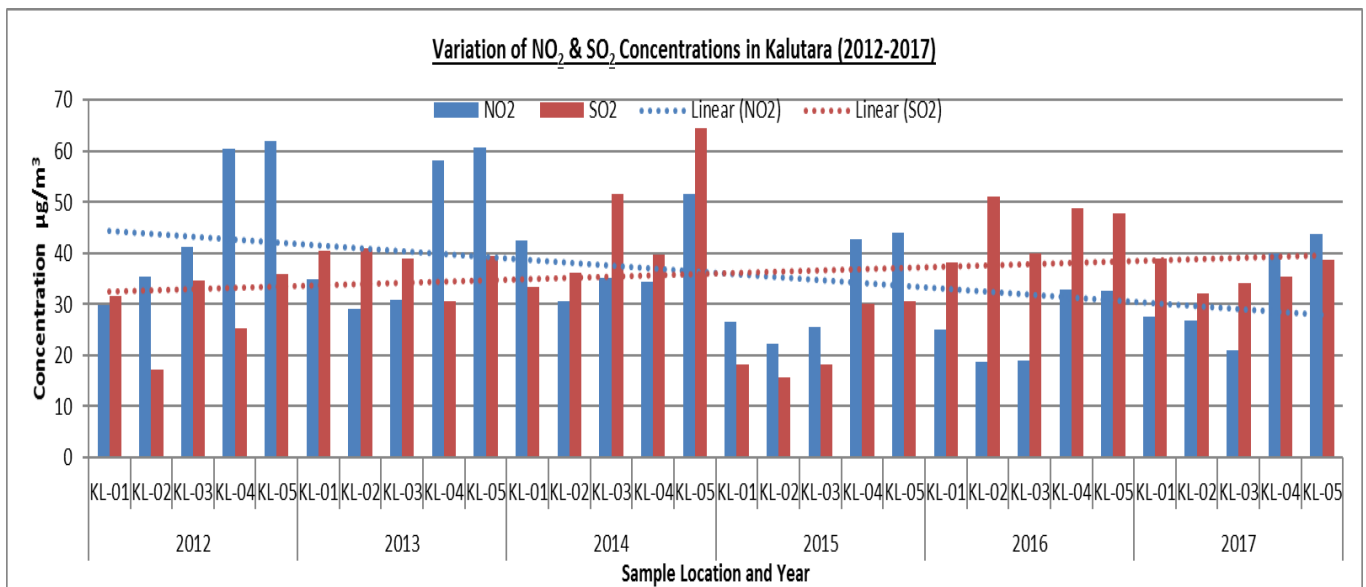


Figure 6.3.6: Average NO₂ and SO₂ variations from 2012-2017

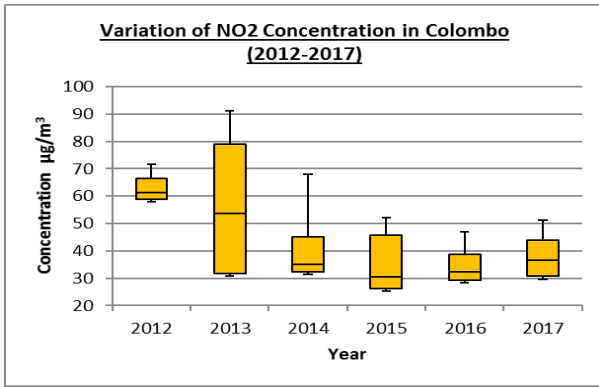


Figure 6.3.7: Boxplot of NO₂ Concentration variation in Kalutara 2012-2017

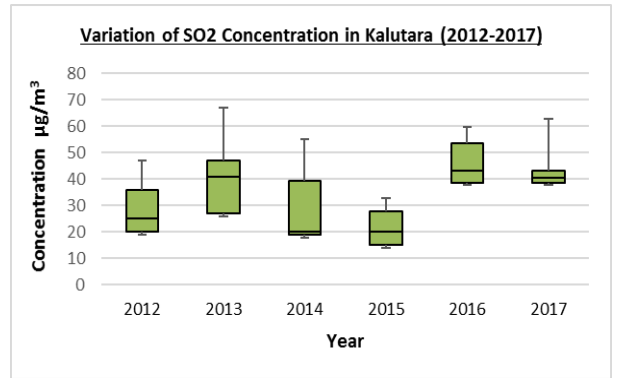


Figure 6.3.8: Boxplot of SO₂ Concentration variation in Kalutara 2012-2017

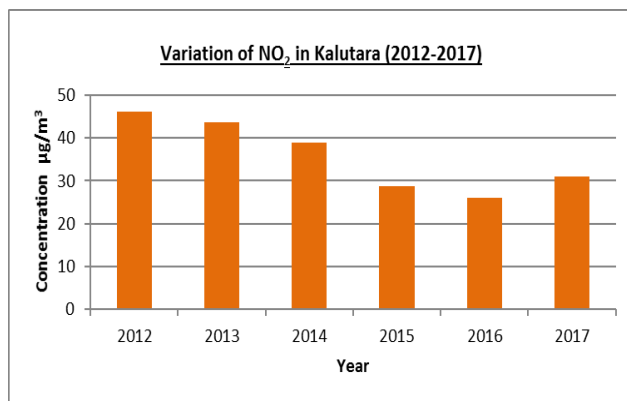


Figure 6.3.9: Annual average NO₂ variations from 2012-2017 in Kalutara Urban Area

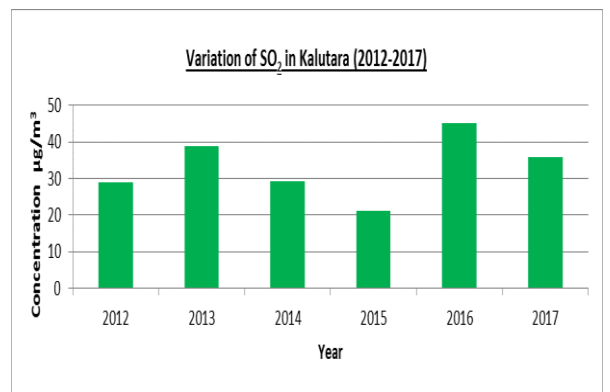
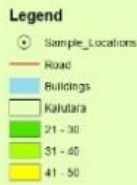
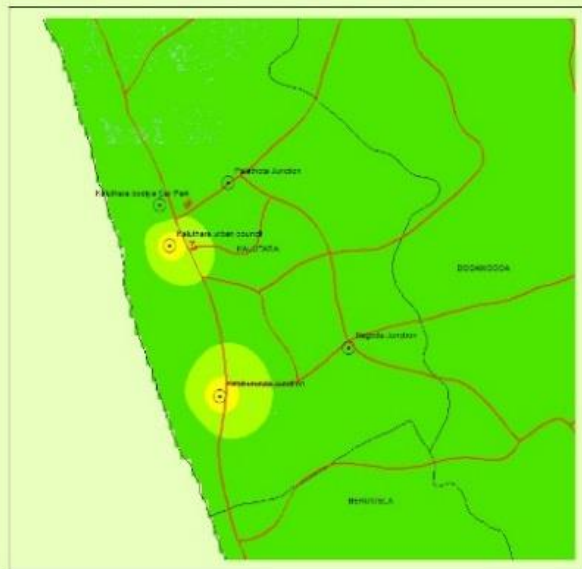


Figure 6.3.10: Annual average SO₂ variations from 2012-2017 in Kalutara Urban Area

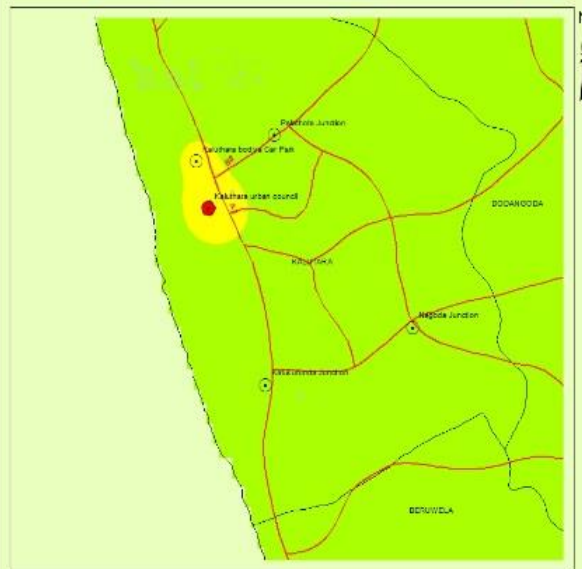
Annual geographical variation of NO₂ exposure has shown below from 2012 to 2017 in Colombo urban city in figure 6.3.11 and the same variation for SO₂ exposure has shown below from figures 6.3.12.

Variation of NO2 Concentration at Kalutara Urban Area in 2013



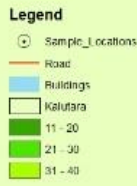
National Building Research Organisation
Ministry of Disaster Management

Variation of NO2 Concentration at Kalutara Urban Area in 2014



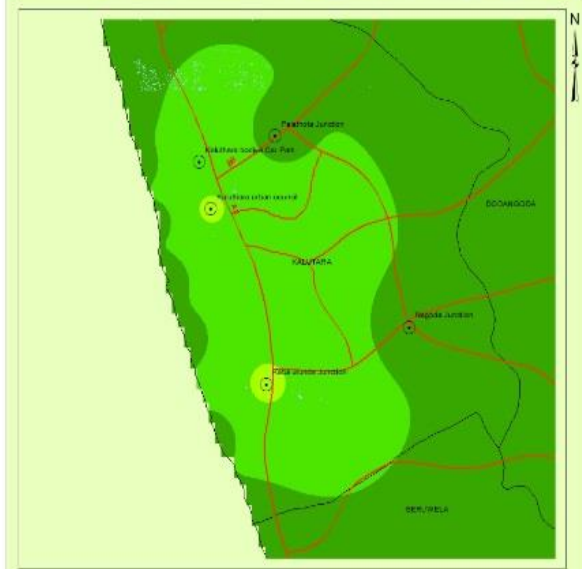
National Building Research Organisation
Ministry of Disaster Management

Variation of NO2 Concentration at Kalutara Urban Area in 2015



National Building Research Organisation
Ministry of Disaster Management

Variation of NO2 Concentration at Kalutara Urban Area in 2016



National Building Research Organisation
Ministry of Disaster Management

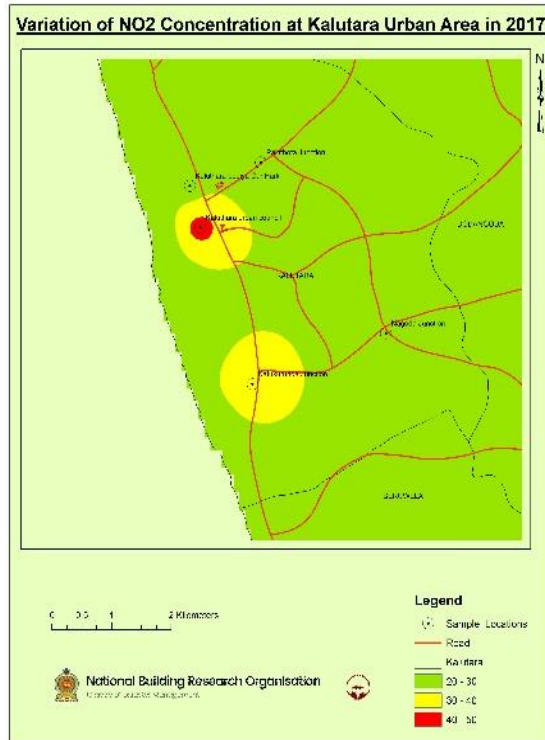
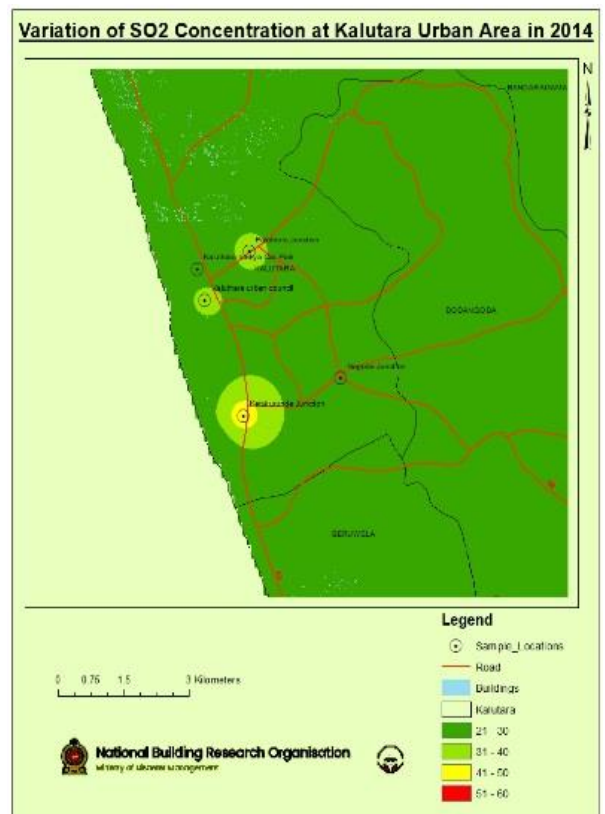
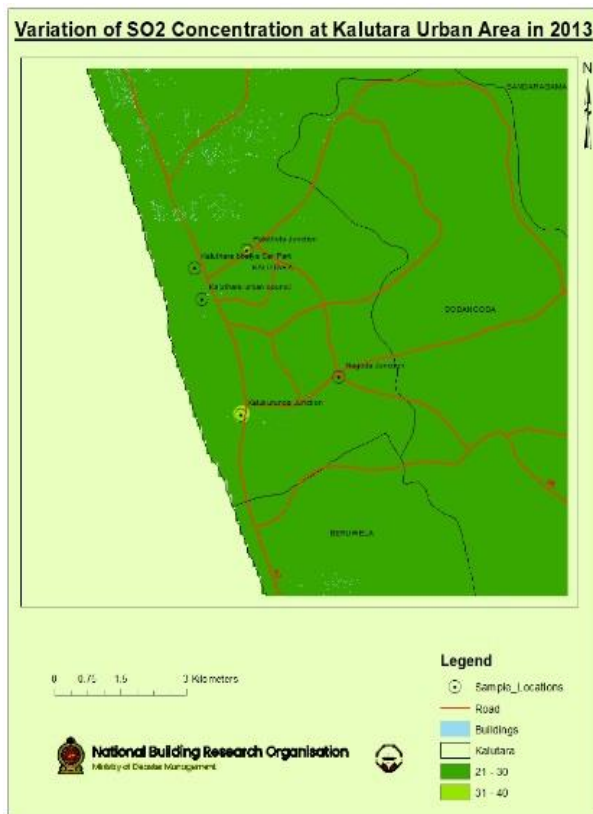


Figure 6.3.11: Variation of NO₂ concentration within Kalutara Urban Area from 2013 to 2017



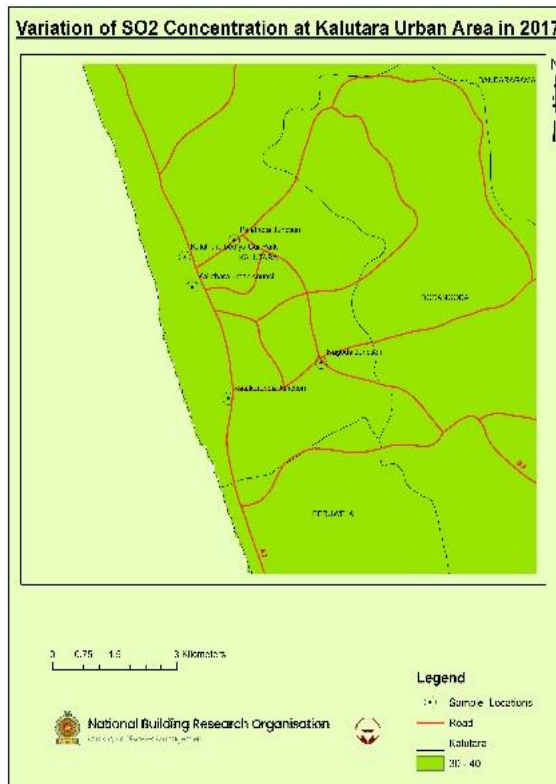
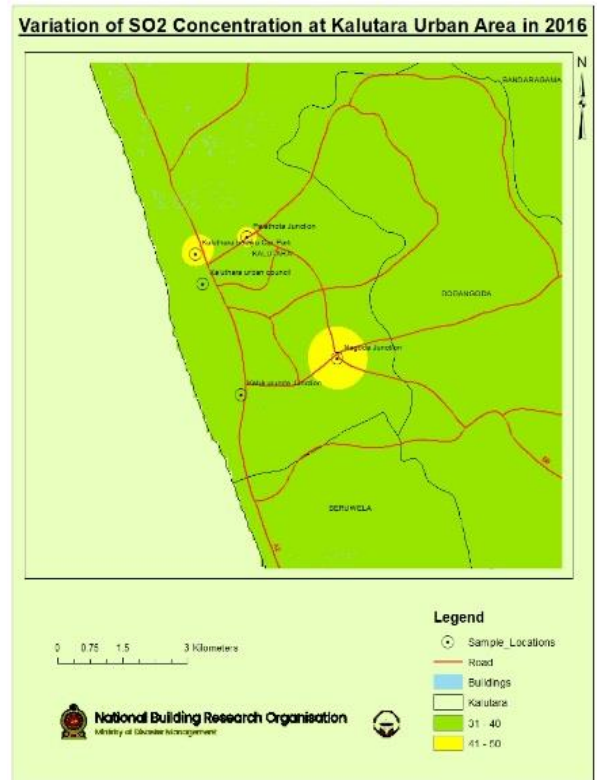
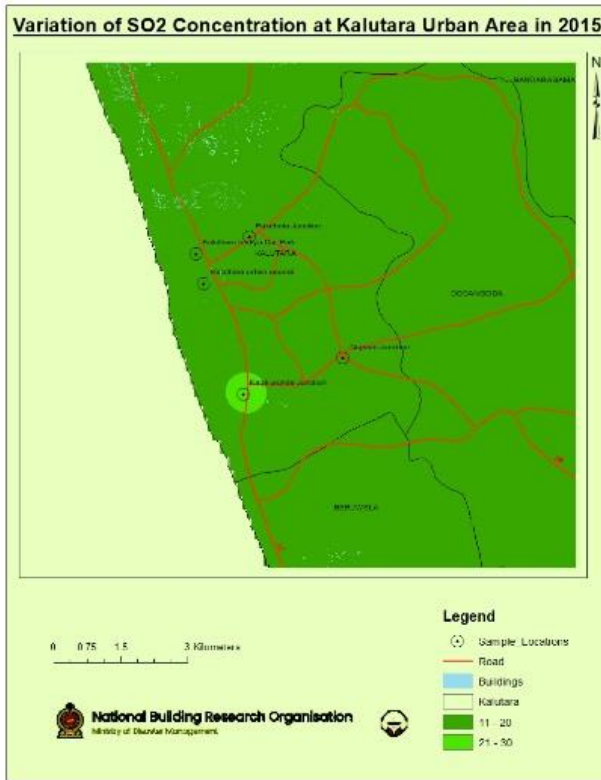
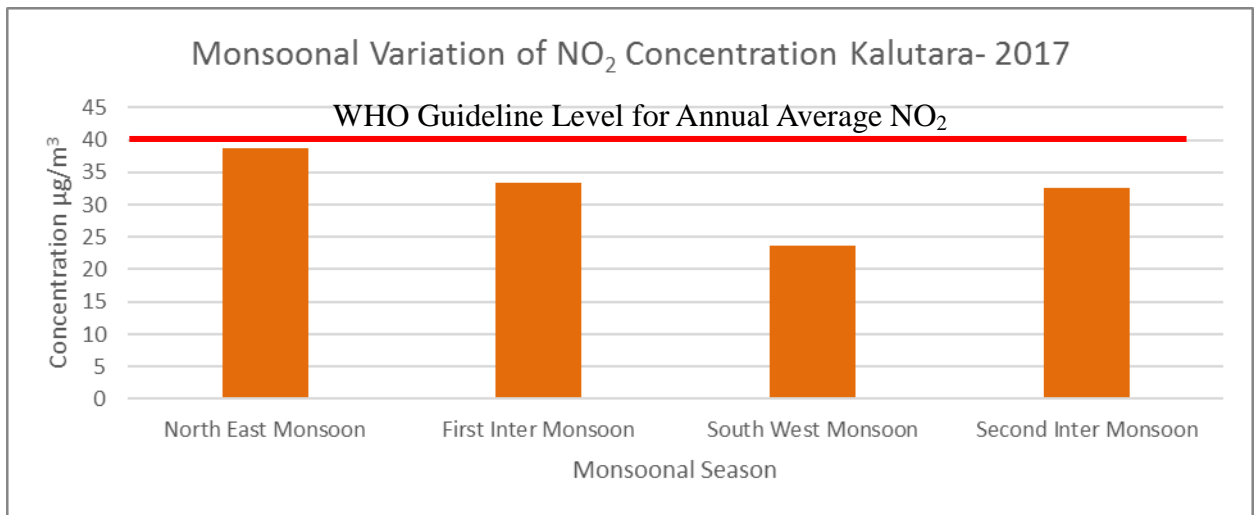


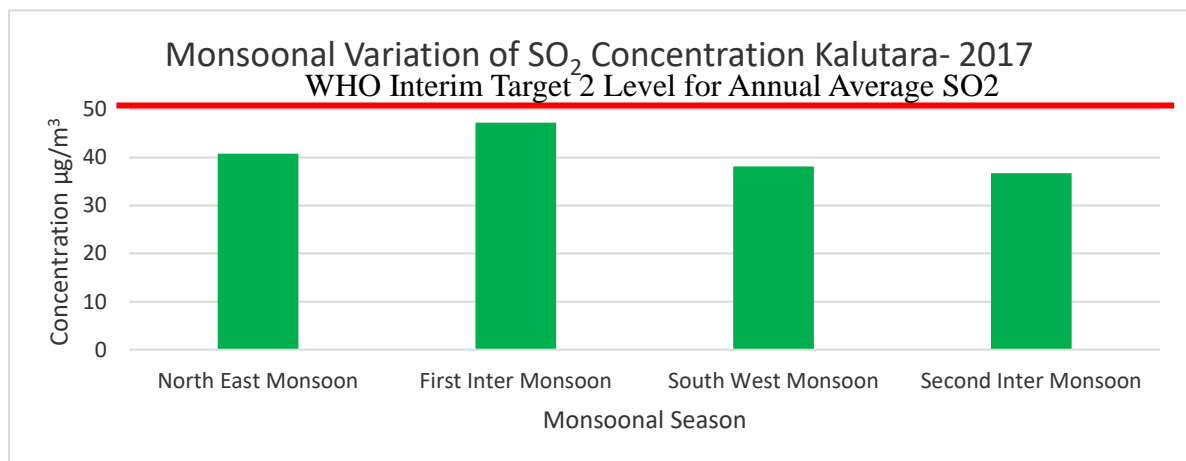
Figure 6.3.12: Variation of SO₂ concentration within Kalutara Urban Area from 2013 to 2017

As an island, monsoonal variation of the climate is highly affected for the dispersion of these chemical agents. The average exposure of NO₂ and SO₂ level trend has analysed below in figures 6.3.13 (a) and 6.3.13 (b) respectively. According to that trend analysis, it has same trend for NO₂ exposure as Colombo which has highest exposure in North East Monsoonal

and lowest exposure in South West Monsoonal season. But SO₂ has shown another trend, which has highest exposure in first inter monsoonal season and lowest exposure in second inter monsoonal season. However, north east monsoonal season has higher exposure than south west monsoonal season. This is due to north east monsoonal wind came through large Indian land area while south west monsoon came through Indian ocean. However, throughout the year 2017, in all monsoonal level, NO₂ exposure has achieved accepted exposure level while SO₂ exposure has achieved interim target level 2. The SO₂ exposure level has exceeded accepted exposure level according to the WHO guidelines.



(a)



(b)

Figure 6.3.13: Monsoonal Variation of (a).NO₂, (b).SO₂ concentration within Kalutara Urban Area

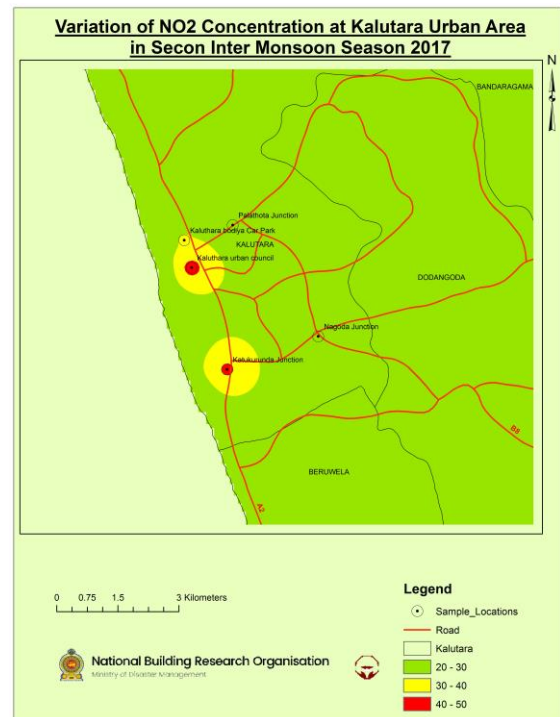
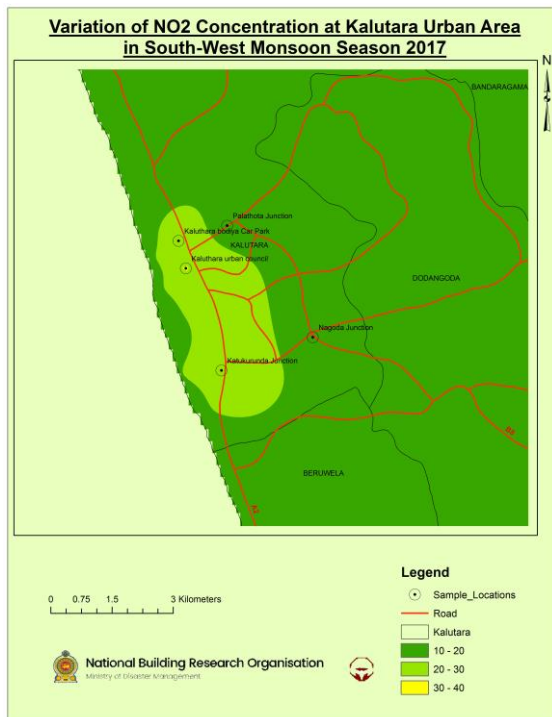
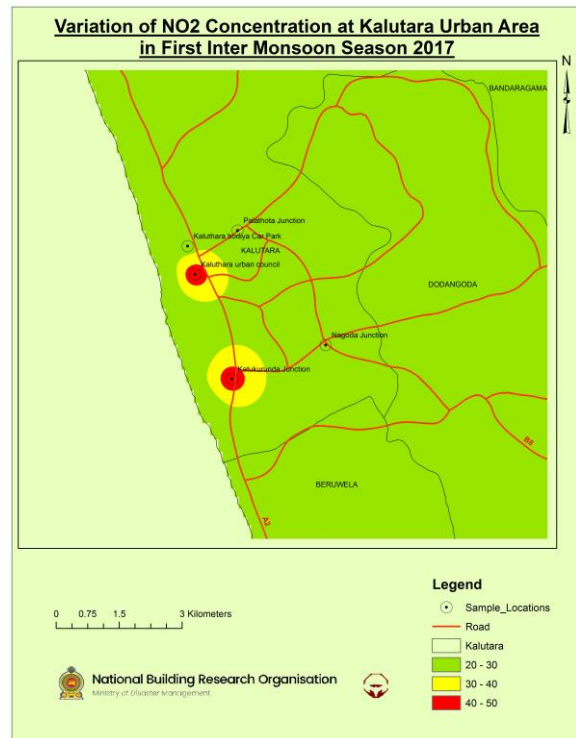
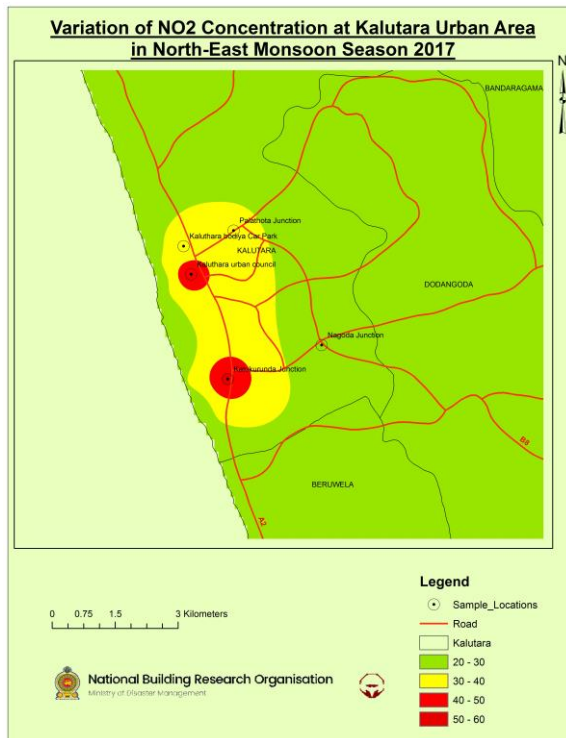


Figure 6.3.14: Monsoonal Seasonal Variation of NO₂ Exposure Kalutara Urban City in 2107. From left to right it shows North East Monsoonal Season Exposure, First Inter Monsoon Seasonal Exposure, South West Monsoonal Season Exposure and Second Inter Monsoon Season Exposure respectively.

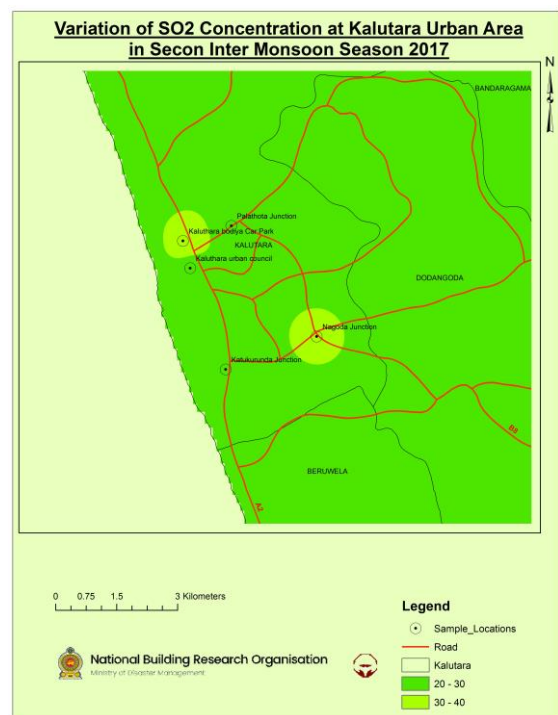
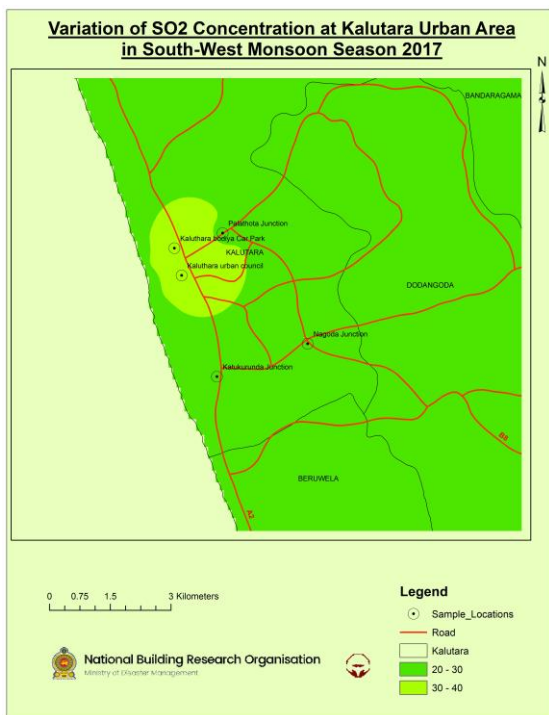
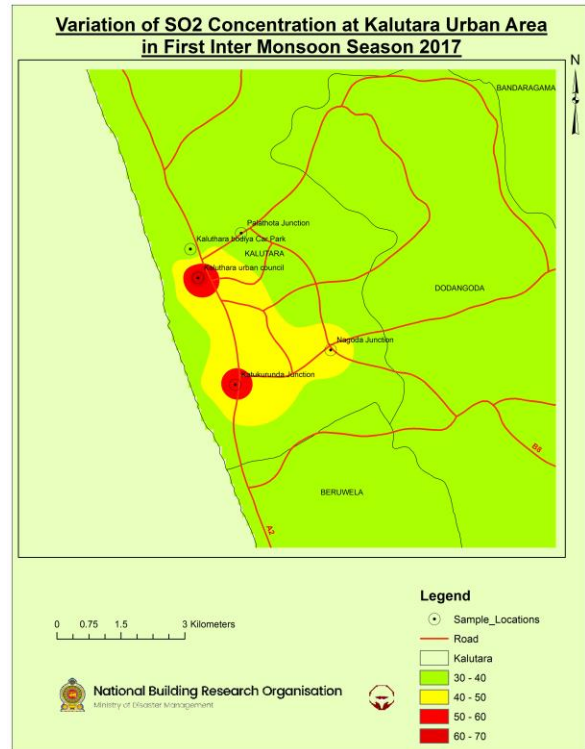
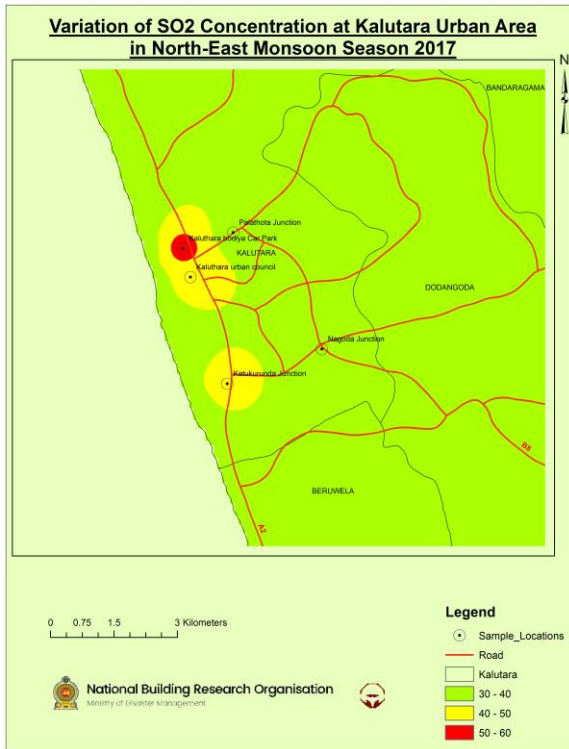


Figure 6.3.15: Monsoonal Seasonal Variation of SO₂ Exposure Kalutara Urban City in 2107. From left to right it shows North East Monsoonal Season Exposure, First Inter Monsoon Seasonal Exposure, South West Monsoonal Season Exposure and Second Inter Monsoon Season Exposure respectively.

6.4 AMBIENT AIR QUALITY IN 2017 – AT HORANA URBAN AREA

Horana is a town in Kalutara District, in the Western Province of Sri Lanka. It is on the road from Panadura to Rathnapura. It is located in 42 km away from Colombo and 18 km away from Panadura.

Air quality exposure levels with respect to NO₂ and SO₂ in Horana Urban area was started in 2012 at five locations within the Horana Urban area and surrounding areas with the financial assistant of VET found. The monitoring program was continued in 2016 to measure monthly average NO₂ and SO₂ level. The monthly average NO₂ and SO₂ exposure levels at each measuring location within Horana urban area in 2017 is summarised in table 6.4.3 and 6.4.4 respectively. Table 6.4.5 shows that PM_{2.5} concentration of selected sample locations in Horana in 2017.

Air quality exposure levels measuring activities with respect to NO₂ and SO₂ in Horana Urban area were continued in 2017 as well under this project. The sample locations description is given in table 6.4.1 and figure 6.4.1 shows the locations map. The Table 6.4.2 presents the overview of each location in the Horana urban area.

Table 6.4.1: Selected Sampling Locations in Horana Urban area

Urban Area	No of Points	Sampling Location	Location Description
Horana	5	HR1	Horana Town
		HR2	Rathnapura Road
		HR3	Horana Urban Council
		HR4	Sri Somananda Road
		HR5	Sri Devananda Road

Sample Locations at Horana Urban Area

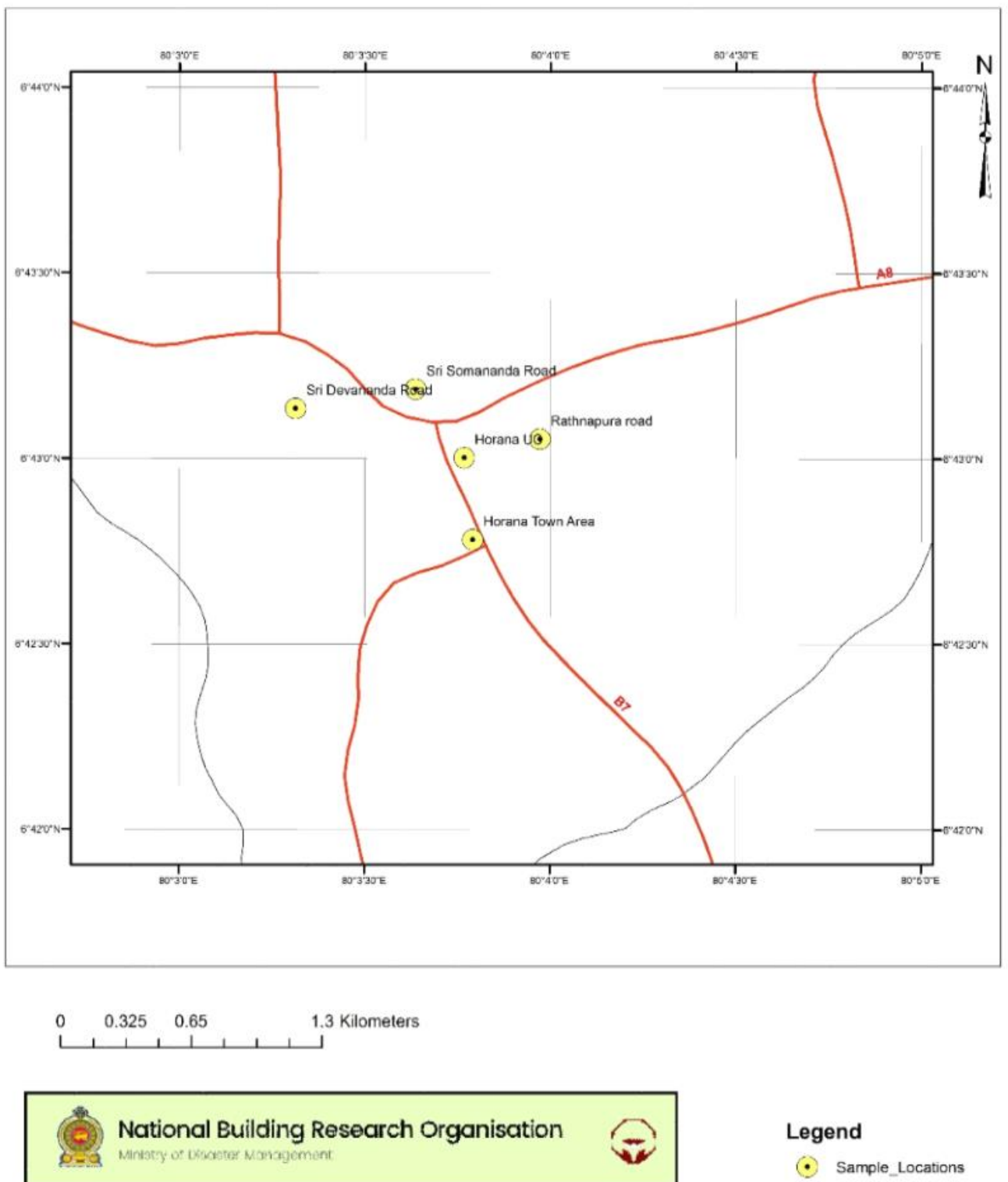


Figure 6.4.1: Sampling Locations Map in Horana Urban area

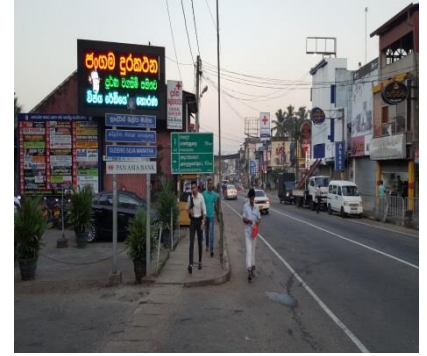
Table 6.4.2: Overview of each location in the Horana urban area



Location No: HR1
Location Name: Rathnapura Rd
GPS Coordinates:
6.7175360N 80.0662210E



Location No: HR2
Location Name: Town Area
GPS Coordinates:
6.7130140N 80.0632090E



Location No: HR3
Location Name: Municipal Council
GPS Coordinates:
6.7167050N,
80.0628240E



Location No: HR4
Location Name: Somananda Mw
Horana
GPS Coordinates:
6.7197820N,
80.0606310E



Location No: HR5
Location Name: Dewananda Mw, MHorana
GPS Coordinates:
6.7189100N,
80.0552410E

Monthly average NO₂ and SO₂ exposure levels at each measuring location within Horana urban area for the year 2016 is summarised in table 6.4.3 and 6.4.4 respectively. Table 6.4.5 shows that PM_{2.5} concentration of selected sample locations in Horana in 2017.

Table 6.4.3: Monthly Average Exposure Levels of NO₂ at each location in Horana Urban Area

Urban Area	Location	NO ₂ Concentration(µg/m ³)											
		Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
Horana Town	HR1	64	59	56	45	37	43	39	41	41	46	54	67
Rathnapura Road	HR2	30	31	39	37	33	30	32	31	24	26	22	21
Horana Urban Council	HR3	54	68	53	55	50	51	45	47	-	45	48	53
Sri Somananda Road	HR4	24	21	21	16	19	16	19	20	26	26	27	29
Sri Devananda Road	HR5	10	14	13	11	12	13	8	8	7	11	15	19

Table 6.4.4: Monthly Average Exposure Levels of SO₂ at each location in Horana Urban Area

Urban Area	Location	SO ₂ Concentration(µg/m ³)											
		Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
Horana Town	HR1	45	40	39	45	47	35	50	19	39	47	33	49
Rathnapura Road	HR2	61	34	46	56	57	46	31	36	41	39	27	47
Horana Urban Council	HR3	68	51	42	-	50	47	37	43	-	44	48	52
Sri Somananda Road	HR4	51	32	39	56	46	36	32	39	34	41	46	51
Sri Devananda Road	HR5	35	32	38	38	26	29	25	27	19	26	28	26

Table 6.4.5: 24 hourly Average Levels of PM_{2.5} at Selected location in Horana Urban Area

Urban Area	Location	PM _{2.5} (µg/m ³)											
		Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
Horana Town	HR1	-	-	-	-	-	-	-	-	-	-	51	53

The figure 6.4.2(a) and 6.4.2(b) present the variation of NO₂ and SO₂ in each location within the year 2016 in Horana Urban Area. It indicates that at the levels are highly subjective to the wind condition. Almost all locations, high exposure levels are recorded in during North-East monsoon period (December – February) compared to South-West monsoon period (May-September). Figure 6.4.3 shows that variation of PM_{2.5} concentration in selected sample locations in Colombo in 2017.

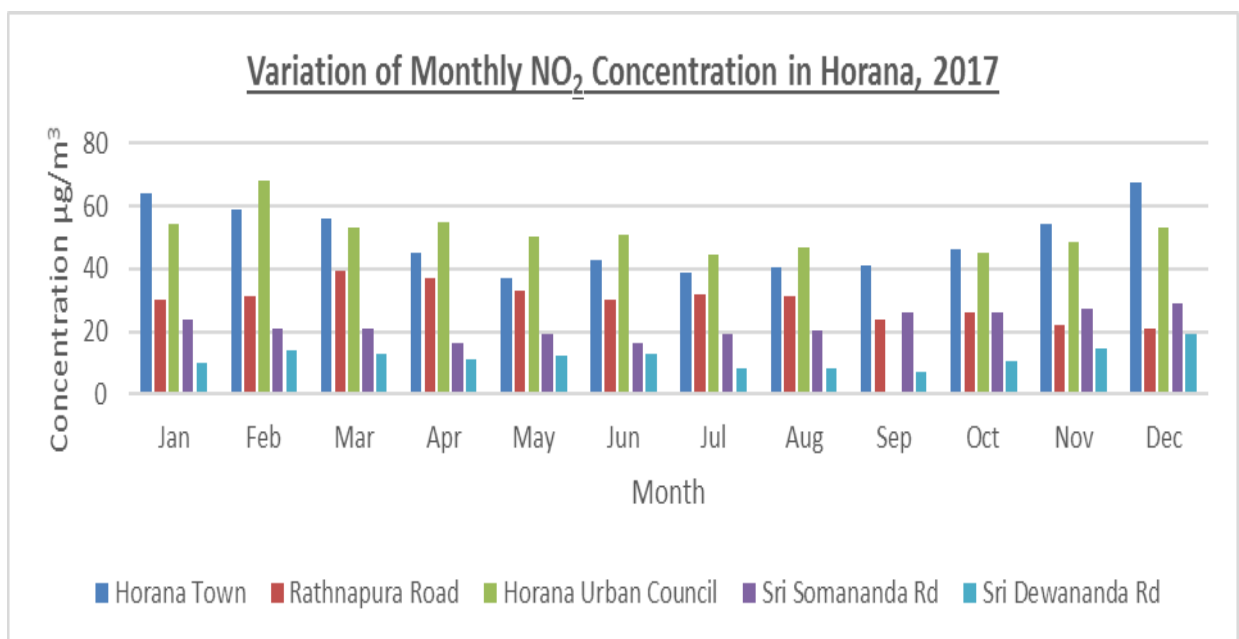


Figure 6.4.2 (a): Variation of NO₂ concentration within Horana Urban Area in 2017

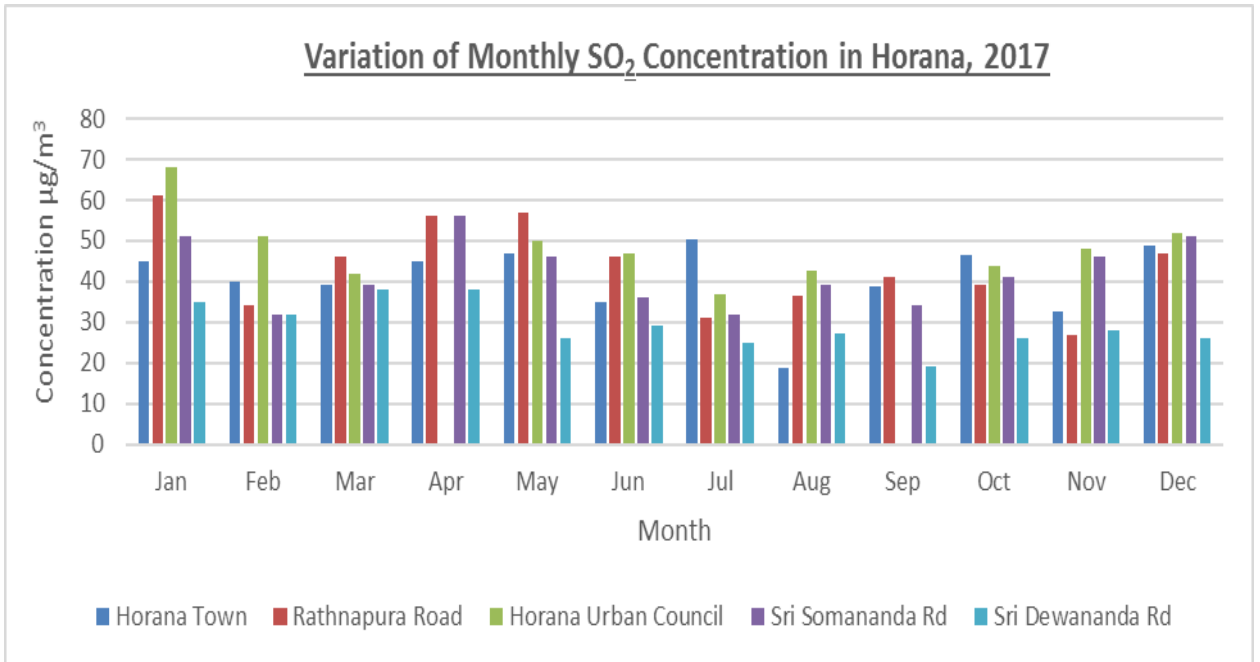


Figure 6.4.2 (b): Variation of SO₂ concentration within Horana Urban Area in 2017

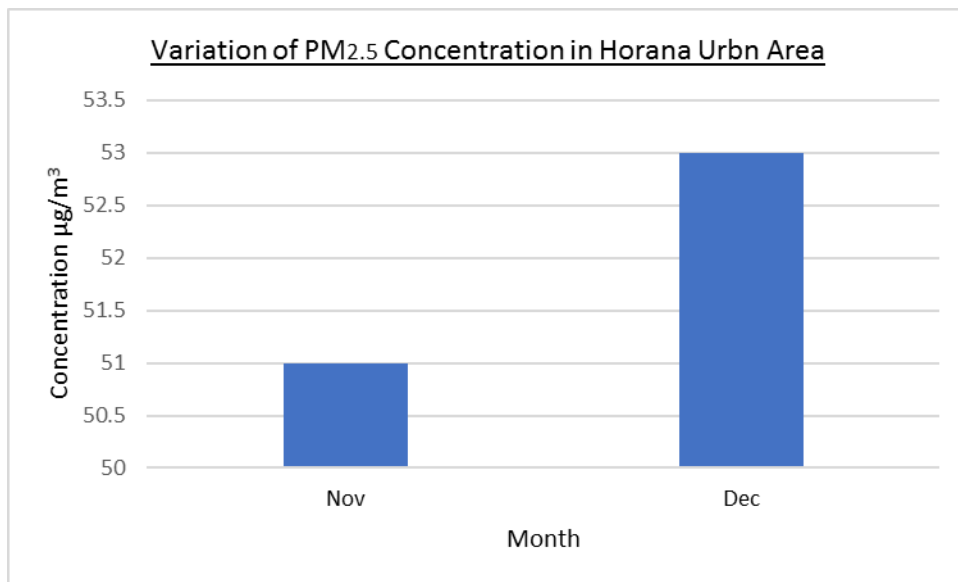


Figure 6.4.3: Variation of PM_{2.5} concentration within Horana Urban Area

Figure 6.4.4 and 6.4.5 represent the annual average NO₂ and SO₂ concentration levels at each sampling location in Horana urban area during the year, 2017. The annual average SO₂ and NO₂ levels in year 2017 are in between 12 µg/m³ - 52 µg/m³ and 29 µg/m³ - 48 µg/m³ respectively. The high levels are representing areas with high traffic areas such as Horana Town (HR1) and Horana Urban Council (HR2) where exceeded the annual WHO guideline values for NO₂ while all the sample locations have exceeded 24 hour WHO guideline values for SO₂. But none of each exceeded the interim target 2 level for SO₂. Low levels are recorded at locations away from the urban area such as Sri Somananade (HR4) and Sri Devananda Road (HR5) for NO₂.

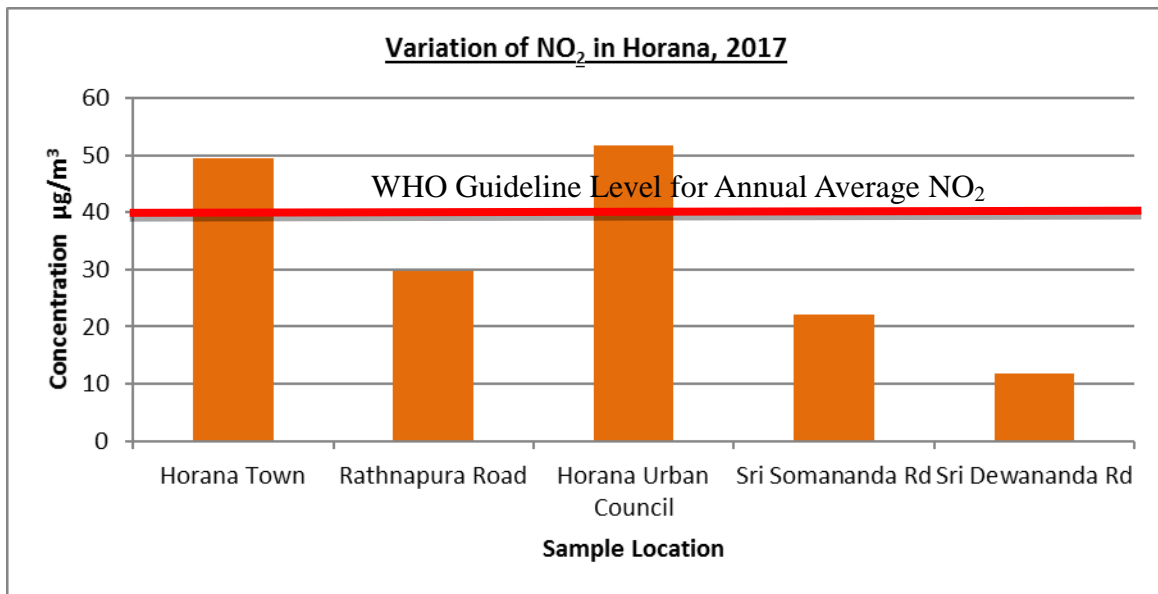


Figure 6.4.4: Annual average NO₂ concentration within Horana Urban Area in 2017

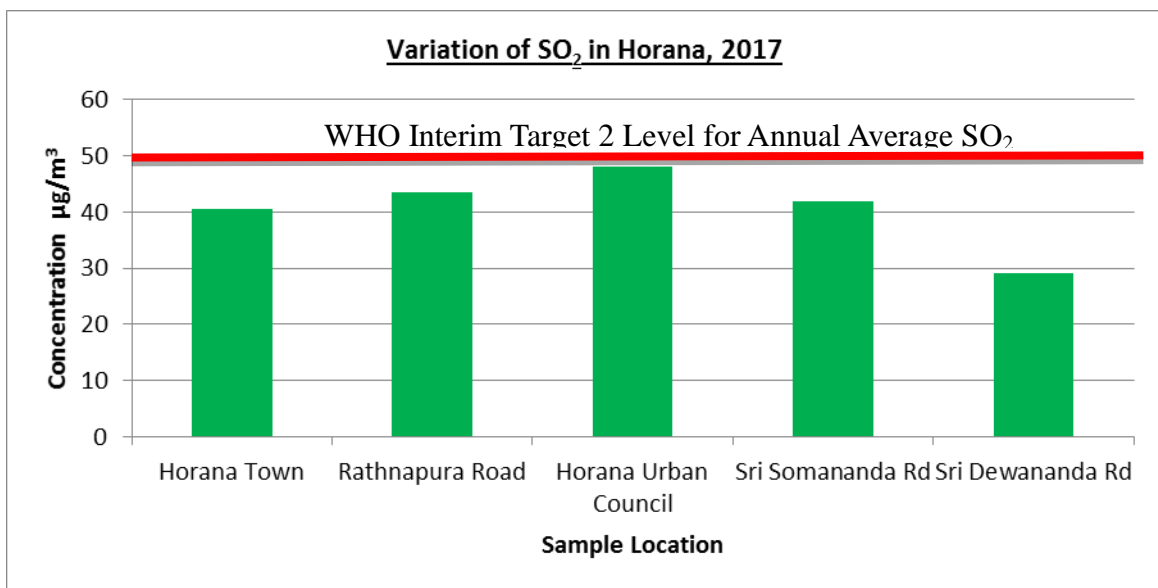


Figure 6.4.5: Annual average SO₂ concentration within Horana Urban Area in 2017

Annual average levels of NO₂ and SO₂ in each location at Horana area from 2012 to 2017 are represented in figure 6.4.6 and boxplot of each pollutant for the same period are given in figure 6.4.7 & 6.4.8 respectively. Accordingly, the exposure levels of NO₂ were in decreasing trend while SO₂ levels were in increasing trend from 2012 to 2017. This reduction of pollutant levels in Horana urban area should be due to the actions implemented to manage air quality in Sri Lanka including vehicular emission control through VET program and development of road surface etc. as well as introduction of cleaner fuel vehicles such as hybrid and electric vehicles to the fleet etc.

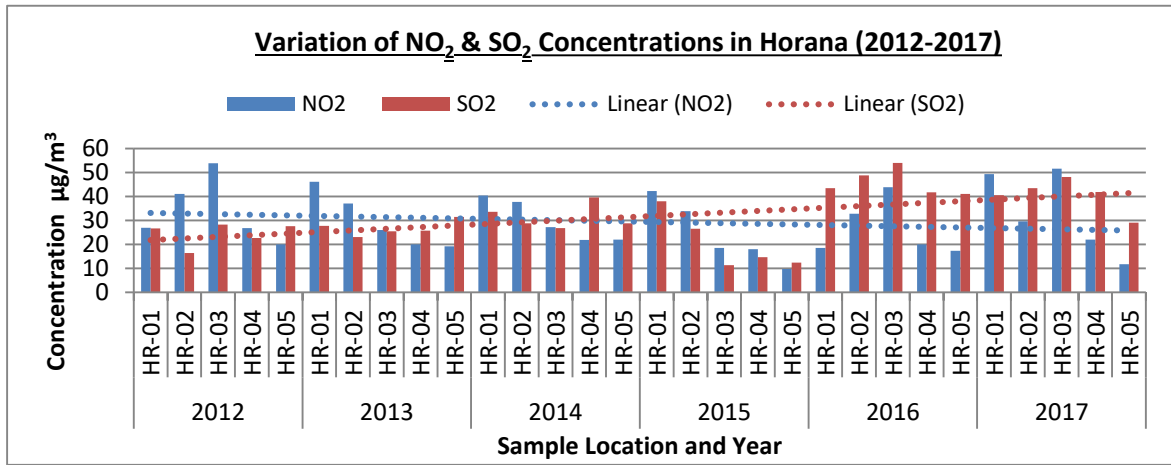


Figure 6.4.6: Average NO₂ and SO₂ variations from 2012-2017

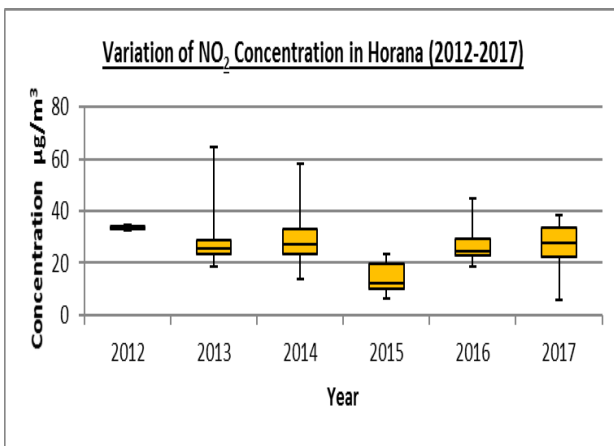


Figure 6.4.7: Boxplot of NO₂ Concentration variation in Horana (2012-2017)

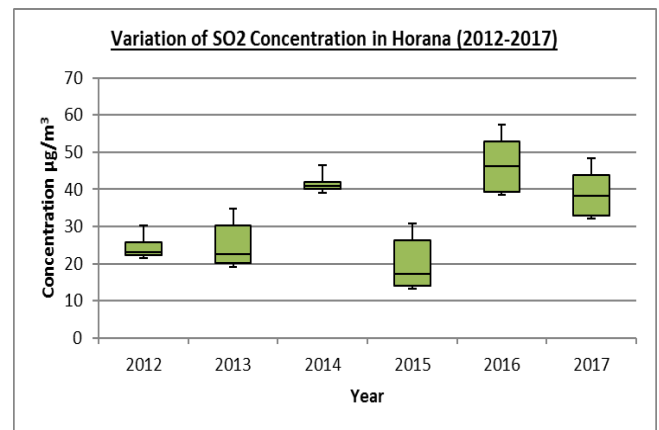


Figure 6.4.8: Boxplot of SO₂ Concentration variation in Horana (2012-2017)

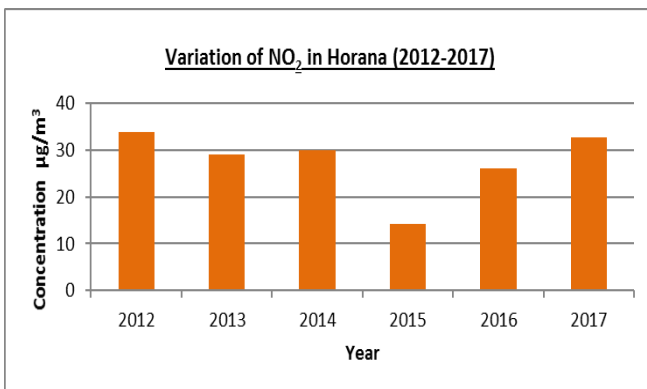


Figure 6.4.9: Annual average NO₂ variations from 2012-2017 in Horana Urban area

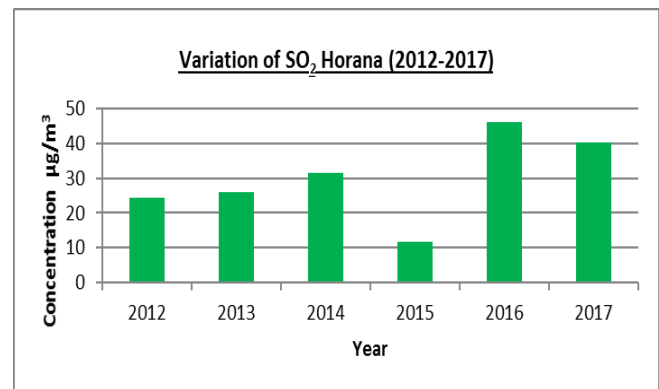
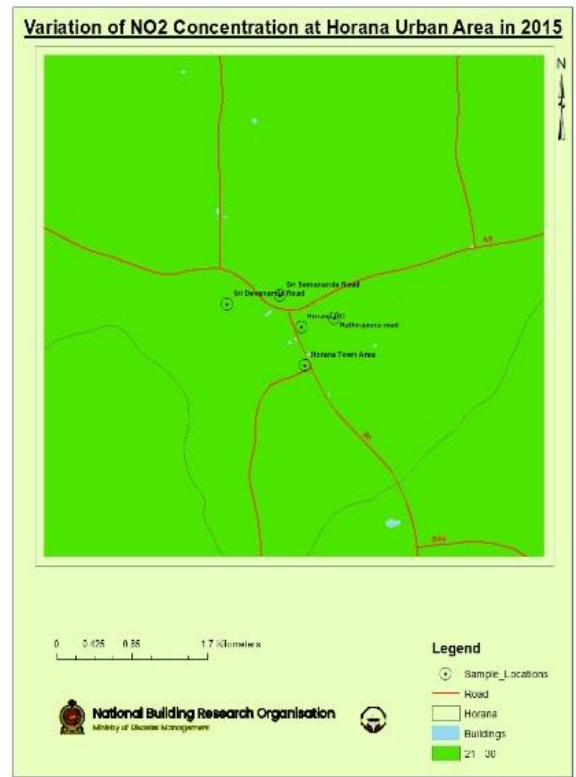
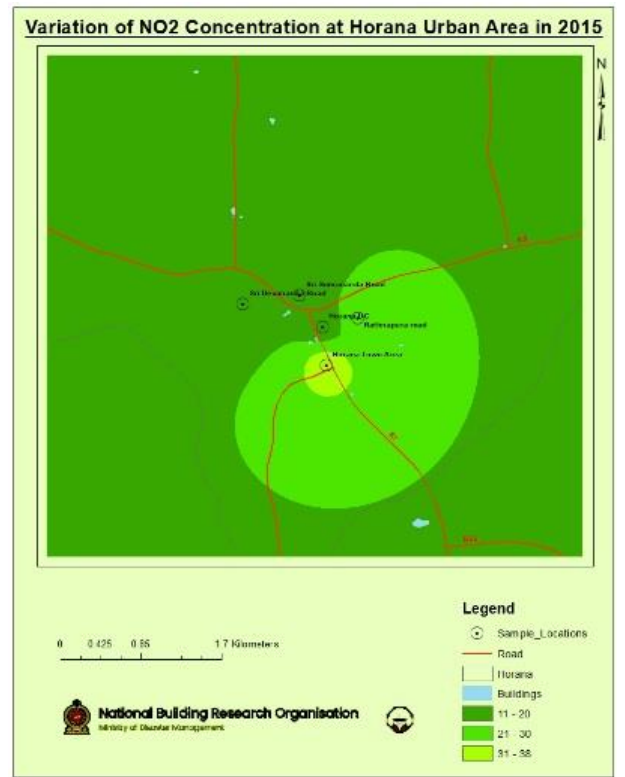
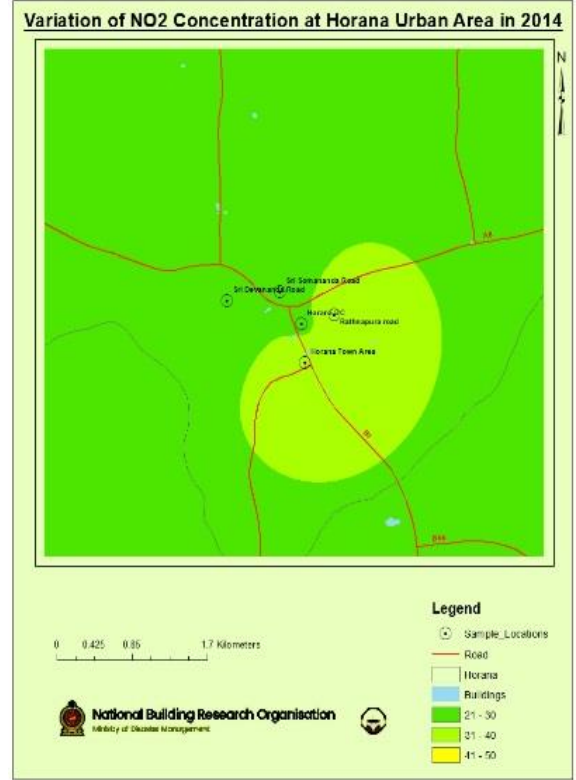
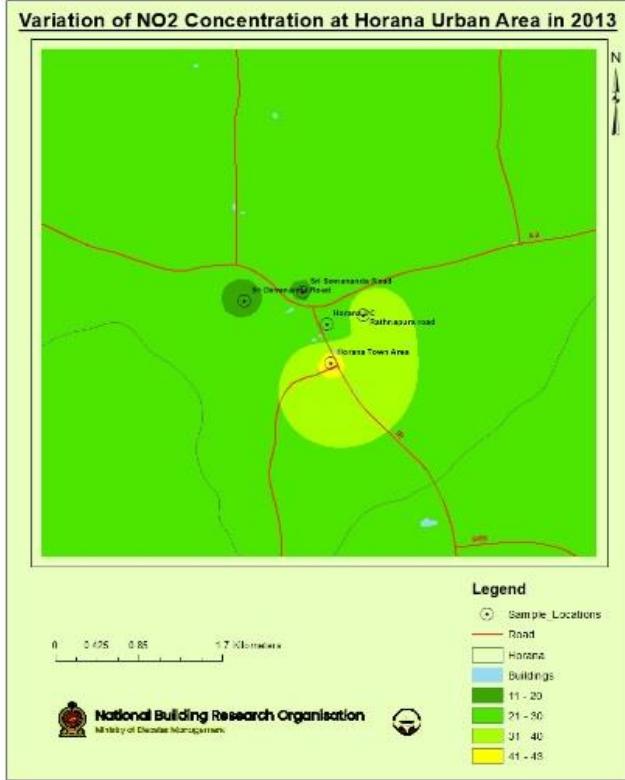


Figure 6.4.10: Annual average SO₂ variations from 2012-2017 in Horana Urban area



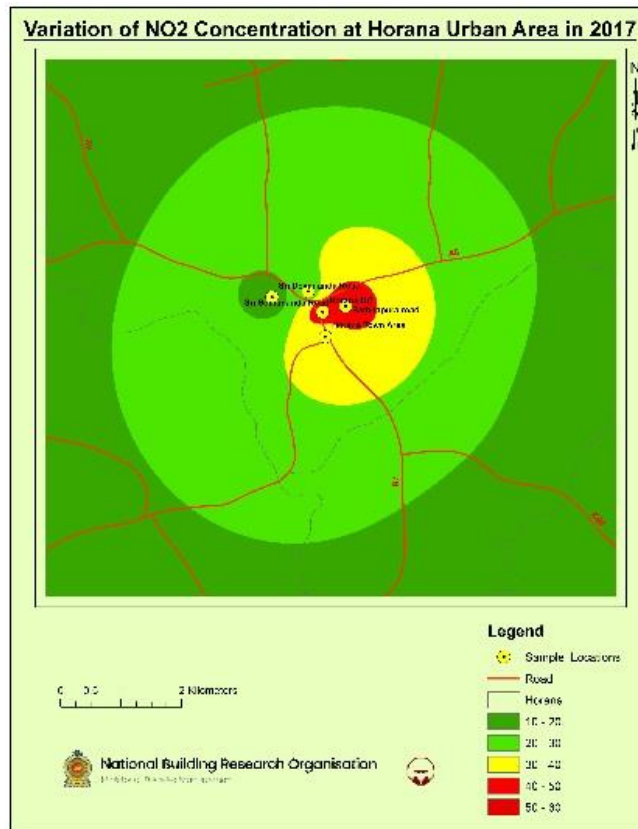
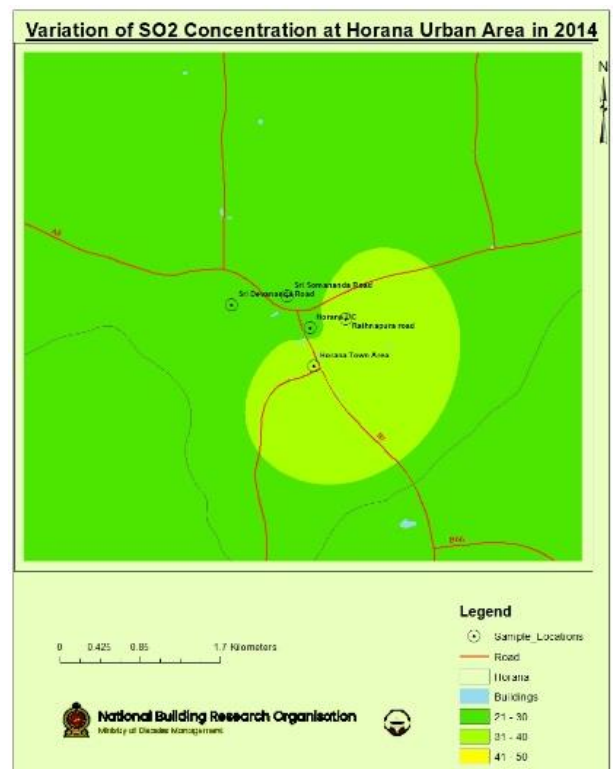
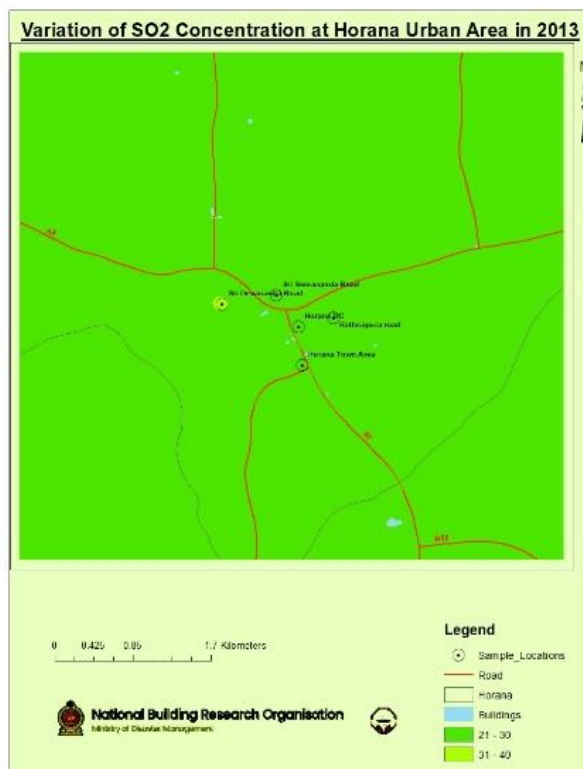


Figure 6.4.11: Variation of NO₂ concentration within Horana Urban Area from 2013 to 2017



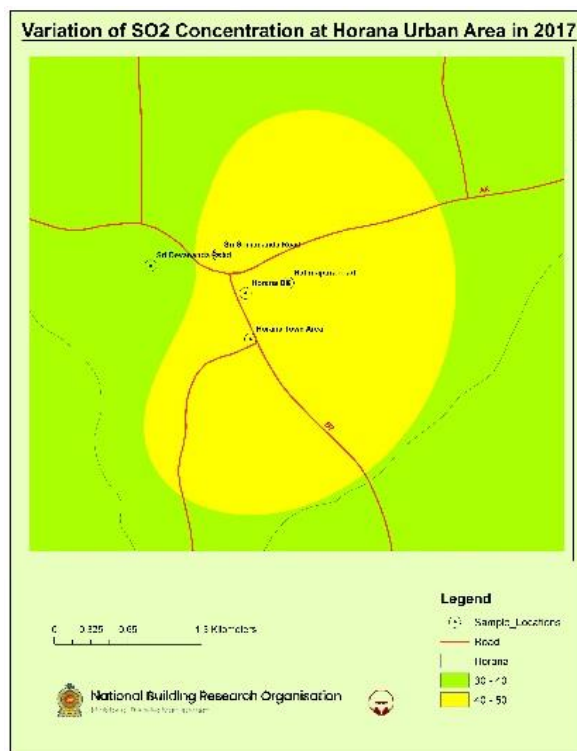
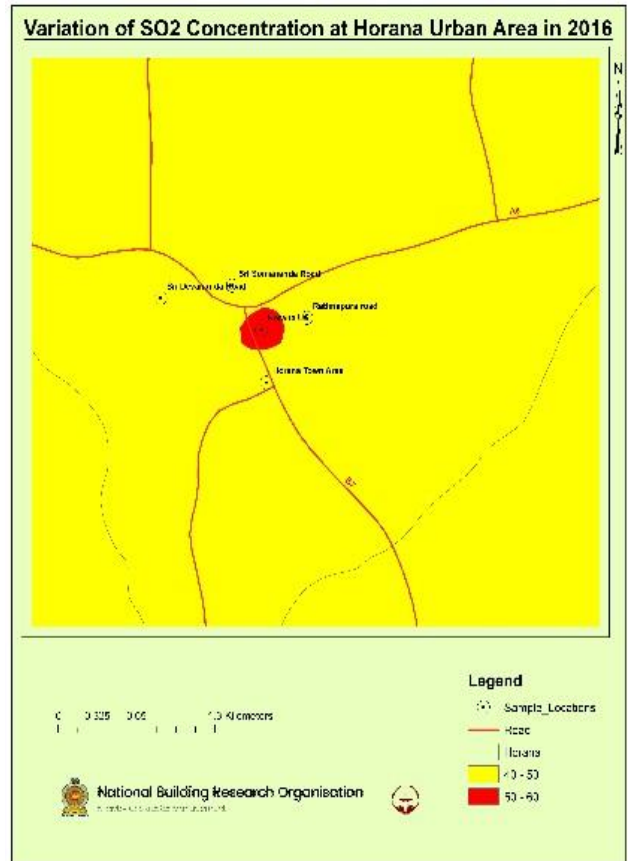
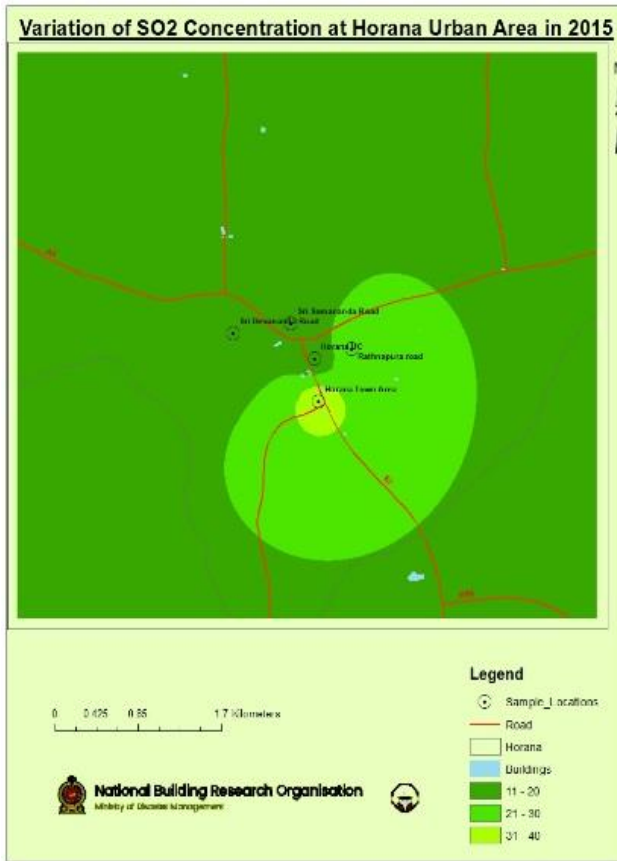
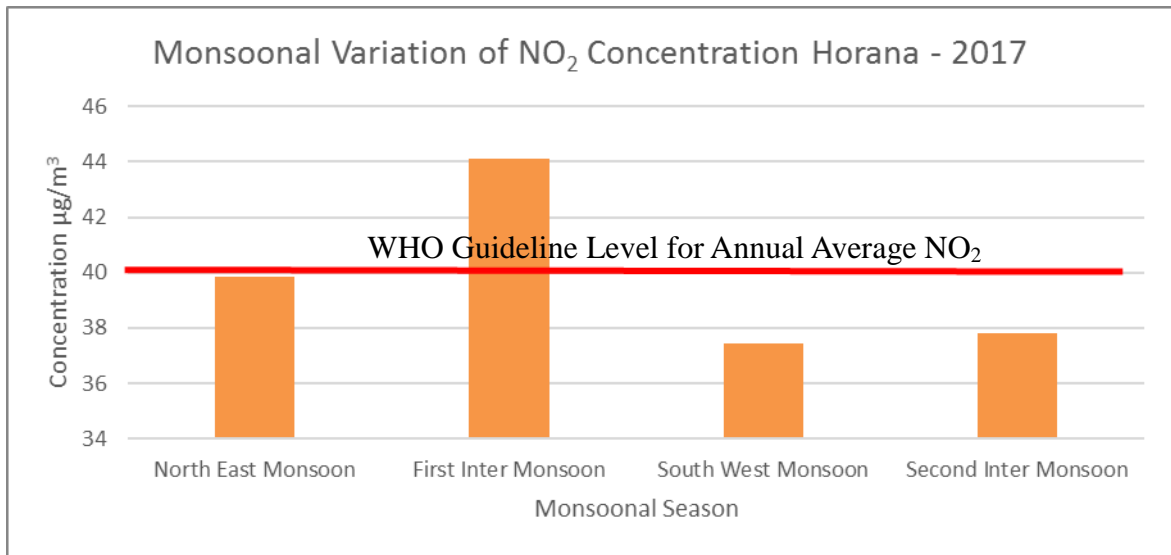
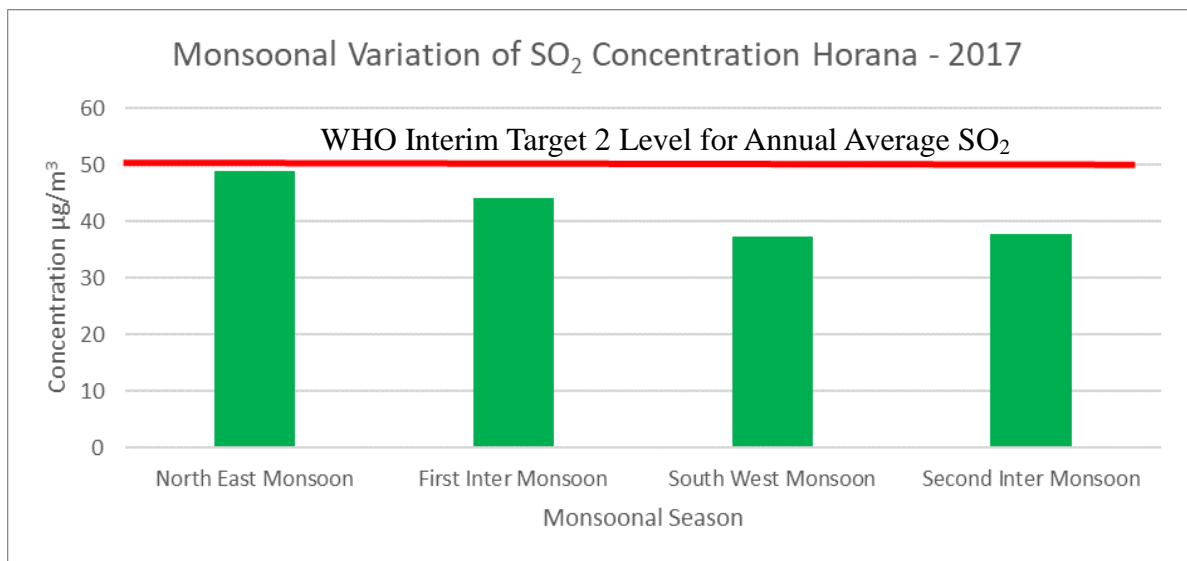


Figure 6.4.12: Variation of SO₂ concentration within Kalutara Urban Area from 2013 to 2017

As an island, monsoonal variation of the climate is highly affected for the dispersion of these chemical agents. The average exposure of NO₂ and SO₂ level trend has analysed below in figures 6.4.13 (a) and 6.4.13 (b) respectively. According to that trend analysis, SO₂ exposure has highest exposure in North East Monsoonal and lowest exposure in South West Monsoonal season. But NO₂ has shown another trend, which has highest exposure in first inter monsoonal season and lowest exposure in South West Monsoonal season. However, North East Monsoonal season has higher exposure than South West Monsoonal season. This is due to North East Monsoonal wind came through large Indian land area while South West Monsoonal came through Indian ocean. However, throughout the year 2017, NO₂ exposure has exceeded accepted exposure level in North East Monsoonal season while SO₂ exposure has achieved interim target level 2. The SO₂ exposure level has exceeded accepted exposure level according to the WHO guidelines.



(a)



(b)

Figure 6.4.13: Monsoonal Variation of (a).NO₂, (b).SO₂ concentration within Horana Urban Area

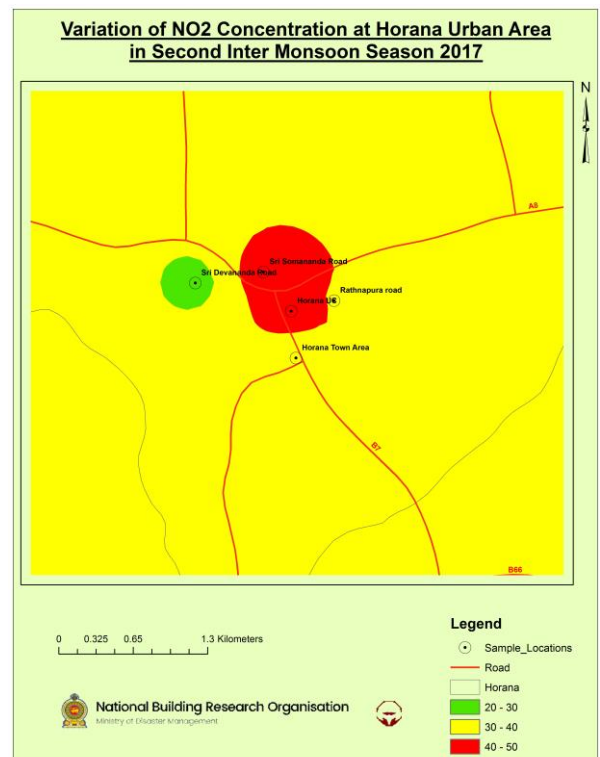
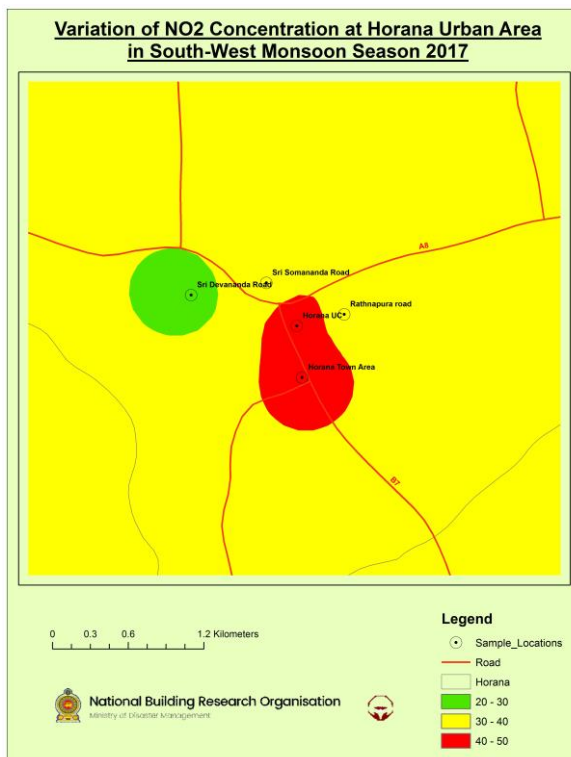
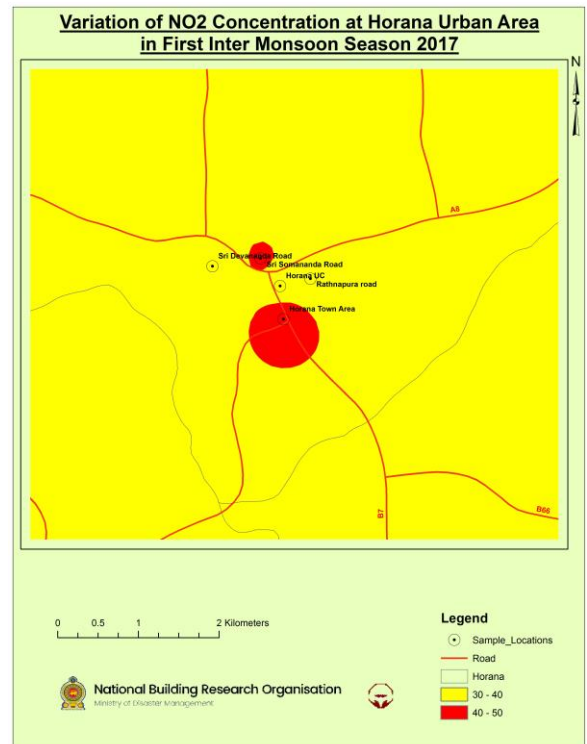
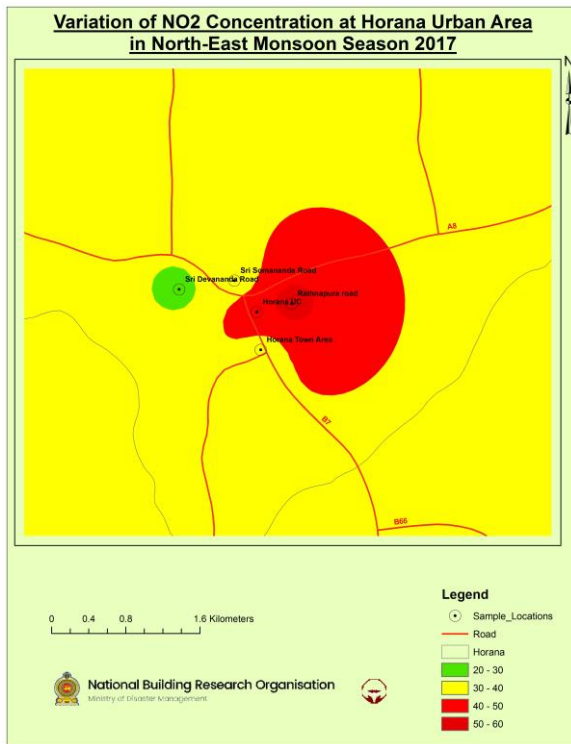


Figure 6.4.14: Monsoonal Seasonal Variation of NO₂ Exposure Horana Urban City in 2017. From left to right it shows North East Monsoonal Season Exposure, First Inter Monsoon Seasonal Exposure, South West Monsoonal Season Exposure and Second Inter Monsoon Season Exposure respectively.

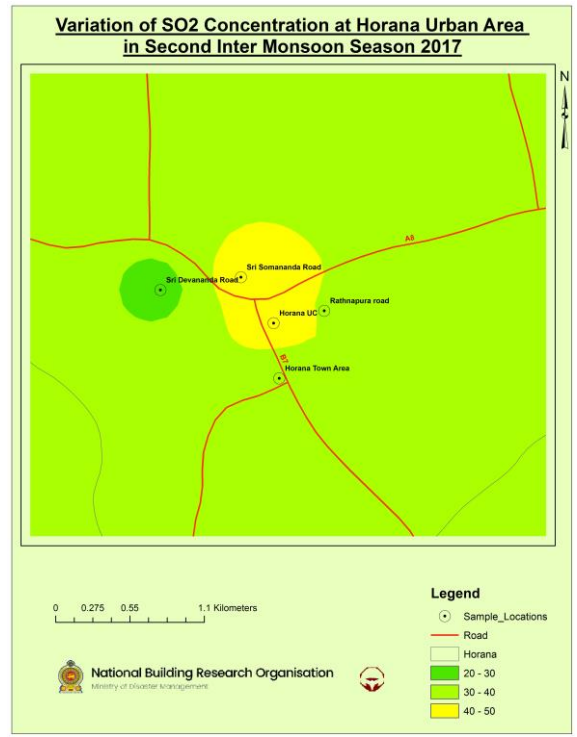
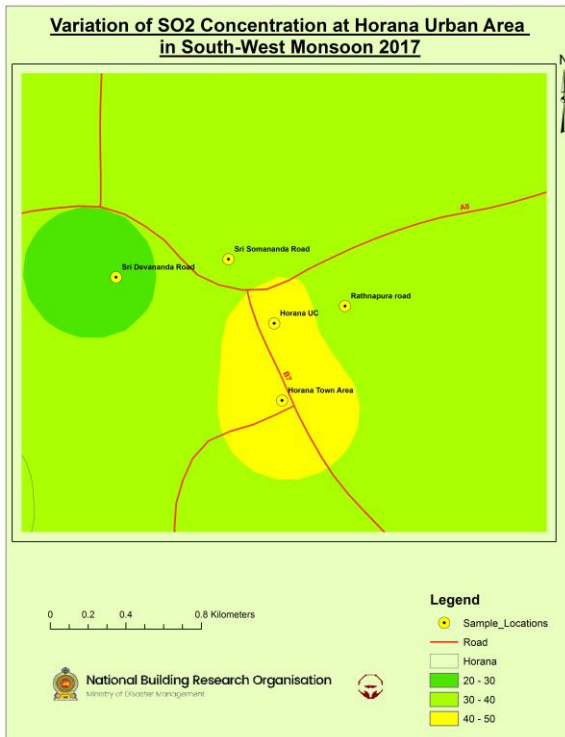
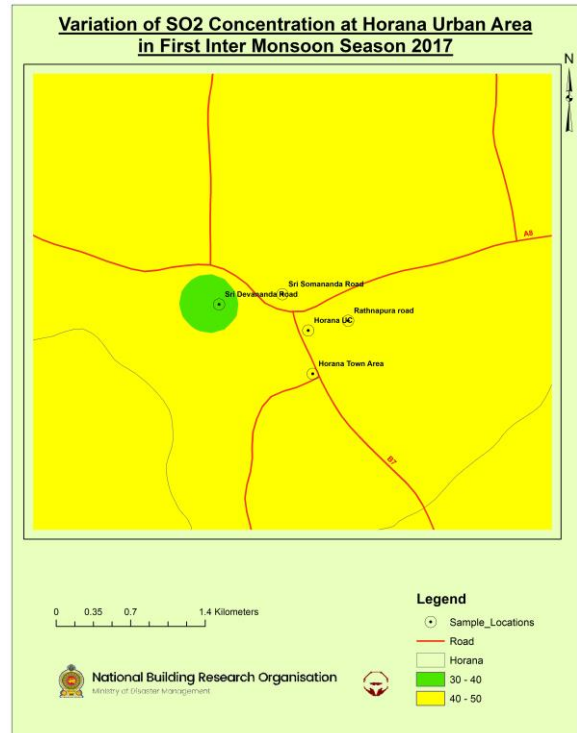
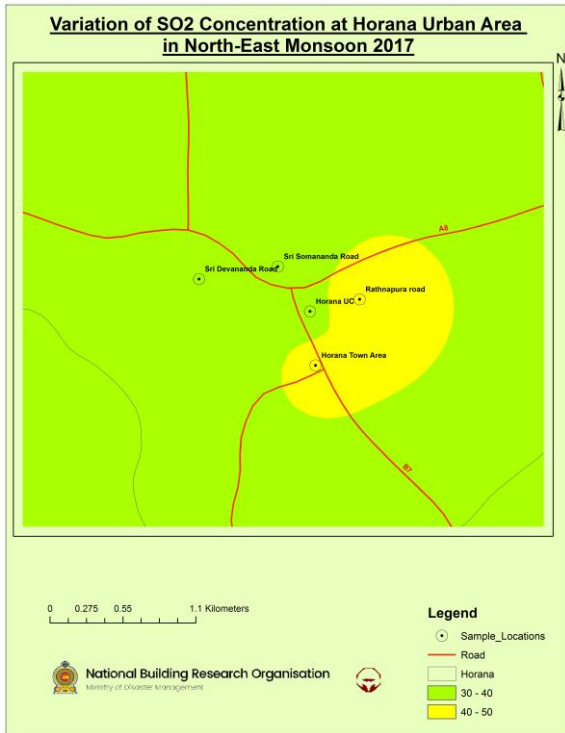


Figure 6.4.15: Monsoonal Seasonal Variation of SO₂ Exposure Horana Urban City in 2017. From left to right it shows North East Monsoonal Season Exposure, First Inter Monsoonal Season Exposure, South West Monsoonal Season Exposure and Second Inter Monsoonal Season Exposure respectively.

6.5 AMBIENT AIR QUALITY IN 2017 – AT GALLE URBAN AREA

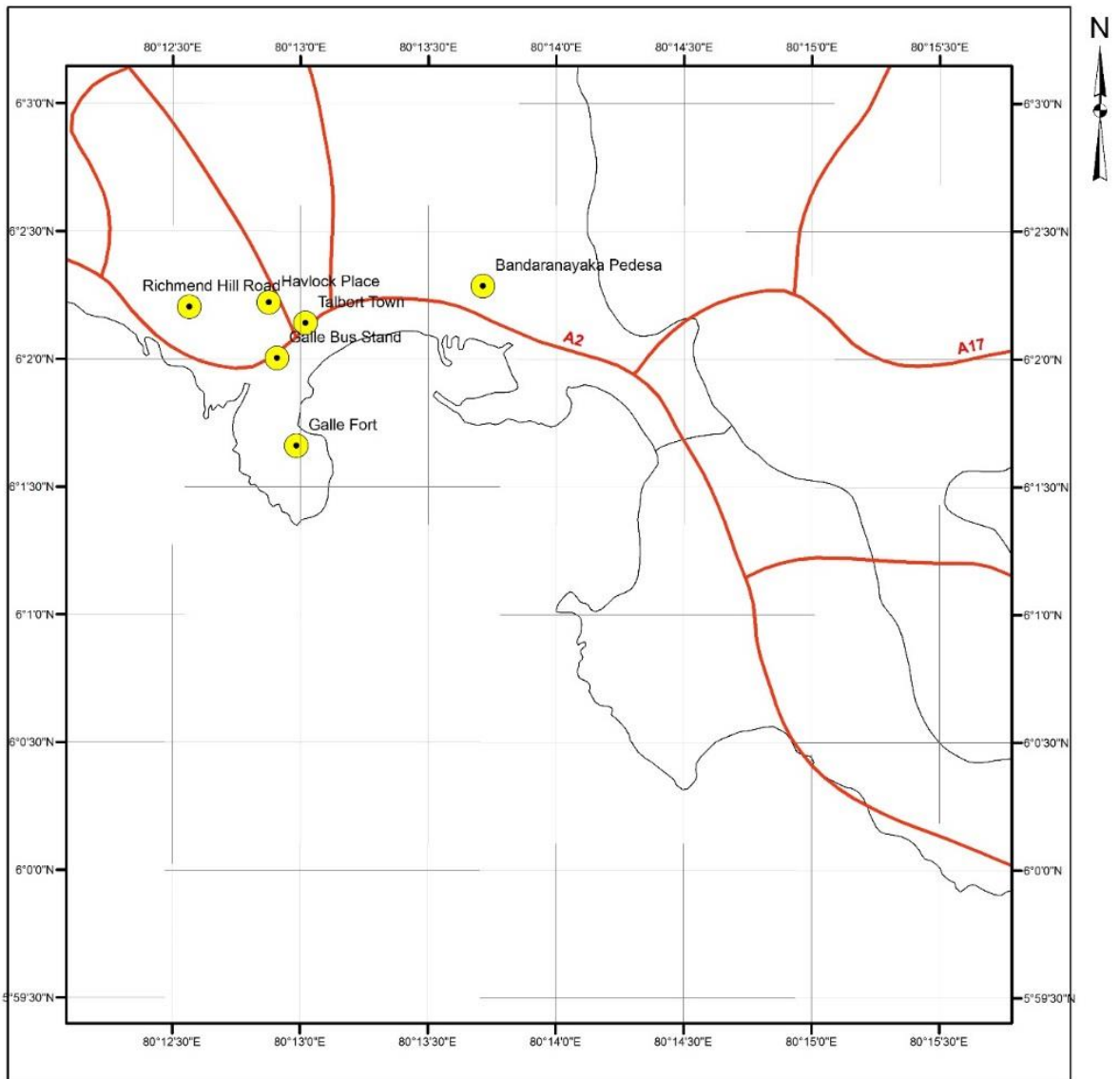
The Galle city is the capital city of Southern Province located in costal belt of Sri Lanka. The city has a World Heritage Site to its name because there are several historical, archaeological and architectural heritage monuments located within the city and those are predominantly responsible for its popularity with tourists. The city area is limited to about 18.7 Km² and relatively high number of vehicles operates in the city. The continuous air quality monitoring in the city show that the pollutant levels are relatively high within the city area.

Air quality exposure levels with respect to NO₂ and SO₂ in Galle Urban area was started in 2012 at six locations within the Galle Urban area and surrounding areas with the financial assistant of VET fund. The monitoring program was continued in 2017 to measure monthly average NO₂ and SO₂ level. The monthly average NO₂ and SO₂ exposure levels at each measuring location within Galle urban area in 2017 is summarised in table 6.5.3 and 6.5.4 respectively. Table 6.5.5 shows that PM_{2.5} concentration of selected sample locations in Galle in 2017. Air quality exposure levels measuring activities with respect to NO₂ and SO₂ in Galle Urban area were continued in 2017 as well under this project. The sample locations description is given in table 6.5.1 and figure 6.5.1 shows the locations map. The Table 6.5.2 presents the overview of each location in the Galle urban area.

Table 6.5.1: Selected Sampling Locations in Galle Urban area

Urban Area	No of Points	Sampling Location	Location Description
Galle	6	GL1	Richmend Hill Road
		GL2	Havlock Place
		GL3	Galle Bus Stand
		GL4	Galle Fort
		GL5	Talbort Town
		GL6	Bandaranayaka Pedesa

Sample Locations at Galle Urban Area



0 0.5 1 2 Kilometers



Legend

- Sample_Locations
- Road
- Galle

Figure 6.5.1: Sampling Locations Map in Galle Urban area

Table 6.5.2: Overview of each location in the Galle urban area



Location No: GL1
 Location Name: Richmond Hill Rd
 GPS Coordinates:
 6.0367140N,
 80.2094390E



Location No: GL2
 Location Name: Havlock Place
 GPS Coordinates:
 6.0370170N,
 80.2146180E



Location No: GL3
 Location Name: Bus Stand
 GPS Coordinates:
 6.0333700N,
 80.2151430E



Location No: GL4
 Location Name: Galle Fort
 GPS Coordinates:
 6.0276500N,
 80.2164210E



Location No: GL5
 Location Name: Talbort Town
 GPS Coordinates:
 6.0356700N,
 80.2170030E



Location No: GL6
 Location Name: Bandaranayake
 GPS Coordinates:
 6.0380860N,
 80.2285770E

Monthly average NO₂ and SO₂ exposure levels at each measuring location within Galle urban area for the year 2017 is summarised in table 6.5.3 and 6.5.4 respectively. However, some of data were missing due to the missing of passive sampler due to unavoidable situations such as personal or urban council activities, attacking of animals or birds and some climatic conditions such as rain and flood etc.

Table 6.5.3- Monthly Average Exposure Levels of NO₂ at each location in Galle Urban Area

Urban Area	Location	NO ₂ Concentration(µg/m ³)											
		Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
Richmend Hill Road	GL1	37	44	36	33	37	31	22	19	29	31	35	36
Havlock Place	GL2	38	35	35	41	39	39	28	16	22	20	17	21
Galle Bus Stand	GL3	-	58	48	45	51	52	28	29	24	33	47	39
Galle Fort	GL4	22	21	18	12	15	12	8	10	17	28	22	26
Talbort Town	GL5	24	27	22	21	30	16	-	-	19	26	24	22
Bandaranayaka Pedesa	GL6	25	29	22	19	-	17	17	17	15	16	20	23

Table 6.5.4: Monthly Average Exposure Levels of SO₂ at each location in Galle Urban Area

Urban Area	Location	SO ₂ Concentration(µg/m ³)											
		Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
Richmend Hill Road	GL1	37	44	44	47	41	48	37	39	40	53	39	38
Havlock Place	GL2	46	51	52	42	49	39	47	58	36	50	47	47
Galle Bus Stand	GL3	-	72	72	74	79	73	69	66	66	82	71	65
Galle Fort	GL4	58	57	56	68	66	47	38	29	32	50	43	53
Talbort Town	GL5	31	44	44	41	35	27	28	26	29	42	31	40
Bandaranayaka Pedesa	GL6	39	41	45	49	43	34	38	53	39	46	30	43

Table 6.5.5: 24 hourly Average Levels of PM_{2.5} at Selected location in Galle Urban Area

City	Site Name	PM _{2.5} (µg/m ³)											
		Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
Galle	Bus stand GL3	-	-	-	-	-	-	-	-	-	-	44	50

The figure 6.5.2(a) and 6.5.2(b) presented the variation of NO₂ and SO₂ in each location within the year 2017 in Galle Urban Area. It indicates that at the levels are highly subjective to the wind condition. Most of locations, high exposure levels are recorded in during North-East monsoon period (December – February) compared to South-West monsoon period (May-September). The pattern was changed at some locations depending on the localised wind pattern. Figure 6.5.3 shows that variation of PM_{2.5} concentration in selected sample locations in Galle in 2017.

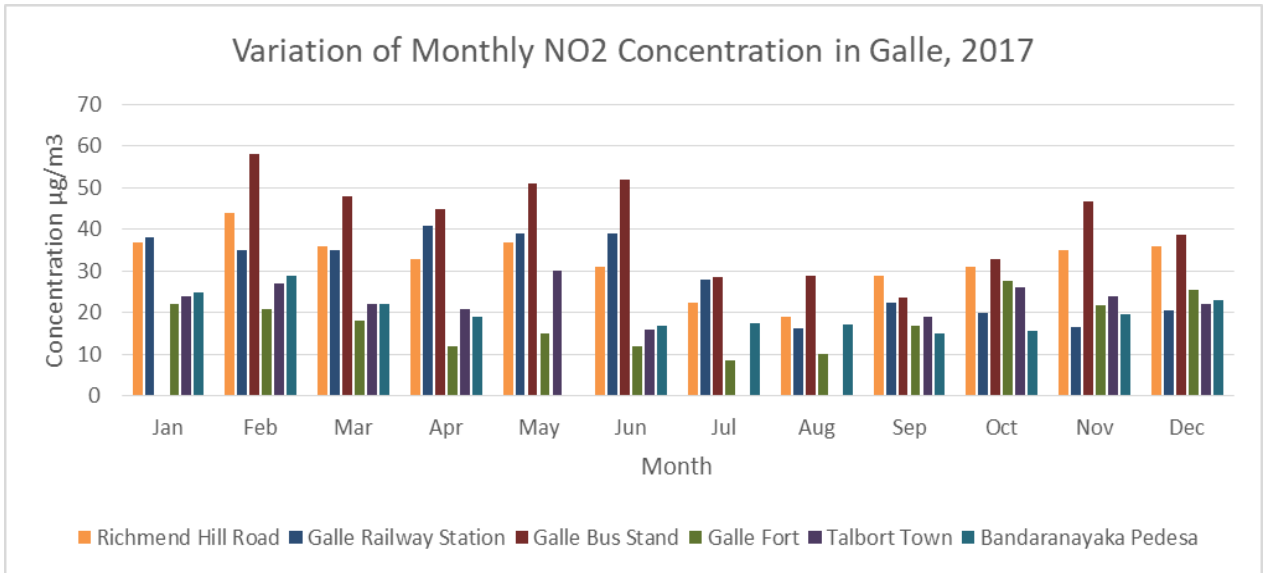


Figure 6.5.2 (a): Variation of NO₂ concentration within Galle Urban Area in 2017

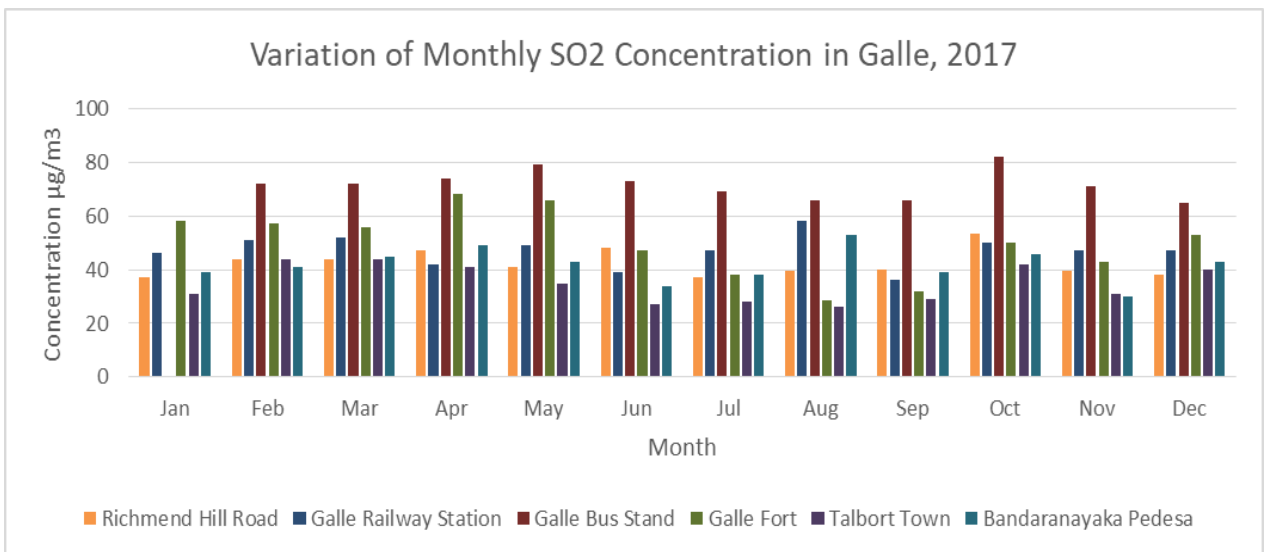


Figure 6.5.2 (b): Variation of SO₂ concentration within Galle Urban Area in 2017

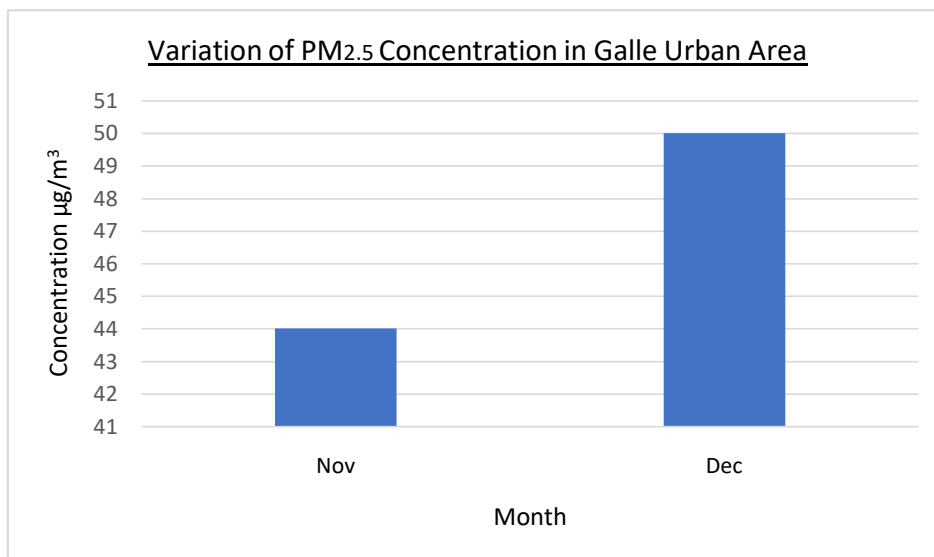


Figure 6.5.3: Variation of PM_{2.5} concentration within Galle Urban Area

Figure 6.5.4 and 6.5.5 represent the annual average NO₂ and SO₂ concentration levels at each sampling location in Galle urban area during the year, 2017. The annual average NO₂ and SO₂ levels in year 2017 are in between 18 µg/m³ - 41 µg/m³ and 35 µg/m³ - 72 µg/m³ respectively. The high levels are representing areas with high traffic areas such as Galle Bus Stand (GL3) where exceeded the annual WHO guideline values for NO₂ and 24 hour WHO guideline values for SO₂. Low levels are recorded at locations away from the urban area such as Galle Fort (GL4), Talbort Town (GL5) and Bandaranayaka Pedesa (GL6) etc.

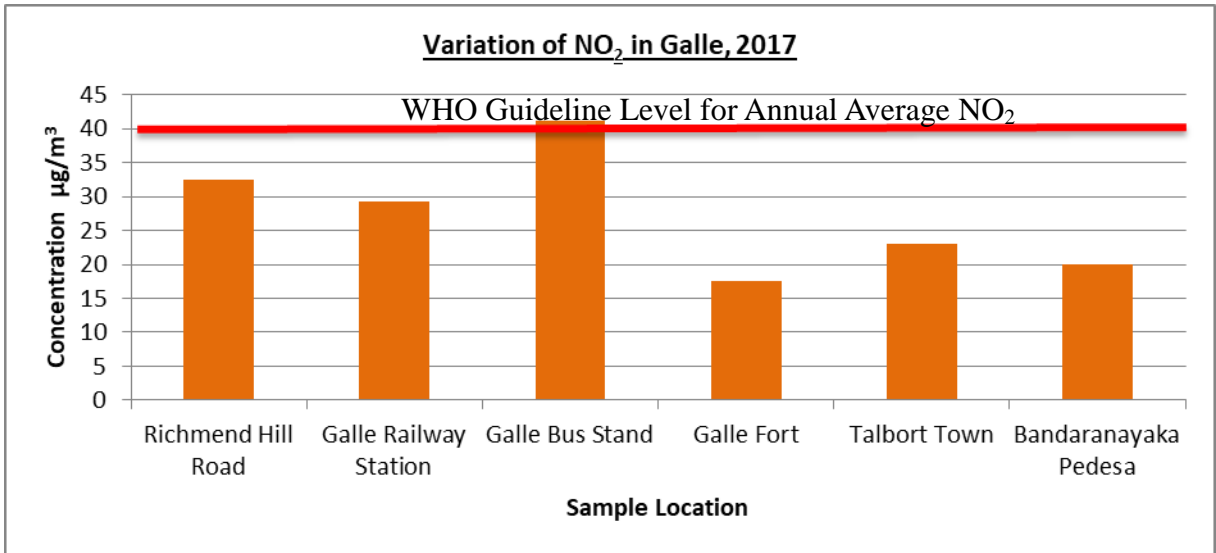


Figure 6.5.4: Annual average NO₂ concentration within Galle Urban Area in 2017

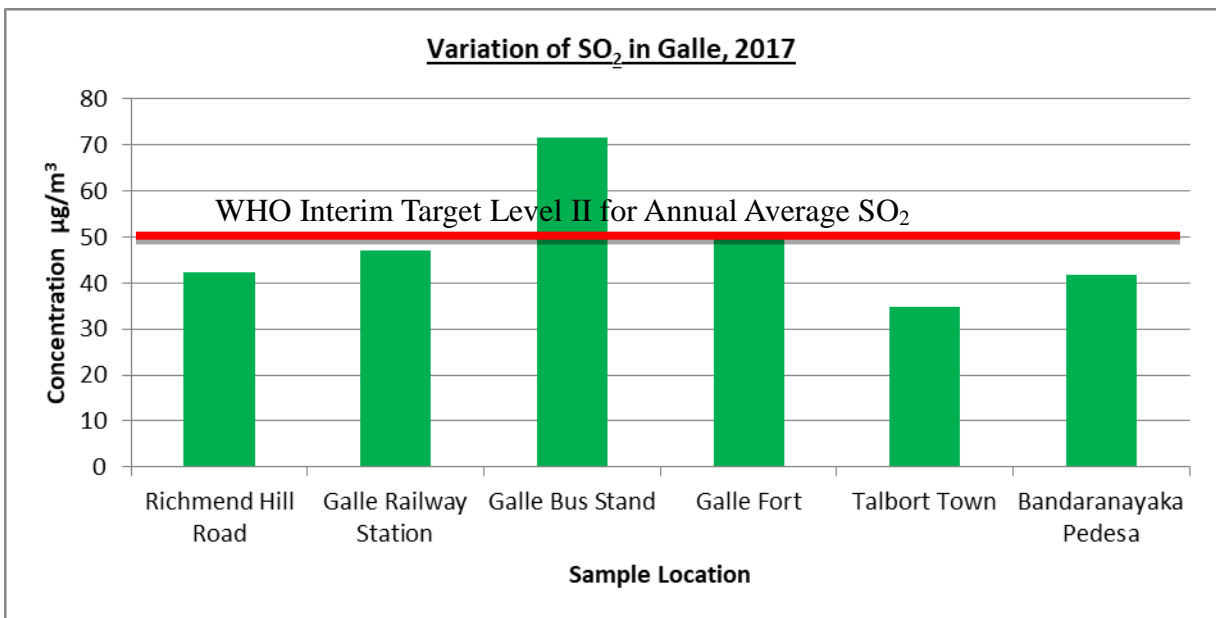


Figure 6.5.5: Annual average SO₂ concentration within Galle Urban Area in 2017

Annual average levels of NO₂ and SO₂ in each location at Galle urban area from 2012 to 2017 are represents in figure 6.5.6 and boxplot of each pollutant for the same period are given in figure 6.5.7 & 6.5.8 respectively. Accordingly, the exposure levels of NO₂ were in decreasing trend while SO₂ levels were in increasing trend from 2012 to 2017. This reduction of pollutant levels in Galle urban area should be due to the actions implemented to manage air quality in Sri Lanka including vehicular emission control through VET program and

development of road surface etc. as well as introduction of cleaner fuel vehicles such as hybrid and electric vehicles to the fleet etc.

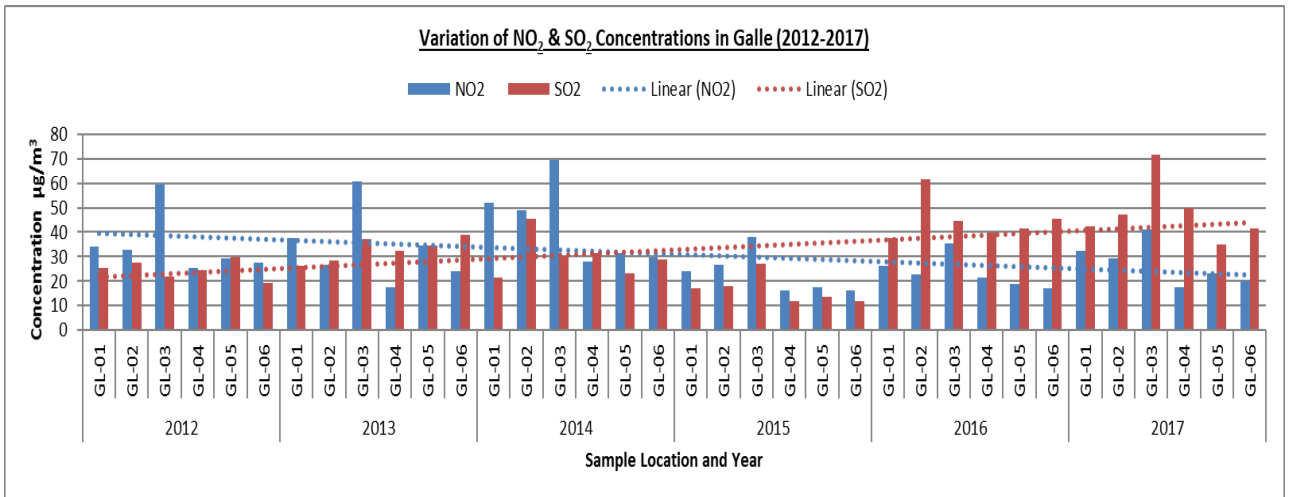


Figure 6.5.6: Average NO₂ and SO₂ variations from 2012-2017

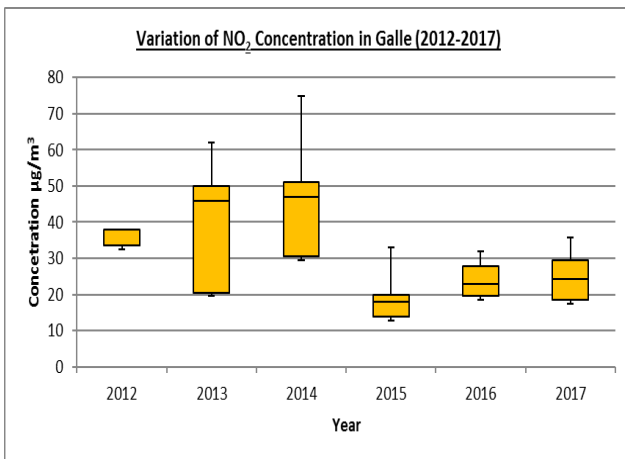


Figure 6.5.7: Boxplot of NO₂ Concentration variation in Galle (2012-2017)

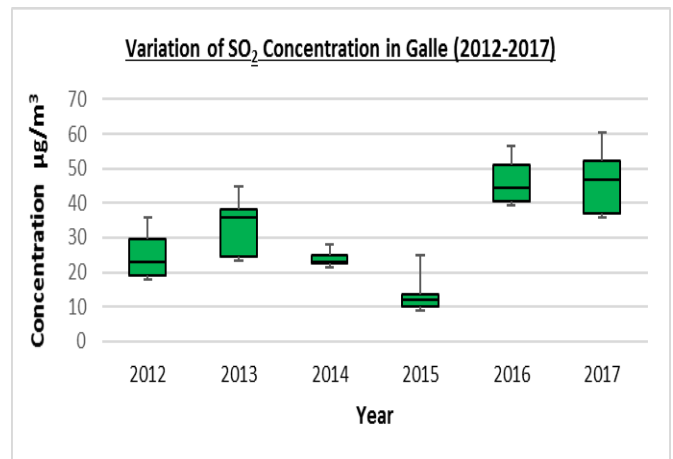


Figure 6.5.8: Boxplot of SO₂ Concentration variation in Galle (2012-2017)

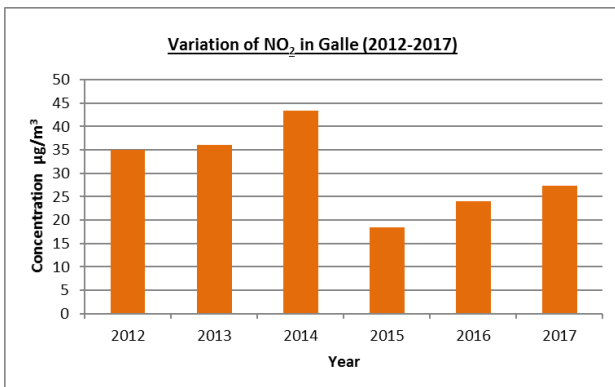


Figure 6.5.9: Annual average NO₂ variations from 2012-2017 in Galle Urban area

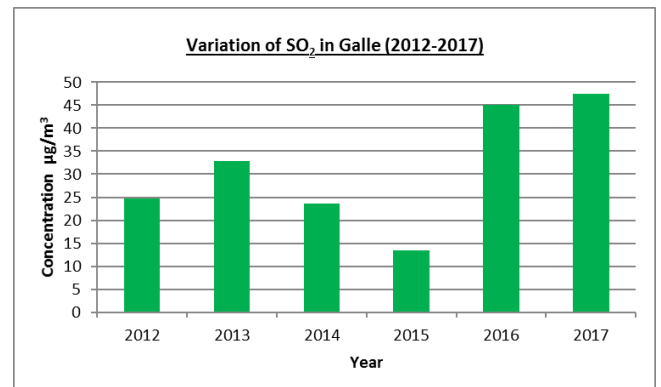
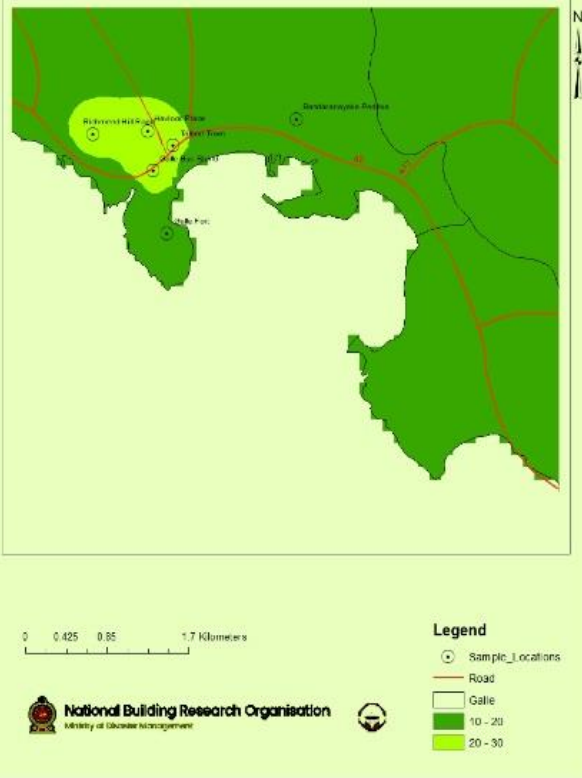
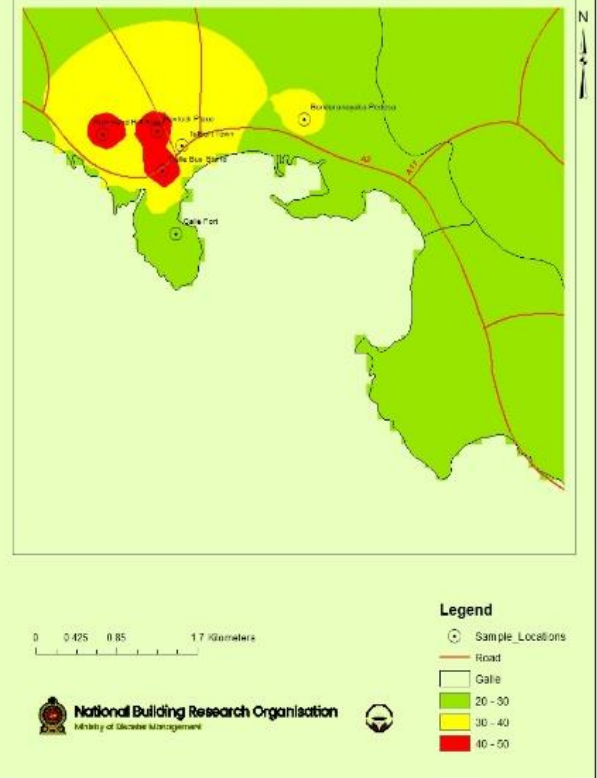


Figure 6.5.10: Annual average SO₂ variations from 2012-2017 in Galle Urban area

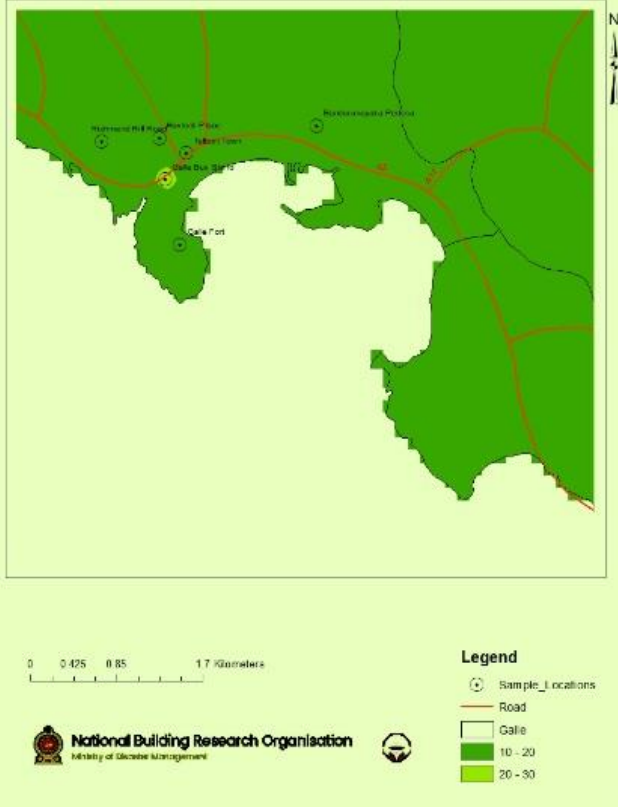
Variation of NO2 Concentration at Galle Urban Area in 2013



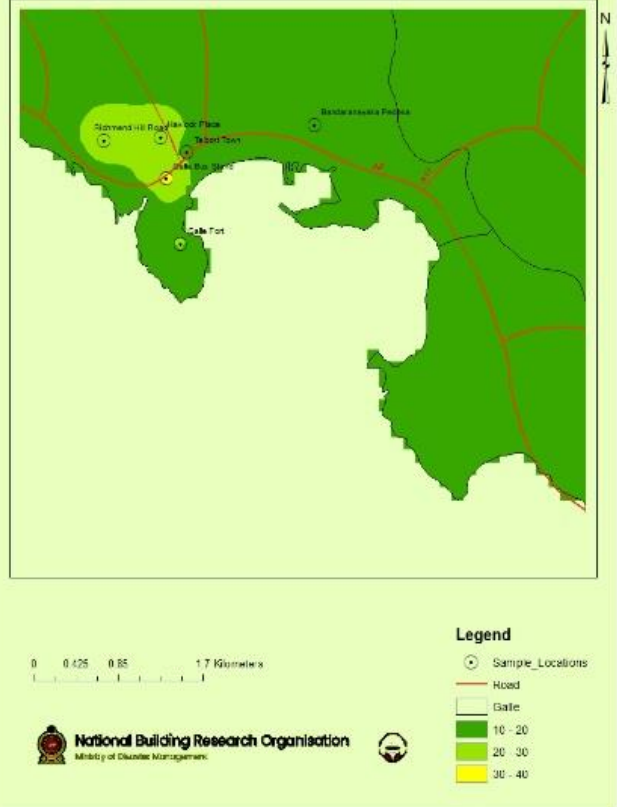
Variation of NO2 Concentration at Galle Urban Area in 2014



Variation of NO2 Concentration at Galle Urban Area in 2015



Variation of NO2 Concentration at Galle Urban Area in 2016



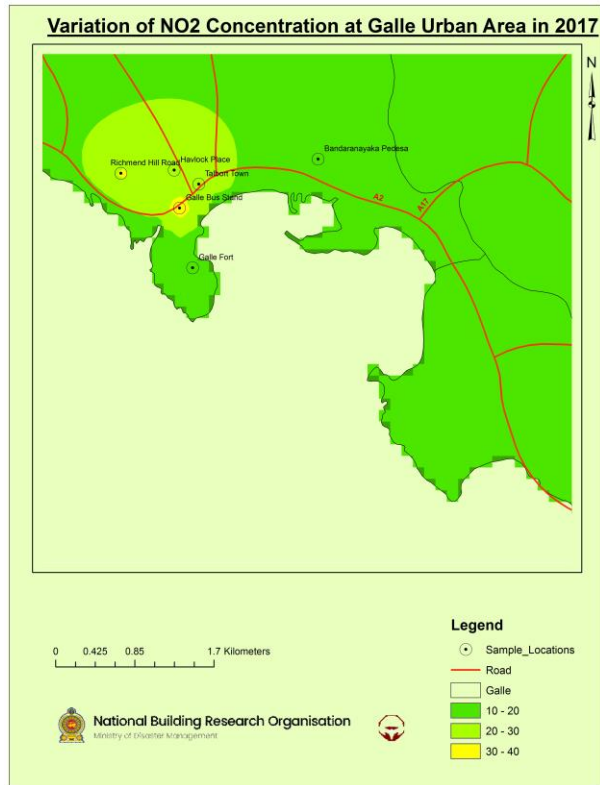
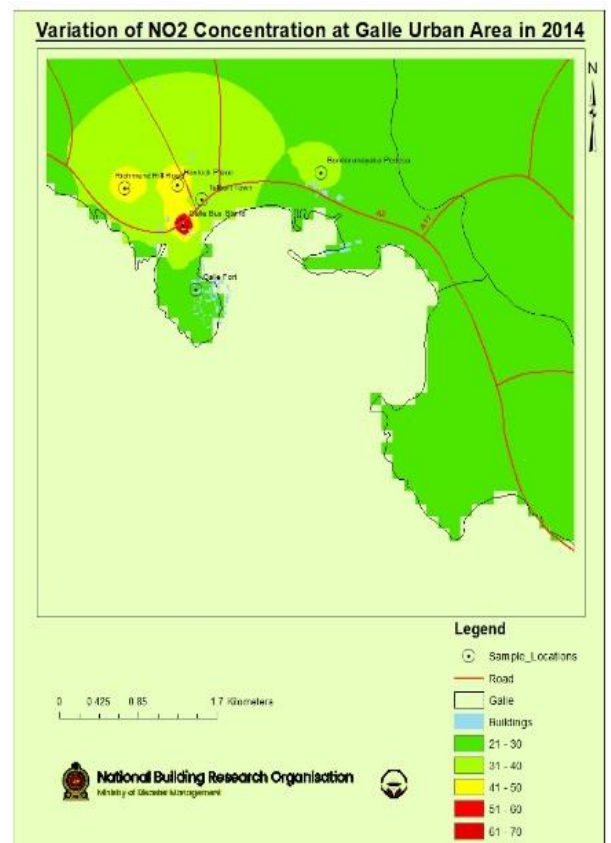
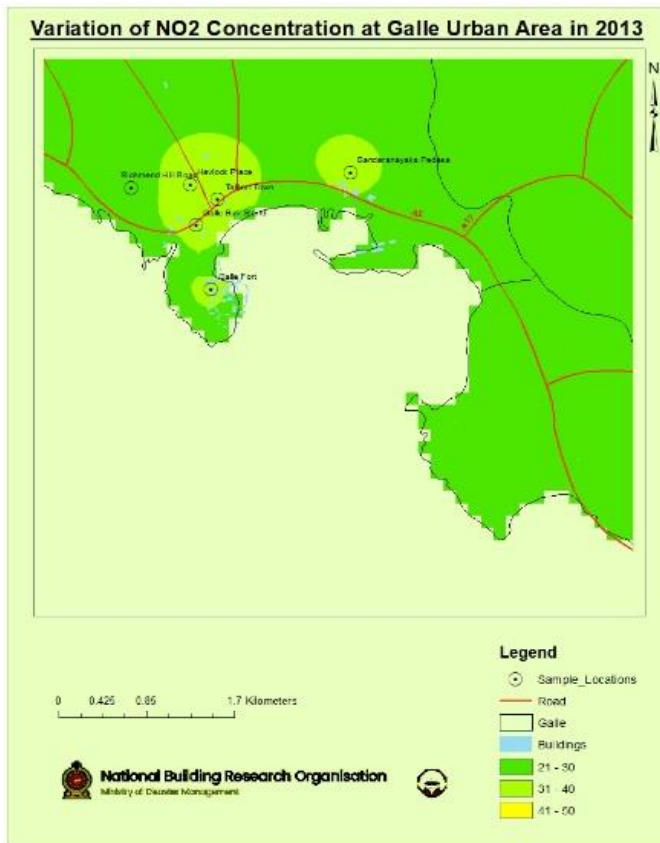


Figure 6.5.11: Variation of NO₂ concentration within Galle Urban Area from 2013 to 2017



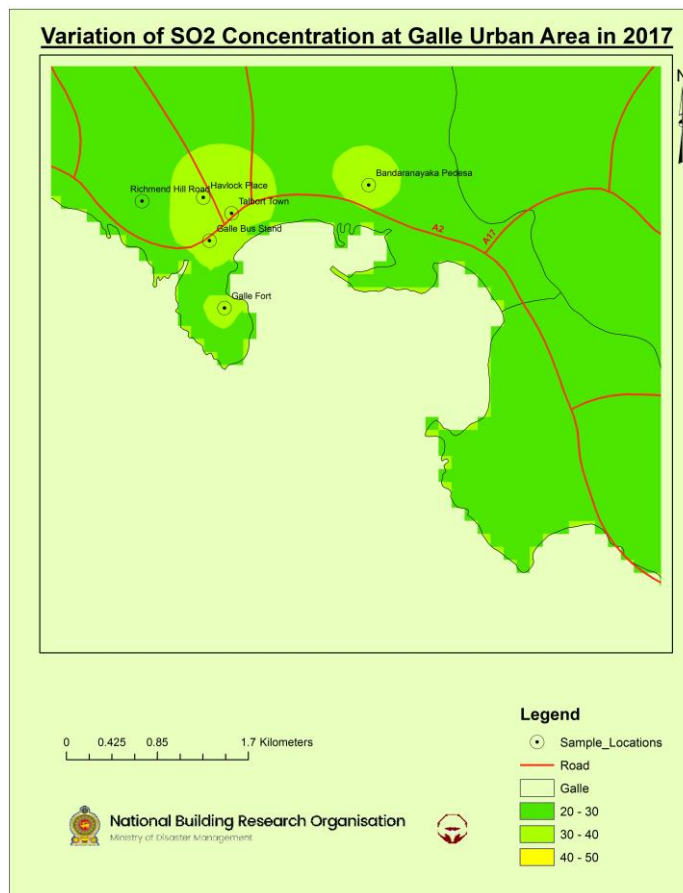
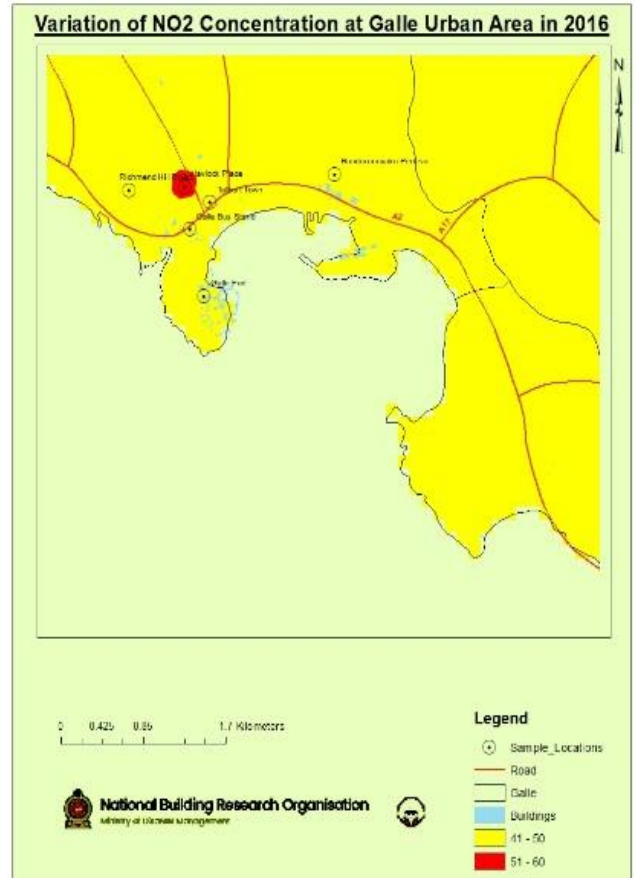
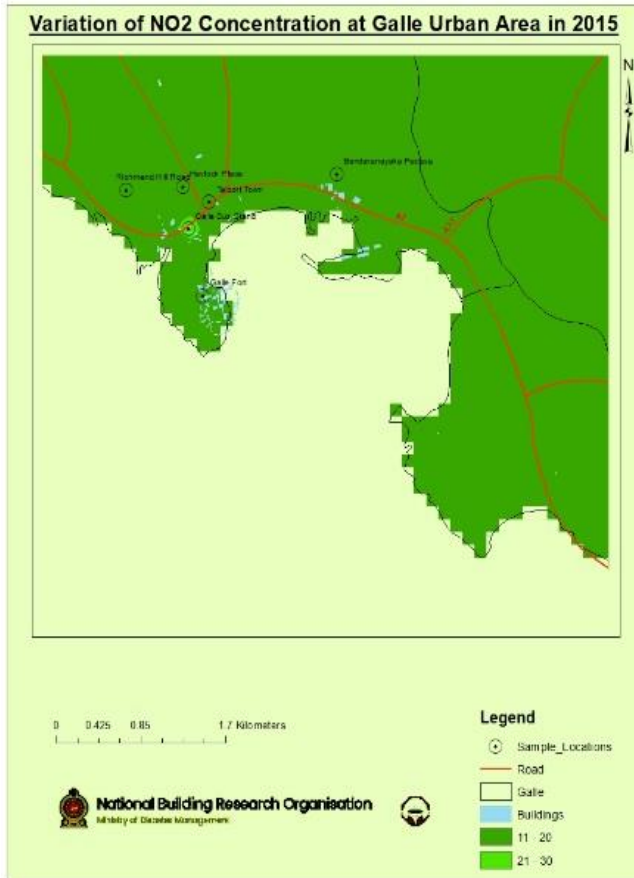
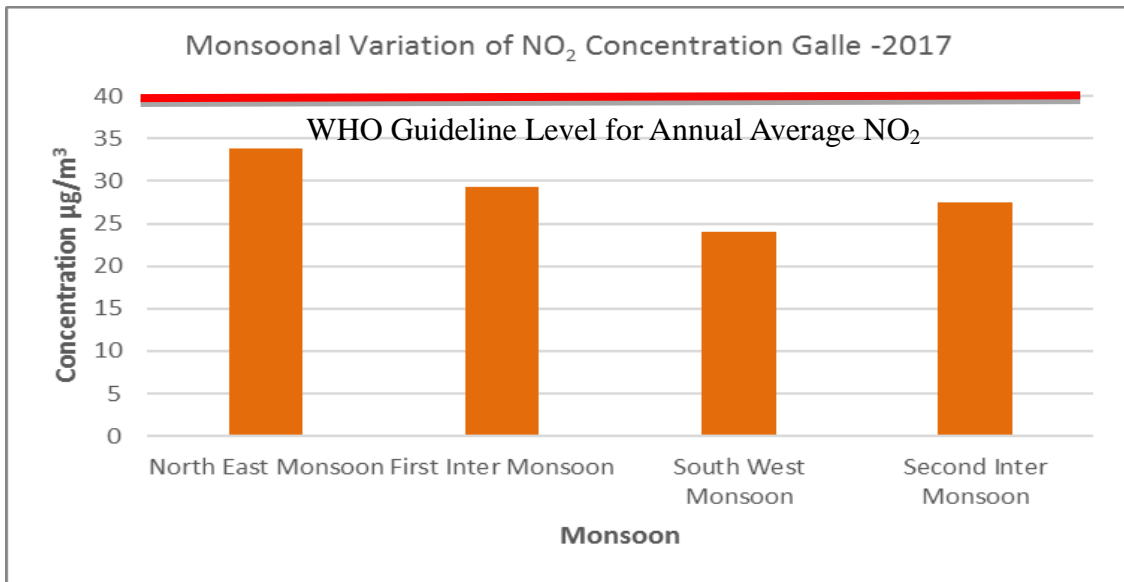
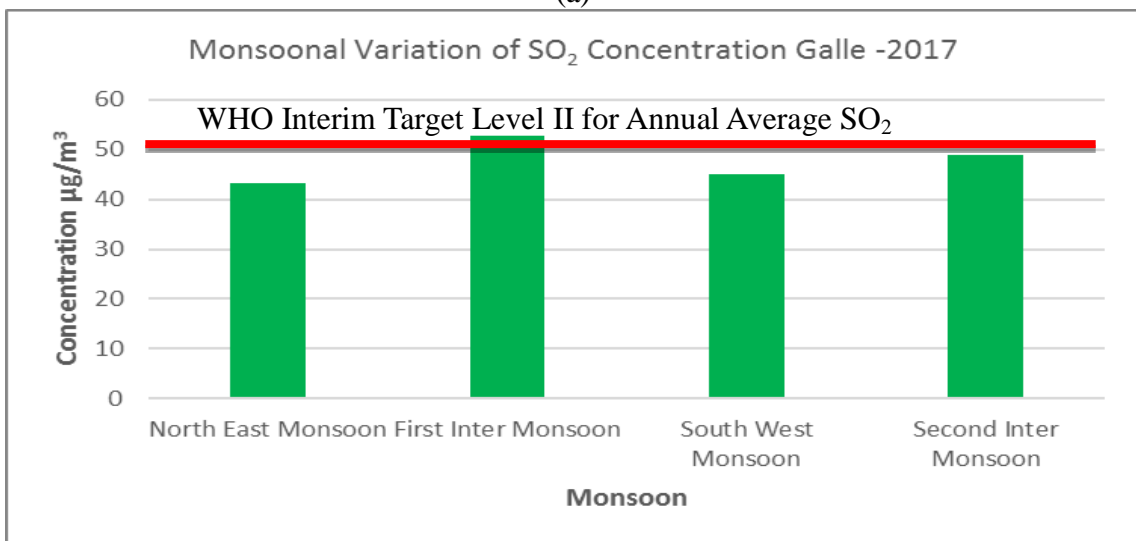


Figure 6.5.12: Variation of SO₂ concentration within Galle Urban Area from 2013 to 2017

As an island, monsoonal variation of the climate is highly affected for the dispersion of these chemical agents. The average exposure of NO₂ and SO₂ level trend has analysed below in figures 6.1.13(a) and 6.1.13(b) respectively. According to that trend analysis, NO₂ exposure has highest exposure in North East Monsoonal and lowest exposure in South West Monsoonal season. But SO₂ has shown another trend, which has highest exposure in first inter monsoonal season and lowest exposure in South West Monsoonal season. However, North East Monsoonal season has higher exposure than South West Monsoonal season in NO₂. This is due to North East Monsoonal wind came through large Indian land area while South West Monsoonal came through Indian ocean. However, throughout the year 2017, NO₂ exposure has accepted exposure level in North East Monsoonal season while SO₂ exposure has achieved interim target level 2. The SO₂ exposure level has exceeded accepted exposure level according to the WHO guidelines.



(a)



(b)

Figure 6.5.13: Monsoonal Variation of (a).NO₂, (b).SO₂ concentration within Horana Urban Area

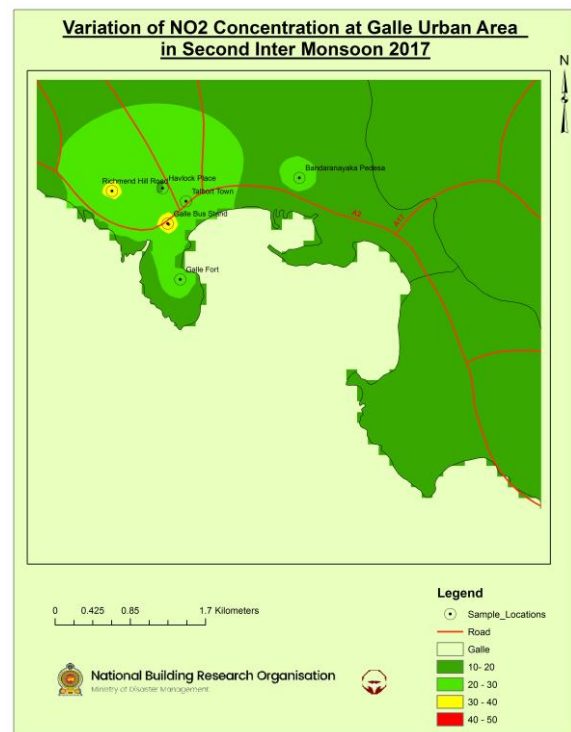
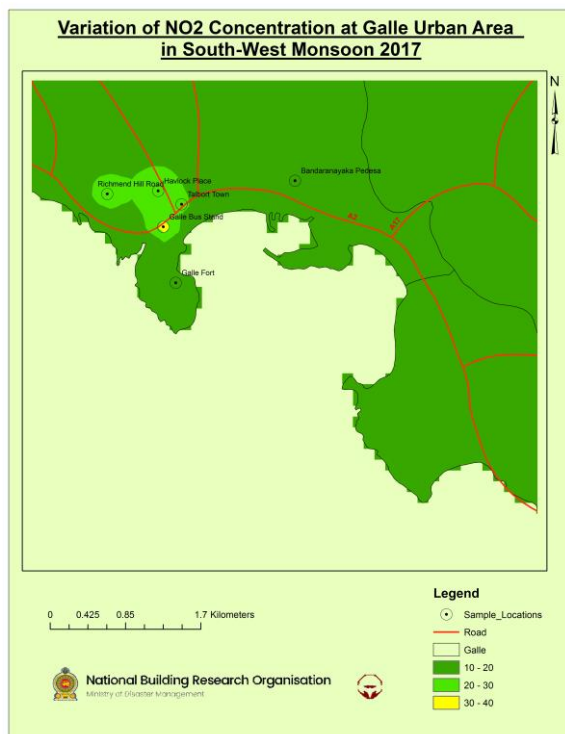
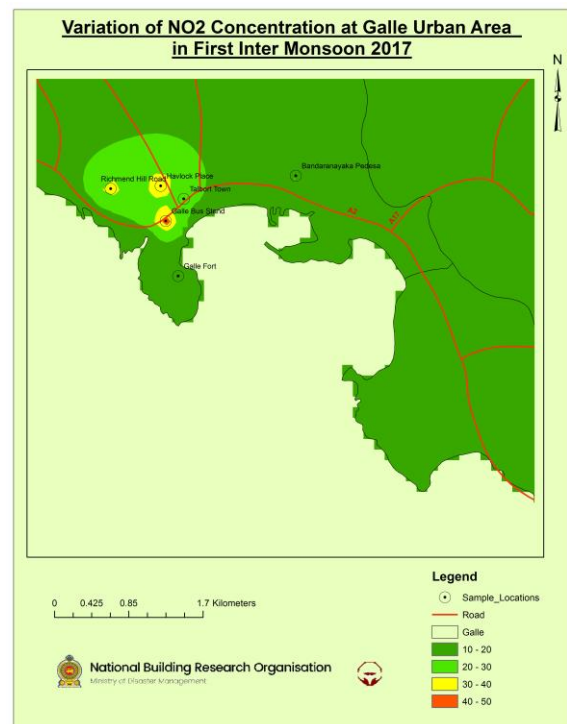
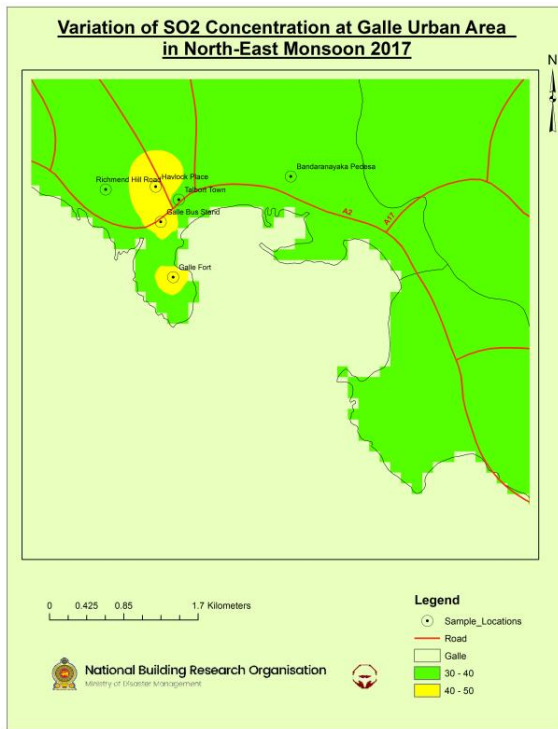


Figure 6.5.14: Monsoonal Seasonal Variation of NO₂ Exposure Galle Urban City in 2107. From left to right it shows North East Monsoonal Season Exposure, First Inter Monsoon Seasonal Exposure, South West Monsoonal Season Exposure and Second Inter Monsoon Season Exposure respectively.

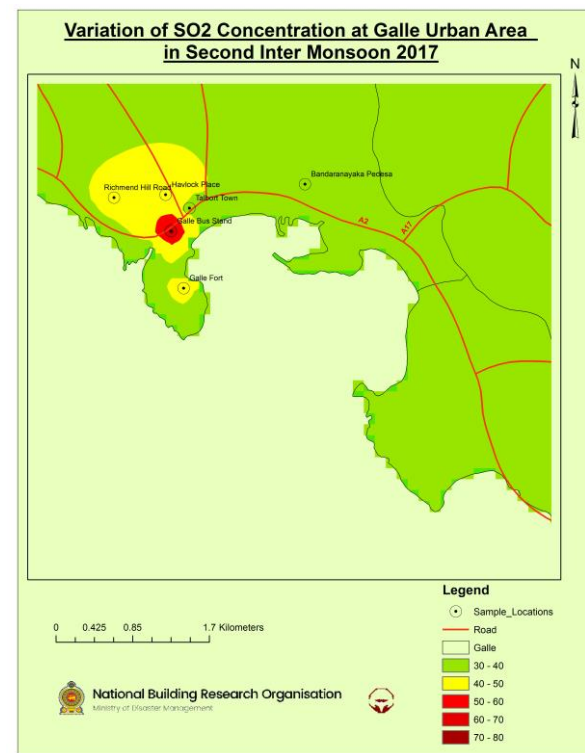
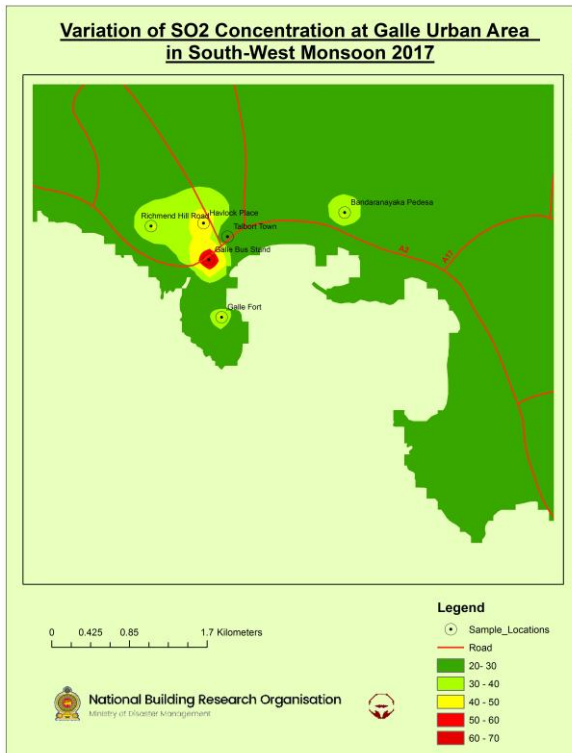
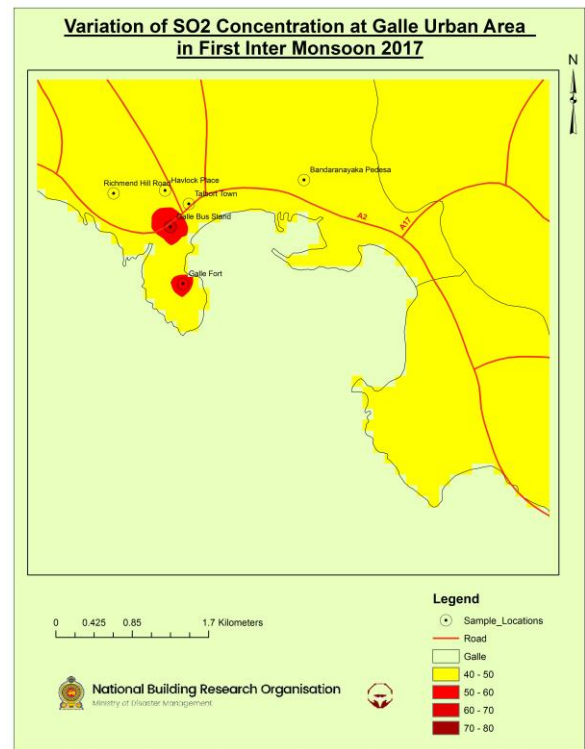
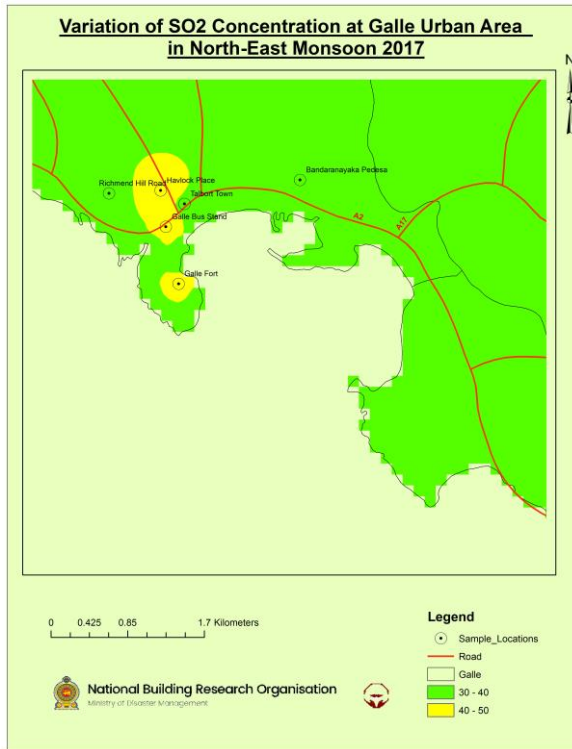


Figure 6.5.15: Monsoonal Seasonal Variation of NO₂ Exposure Galle Urban City in 2107. From left to right it shows North East Monsoonal Season Exposure, First Inter Monsoon Seasonal Exposure, South West Monsoonal Season Exposure and Second Inter Monsoon Season Exposure respectively.

6.6 AMBIENT AIR QUALITY IN 2017 – AT RATNAPURA URBAN AREA

Ratnapura city is the capital city of the Sabaragamuwa Province and the traditional centre for the Sri Lankan gem trade. The city is surrounded by large green areas of tea and rubber plantations as well as several natural forest areas such as Sinharaja Forest Reserve, Udawalawe National Park, Kitulgala, and Adam's Peak etc are closer to the city. The city area is limited to about 20 Km² and relatively high number of vehicles are operated in the city.

Air quality exposure levels with respect to NO₂ and SO₂ in Ratnapura Urban area was started in 2012 at eight locations within the Ratnapura Urban area and surrounding areas with the financial assistant of VET fund. The monitoring program was continued in 2017 to measure monthly average NO₂ and SO₂ level. The monthly average NO₂ and SO₂ exposure levels at each measuring location within Ratnapura urban area in 2017 is summarised in table 6.6.3 and 6.6.4 respectively. Table 6.6.5 shows that PM_{2.5} concentration of selected sample locations in Colombo in 2017.

Air quality exposure levels measuring activities with respect to NO₂ and SO₂ in Ratnapura Urban area were continued in 2017 as well under this project. The sample locations description is given in table 6.6.1 and figure 6.6.1 shows the locations map. The table 6.6.2 presents the overview of each location in the Ratnapura urban area.

Table 6.6.1: Selected Sampling Locations in Ratnapura Urban area

Urban Area	No of Points	Sampling Location	Location Description
Ratnapura	8	RT1	PRP-Ratnapura Town
		RT2	Good Shed Road
		RT3	Kudalawaththa
		RT4	Batugedara
		RT5	Ratnapura Police Station
		RT6	RDA-Muwagama
		RT7	Saman Dewalaya
		RT8	New Town

Sample Locations at Rathnapura Urban Area

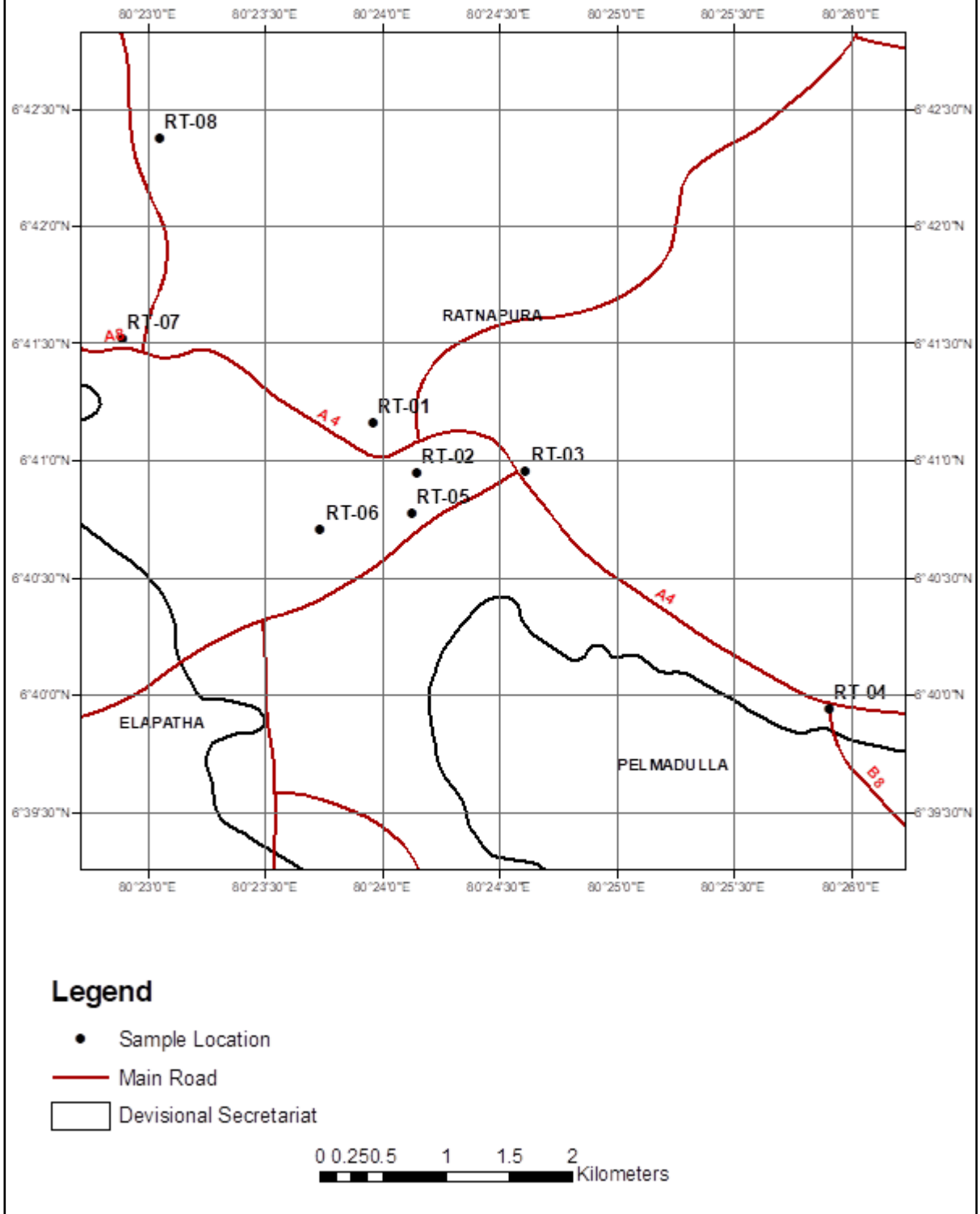


Figure 6.6.1: Sampling Locations Map in Rathnapura Urban area

Table 6.6.2: Overview of each location in the Ratnapura urban area



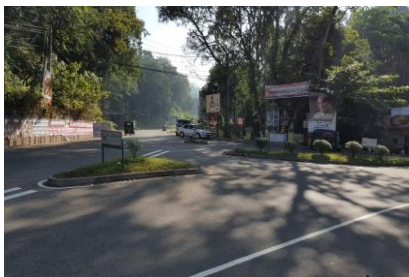
Location No: RT1
 Location Name: New Town
 GPS Coordinates: 6.6859740N,
 80.3993010E



Location No: RT2
 Location Name: Goodshed Rd
 GPS Coordinates: 6.6824210N
 80.4024180E



Location No: RT3
 Location Name: Udugalwatta
 GPS Coordinates: 6.6825300N
 80.4101800E



Location No: RT4
 Location Name: Batugedara
 GPS Coordinates: 6.6656150N,
 80.4317770E



Location No: RT5
 Location Name: Police Station
 GPS Coordinates: 6.6795860N
 80.4020370E



Location No: RT6
 Location Name: Muwagama
 GPS Coordinates: 6.6784070N
 80.3955637E



Location No: RT7
 Location Name: Saman Dewa.
 GPS Coordinates: 6.6920270N,
 80.3815000E



Location No: RT8
 Location Name: Town Area
 GPS Coordinates: 6.7062650N
 80.3840720E

Monthly average NO₂ and SO₂ exposure levels at each measuring location within Ratnapura urban area for the year 2017 is summarised in table 6.6.3 and 6.6.4 respectively. However, some of data were missing due to the missing of passive sampler due to unavoidable situations such as personal or urban council activities, attacking of animals or birds and some climatic conditions such as rain and flood etc.

Table 6.6.3: Monthly Average Exposure Levels of NO₂ at each location in Ratnapura Urban Area

Urban Area	Location	NO ₂ Concentration(µg/m ³)											
		Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
Ratnapura Town	RT 1	33	35	28	28	20	19	19	17	25	37	37	51
Good Shed Road	RT 2	43	31	45	28	31	45	-	51	-	28	27	36
Kudalawaththa	RT 3	40	46	37	30	35	35	35	38	26	37	34	42
Batugedara	RT 4	35	39	33	31	29	26	26	21	23	37	27	34
Ratnapura Police Station	RT 5	45	56	37	31	34	38	38	32	26	32	38	45
RDA-Muwagama	RT 6	25	35	22	24	17	18	18	13	18	36	25	28
Saman Dewalaya	RT 7	33	37	27	22	-	16	16	17	15	22	26	29
New Town	RT 8	34	44	26	29	26	20	20	17	14	30	25	28

Table 6.6.4: Monthly Average Exposure Levels of SO₂ at each location in Ratnapura Urban Area

Urban Area	Location	SO ₂ Concentration(µg/m ³)											
		Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
Ratnapura Town	RT 1	40	41	48	49	52	51	35	36	51	59	44	51
Good Shed Road	RT 2	57	52	43	-	58	54	23	39	31	55	49	36
Kudalawaththa	RT 3	52	43	34	48	52	40	23	41	39	56	52	58
Batugedara	RT 4	49	43	44	45	50	56	34	39	38	61	23	57
Ratnapura Police Station	RT 5	55	42	43	57	62	66	32	43	22	55	36	39
RDA-Muwagama	RT 6	47	33	30	49	45	52	42	32	40	44	48	41
Saman Dewalaya	RT 7	40	42	36	39	30	40	23	21	18	37	28	35
New Town	RT 8	42	40	42	35	49	55	21	52	44	54	51	40

Table 6.6.5: 24 hourly Average Levels of PM_{2.5} at Selected location in Ratnapura Urban Area

City	Site Name	PM _{2.5} (µg/m ³)											
		Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
Ratnapura	Police station (RT 5)	-	-	-	-	-	-	-	-	-	-	44	45

The figure 6.6.2(a) and 6.6.2(b) presented the variation of NO₂ and SO₂ in each location within the year 2017 in Ratnapura Urban Area. When considering both NO₂ and SO₂ concentrations it can be seen that the highest pollutant concentrations are at “Good Shed Road” urban area for several months. Figure 6.6.3 shows that variation of PM_{2.5} concentration in selected sample locations in Colombo in 2017

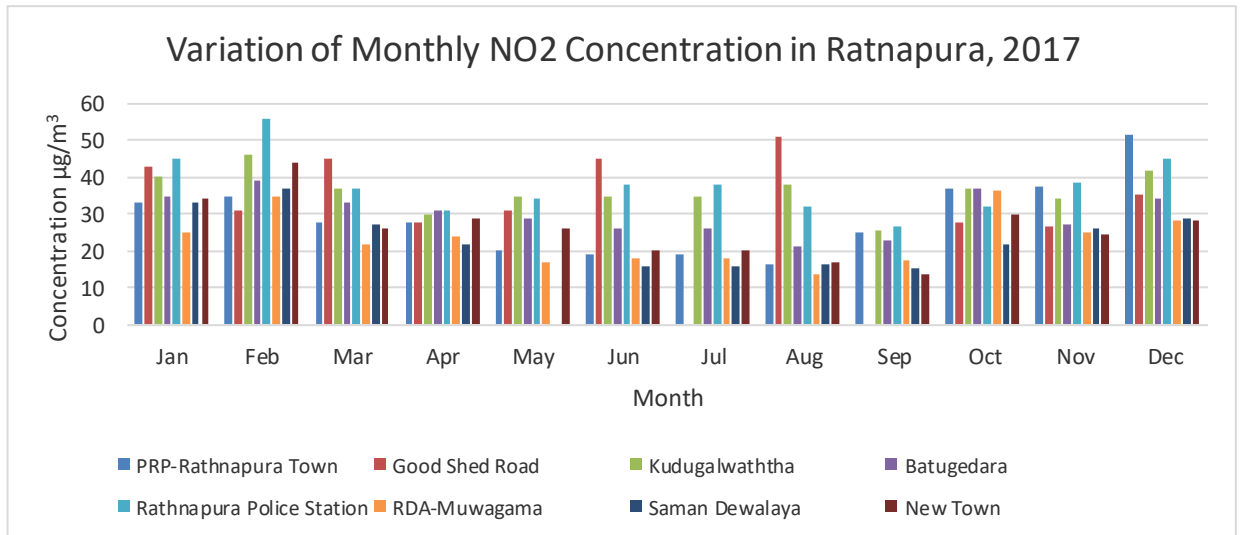


Figure 6.6.2(a): Variation of NO₂ concentration within Ratnapura Urban Area in 2017

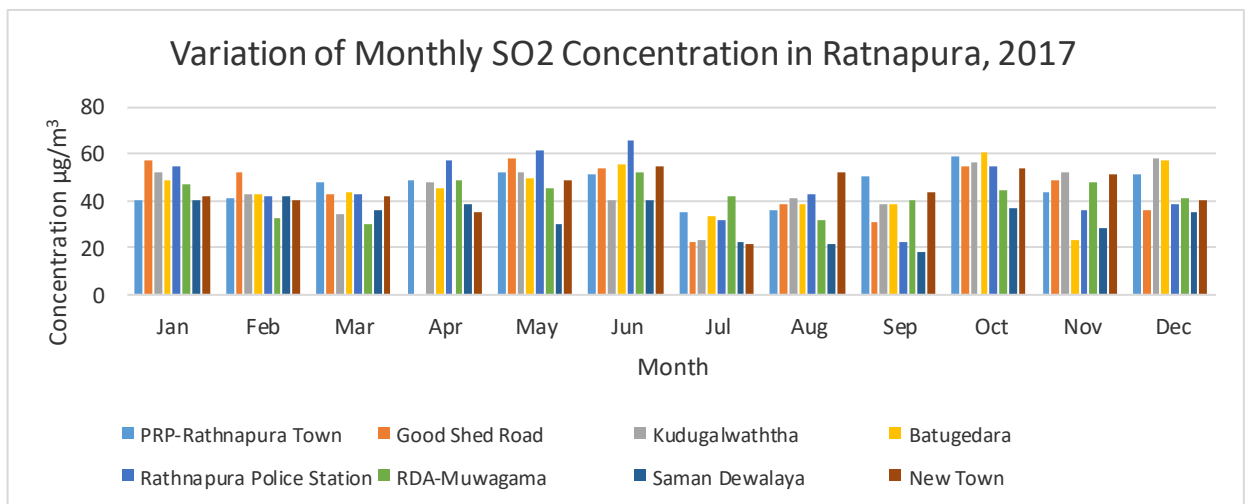


Figure 6.6.2(b): Variation of SO₂ concentration within Ratnapura Urban Area in 2017

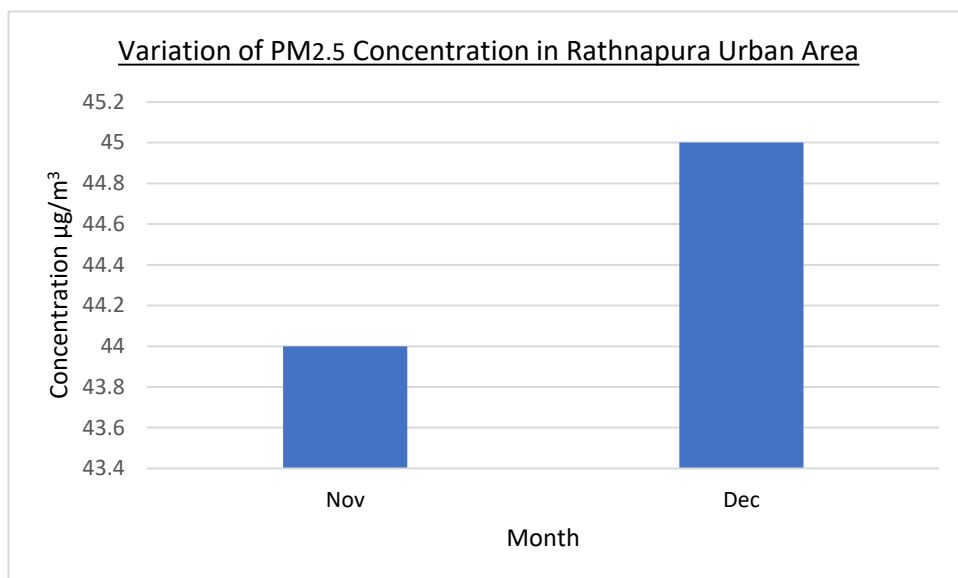


Figure 6.6.3: Variation of PM_{2.5} concentration within Ratnapura Urban Area

Figure 6.6.4 and 6.6.5 represent the annual average NO₂ and SO₂ concentration levels at each sampling location in Ratnapura urban area during the year 2017. The annual average NO₂ and SO₂ levels in year 2017 are in between 23 µg/m³ – 38 µg/m³ and 32 µg/m³ - 46 µg/m³ respectively. The high levels are representing areas with high traffic areas such as Good Shed Road (RT2), Kudugalwaththa (RT3) and Police Station (RT5) where exceeded the annual WHO guideline values for NO₂ and 24 hour WHO guideline values for SO₂. Low levels are recorded at locations away from the city area such as Muwagama (RT6), Saman Dewalaya (RT7) and New Town (RT8) etc.

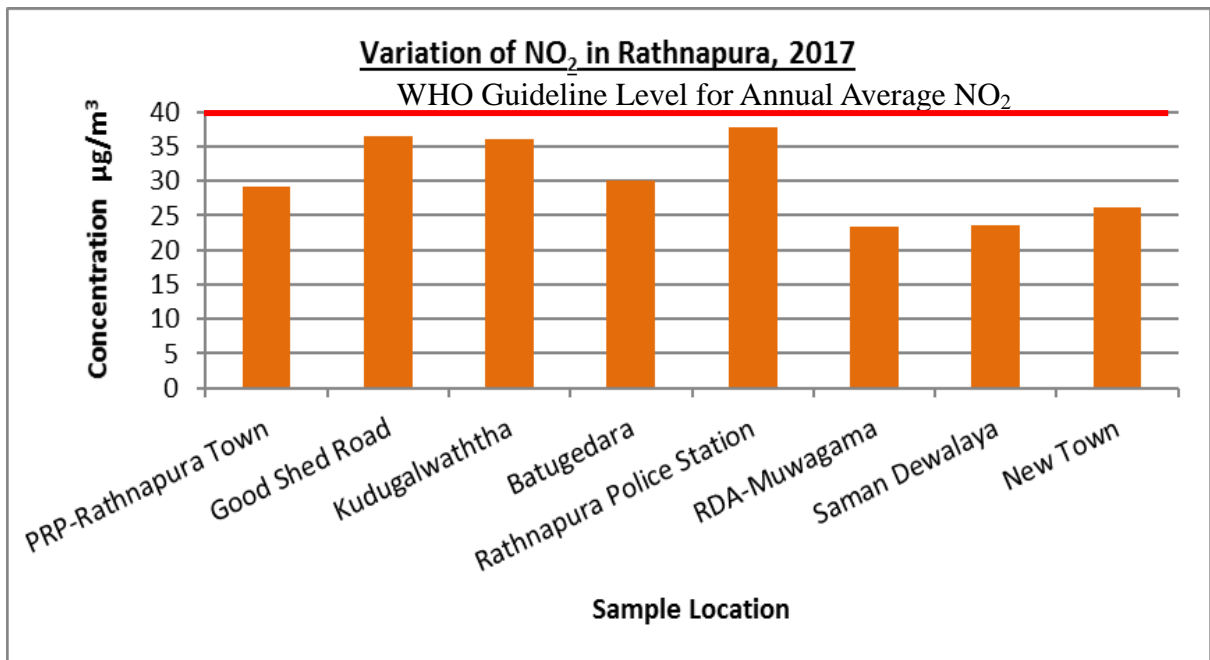


Figure 6.6.4: Annual average NO₂ concentration within Ratnapura Urban Area in 2017

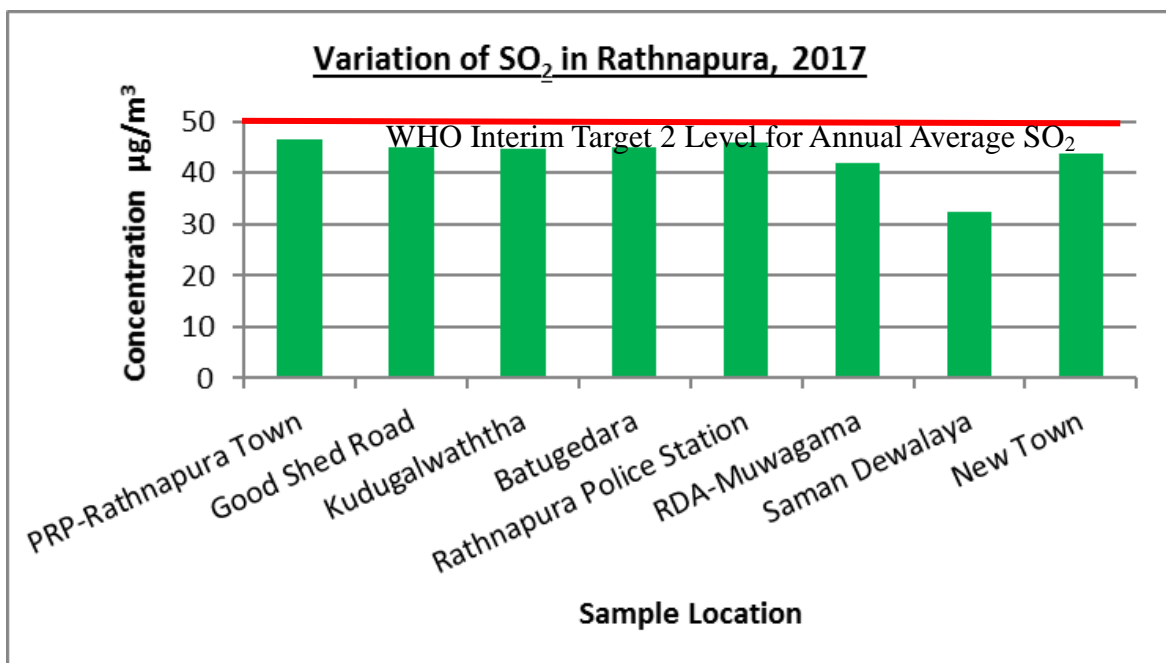


Figure 6.6.5: Annual average SO₂ concentration within Ratnapura Urban Area in 2017

Annual average levels of NO₂ and SO₂ in each location at Ratnapura urban area from 2012 to 2017 are represents in figure 6.6.6 and boxplot of each pollutant for the same period are given in figure 6.6.7 & 6.6.8 respectively. Also, representative maps for NO₂ and SO₂ from 2012 to 2017 are shown in figure 6.6.9 and 6.2.10 respectively. Accordingly, the exposure levels of NO₂ were in decreasing trend while SO₂ levels were in slightly increasing trend from 2012 to 2017. This reduction of pollutant levels in Ratnapura urban area should be due to the actions implemented to manage air quality in Sri Lanka including vehicular emission control through VET program and development of road surface etc. as well as introduction of cleaner fuel vehicles such as hybrid and electric vehicles to the fleet etc.

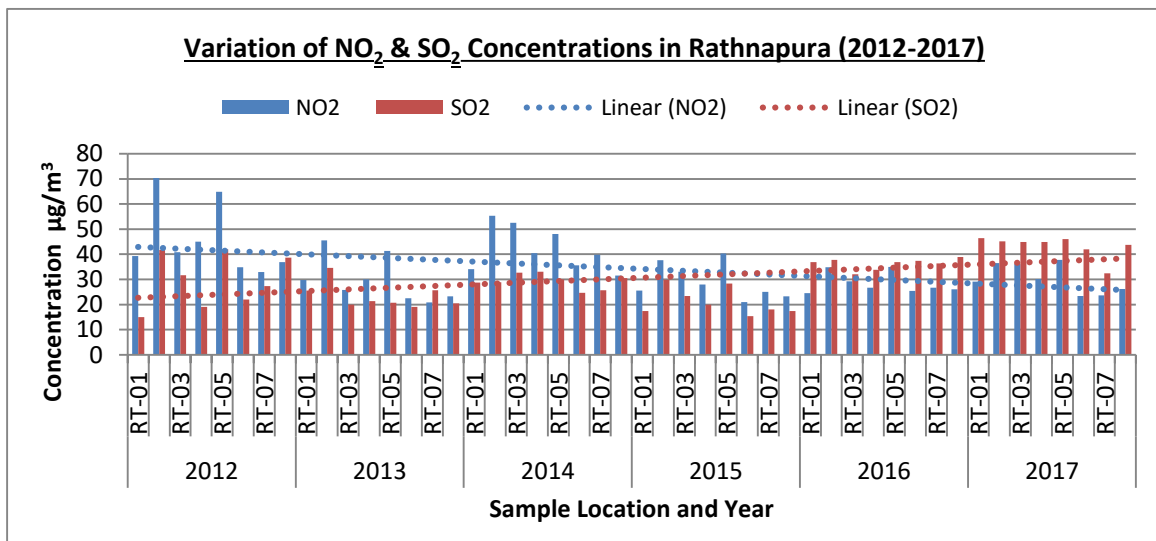


Figure 6.6.6: Average NO₂ and SO₂ variations from 2012-2017

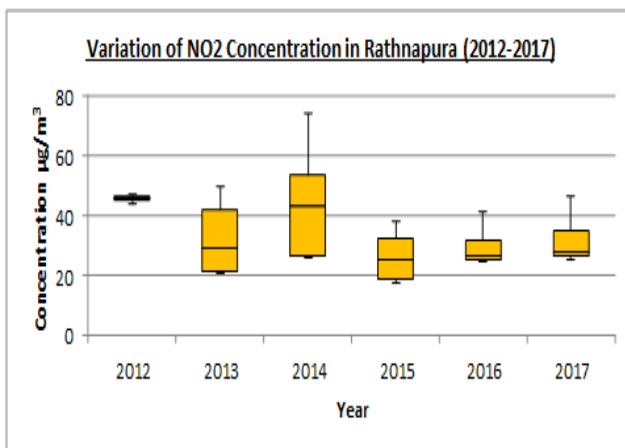


Figure 6.6.7: Boxplot of NO₂ Concentration variation in Ratnapura (2012-2017)

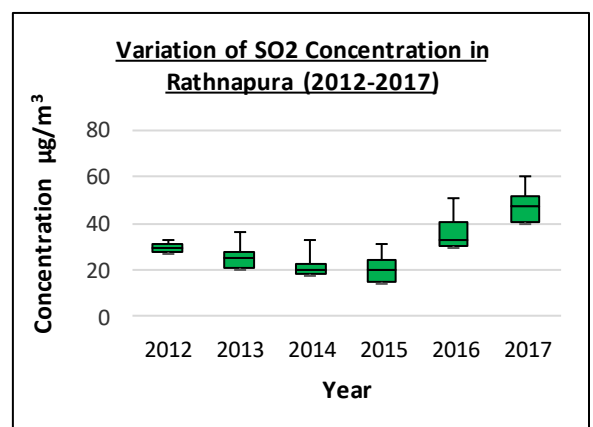


Figure 6.6.8: Boxplot of SO₂ Concentration variation in Ratnapura (2012-2017)

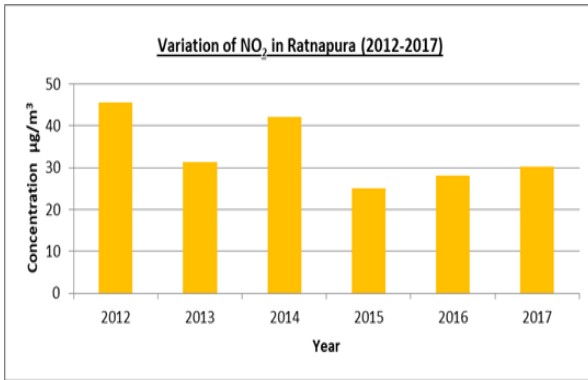


Figure 6.6.9: Annual average NO₂ variations from 2012-2017 in Ratnapura Urban area

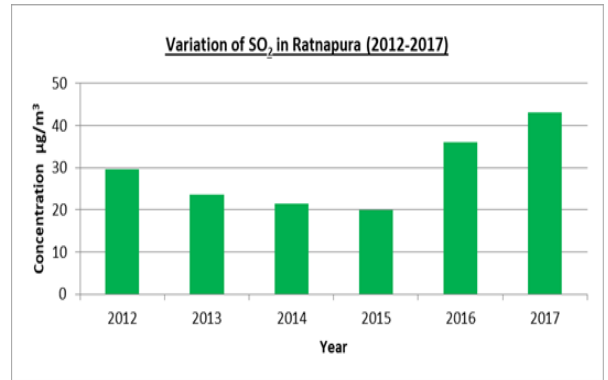
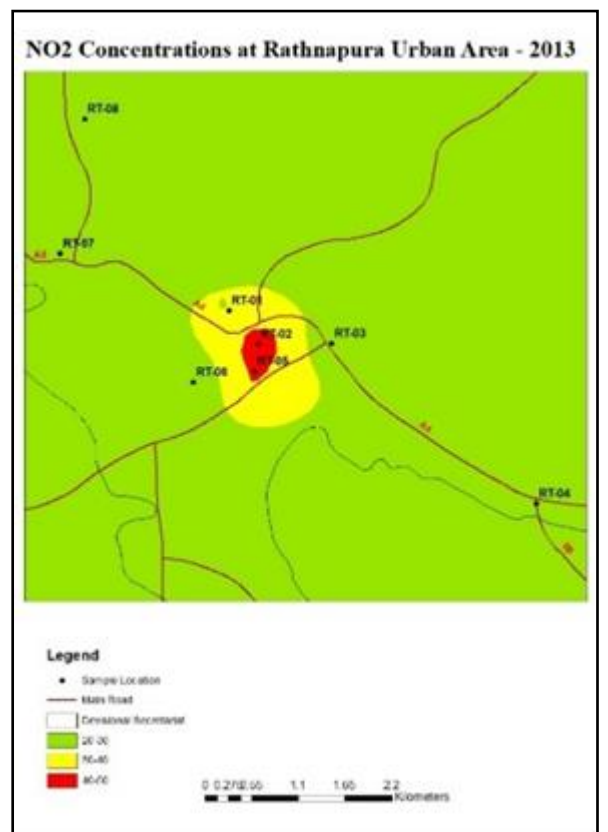
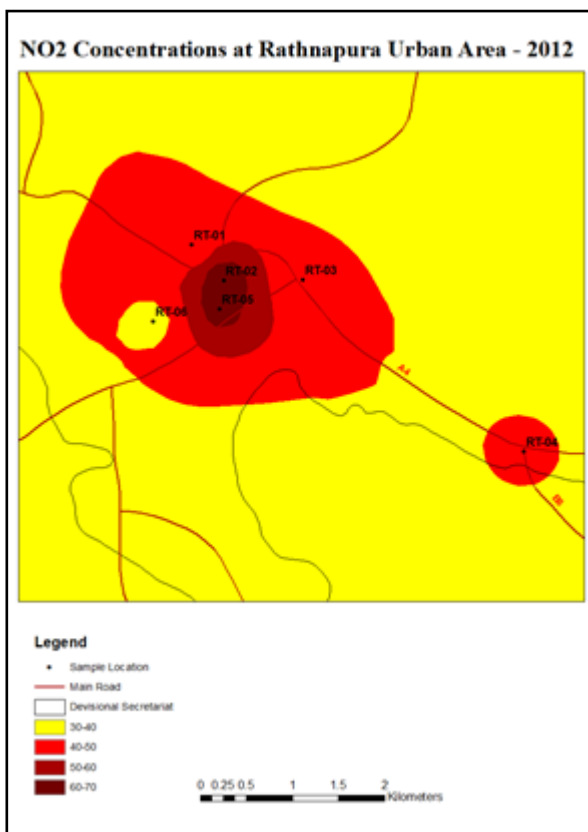


Figure 6.6.10: Annual average SO₂ variations from 2012-2017 in Ratnapura Urban area



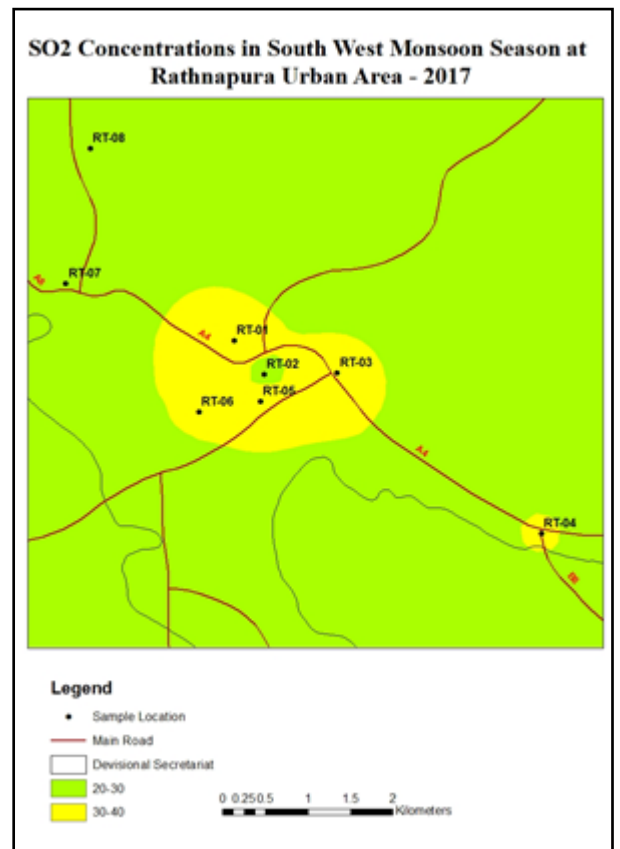
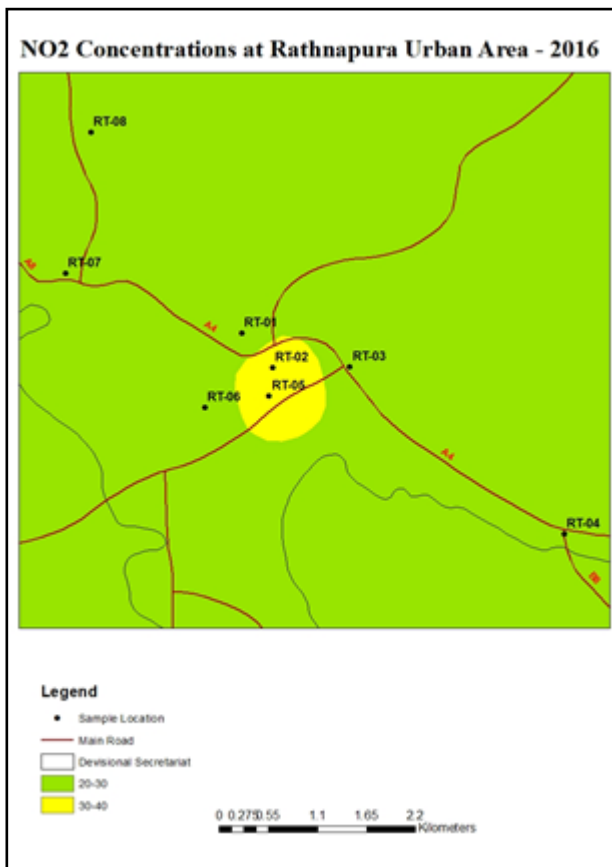
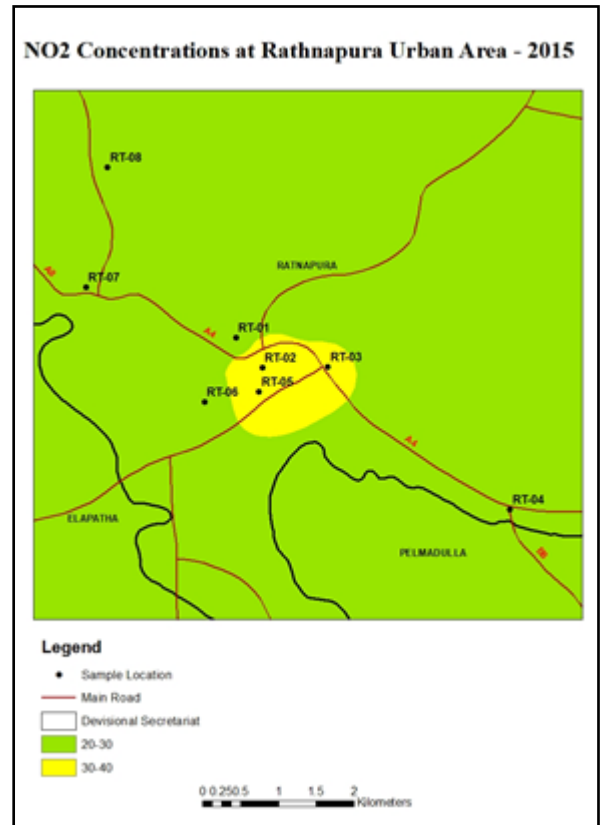
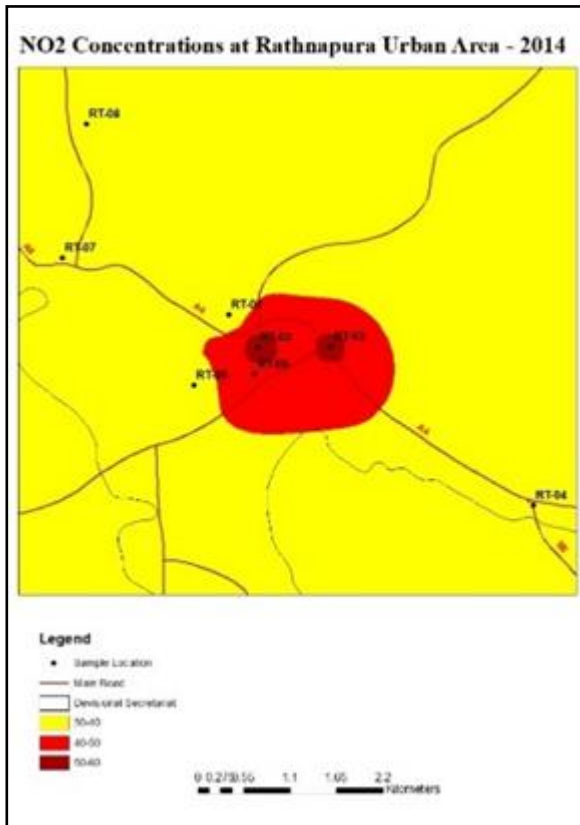
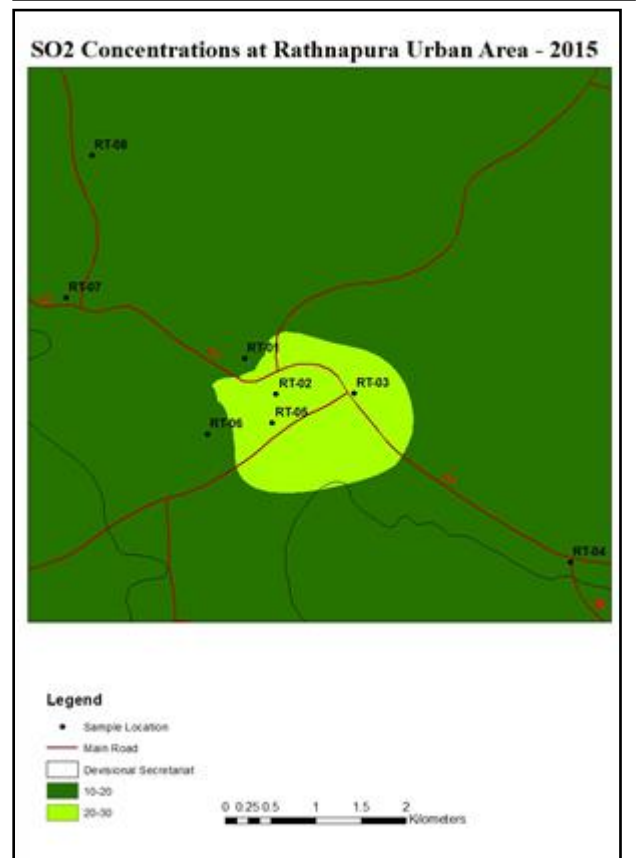
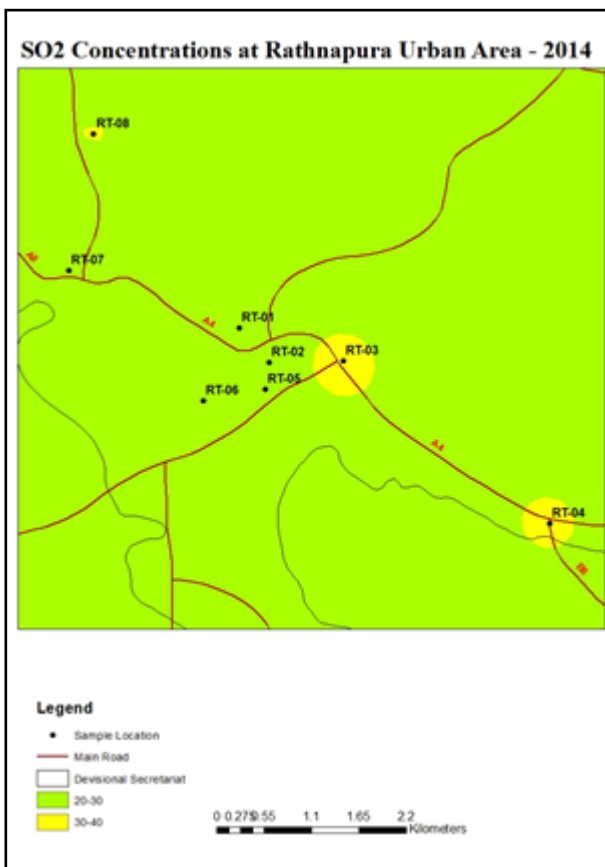
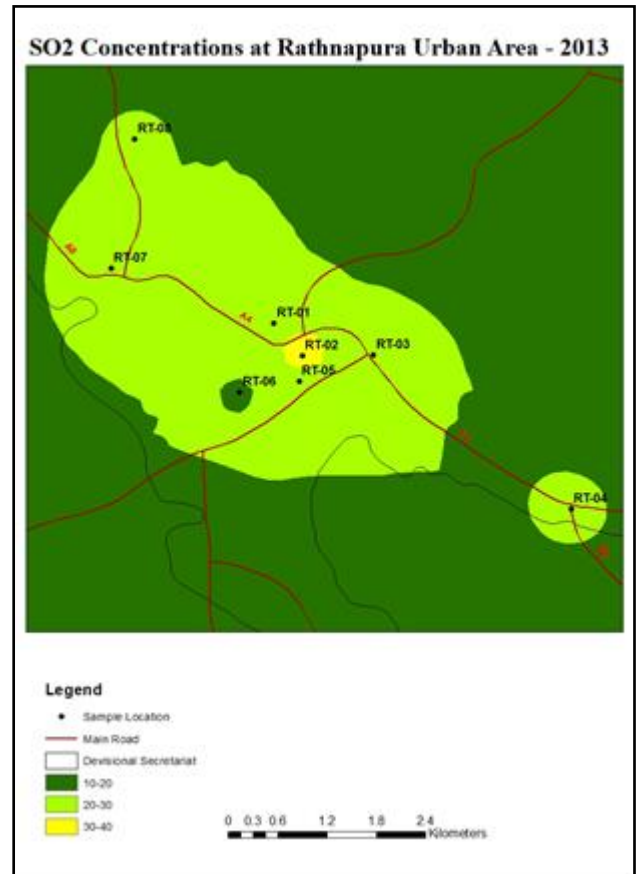
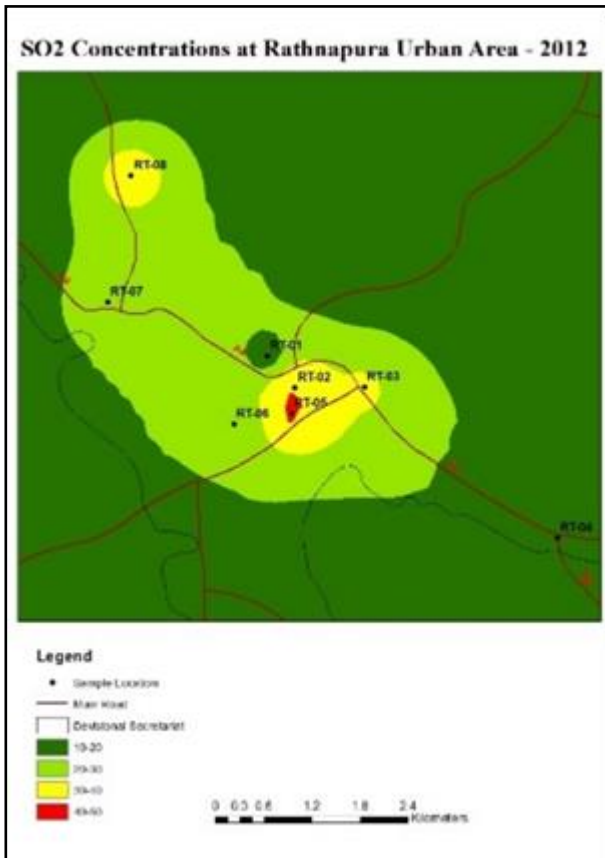


Figure 6.6.11: Annual average NO₂ concentration within Rathnapura Urban Area 2012 – 2017



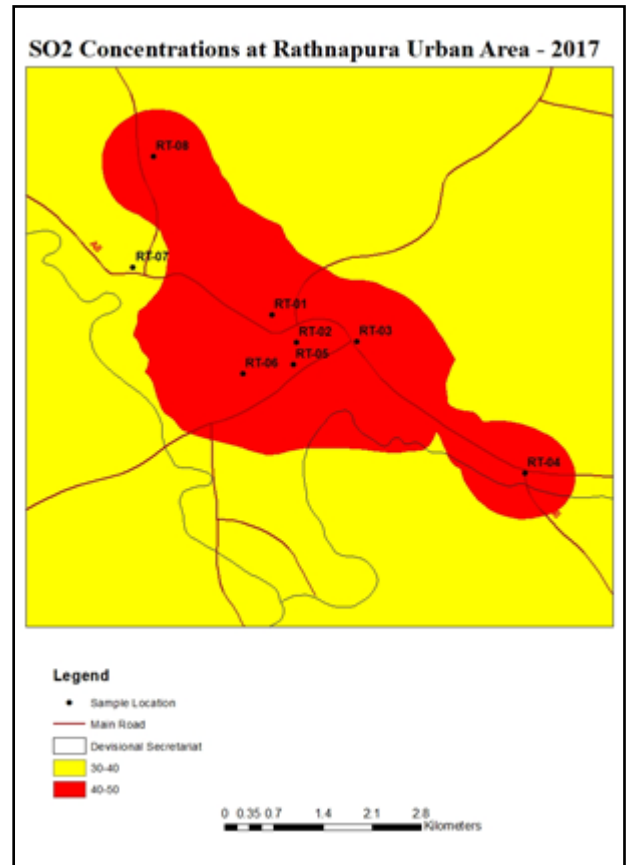
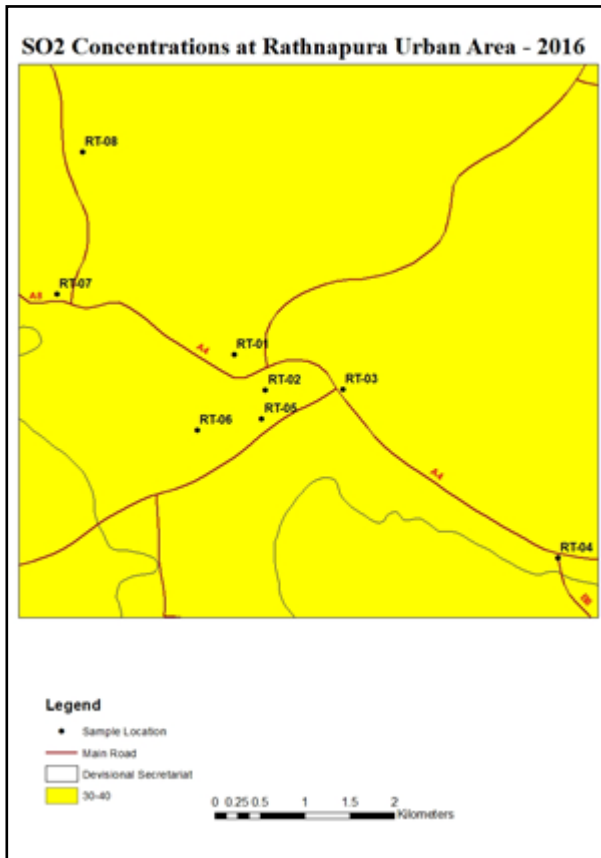
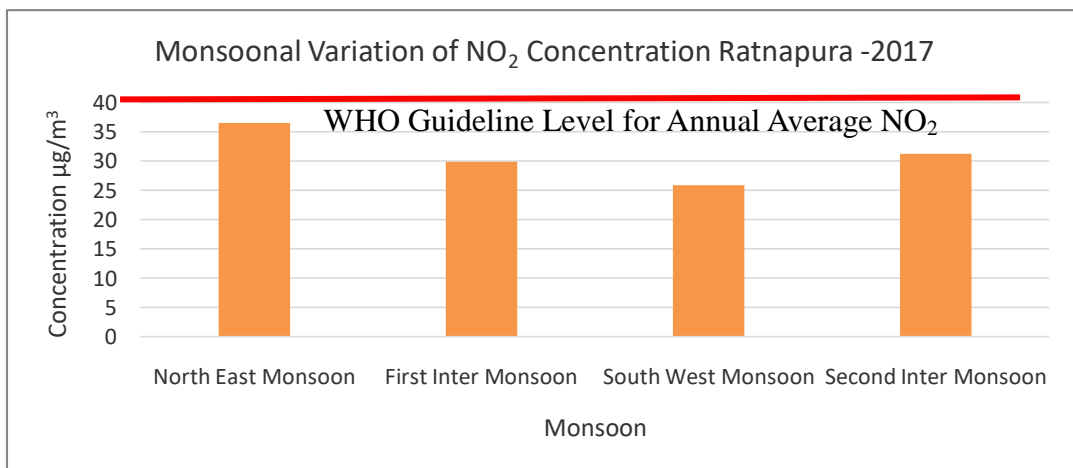
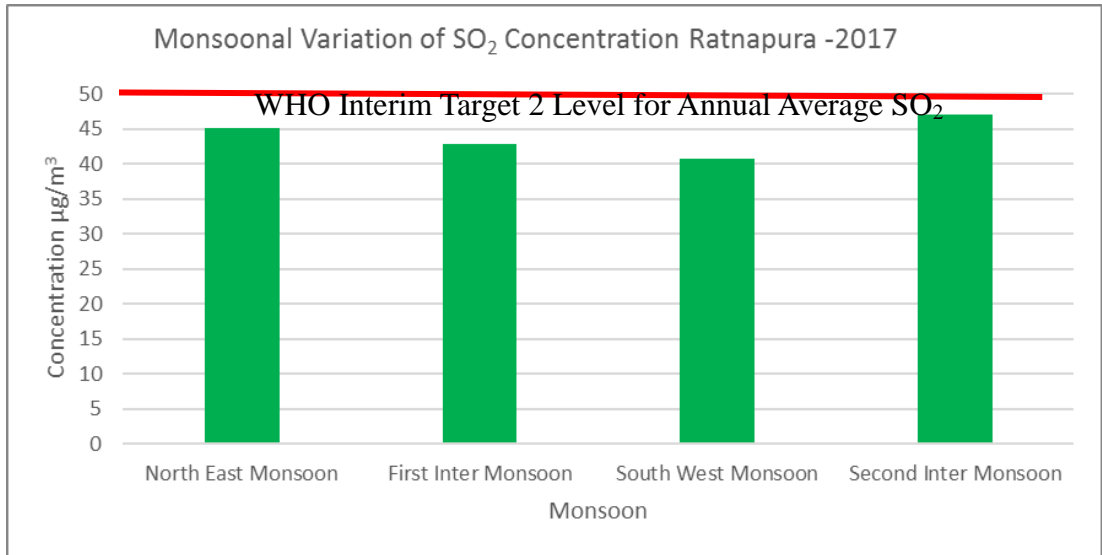


Figure 6.6.12: Annual average SO₂ concentration within Rathnapura Urban Area 2012 – 2017



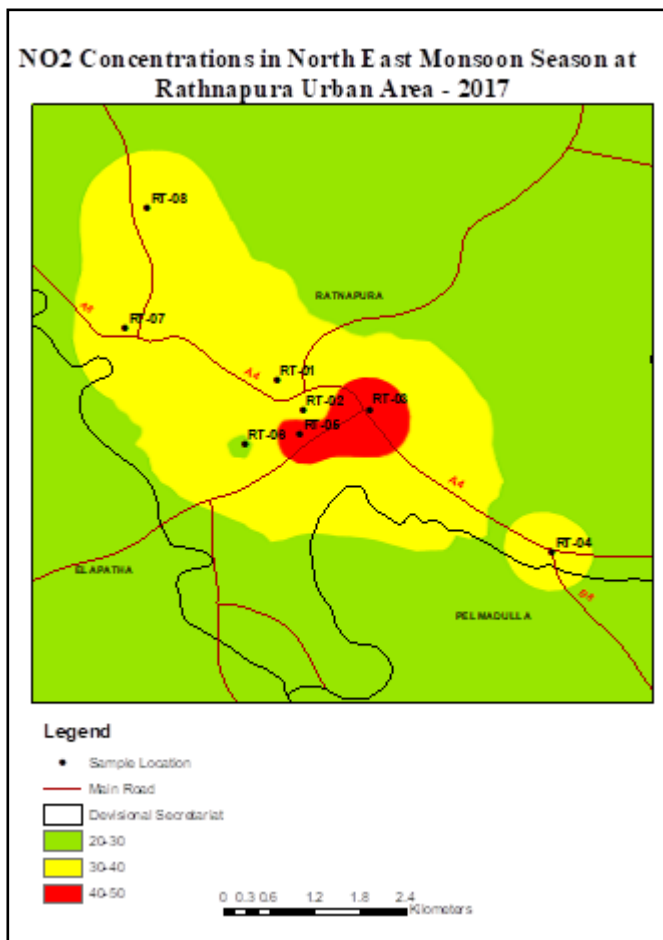
(a)



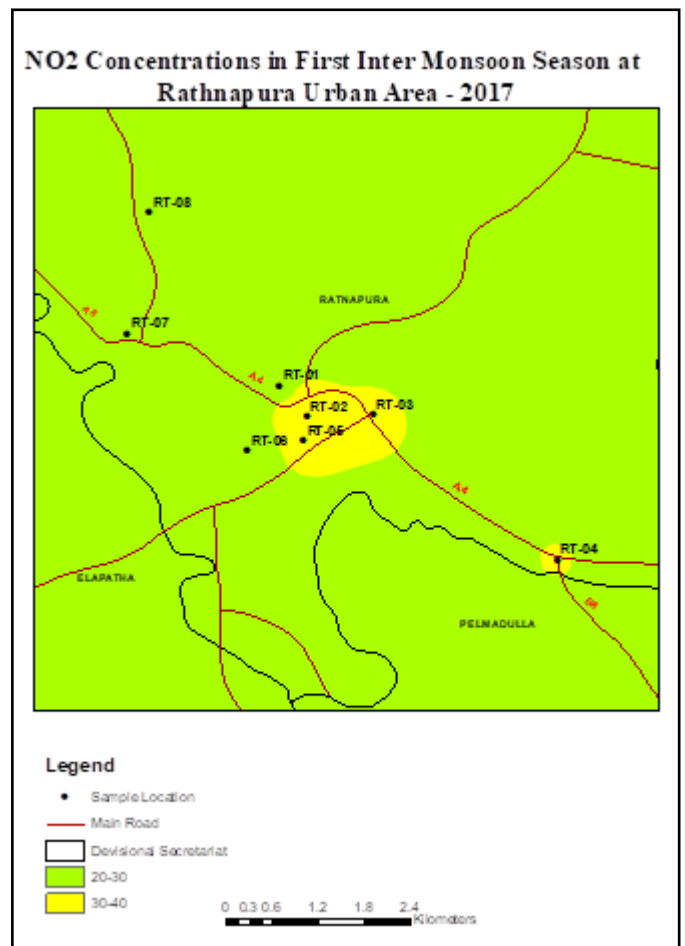
(b)

Figure 6.6.13: Variation of (a) NO₂ (b) SO₂ Concentration due to monsoon seasons at Ratnapura urban area in 2017

(a)



(b)



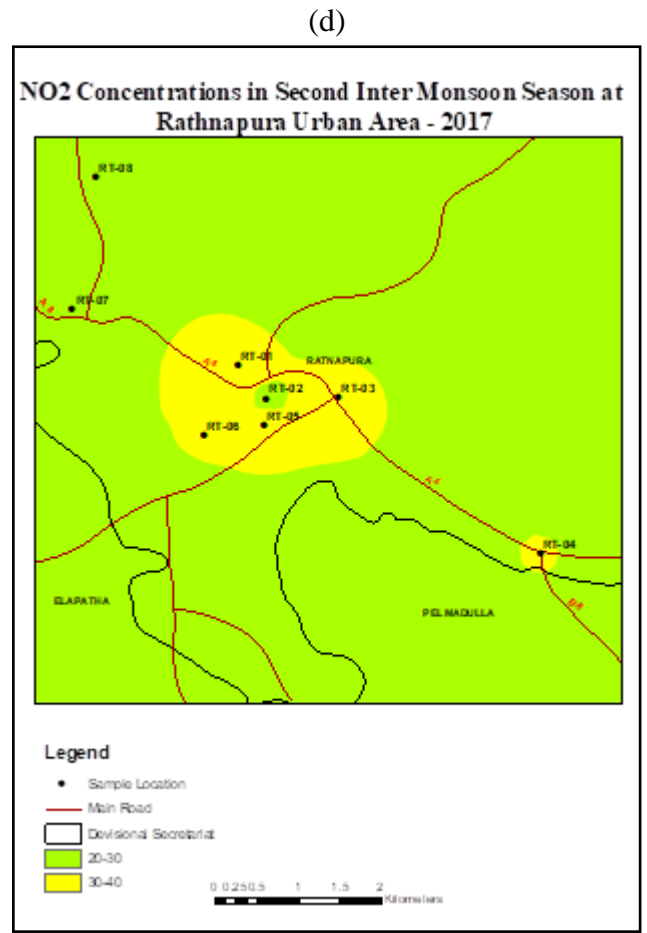
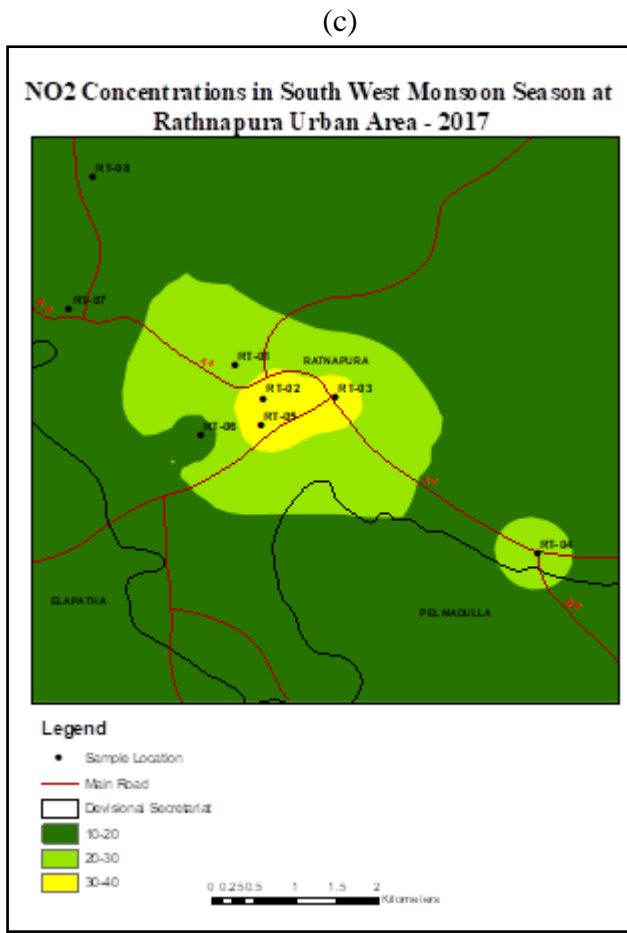


Figure 6.6.14: Variation of NO₂ exposure levels due to monsoon seasons at Rathnapura Urban City in 2107. (a)North East Monsoon (b) First Inter Monsoon (c) South West Monsoon (d)Second Inter Monsoon.

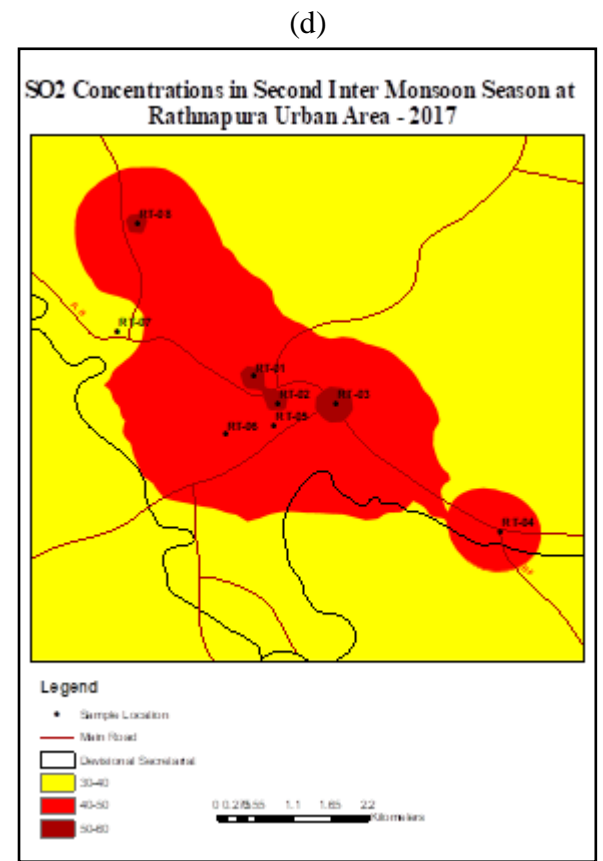
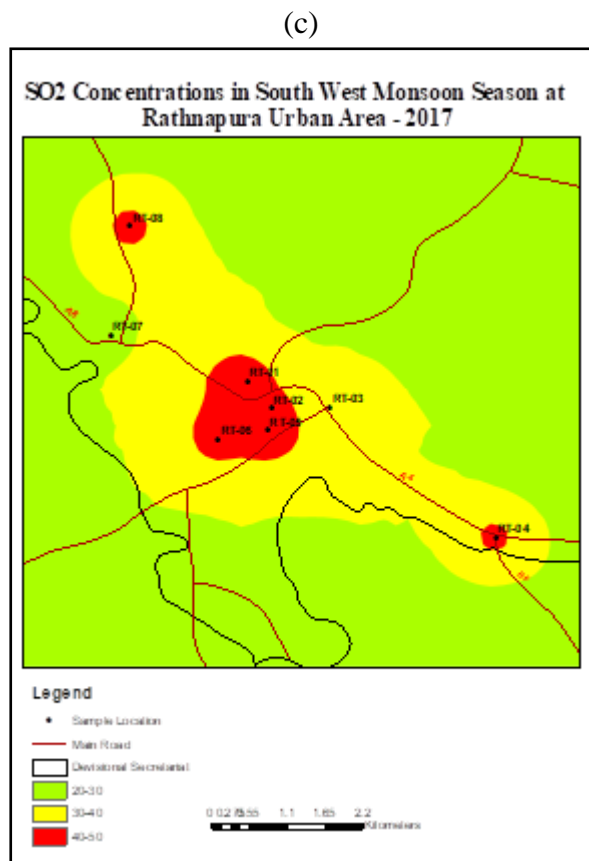
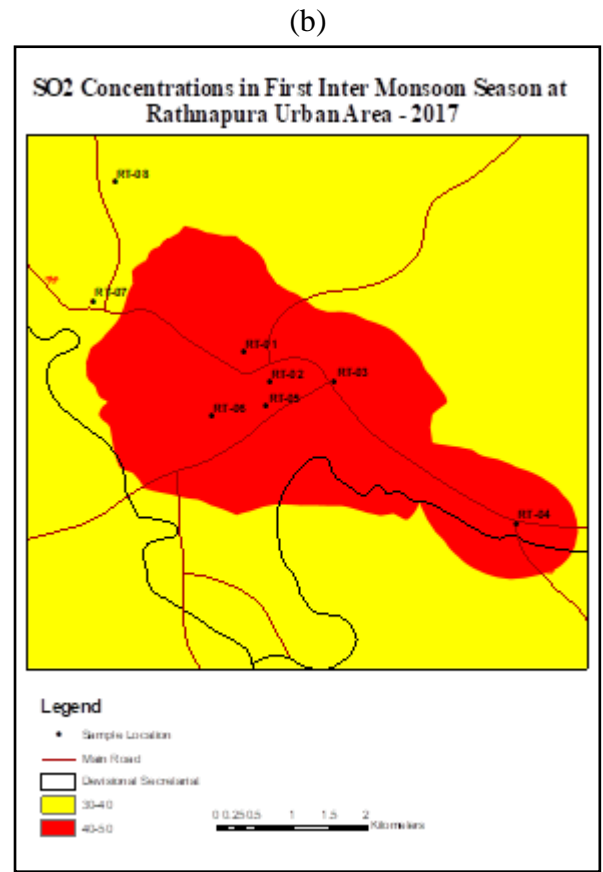
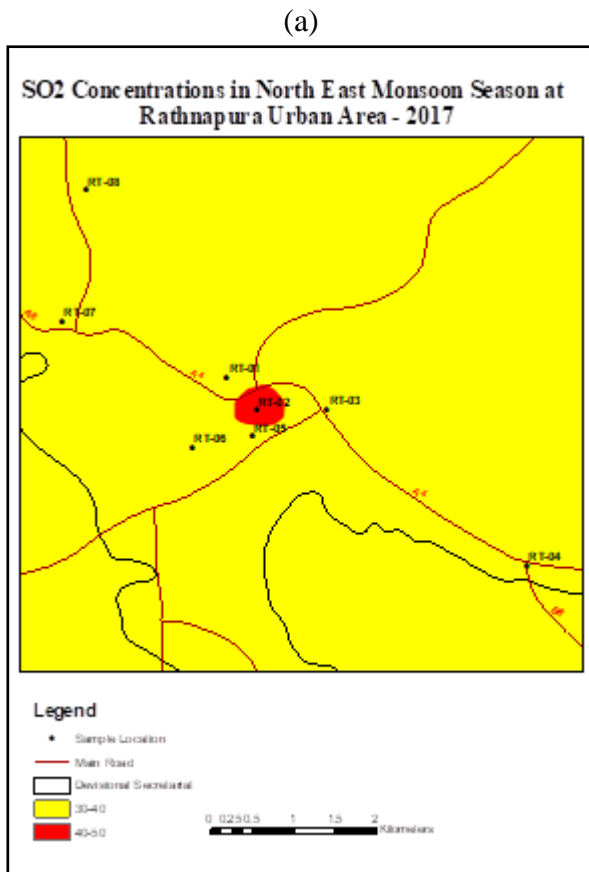


Figure 6.6.15: Variation of SO₂ exposure levels due to monsoon seasons at Rathnapura Urban City in 2107. (a)North East Monsoon (b) First Inter Monsoon (c)South West Monsoon (d)Second Inter Monsoon.

6.7 AMBIENT AIR QUALITY IN 2017 – AT KANDY URBAN AREA

The study area is the city of Kandy, one of the commercial capitals of Sri Lanka and suburban areas. The area has been identified as a prominent area by the urban geographers based on the magnitude of the population density in the city compared to other cities of the country. The Kandy city area (Kandy Municipal Council area) covers a total area of 37.3Km² with the population density of 17,200 persons per sq kilometer according to 2001 statistics. High population, large number of daily travelers, high traffic flow and traffic congestions, large number of dwelling of the under privileged are significant characteristics in the study area that pose negative effects on air quality of the area.

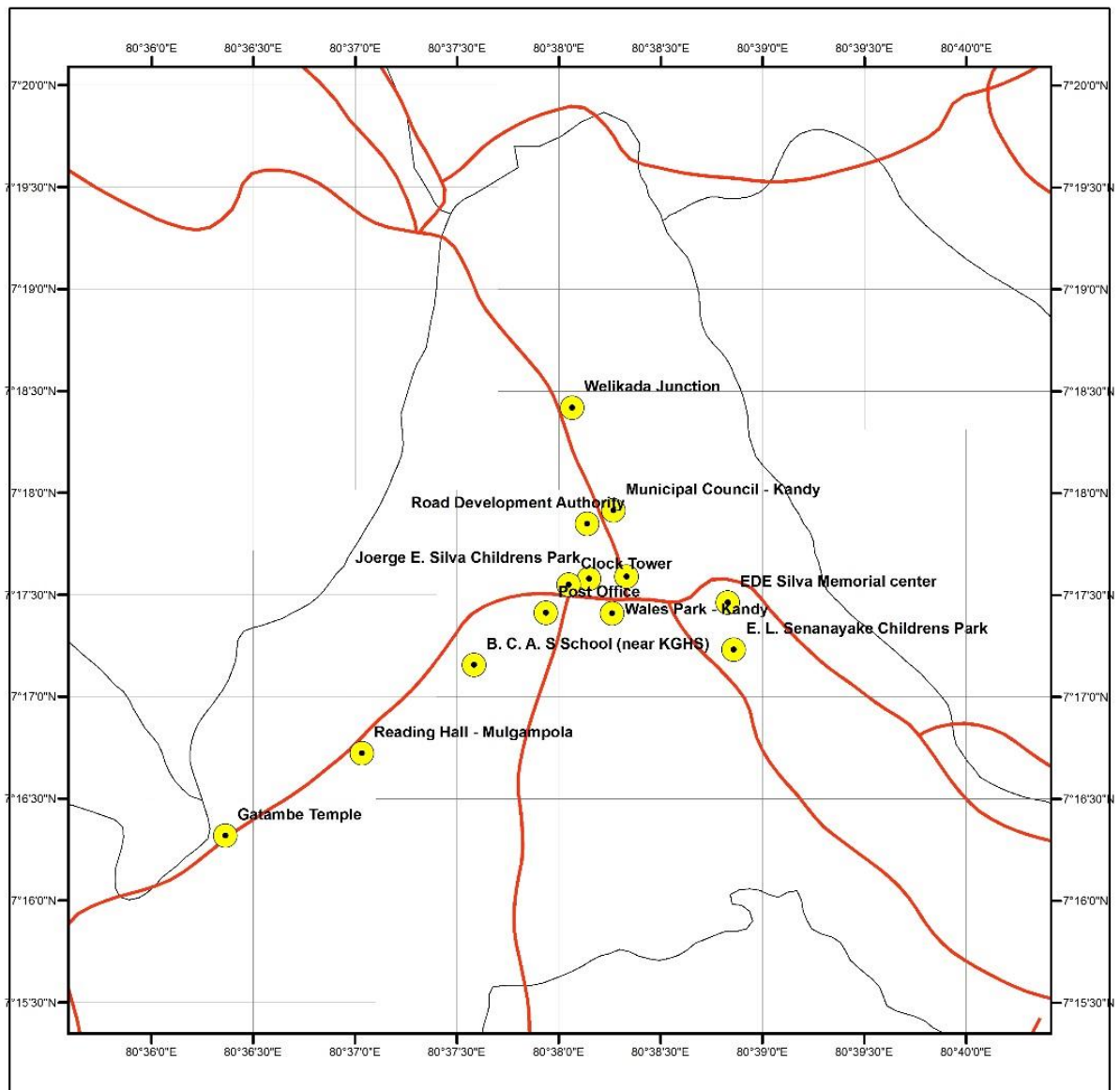
Kandy is surrounded mainly by Hantana and Hunnasgiriya mountain ranges, and Bahirawa, Kurusa and Darmaraja mountains. Therefore, the wind coming to the city goes up after striking on the mountains. Kandy town is in a low-lying area and its condition is similar to a bottom of a basin. Measured Air Quality Exposure levels at each selected location in Kandy urban area during the study period are summarized in following sections. The sample locations description is given in table 6.7.1 and figure 6.7.1 shows the locations map. The table 6.7.2 presents the overview of each location in the Kandy urban area.

The monthly average NO₂ and SO₂ exposure levels at each measuring location within Kandy urban area in 2017 is summarised in table 6.7.3 and 6.7.4 respectively. However, some of data were missing due to the missing of passive sampler due to unavoidable situations such as personal or urban council activities, attacking of animals or birds and some climatic conditions such as rain, landslides and flood etc. Table 6.7.5 shows that PM_{2.5} concentration of selected sample locations in Kandy in 2017.

Table 6.7.1: Selected Sampling Locations in Kandy Urban Area

Urban Area	No of Points	Sampling Location	Location Description
Kandy	13	KD1	Reading Hall - Mulgampola
		KD2	B. C. A. S School (near KGHS)
		KD3	Road Development Authority
		KD4	Welikada Junction
		KD5	Municipal Council - Kandy
		KD6	EDE Silva Memorial center
		KD7	E. L. Senanayake Childrens Park
		KD8	Temple of Tooth
		KD9	Wales Park - Kandy
		KD10	Joerge E. Silva Childrens Park
		KD11	Clock Tower
		KD12	Post Office (Good shed)
		KD13	Diyakapanaramaya, Gatambe

Sample Locations at Kandy Urban Area



0 0.5 1 2 Kilometers



Legend

- Sample_Locations
- Road
- Kandy

Figure 6.7.1: Sampling Locations Map in Kandy Urban area

Table 6.7.2: Overview of each location in the Kandy Urban Area



Location No: KD1
 Location Name: Reading Hall,
 Kandy
 GPS Coordinates: 7.2786930N
 80.6172150E



Location No: KD2
 Location Name: BCAS School
 GPS Coordinates: 7.2859260N,
 80.6264040E



Location No: KD3
 Location Name: RDA Office
 Yatinuwara Veediya, Kandy
 GPS Coordinates: 7.2974670N,
 80.6356490E



Location No: KD4
 Location Name: Welikada
 Junction
 GPS Coordinates: 7.3069480N
 80.6344170E



Location No: KD5
 Location Name: Municipal
 Council
 GPS Coordinates: 7.2985750N
 80.6377910E



Location No: KD6
 Location Name: EDE Silva
 Memorial Center
 GPS Coordinates: 7.2910380N
 80.6471580E



Location No: KD7
 Location Name: ELS Children's
 Park, Kandy
 GPS Coordinates: 7.2871710N
 80.6476470E



Location No: KD8
 Location Name: Close to the
 Temple of Tooth, Kandy.
 GPS
 Coordinates: 7.2931497N
 80.6388602E



Location No: KD9
 Location Name: Wales Park,
 Kandy
 GPS Coordinates: 7.2901440N,
 80.6377020E



Location No: KD10
Location Name: Joerge ES
Park, Kandy
GPS Coordinates: 7.2929680N,
80.6358040E



Location No: KD11
Location Name: Basted close
to the Clock Tower, Kandy
GPS Coordinates: 7.2924980N
80.6341370E



Location No: KD12
Location Name: Post Office,
Kandy
GPS Coordinates: 7.2901810N
80.6322800E



Location No: KD13
Location Name:
Diyakapanaramaya, Gatambe
GPS Coordinates: 7.2720350N,
80.6059650E

Table 6.7.3: Monthly Average Exposure Levels of NO₂ at each location in Kandy Urban Area 2017

Urban Area	Location	NO ₂ Concentration(µg/m ³)											
		Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
Reading Hall - Mulgampola	KD1	39	47	45	44	37	37	36	36	37	-	33	33
B. C. A. S School (near KGHS)	KD2	36	39	29	31	23	39	34	35	24	27	30	38
RDA Office Yatinuwara Street,	KD3	35	56	45	41	28	38	38	33	25	31	46	35
Welikada Junction	KD4	36	44	35	31	22	47	20	22	32	28	37	44
Municipal Council - Kandy	KD5	22	29	32	28	23	20	26	23	22	21	23	25
EDE Silva Memorial center	KD6	34	49	57	45	36	34	41	49	38	40	44	35
E. L. Senanayake Childrens Park	KD7	36	37	33	30	29	36	29	-	31	25	31	42
Temple of Tooth	KD8	19	30	33	28	27	19	33	27	25	25	29	24
Wales Park - Kandy	KD9	29	29	31	29	34	36	26	34	22	25	27	35
Joerge E. Silva Childrens Park	KD10	57	60	62	54	38	47	54	62	54	34	36	60
Clock Tower	KD11	54	61	60	63	60	44	46	49	43	52	44	75
Post Office	KD12	59	62	72	74	60	84	46	59	64	41	50	54
Gatambe Temple	KD13	51	50	52	57	54	53	40	45	32	39	-	45

Table 6.7.4: Monthly Average Exposure Levels of SO₂ at each location in Kandy Urban Area 2017

Urban Area	Location	SO ₂ Concentration(µg/m ³)											
		Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
Reading Hall - Mulgampola	KD1	28	35	46	45	28	37	34	40	34	32	30	43
B. C. A. S School (near KGHS)	KD2	51	28	43	36	31	39	39	25	35	47	28	27
RDA Office Yatinuwara Street	KD3	62	59	69	65	41	38	50	45	47	48	50	60
Welikada Junction	KD4	41	44	47	42	42	47	57	51	44	34	34	41
Municipal Council - Kandy	KD5	46	65	60	59	46	40	52	51	55	53	40	35
EDE Silva Memorial center	KD6	35	29	51	62	31	34	32	36	35	45	33	32
E. L. Senanayake Childrens Park	KD7	42	33	52	38	30	36	34	-	34	53	41	47
Temple of Tooth	KD8	40	35	54	55	38	29	27	23	30	37	39	38
Wales Park - Kandy	KD9	28	35	44	44	29	24	22	18	20	40	50	48
Joerge E. Silva Childrens Park	KD10	31	35	58	-	40	25	31	20	23	41	39	37
Clock Tower	KD11	41	51	60	64	35	-	-	39	32	46	50	54
Post Office	KD12	81	81	92	78	80	91	66	69	65	66	69	56
Gatambe Temple	KD13	59	48	55	54	61	66	45	48	38	43	-	39

Table 6.7.5: 24 hourly Average Levels of PM_{2.5} at Selected location in Kandy Urban Area

City	Site Name	PM _{2.5} (µg/m ³)											
		Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
Kandy	Close to the Temple of Tooth (KD8)	-	-	-	-	-	-	-	-	-	-	26	28
	Digaana Bus Stand (KD11)	-	-	-	-	-	-	-	-	-	-	29	32
	Post Office, Good Shed (KD12)	-	-	-	-	-	-	-	-	-	-	50	57

The figure 6.7.2 (a) and 6.7.2 (b) presented the variation of monthly NO₂ and SO₂ in each location within the year 2017 in Kandy Urban Area. It indicates that at the pollutant levels are not significantly change with the month of the year and at all locations, relatively high exposure levels are recorded in during North-East monsoon period (November – February) compared to other seasons and the appropriate maps are shown under Figure 6.7.4 and 6.7.5.

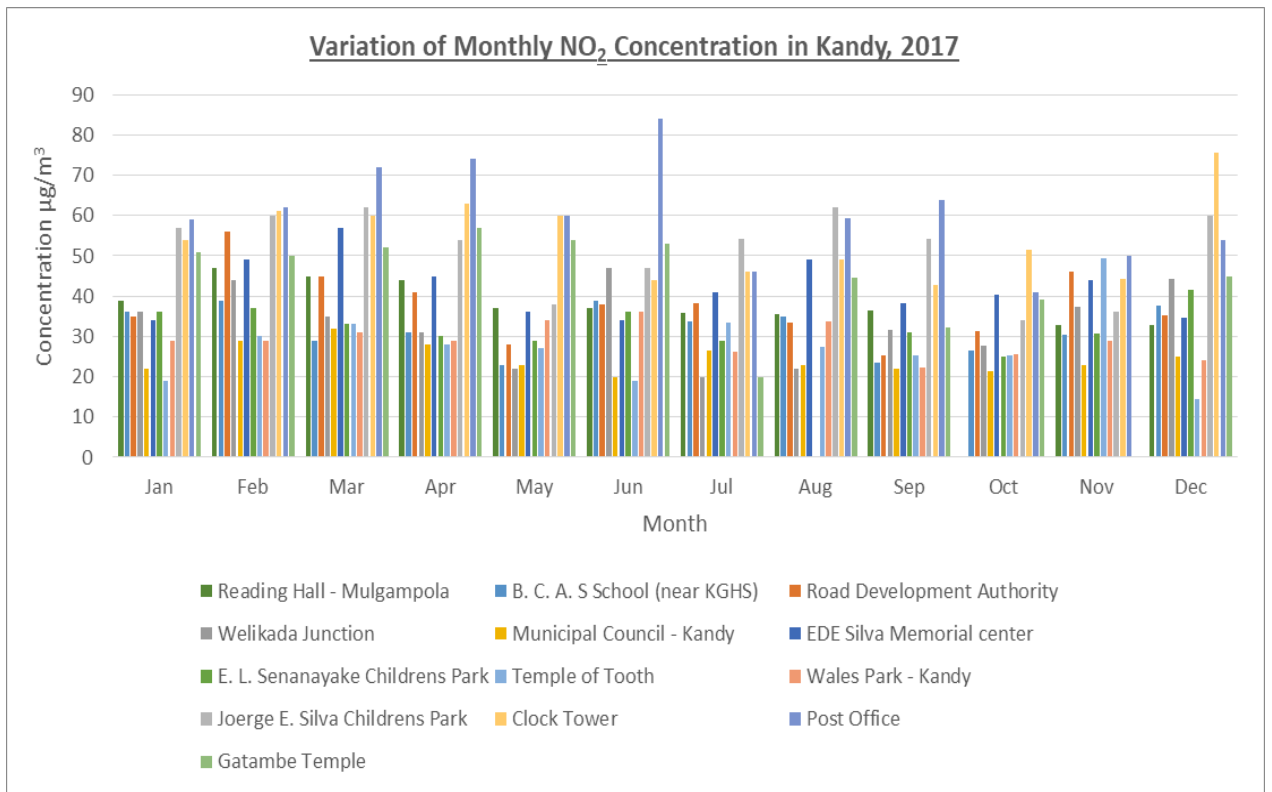


Figure 6.7.2 (a): Variation of monthly NO₂ concentration within Kandy Urban Area in 2017

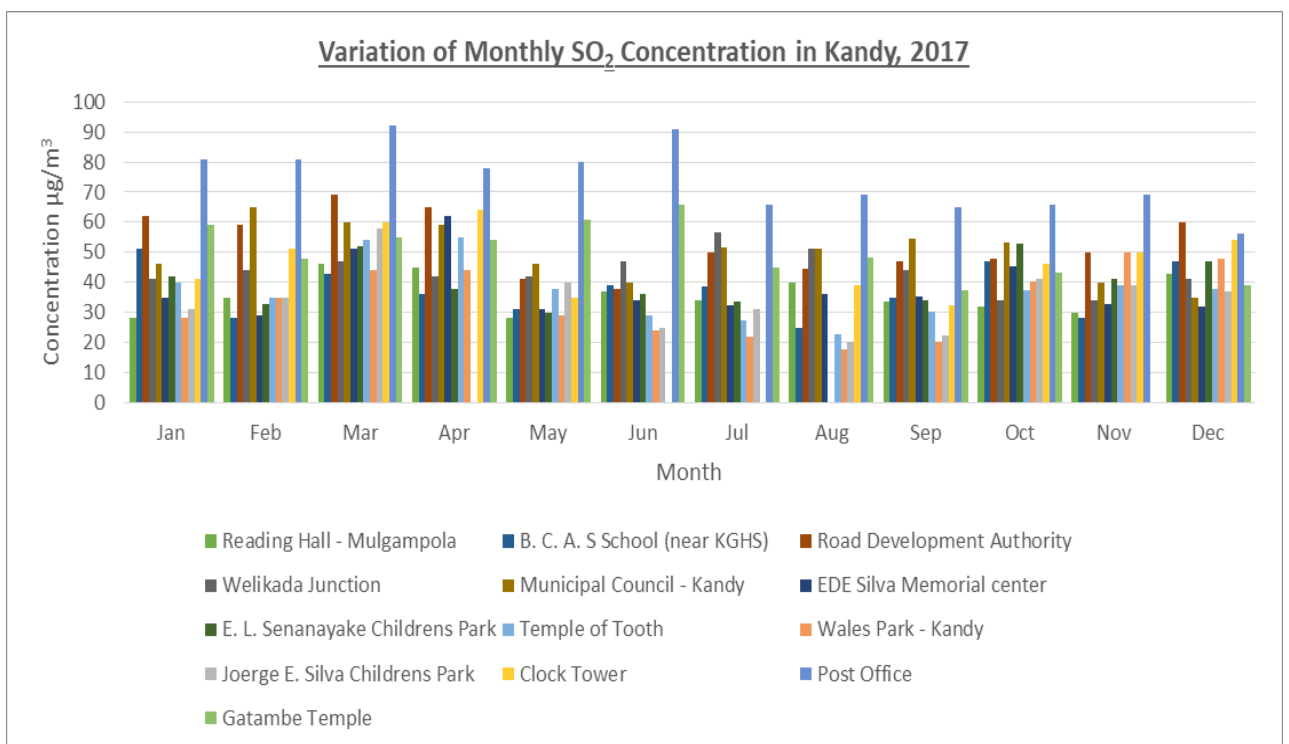


Figure 6.7.2 (b): Variation of monthly SO₂ concentration within Kandy Urban Area in 2017

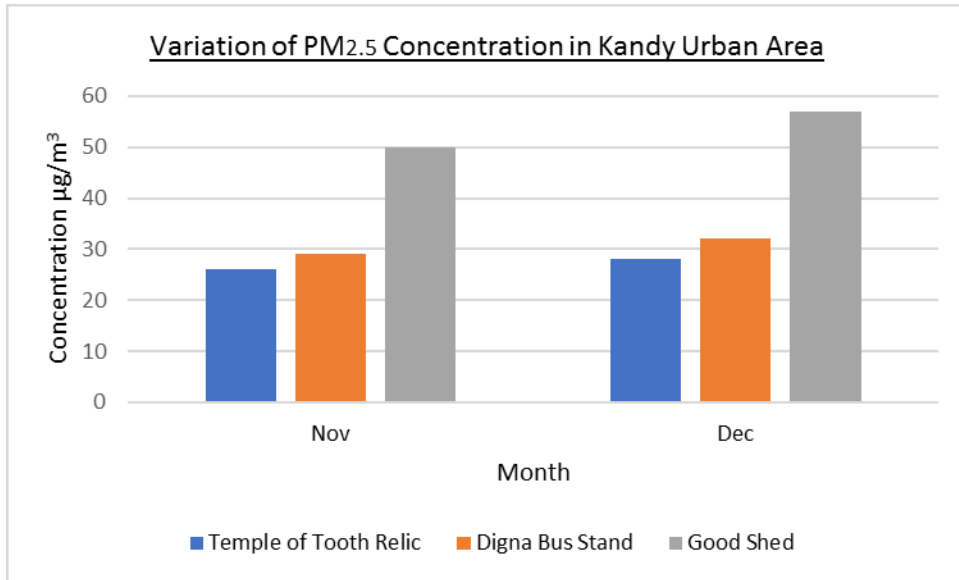


Figure 6.7.3: Variation of monthly PM_{2.5} concentration within Kandy Urban Area in 2017

Figure 6.7.4, 6.7.5 and 6.7.6 represent the annual average NO₂ and SO₂ concentration levels at each sampling location in Kandy urban area during the year, 2017. The annual average NO₂ and SO₂ levels in year 2017 are in between 25 µg/m³ – 60 µg/m³ and 33 µg/m³ – 75 µg/m³ respectively. The high levels are represented with high traffic areas such as Clock Tower (KD11) and Post Office (KD12) and moderate levels are recorded at other locations such as Reading Hall Mulgampola (KD1), Road Development Authority (KD3), EDE Silva Memorial Centre (KD6), E. L. Senanayake Children’s Park (KD7) and Gatambe Temple (KD13). However, both pollutant levels at almost all locations were exceeded the annual WHO guideline values for NO₂ and 24 hour WHO guideline values for SO₂.

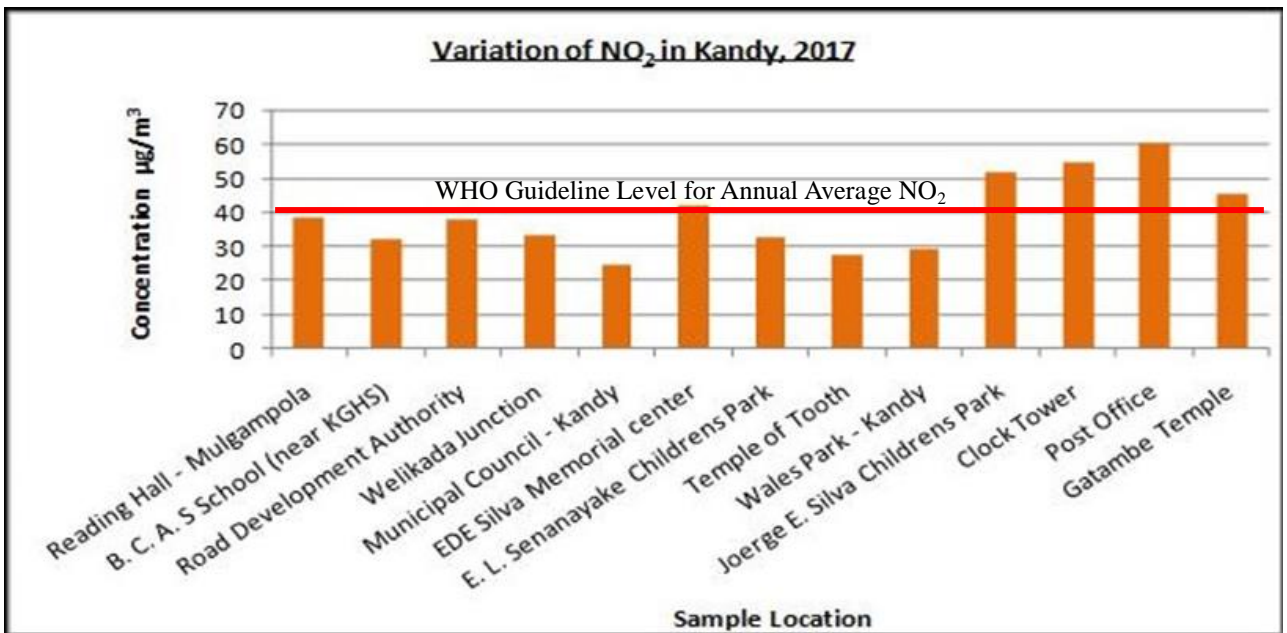


Figure 6.7.4: Annual average NO₂ concentration within Kandy Urban Area in 2017

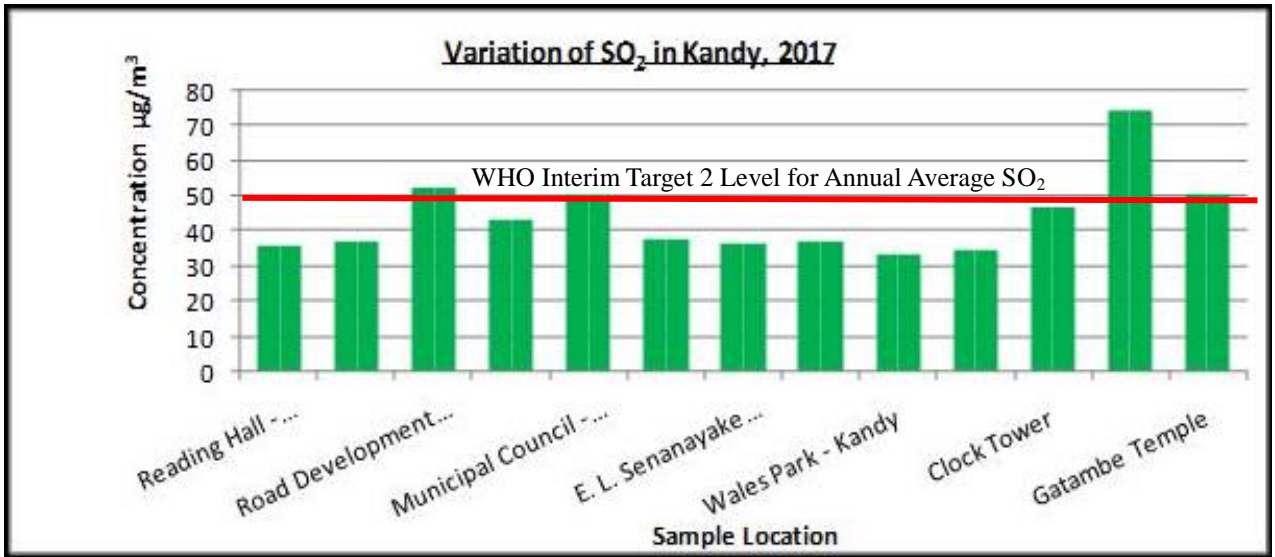


Figure 6.7.5: Annual average SO₂ concentration within Kandy Urban Area in 2017

Annual average levels of NO₂ and SO₂ in each location at Kandy urban area from 2014 to 2017 are represented in figure 6.7.9 and 6.7.10. The Comparison between annual NO₂ and SO₂ concentrations from 2014 to 2017 is shown in figure 6.7.13 and 6.7.14 the relevant maps are shown in figure 6.7.11 and 6.7.12. The overall annual average NO₂ and SO₂ variations from 2014 to 2017 in Kandy Urban area (in all locations) are shown in figure 6.15 and 6.16 respectively. Accordingly, there is no significant change in annual average levels from 2014 to 2017.

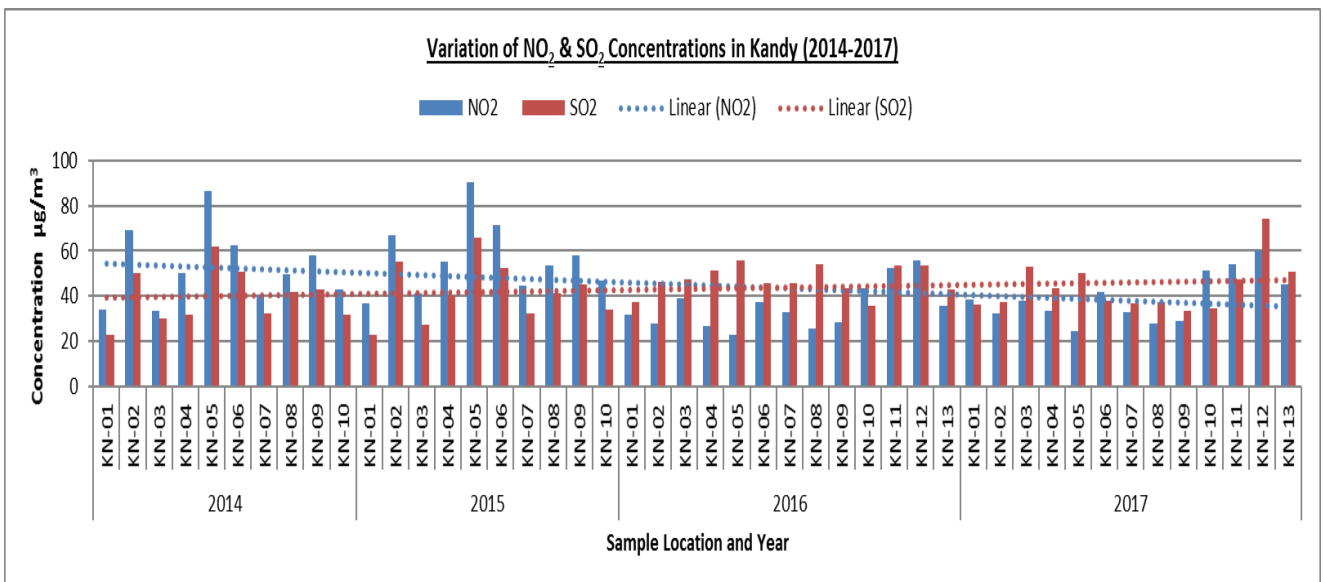


Figure 6.7.6: Average NO₂ and SO₂ variations from 2014 to 2017

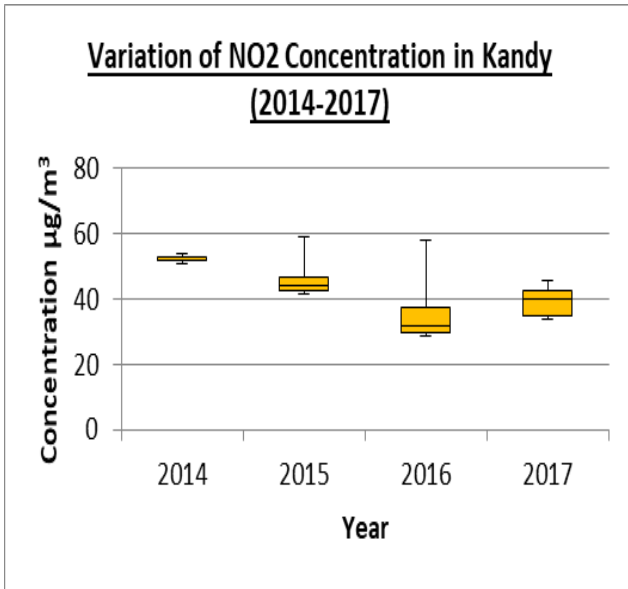


Figure 6.7.7: Boxplot of NO₂ Concentration variation in Kandy 2014-2017

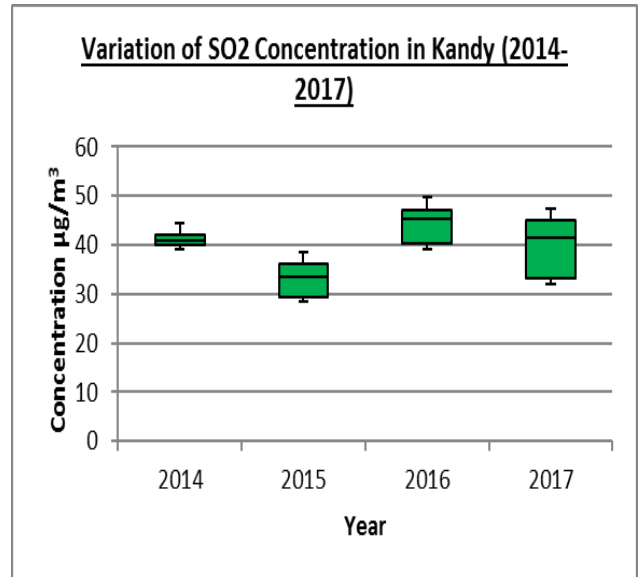


Figure 6.7.8: Boxplot of SO₂ Concentration variation in Kandy 2014-2017

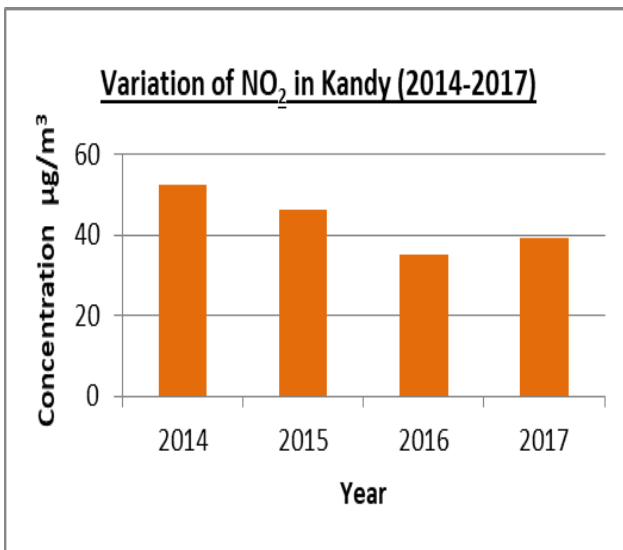


Figure 6.7.9: Annual average NO₂ variations from 2014-2017 in Kandy Urban area

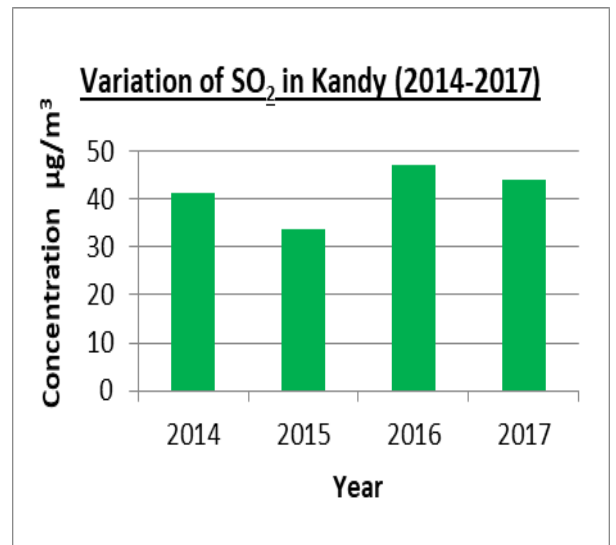


Figure 6.7.10: Annual average SO₂ variations from 2014-2017 in Kandy Urban area

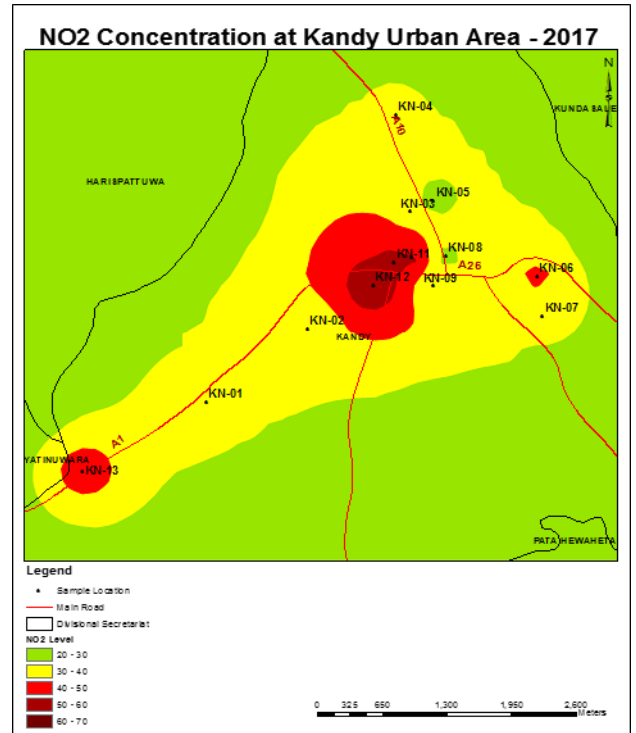
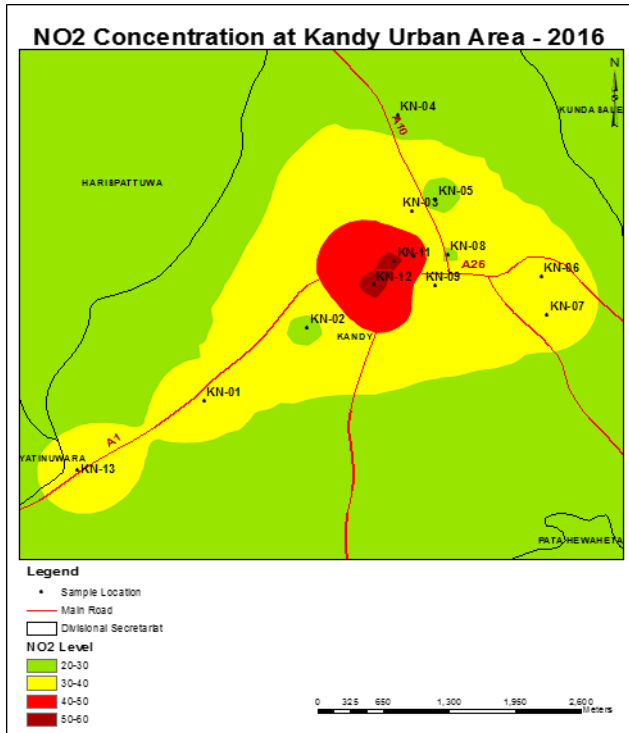


Figure 6.7.11: Annual average NO₂ concentration within Kandy Urban Area 2016 and 2017

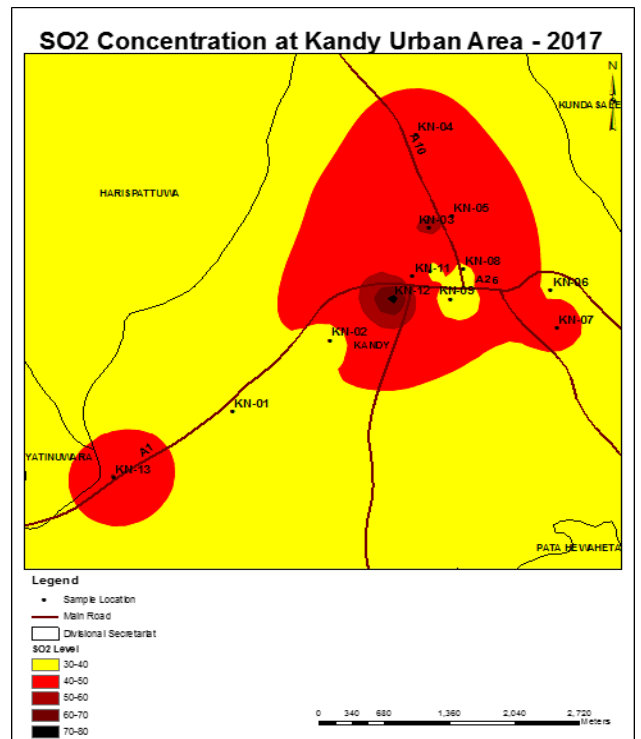
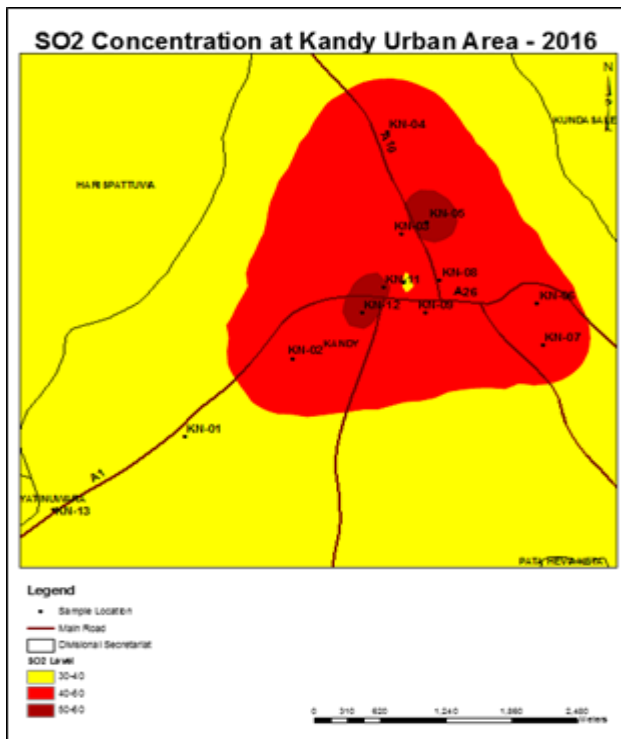


Figure 6.7.12: Annual average SO₂ concentration within Kandy Urban Area 2016 and 2017

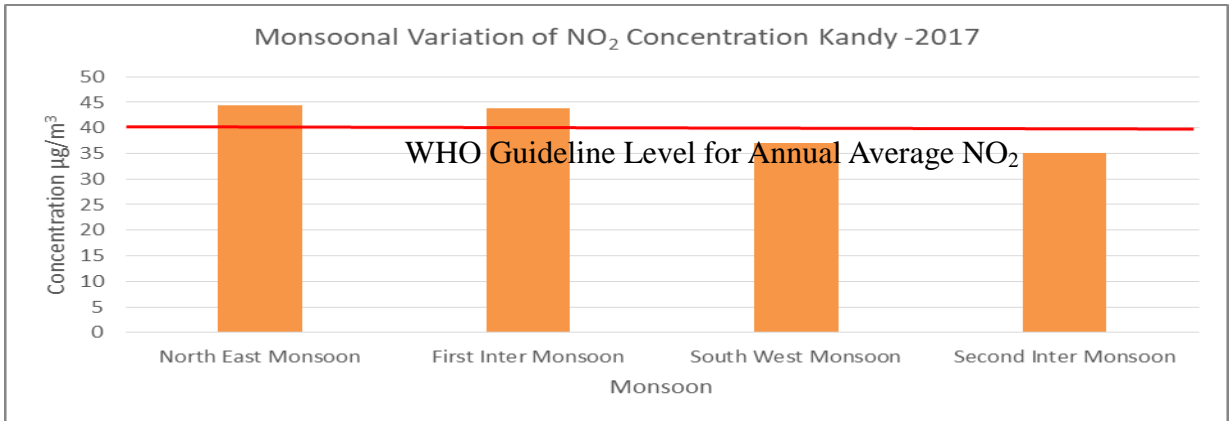


Figure 6.7.13: Variation of NO₂ Concentration due to monsoon seasons at Kandy urban area in 2017

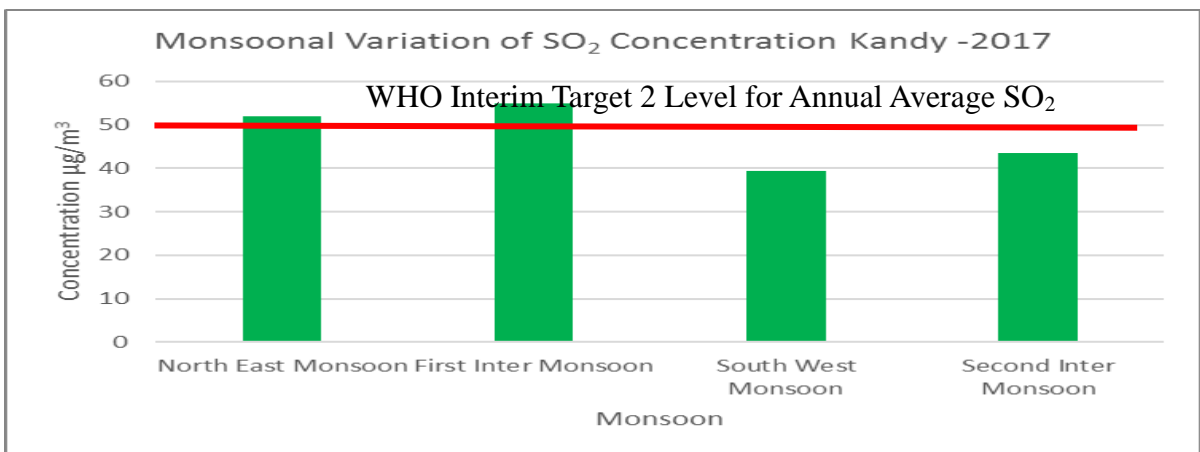
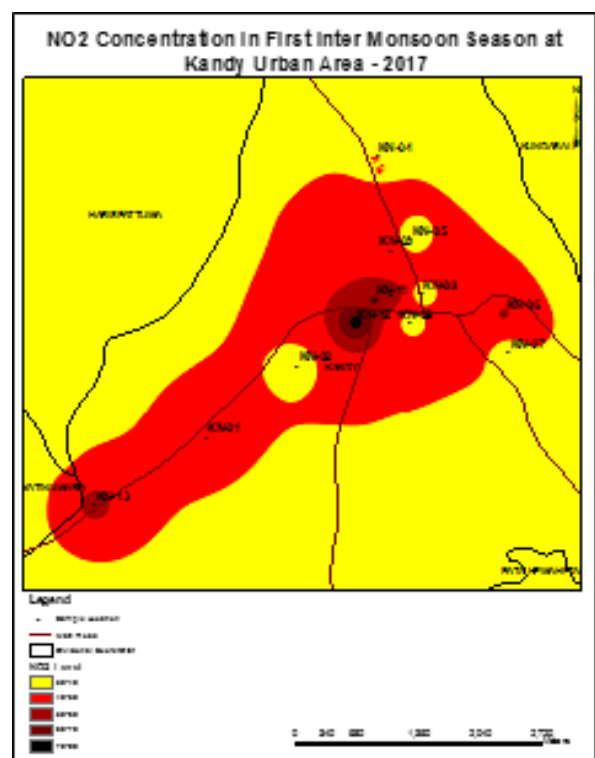
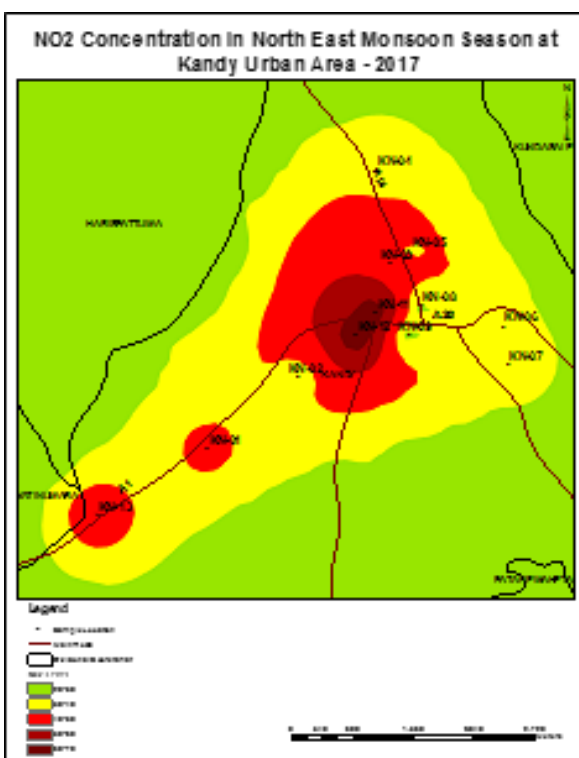


Figure 6.7.14: Variation of SO₂ Concentration due to monsoon seasons at Kandy urban area in 2017



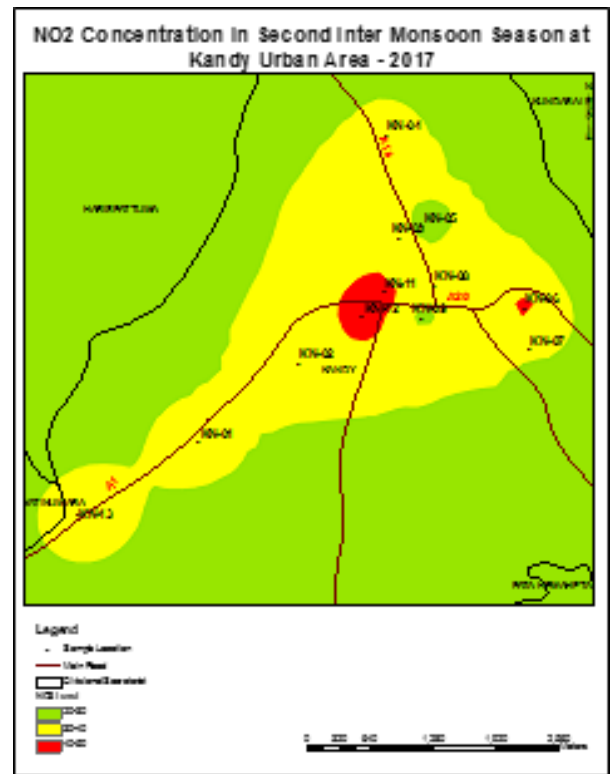
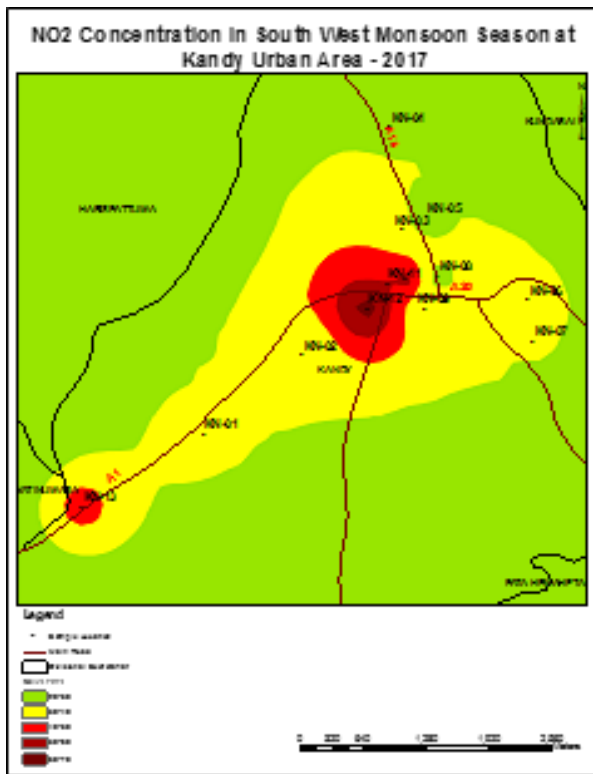
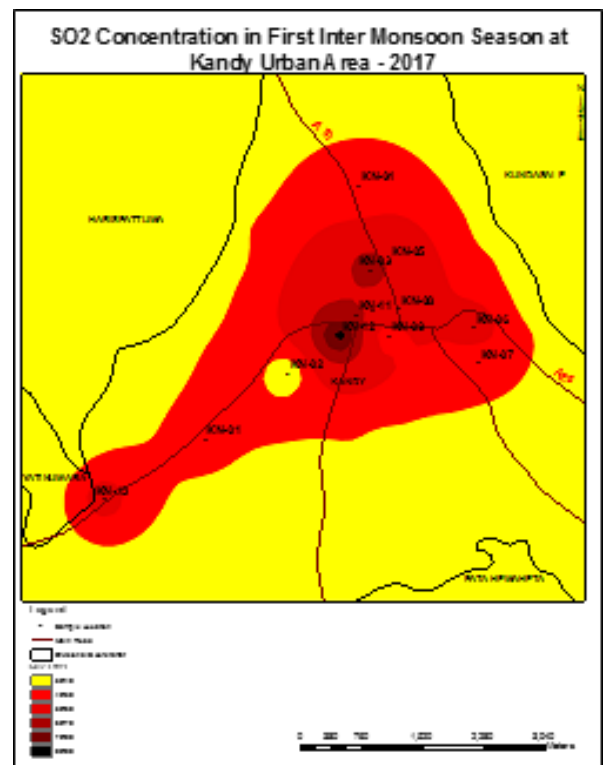
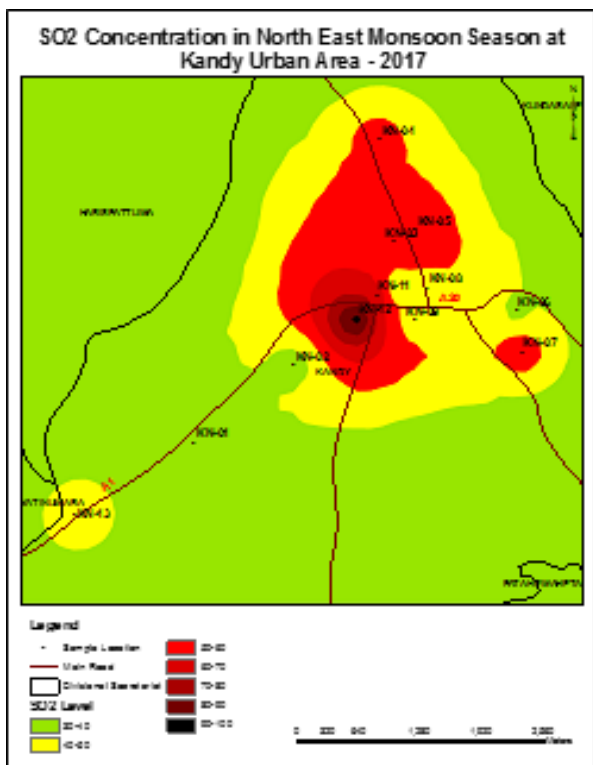


Figure 6.7.15: Variation of NO₂ Concentration due to monsoon seasons at Kandy urban area in 2017



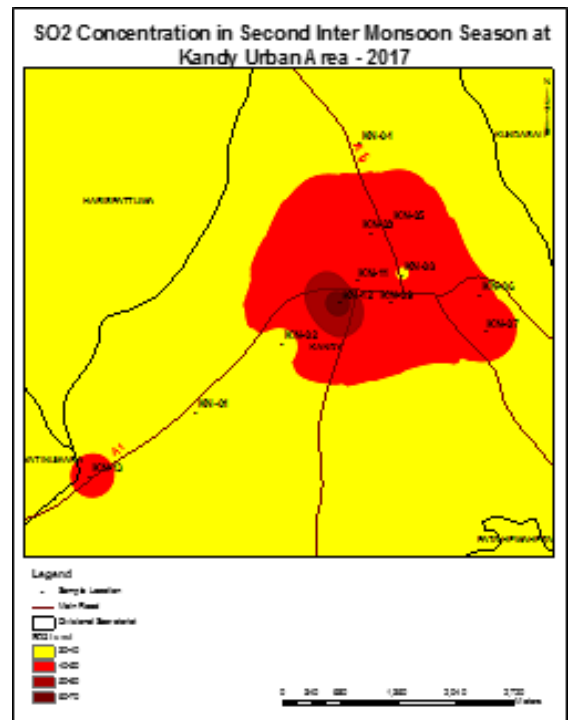
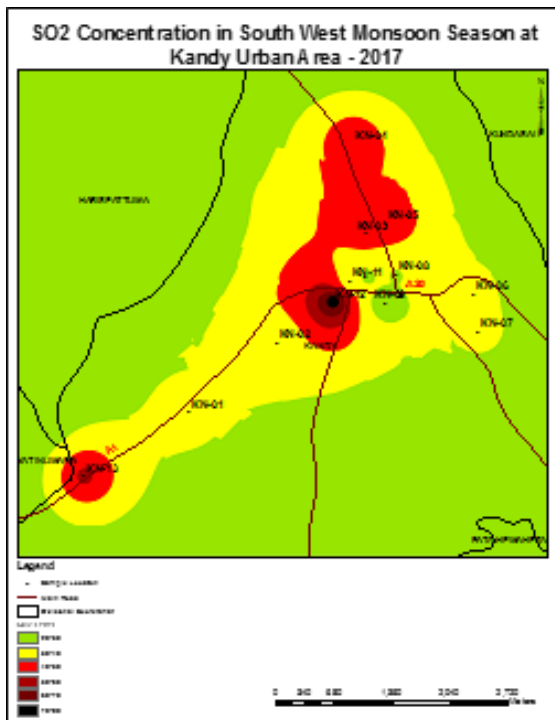


Figure 6.7.16: Variation of SO₂ Concentration due to monsoon seasons at Kandy urban area in 2017

6.8 AMBIENT AIR QUALITY IN 2017 – AT KURUNEGALA URBAN AREA

Kurunegala, is the capital city of the North Western Province and one of major cities in Sri Lanka located in flat terrain within eight very noticeable large rocks that encircle and dominate the city atmosphere. It was an ancient royal capital for 50 years, from the end of the 13th century to the start of the 14th century. Kurunegala is a main junction which links several main roads of the country. Therefore, significant number of vehicles are travelled through this city.

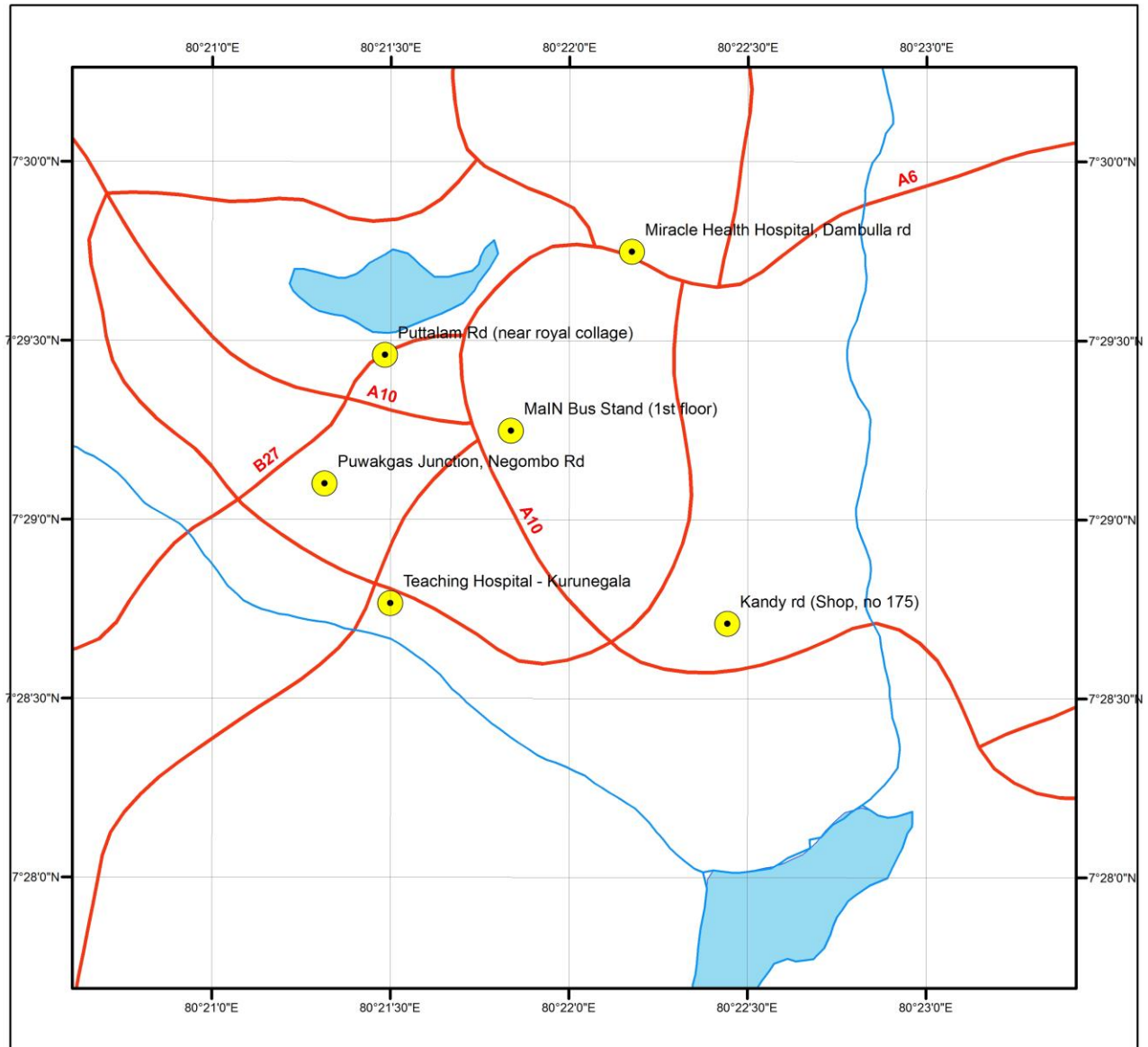
Air quality exposure levels with respect to NO₂ and SO₂ in Kurunegala Urban area was started in October 2015 at six locations within the Kurunegala Municipal Council area and surrounding areas with the financial assistant of VET fund. The monthly average NO₂ and SO₂ exposure levels at each measuring location within Kurunegala urban area in 2017 is summarised in table 6.8.3 and 6.8.4 respectively. Table 6.8.5 shows that PM_{2.5} concentration of selected sample locations in Kurunegala in 2017.

Air quality exposure levels measuring activities with respect to NO₂ and SO₂ in Kurunegala Urban area were continued in 2017 as well under this project. The sample locations description is given in table 6.8.1 and figure 6.8.1 shows the locations map. The table 6.8.2 presents the overview of each location in the Kurunegala urban area.

Table 6.8.1: Selected Sampling Locations in Kurunegala Urban area

Urban Area	No of Points	Sampling Location	Location Description
Kurunegala	6	KU1	Teaching Hospital - Kurunegala
		KU2	Main Bus Stand (1st floor)
		KU3	Puwakgas Junction, Negombo Rd
		KU4	Puttalam Rd (near royal collage)
		KU5	Miracle Health Hospital, Dambulla rd
		KU6	Kandy rd (Shop, no 175)

Sample Locations at Kurunegala Urban Area



0 0.5 1 2 Kilometers



Legend

- Sample Locations
- Streams
- Road
- Tanks

Figure 6.8.1: Sampling Locations Map in Kurunegala Urban area

Table 6.8.2: Overview of each location in the Kurunegala urban area



Location No: KU1
 Location Name: Teaching Hospital
 GPS Coordinates: 7.4794380N
 80.3583110E



Location No: KU2
 Location Name: Super Market (Bus Stand), Kurunegala
 GPS Coordinates: 7.4874640N
 80.3639410E



Location No: KU3
 Location Name: Puwakgas Junction, Kurunegala
 GPS Coordinates: 7.4849960N,
 80.3552470E



Location No: KU4
 Location Name: Puttalam Road
 GPS Coordinates: 7.4909970N
 80.3580510E



Location No: KU5
 Location Name: MH Hospital
 GPS Coordinates: 7.4957950N
 80.3695800E



Location No: KU6
 Location Name: No 175, Kandy Road, Kurunegala
 GPS Coordinates: 7.4784840N,
 80.3740390E

Monthly average NO₂ and SO₂ exposure levels at each measuring location within Kurunegala urban area for the year 2017 is summarised in table 6.8.3 and 6.8.4 respectively. However, some of data were missing due to the missing of passive sampler due to unavoidable situations such as personal or urban council activities, attacking of animals or birds and some climatic conditions such as rain.

Table 6.8.3: Monthly Average Exposure Levels of NO₂ at each location in Kurunegala Urban Area 2017

Urban Area	Location	NO ₂ Concentration(µg/m ³)											
		Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
Teaching Hospital - Kurunegala	KU1	39	36	35	37	36	35	31	44	30	33	40	37
Main Bus Stand (1st floor)	KU2	62	66	63	55	54	53	32	29	49	61	54	62
Puwakgas Junction, Negombo Rd	KU3	44	40	44	44	37	32	36	31	33	35	44	47
Puttalam Rd (near royal collage)	KU4	44	32	36	40	35	38	15	30	20	29	30	43
Miracle Health Hospital, Dambulla rd	KU5	29	31	35	34	36	29	35	-	42	32	27	29
Kandy rd (Shop, no 175)	KU6	52	51	56	60	50	49	58	48	49	43	44	48

Table 6.8.4: Monthly Average Exposure Levels of SO₂ at each location in Kurunegala Urban Area 2017

Urban Area	Location	SO ₂ Concentration(µg/m ³)											
		Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
Teaching Hospital - Kurunegala	KU1	-	-	59	61	64	67	55	56	68	55	53	59
Main Bus Stand (1st floor)	KU2	65	62	66	73	62	56	45	49	58	57	52	56
Puwakgas Junction, Negombo Rd	KU3	46	45	54	51	31	37	50	32	36	62	31	45
Puttalam Rd (near royal collage)	KU4	41	47	43	49	35	36	36	22	24	51	42	41
Miracle Health Hospital, Dambulla rd	KU5	45	49	56	60	54	66	62	43	51	53	47	42
Kandy rd (Shop, no 175)	KU6	39	40	59	64	40	38	-	25	27	49	48	40

Table 6.8.5: 24 hourly Average Levels of PM_{2.5} at Selected location in Kurunegala Urban Area

City	Site Name	PM _{2.5} (µg/m ³)											
		Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
Kurunegala	Clock Tower (KU2)	-	-	-	-	-	-	-	-	-	-	29	30

Figure 6.8.2 (a) and 6.8.2 (b) presented the variation of NO₂ and SO₂ in each location within the year 2017 in Kurunegala Urban Area. When considering both NO₂ and SO₂ concentrations it can be seen that the highest pollutant concentrations are at “Main Bus Stand” area for several months. Figure 6.8.3 shows that variation of PM_{2.5} concentration in selected sample locations in Kurunegala in 2017.

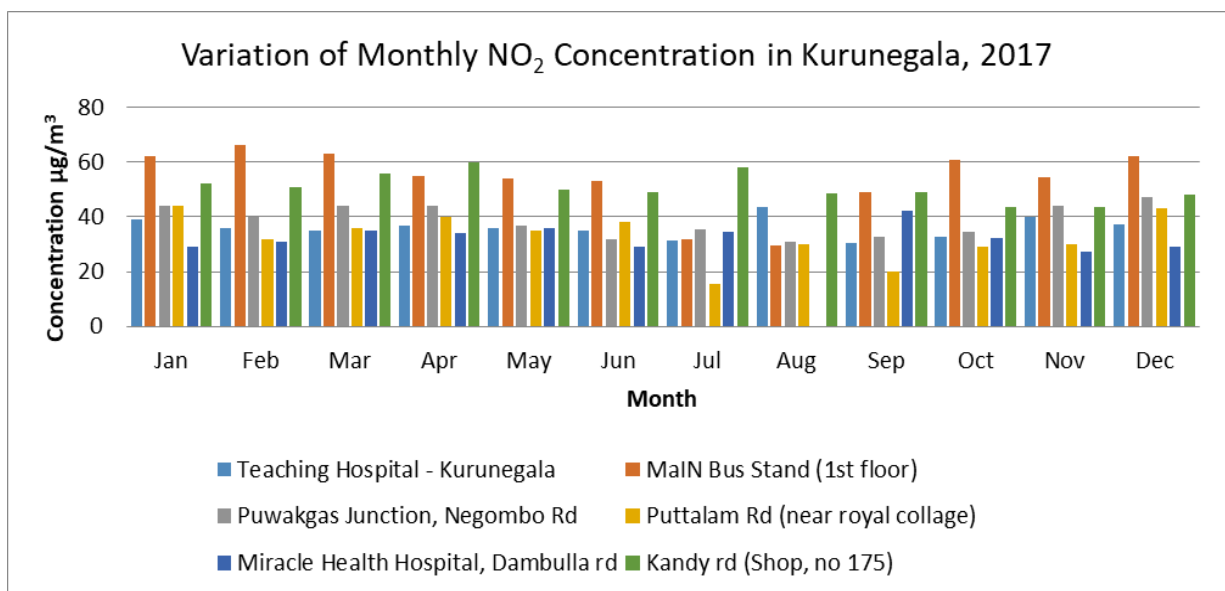


Figure 6.8.2(a): Variation of NO₂ concentration within Kurunegala Urban Area in 2017

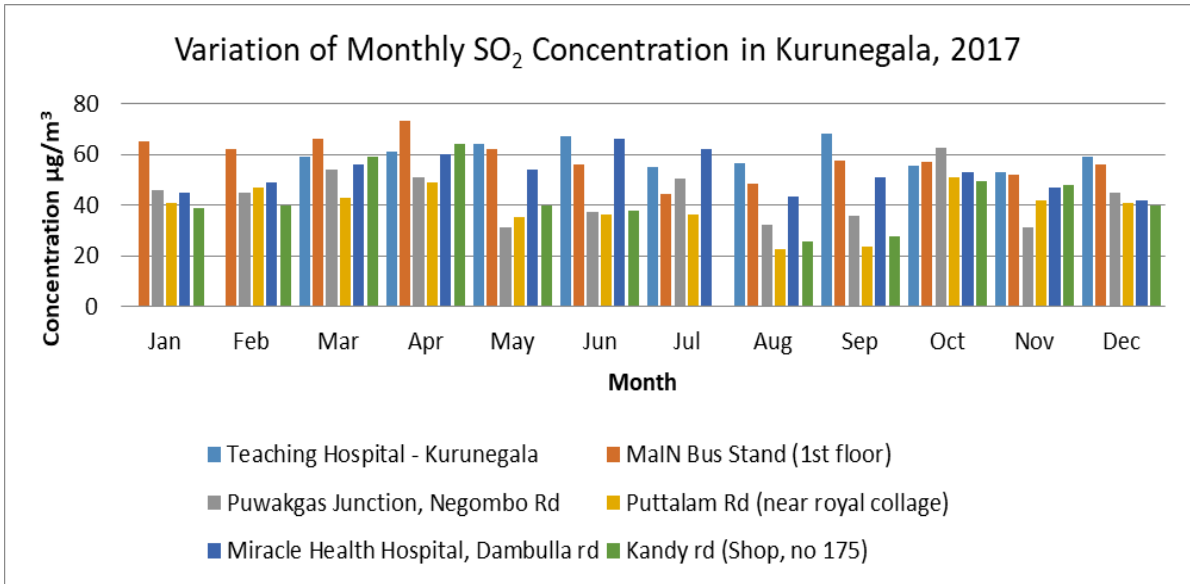


Figure 6.8.2(b): Variation of SO₂ concentration within Kurunegala Urban Area in 2017

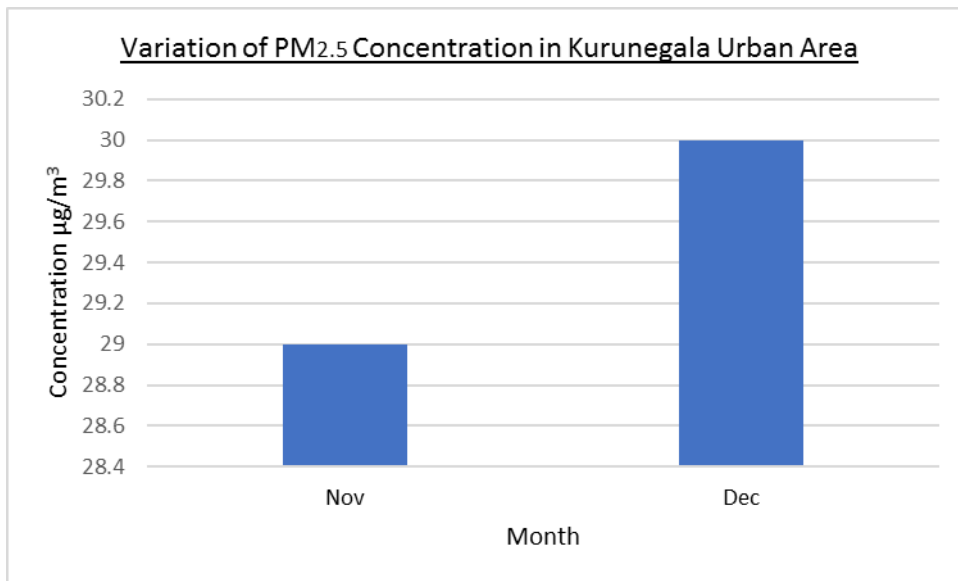


Figure 6.8.3: Variation of PM_{2.5} concentration within Kurunegala Urban Area in 2017

Figure 6.8.4 and 6.8.5 represent the annual average NO₂ and SO₂ concentration levels at each sampling location in Kurunegala urban area during the year, 2017. The annual average NO₂ and SO₂ levels in year 2017 are in between 33 µg/m³ - 53 µg/m³ and 39 µg/m³ - 60 µg/m³ respectively. The high levels are representing areas with high traffic areas such as Kurunegala Main Bus Stand (KU2) and Puwakgas Junction (KU6). Low levels are recorded at locations away from the city area such as Puttalam Road (KU4).

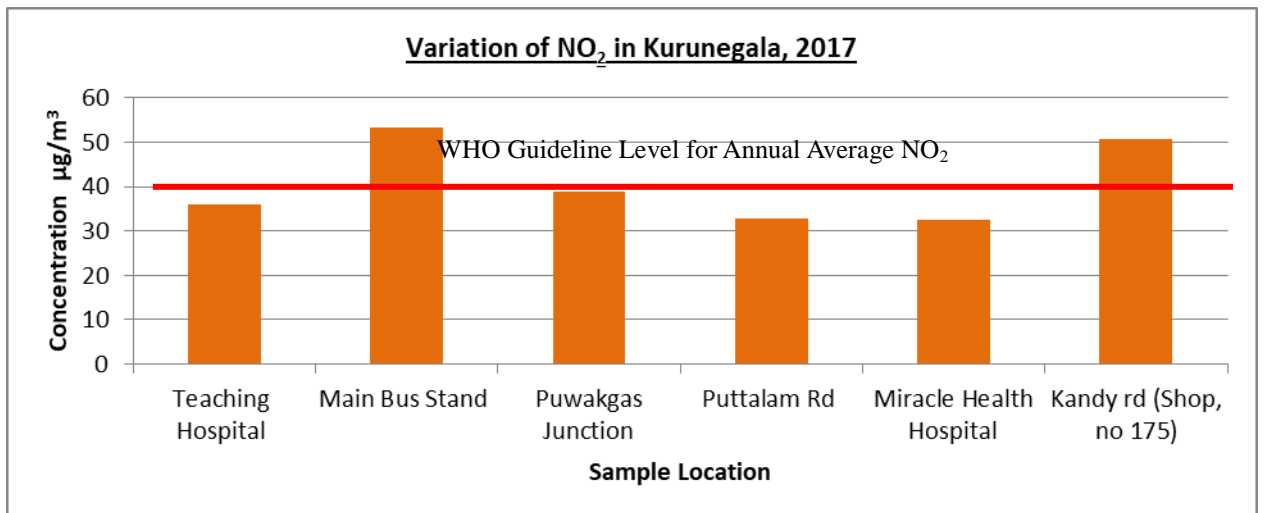


Figure 6.8.4: Annual average NO₂ concentration within Kurunegala Urban Area in 2017

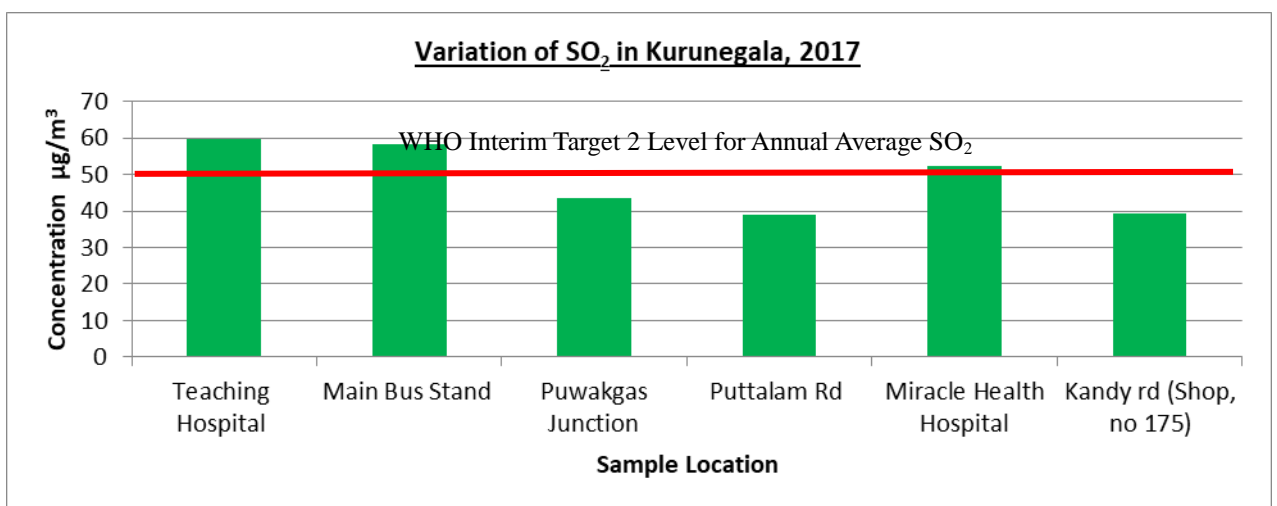


Figure 6.8.5: Annual average SO₂ concentration within Kurunegala Urban Area in 2017

Annual average levels of NO₂ and SO₂ in each location at Kurunegala urban area from 2012 to 2017 are represents in figure 6.8.6 and boxplot of each pollutant for the same period are given in figure 6.8.7 and 6.8.8 respectively. Also, representative maps for NO₂ and SO₂ from 2015 to 2017 are shown in figure 6.8.11 and 6.8.12 respectively. Accordingly, the exposure levels of NO₂ were in decreasing trend while SO₂ levels were in slightly increasing trend from 2015 to 2017.

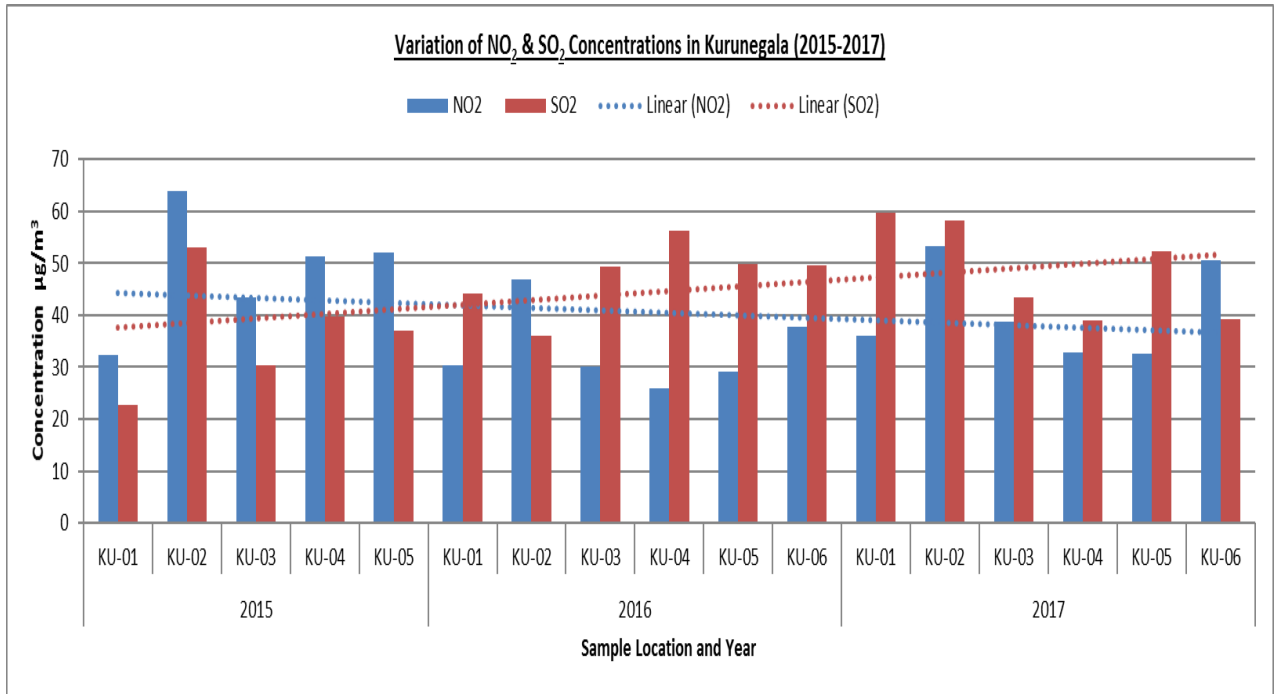


Figure 6.8.6: Average NO₂ and SO₂ variations from 2015-2017

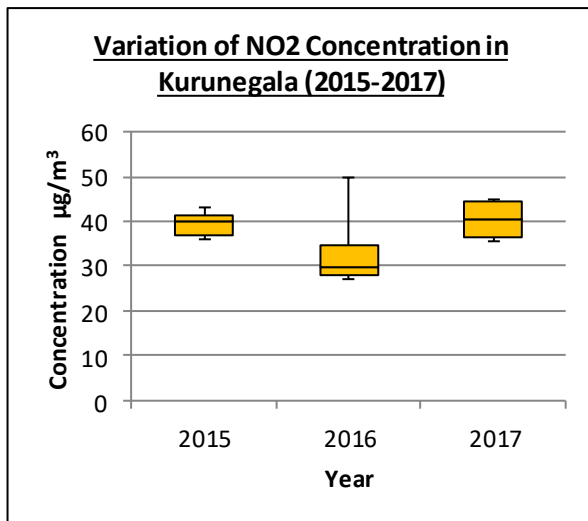


Figure 6.8.7: Boxplot of NO₂ Concentration variation in Kurunegala (2015-2017)

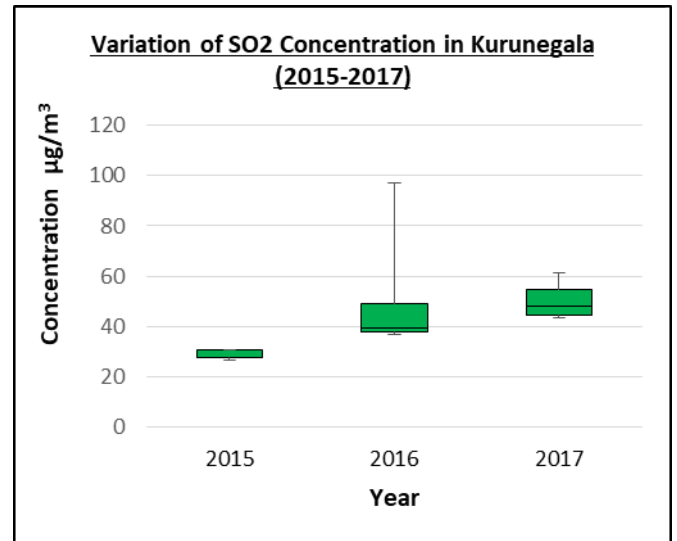


Figure 6.8.8: Boxplot of SO₂ Concentration variation in Kurunegala (2015-2017)

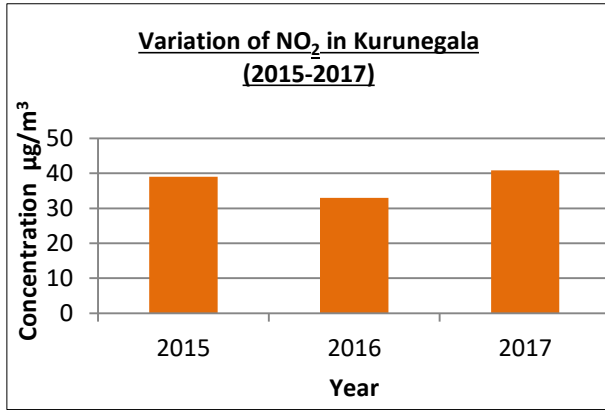


Figure 6.8.9: Annual average NO₂ levels from 2015-2016 in Kurunegala Urban area

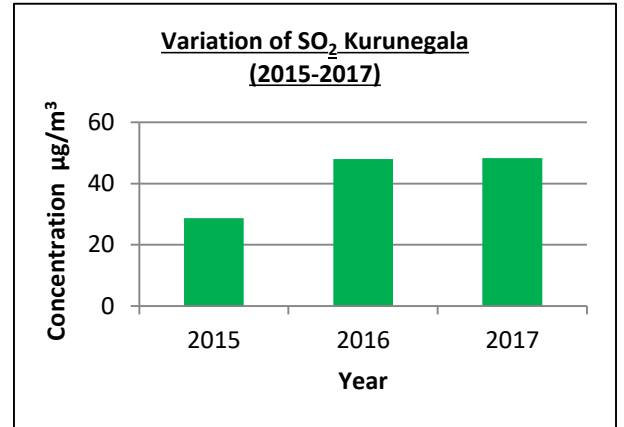
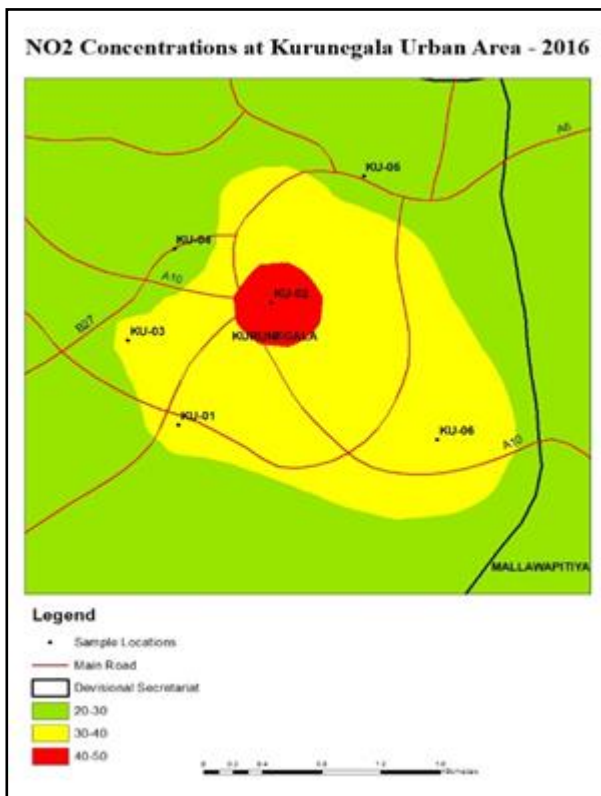


Figure 6.8.10: Annual average SO₂ Levels from 2015-2016 in Kurunegala Urban area

(a)



(b)

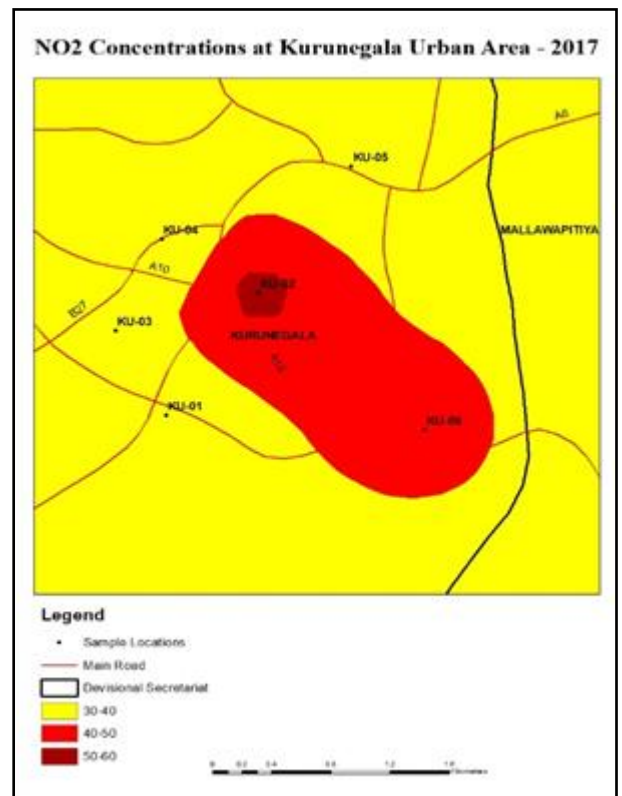


Figure 6.8.11: Variation of NO₂ concentration within Kurunegala Urban Area 2016 and 2017

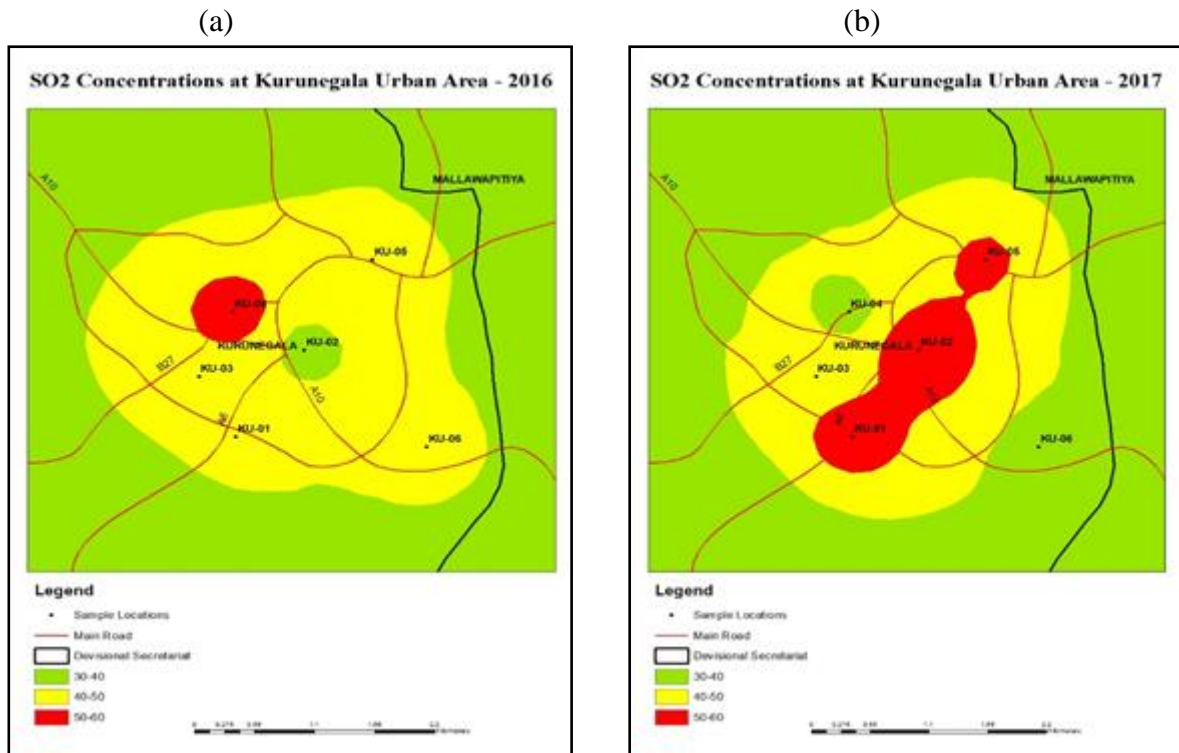
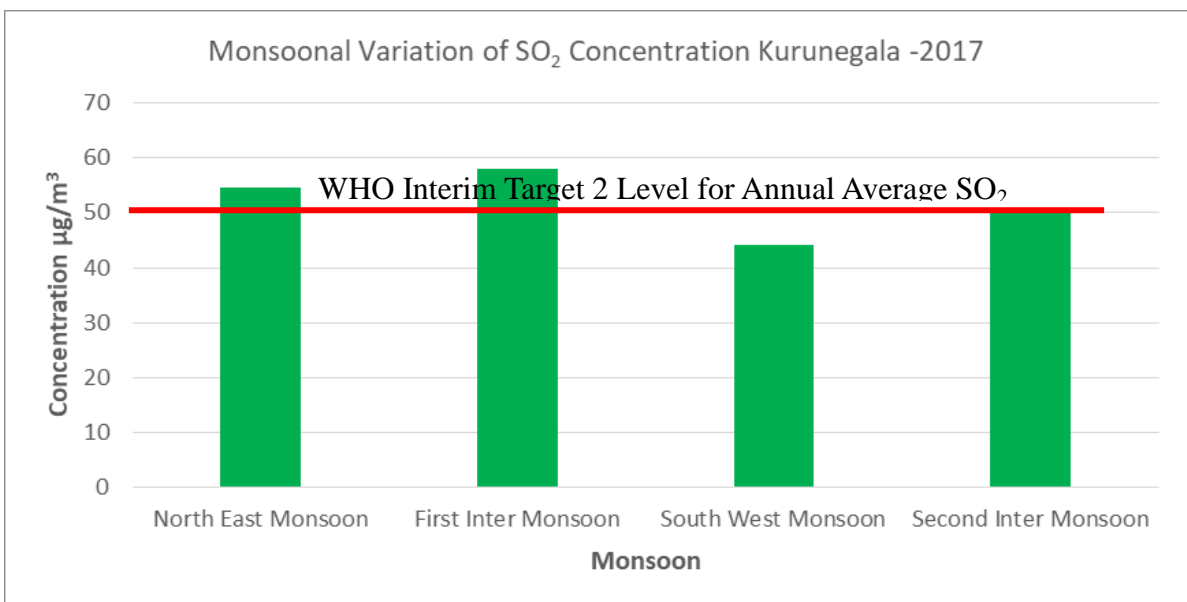
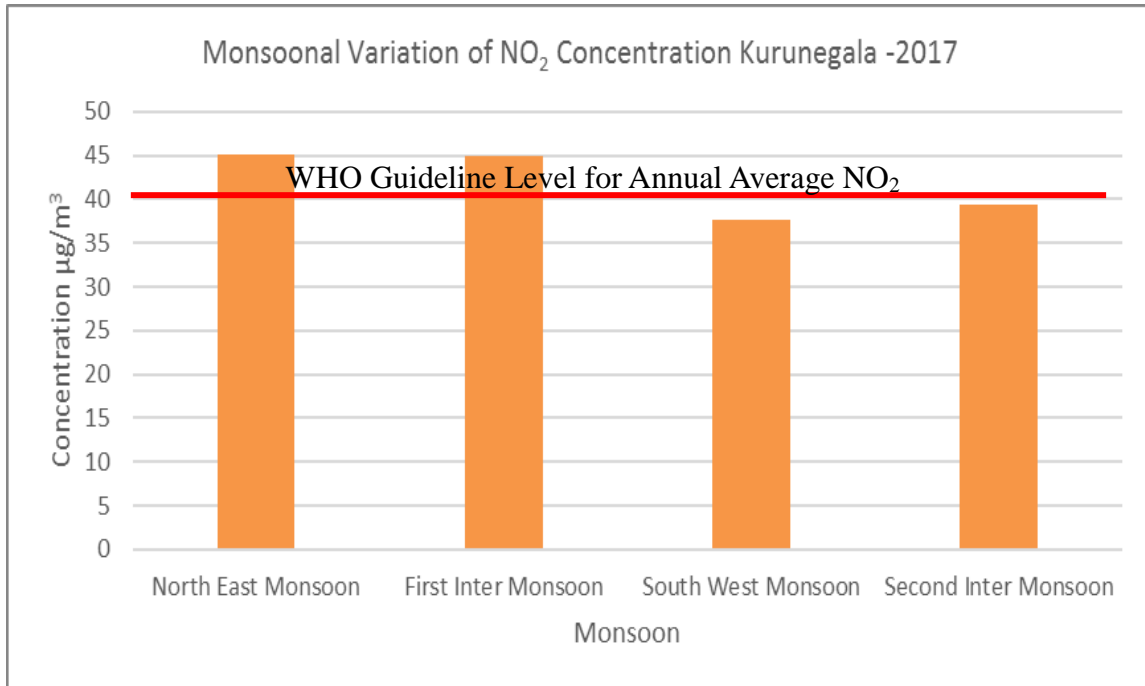


Figure 6.8.12: Variation of SO₂ concentration within Kurunegala Urban Area 2016 and 2017

Being the Kurunegala in the centre of the country, monsoon variation is highly influence on the dispersion and transport of the pollutants. The average NO₂ and SO₂ levels with respective to the monsoon variations are shown figure 6.8.13 (a) and 6.8.13 (b) respectively. It indicates that at the levels are highly subjective to the local wind condition. Most of locations, high exposure levels are recorded in during North-East monsoon period (December – February) compared to South-West monsoon period (May-September).

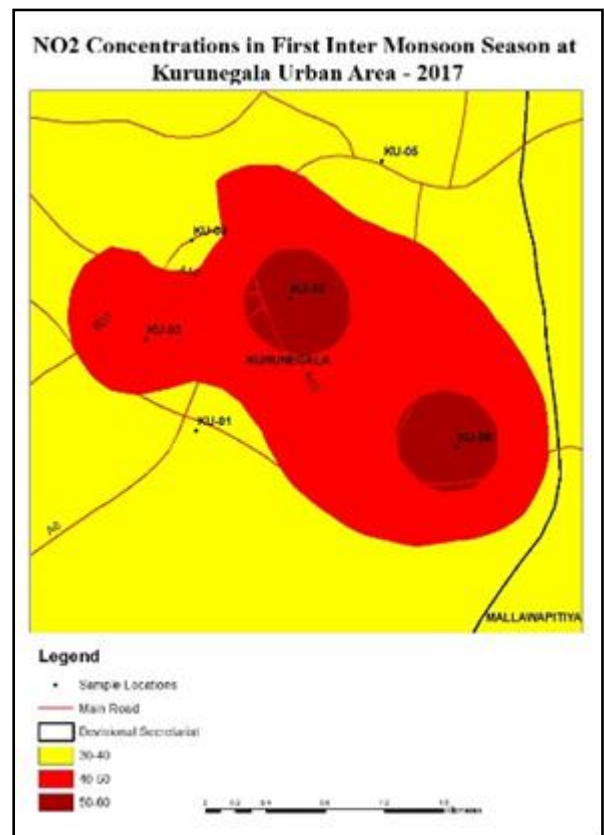
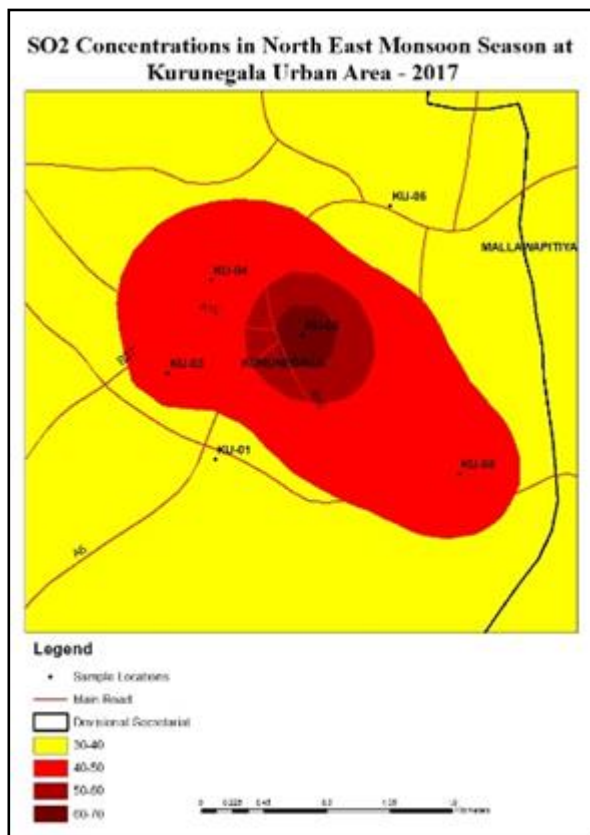


(a)



(b)

Figure 6.8.13: Monsoonal Variation of (a).NO₂, (b).SO₂ concentration within Kurunegala Urban Area



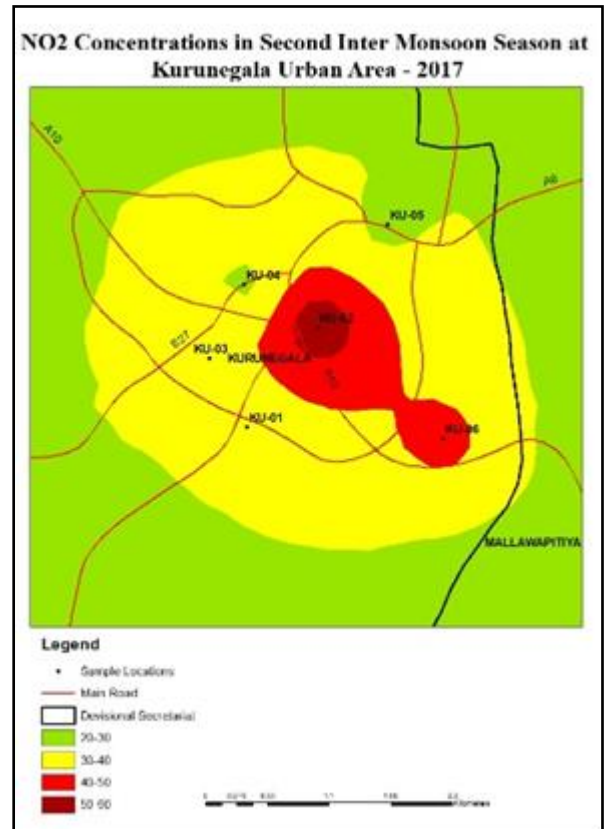
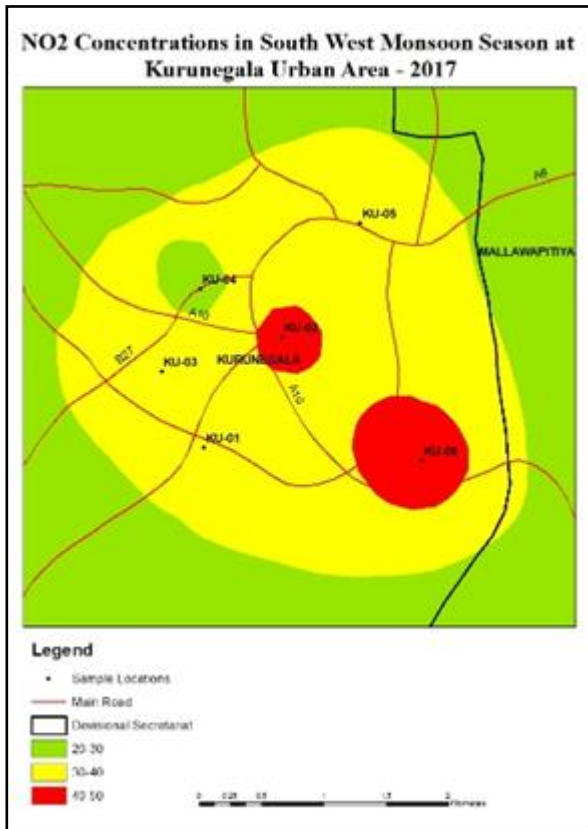
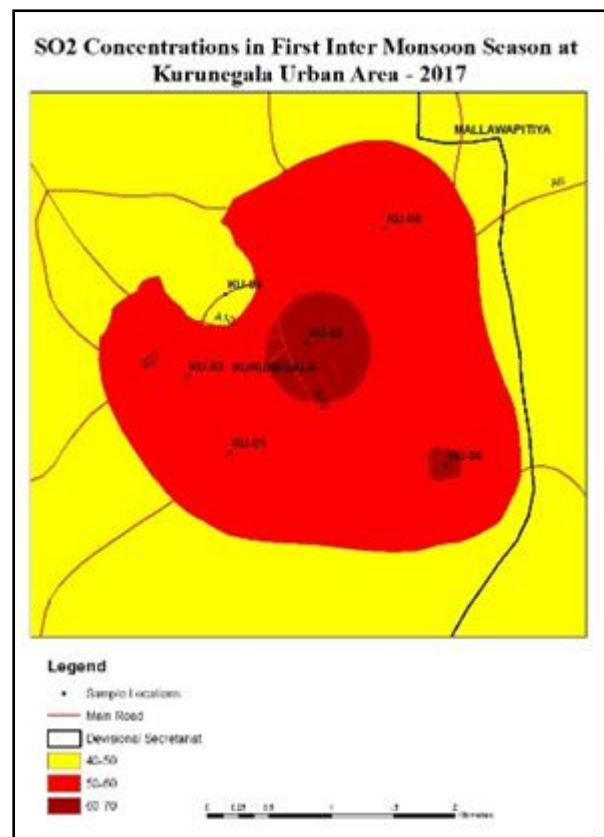
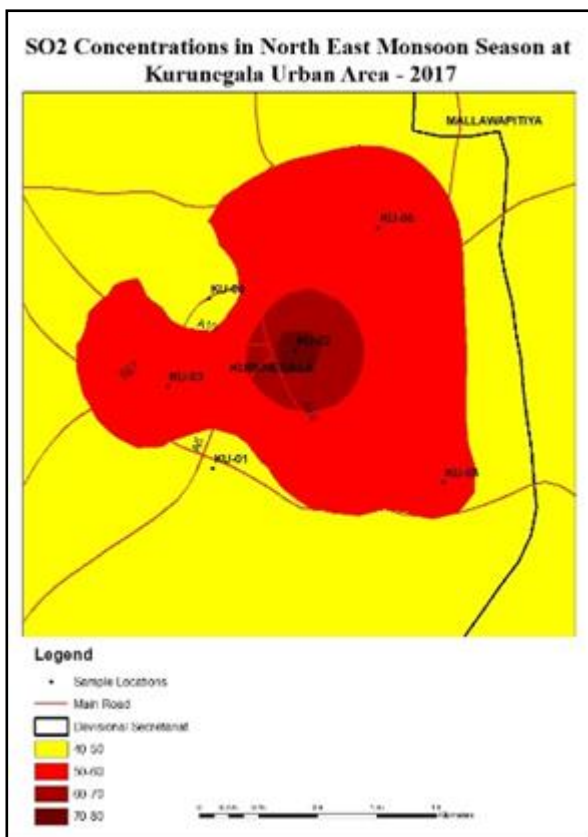


Figure 6.8.14: Variation of NO₂ exposure levels due to monsoon seasons at Kurunegala Urban City in 2017. From left to right it shows North East Monsoonal Season Exposure, First Inter Monsoon Seasonal Exposure, South West Monsoonal Season Exposure and Second Inter Monsoon Season Exposure respectively.



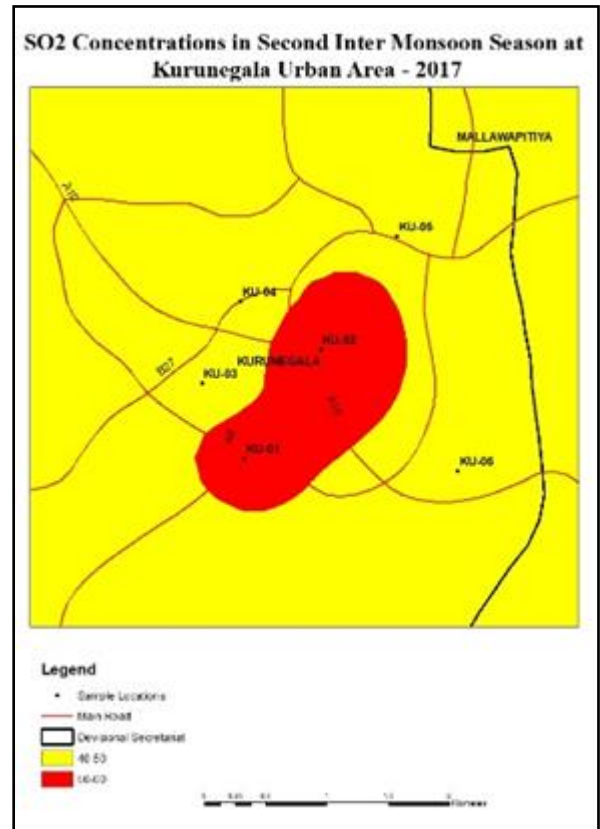
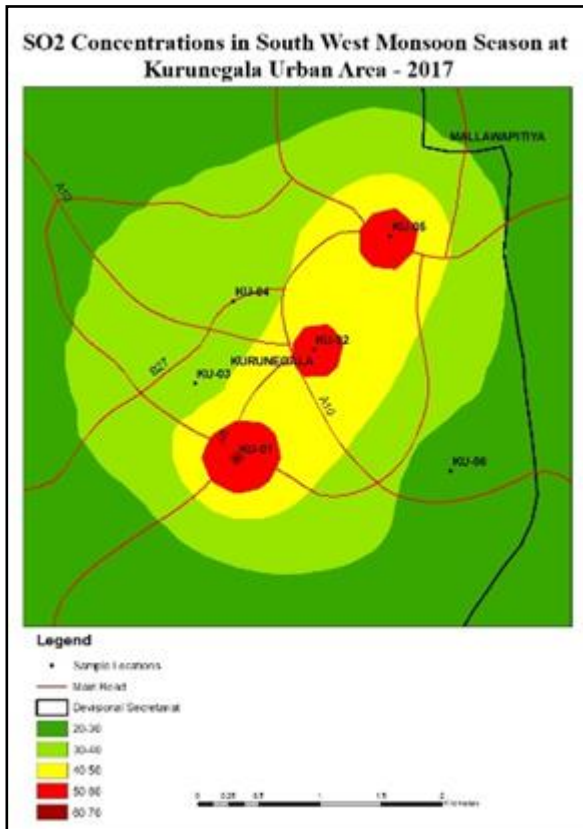


Figure 6.8.15: Variation of SO₂ exposure levels due to monsoon seasons at Kurunegala Urban City in 2017. From left to right it shows North East Monsoonal Season Exposure, First Inter Monsoon Seasonal Exposure, South West Monsoonal Season Exposure and Second Inter Monsoon Season Exposure respectively

6.9 AMBIENT AIR QUALITY IN 2017 – AT ANURADHAPURA URBAN AREA

Anuradhapura is a major city in Sri Lanka. It is the capital city of North Central Province, Sri Lanka and the capital of Anuradhapura District. Anuradhapura is one of the ancient capitals of Sri Lanka, famous for its well-preserved ruins of ancient Sri Lankan civilization. The city, now a UNESCO World Heritage Site, was the centre of Theravada Buddhism for many centuries. The city lies 205 km north of the current capital Colombo in Sri Lanka's North Central Province, on the banks of the historic Malwathu Oya. This ancient city is today surrounded by monasteries covering an area of over 40 km². The urban area of the city consisted of many four-way junctions where vehicles traffics tend to take place around those areas.

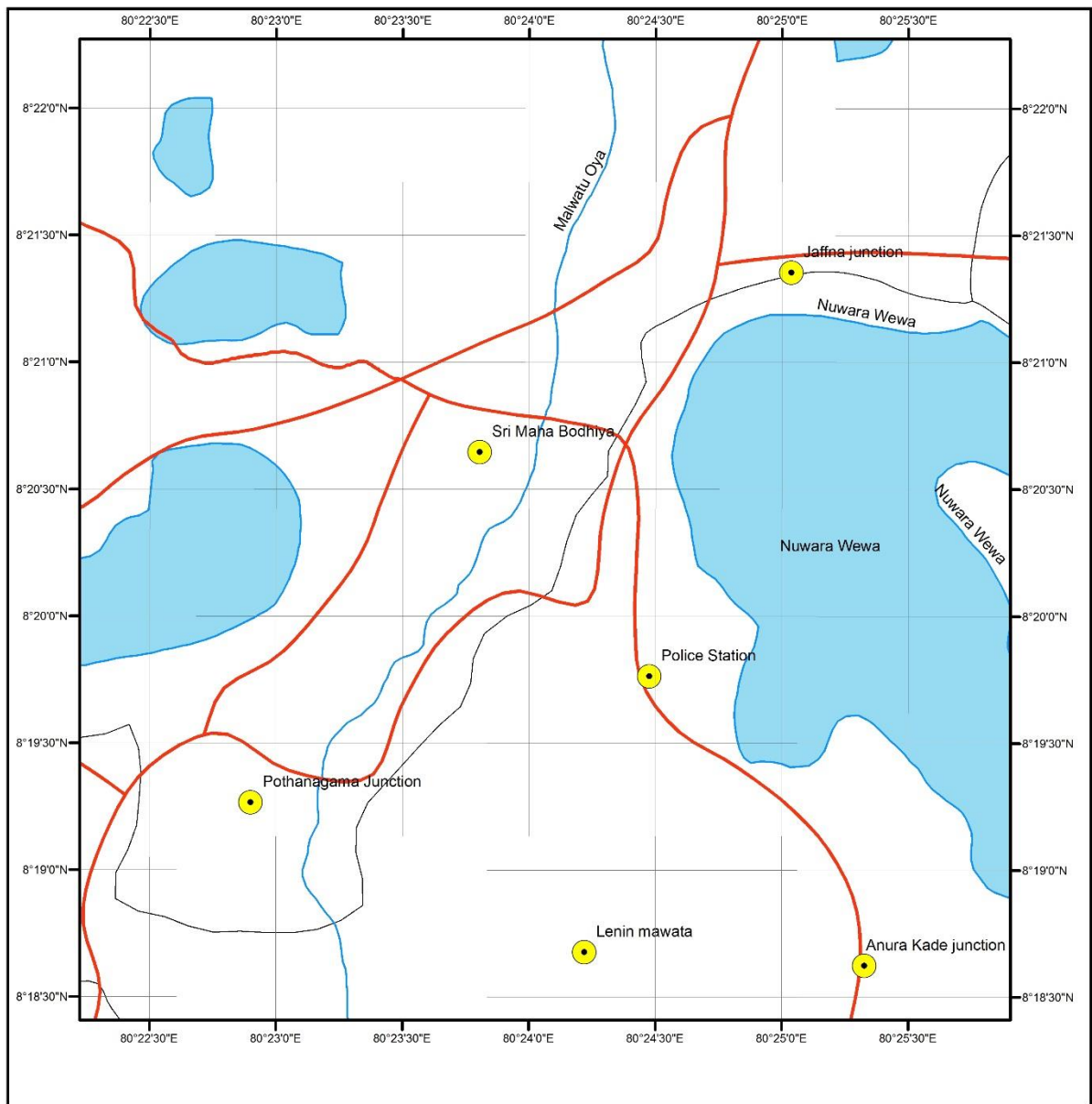
Air quality exposure levels with respect to NO₂ and SO₂ in Anuradapura Urban area was started in October 2015 at five locations within the Anuradapura urban area and surrounding areas with the financial assistant of VET fund. The monthly average NO₂ and SO₂ exposure levels at each measuring location within Anuradapura urban area in 2017 is summarised in table 6.9.3 and 6.9.4 respectively. Table 6.9.5 shows that PM_{2.5} concentration of selected sample locations in Anuradhapura in 2017.

Air quality exposure levels measuring activities with respect to NO₂ and SO₂ in Anuradhapura Urban area were continued in 2017 as well under this project. The sample locations description is given in table 6.9.1 and figure 6.9.1 shows the locations map. The table 6.9.2 presents the overview of each location in the Anuradhapura urban area.

Table 6.9.1: Selected Sampling Locations in Anuradhapura Urban area

Urban Area	No of Points	Sampling Location	Location Description
Anuradhapura	5	AD1	Jaffna junction
		AD2	Police Station
		AD3	Anura Kade junction
		AD4	Lenin mawata
		AD5	Pothanagama Junction
		AD6	Sri Maha Bodhiya

Sample Locations at Anuradhapura Urban Area in 2017



Legend

- AllPoints17
- Road
- Streams
- Tanks

Figure 6.9.1: Sampling Locations Map in Anuradhapura Urban area

Table 6.9.2: Overview of each location in the Anuradhapura urban area



Location No: AD1
Location Name: Jaffna Junction
GPS Coordinates: 8.3558980N, 80.4172650E



Location No: AD2
Location Name: Police Station
GPS Coordinates: 8.3293840N, 80.4079240E



Location No: AD3
Location Name: Anura Kade Jn
GPS Coordinates: 8.3103800N, 80.4221070E



Location No: AD4
Location Name: Lenin Mawatha
GPS Coordinates: 8.3112680N, 80.4036540E



Location No: AD5
Location Name: Pothanagama Junction
GPS Coordinates: 8.3210950N, 80.3816610E



Location No: AD6
Location Name: Sri Maha Bodhiya
GPS Coordinates: 8.3441067N, 80.3967483E

Monthly average NO₂ and SO₂ exposure levels at each measuring location within Anuradhapura urban area for the year 2017 is summarized in table 6.9.3 and 6.9.4 respectively. Table 6.9.5 shows that PM_{2.5} concentration of selected sample locations in Anuradhapura in 2017.

Table 6.9.3: Monthly Average Exposure Levels of NO₂ at each location in Anuradhapura Urban Area

Urban Area	Location	NO ₂ Concentration(µg/m ³)											
		Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
Jaffna junction	AD1	25	28	28	29	22	24	41	24	20	27	25	25
Police Station	AD2	42	35	33	34	38	30	37	39	26	27	36	44
Anura Kade Junction	AD3	21	12	11	11	10	9	9	8	8	11	11	16
Lenin Mawatha	AD4	14	-	14	19	17	15	10	6	6	14	14	24
Pothanagama Junction	AD5	41	43	34	27	29	28	29	32	27	43	29	33
Sri Maha Bodiya	AD6	16	15	17	19	17	17	-	8	15	17	17	19

Table 6.9.4: Monthly Average Exposure Levels of SO₂ at each location in Anuradhapura Urban Area

Urban Area	Location	SO ₂ Concentration(µg/m ³)											
		Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
Jaffna junction	AD1	36	39	39	43	40	37	46	56	38	45	50	50
Police Station	AD2	36	43	38	56	35	36	45	49	38	47	42	56
Anura Kade Junction	AD3	37	39	40	38	42	32	50	32	36	32	40	38
Lenin mawatha	AD4	26	-	36	41	28	41	36	22	24	41	44	41
Pothanagama Junction	AD5	41	34	40	39	36	33	42	43	31	43	45	47
Sri Maha Bodiya	AD6	32	35	37	42	36	44	-	25	27	49	43	40

Table 6.9.5: 24 hourly Average Levels of PM_{2.5} at Selected location in Anuradhapura Urban Area

City	Site Name	PM _{2.5} (µg/m ³)												
		Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	
Anuradhapura	Police Station (AD2)	-	-	-	-	-	-	-	-	-	-	-	40	42

The NO₂ and SO₂ in each location within the measured month at Anuradhapura Urban Area are in the range of 12 µg/m³ - 35 µg/m³ and 35 µg/m³ - 43 µg/m³ respectively. The high levels are representing areas with high traffic areas such as Pothanagama Junction (AD3) and the levels are low when goes away from the city.

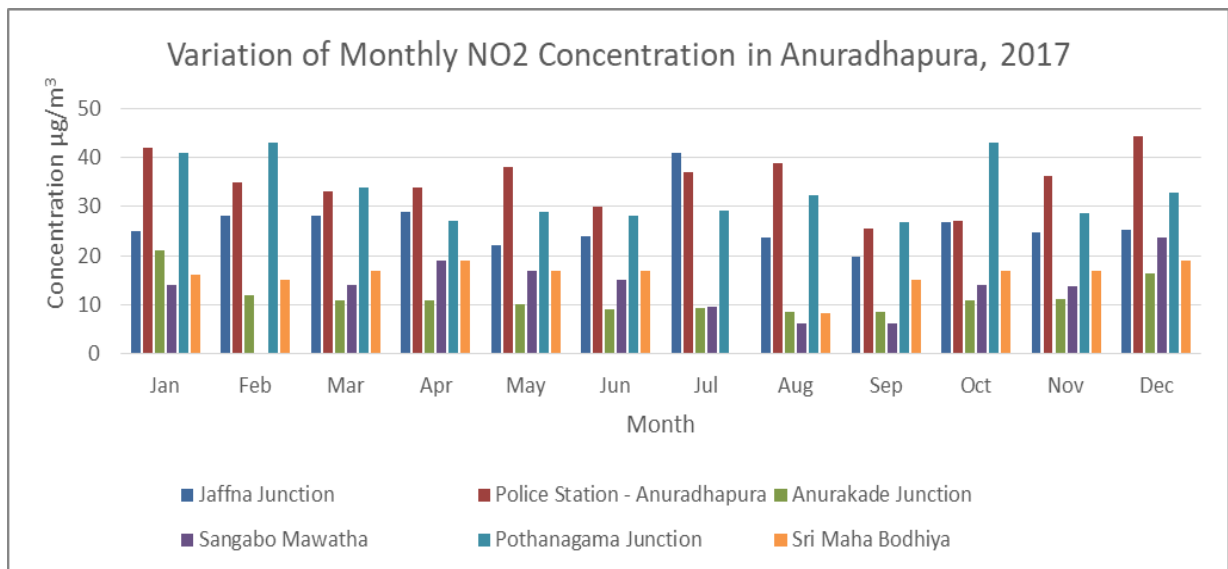


Figure 6.9.2 (a): Variation of NO₂ concentration within Anuradhapura Urban Area in 2017

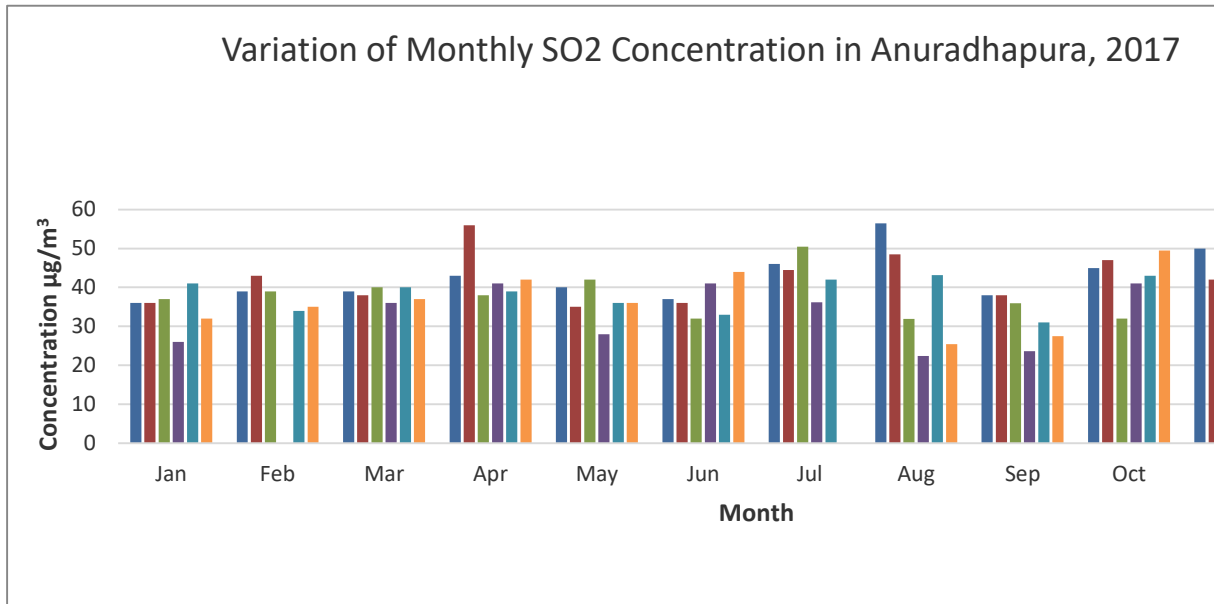


Figure 6.9.2 (b): Variation of SO₂ concentration within Anuradhapura Urban Area in 2017

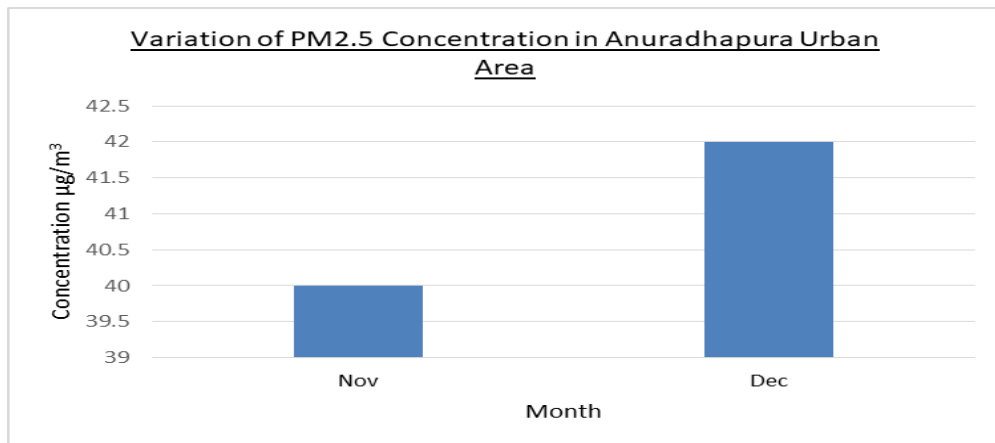


Figure 6.9.3: Variation of PM_{2.5} concentration within Anuradhapura Urban Area in 2017

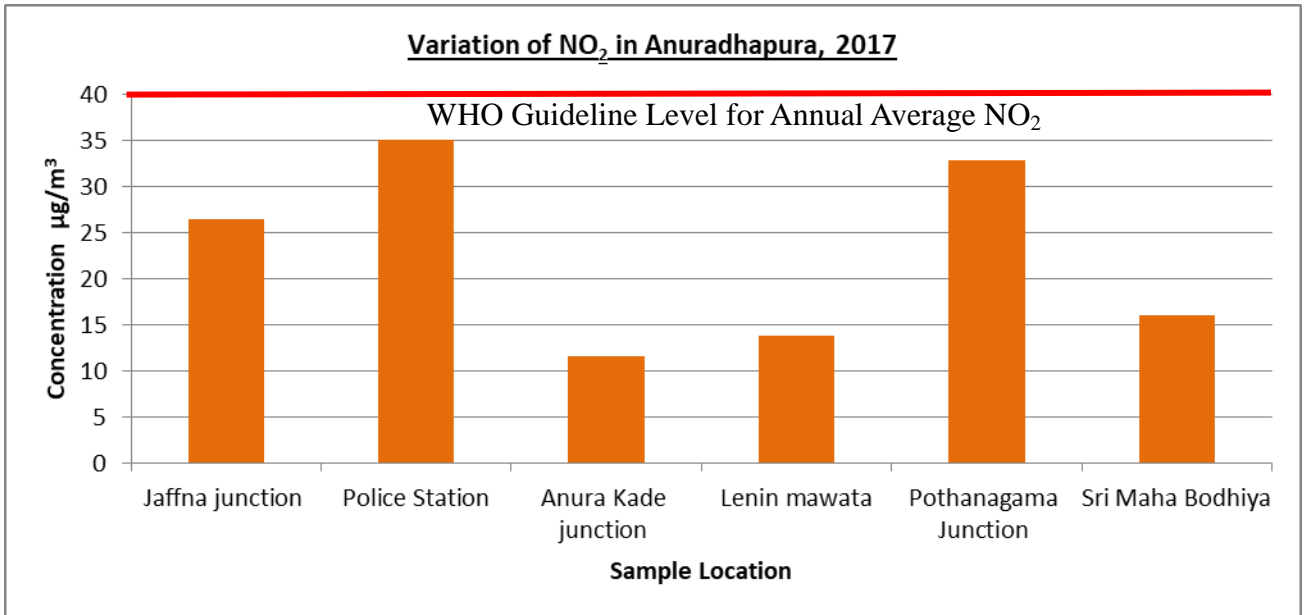


Figure 6.9.4: Annual average NO₂ concentration within Anuradhapura Urban Area in 2017

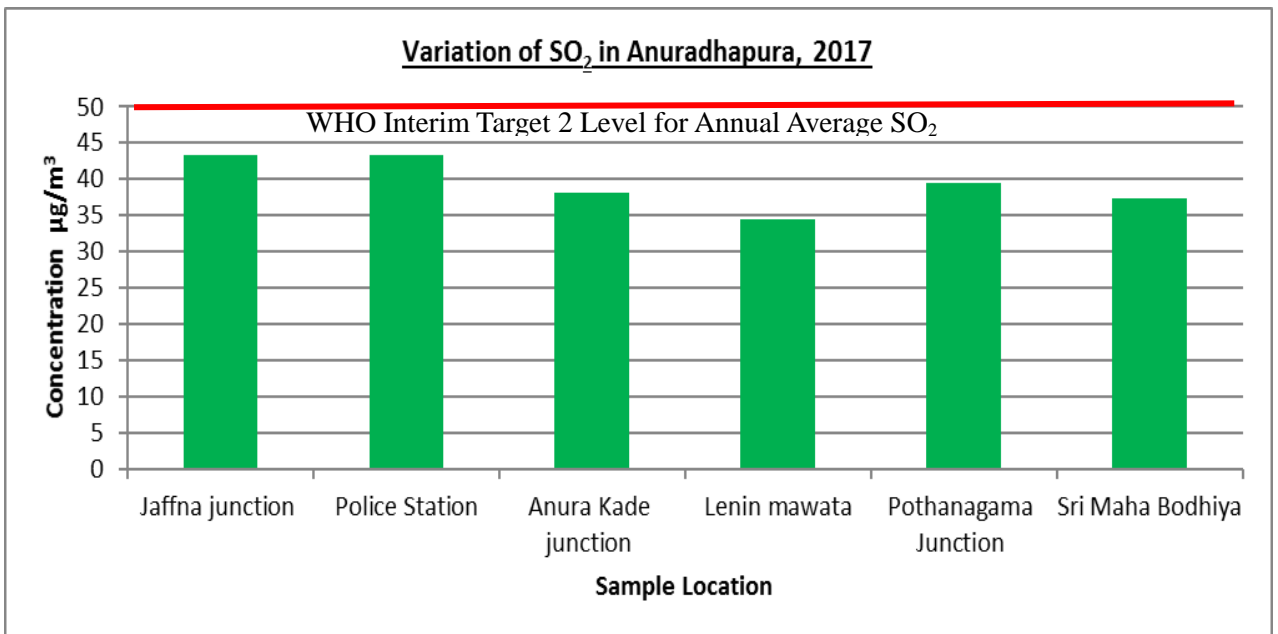


Figure 6.9.5: Annual average SO₂ concentration within Anuradhapura Urban Area in 2017

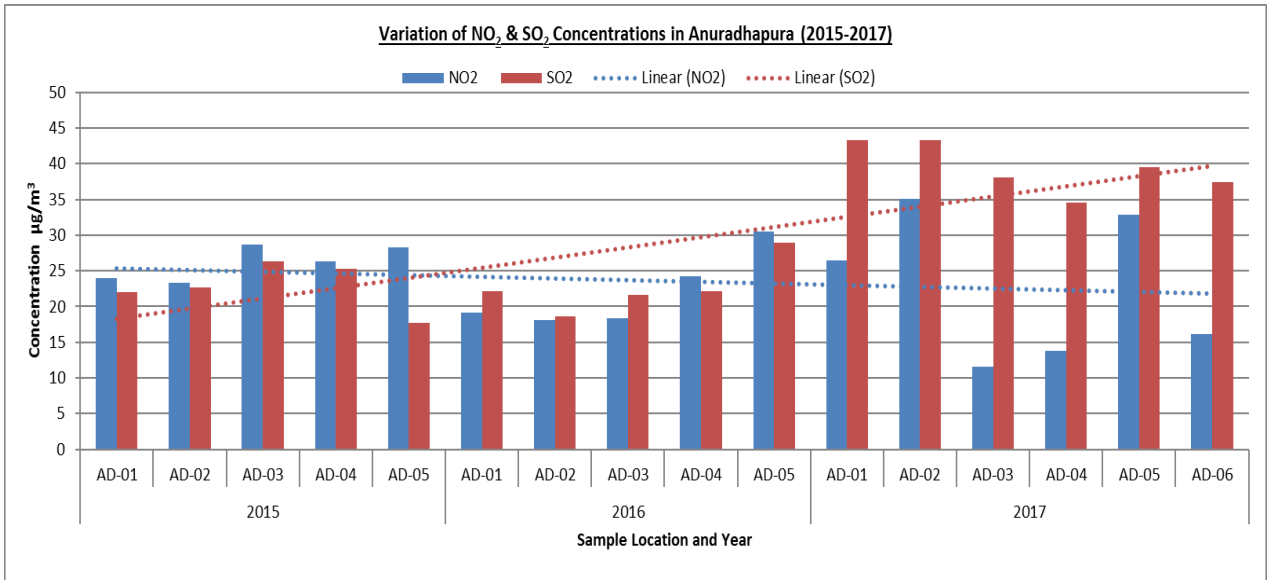


Figure 6.9.6: Average NO₂ and SO₂ variations from 2015-2017

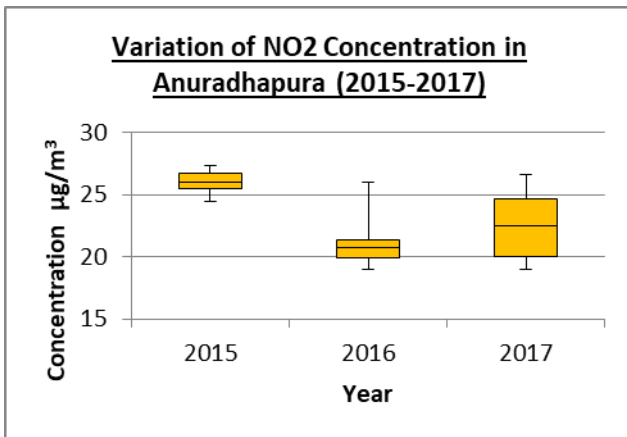


Figure 6.9.7: Boxplot of NO₂ Concentration variation in Anuradhapura (2015-2017)

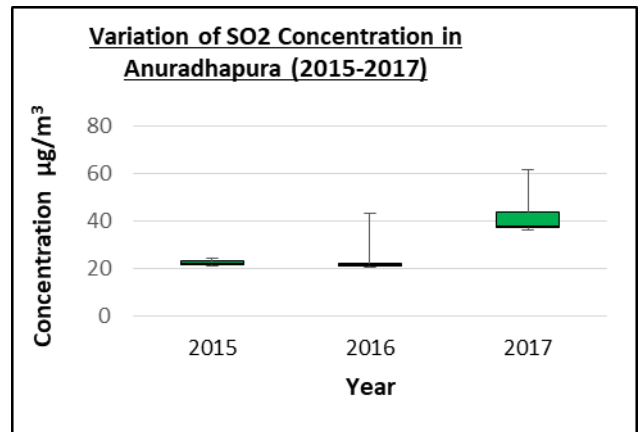


Figure 6.9.8: Boxplot of SO₂ Concentration variation in Anuradhapura (2015-2017)

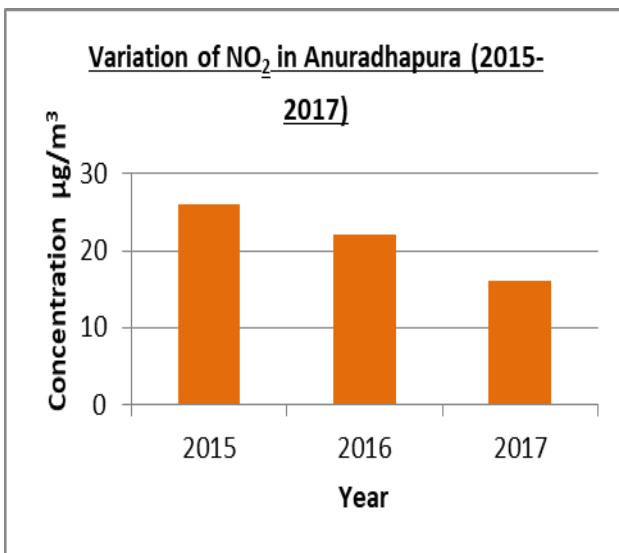


Figure 6.9.9: Annual average NO₂ variations from 2015-2017 in Anuradhapura Urban area

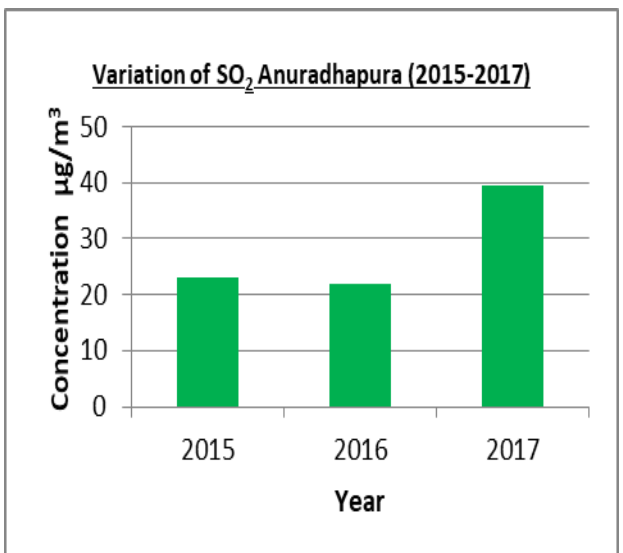


Figure 6.9.10: Annual average SO₂ variations from 2015-2017 in Anuradhapura Urban area

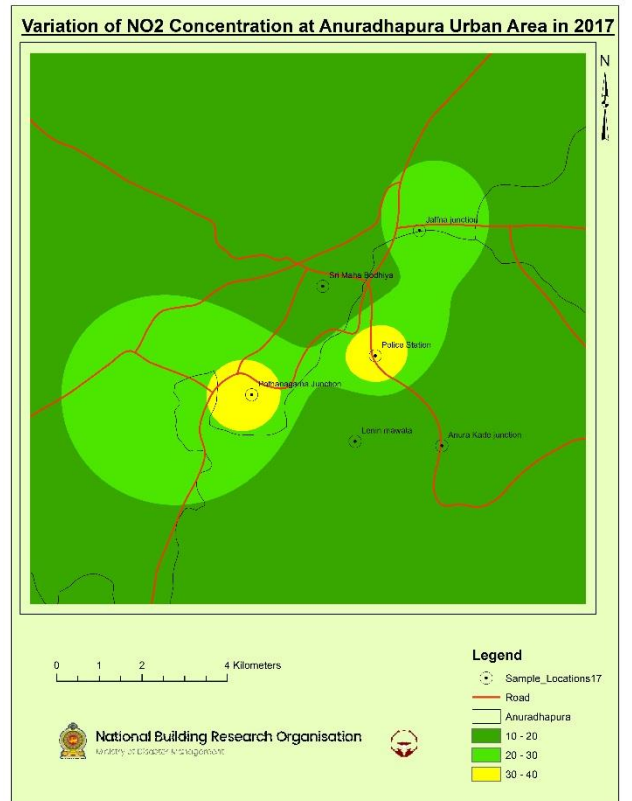
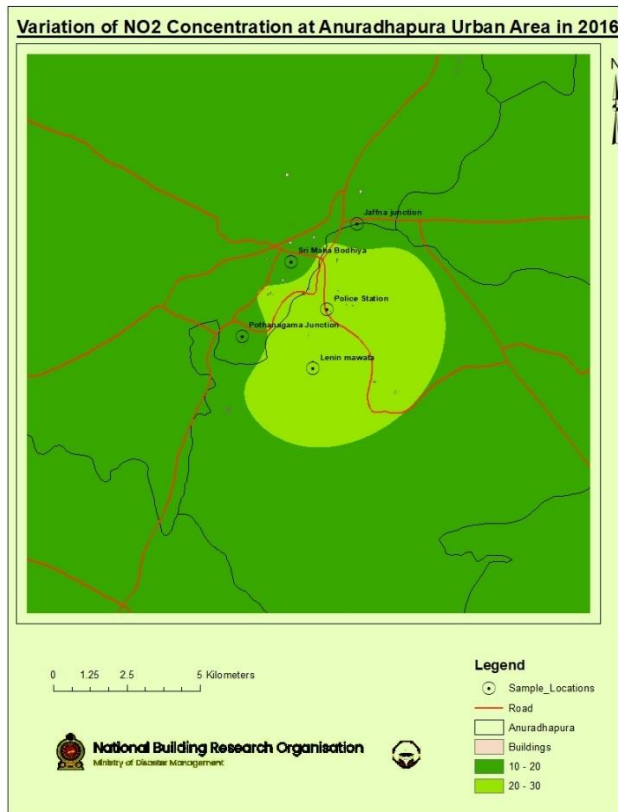


Figure 6.9.11: Variation of NO₂ concentration within Anuradhapura Urban Area 2016 and 2017

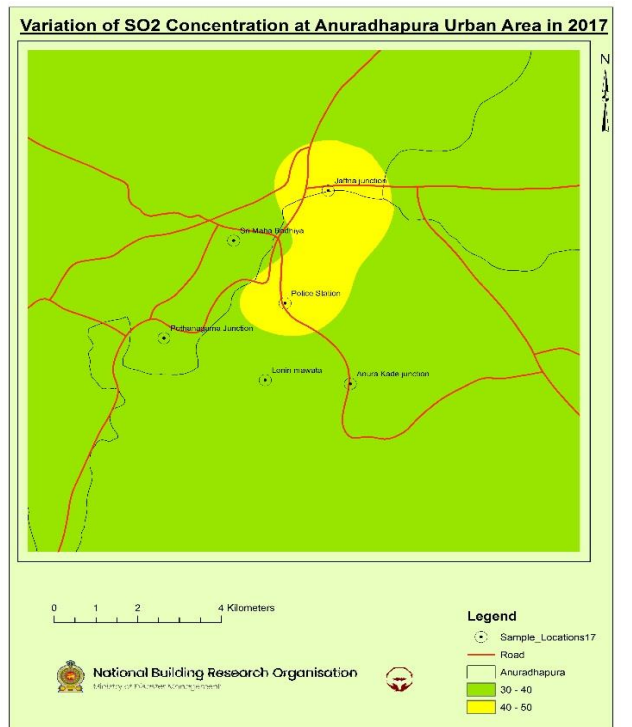
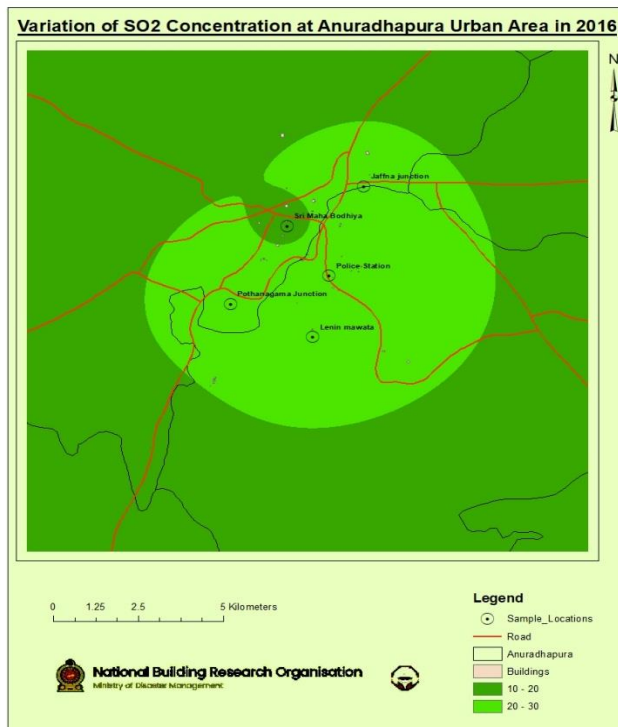


Figure 6.9.12: Variation of SO₂ concentration within Anuradhapura Urban Area 2016 and 2017

As an island, monsoonal variation of the climate is highly affected for the dispersion of these chemical agents. The average exposure of NO₂ and SO₂ level trend has analyzed below in figures 6.4.13 (a) and (b) respectively. According to that trend analysis, NO₂ exposure has highest exposure in North East Monsoonal and lowest exposure in South West Monsoonal season. But SO₂ has shown another trend, which has highest exposure in first inter monsoonal season and lowest exposure in South West Monsoonal season. However, North East Monsoonal season has higher exposure than South West Monsoonal season. This is due to North East Monsoonal wind came through large Indian land area while South West Monsoonal came through Indian ocean. However, throughout the year 2017, NO₂ exposure hasn't exceeded accepted exposure level in any monsoonal season while SO₂ exposure has achieved interim target level 2. The SO₂ exposure level has exceeded accepted exposure level according to the WHO guidelines.

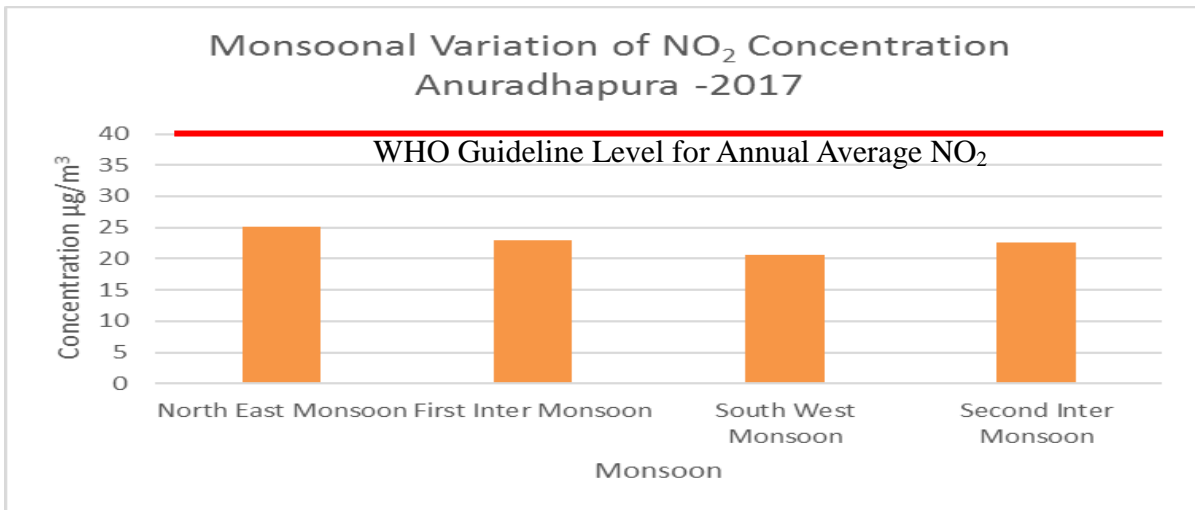


Figure 6.9.13(a): Monsoonal Variation of NO₂ levels within Anuradhapura Urban Area

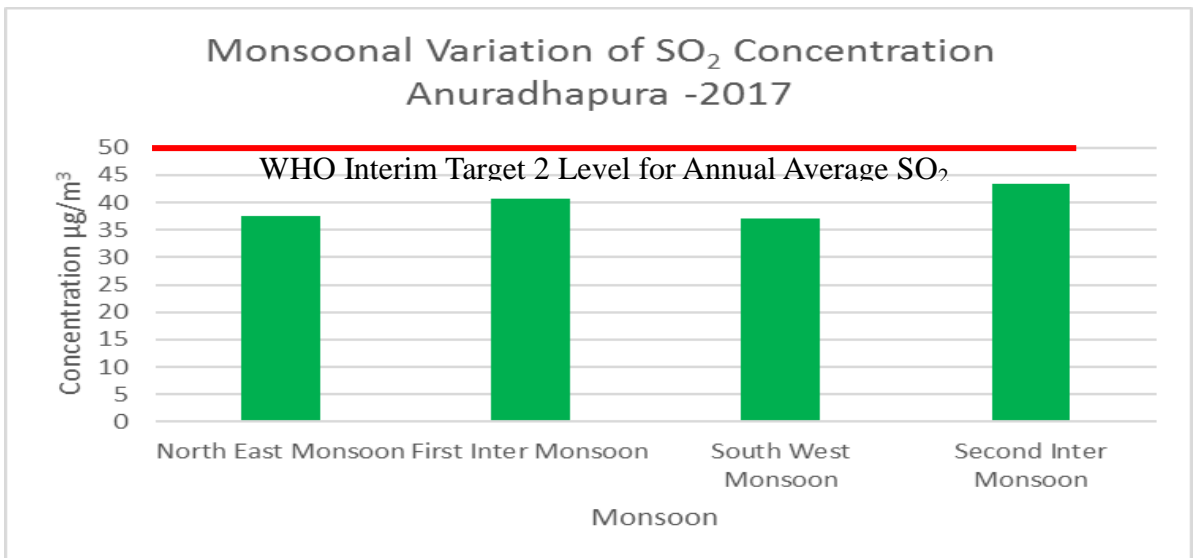


Figure 6.9.13(b): Monsoonal Variation of SO₂ Levels within Anuradhapura Urban Area

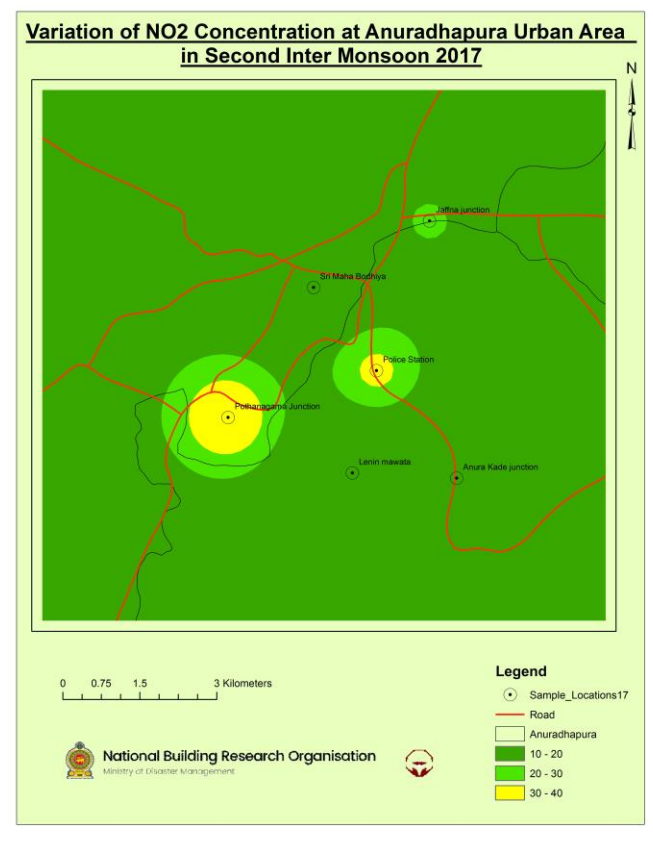
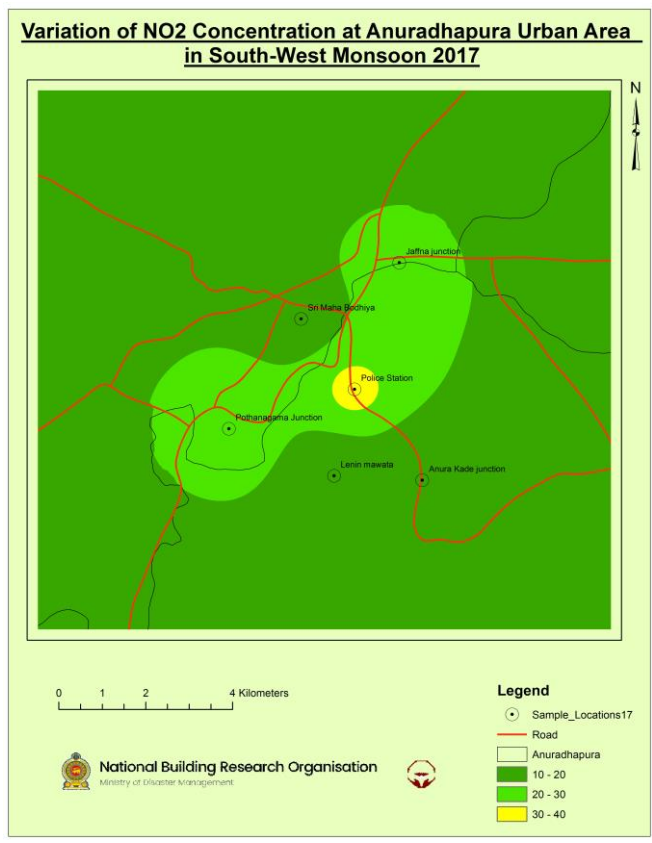
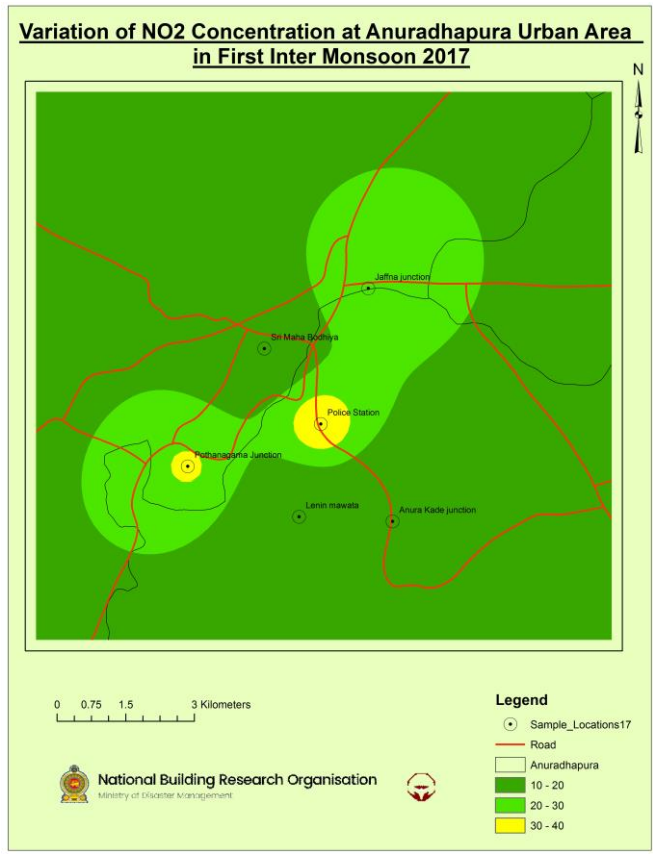
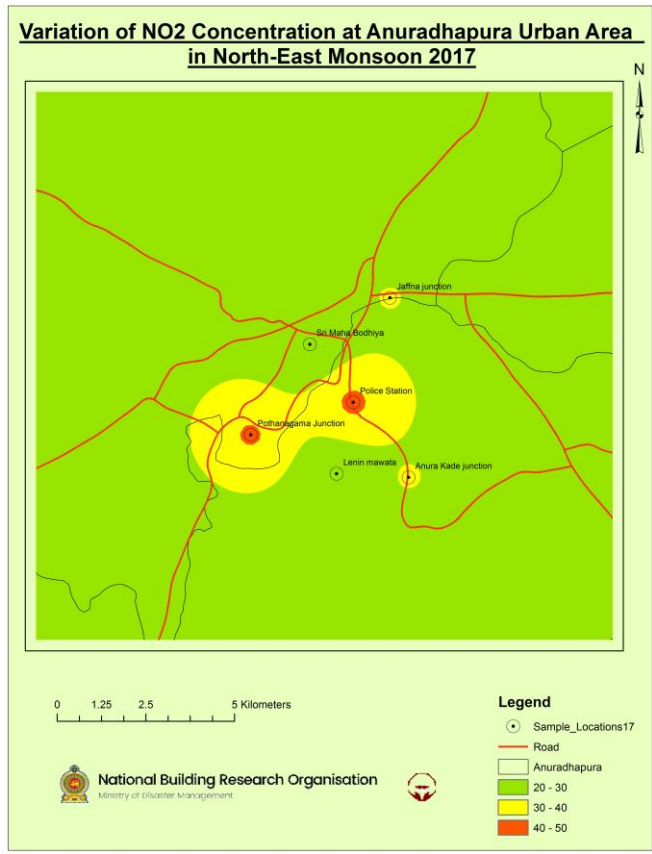


Figure 6.9.14: Monsoonal Seasonal Variation of NO₂ levels in Anuradhapura Urban City in 2017.

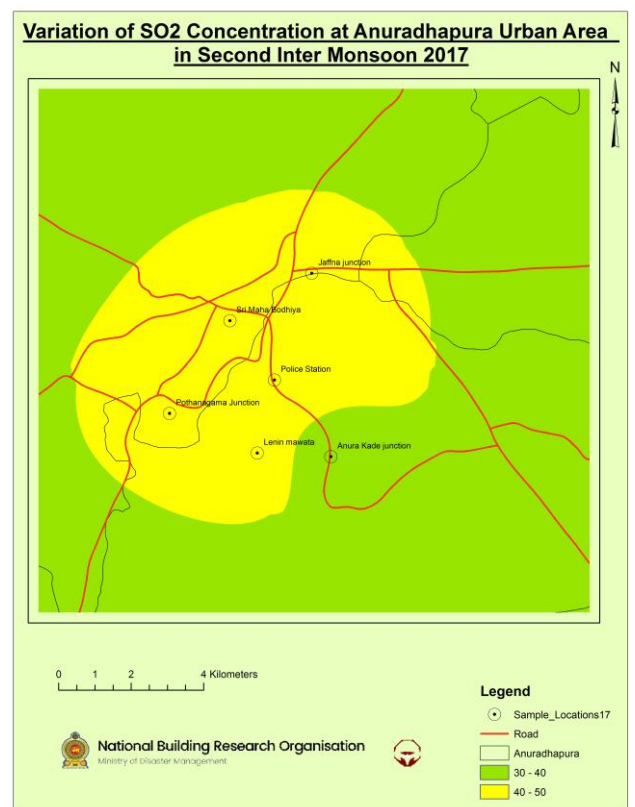
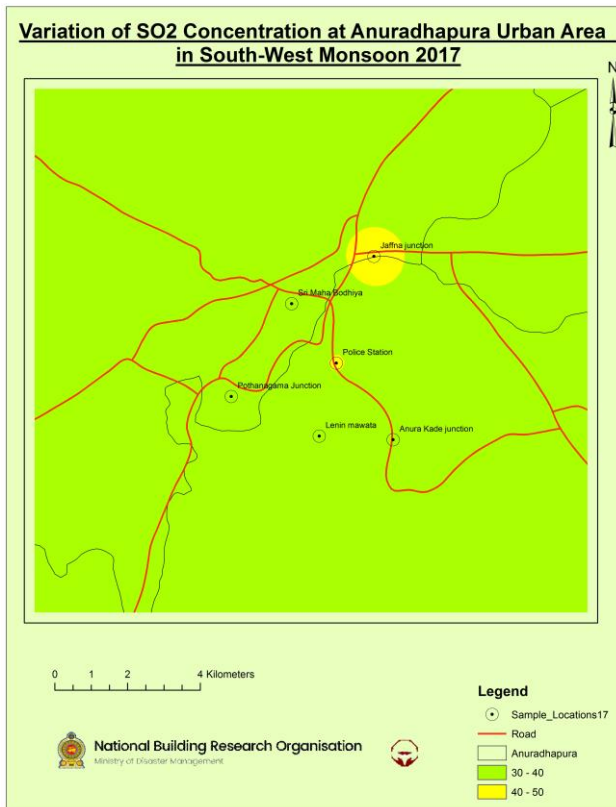
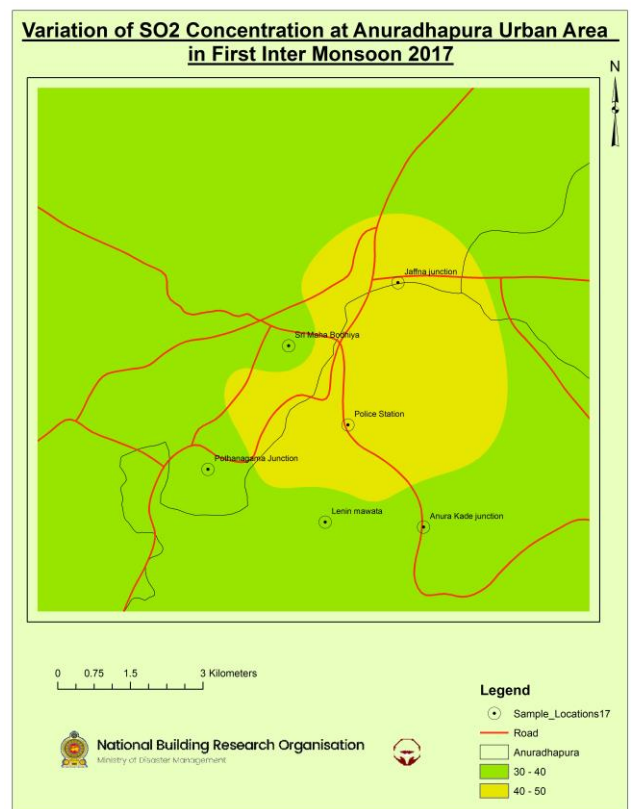
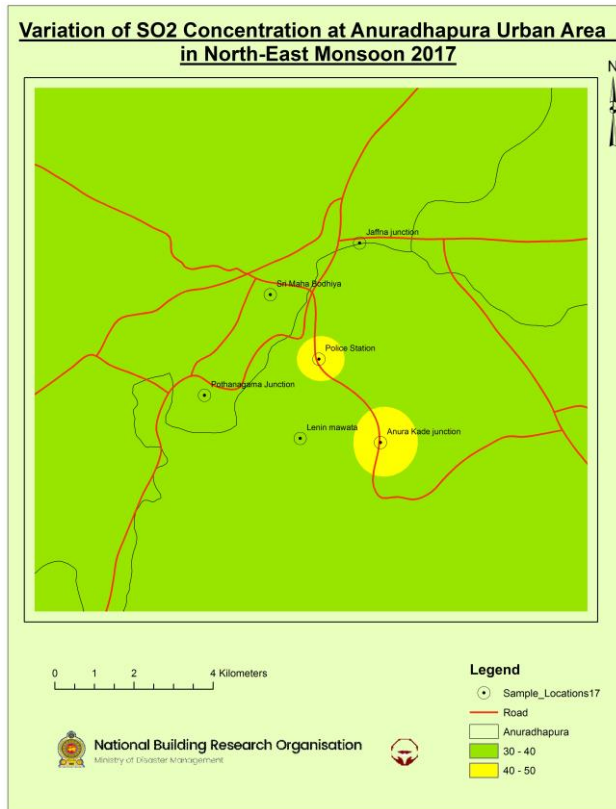


Figure 6.9.15: Monsoonal Seasonal Variation of SO₂ Level Anuradhapura Urban City in 2017.

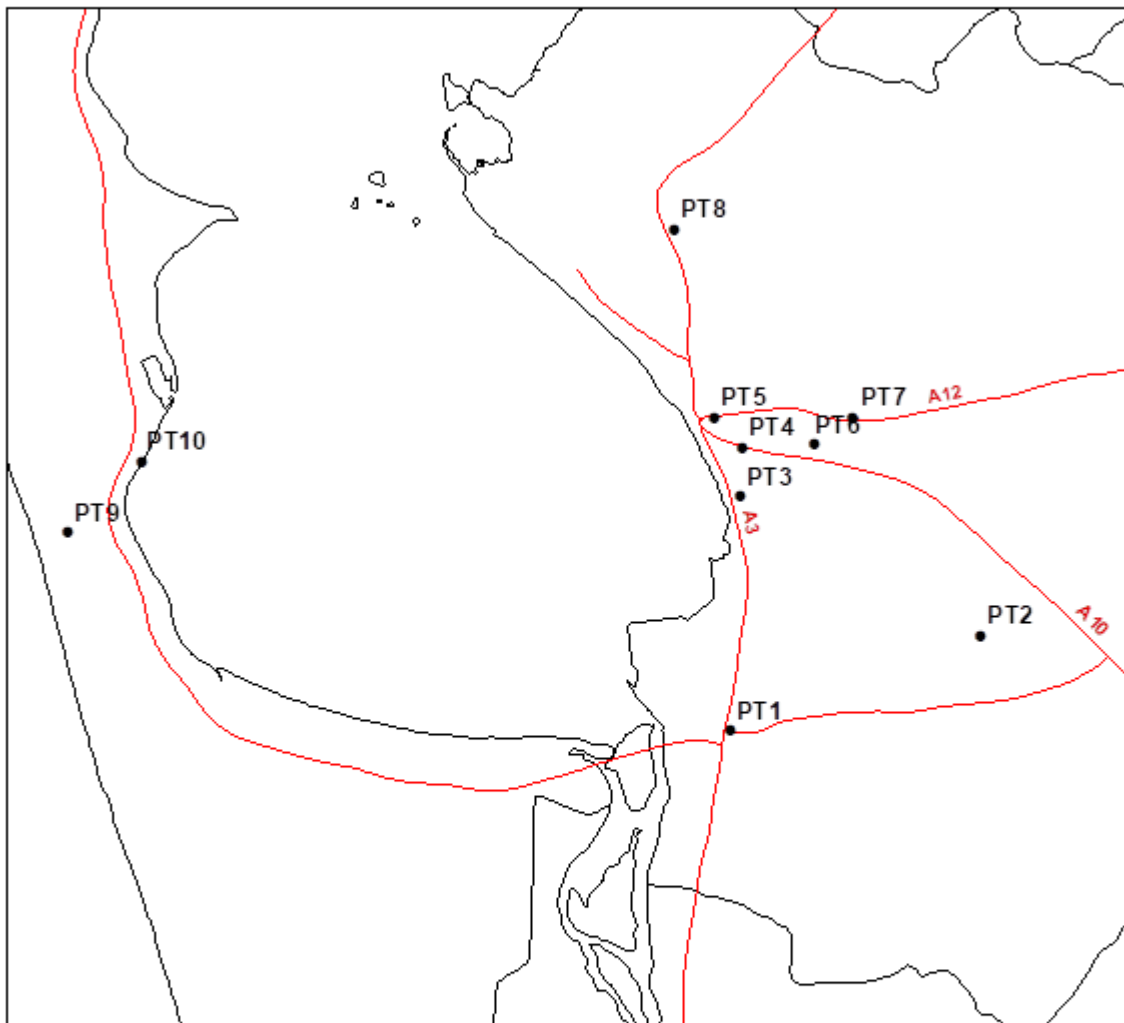
6.10 AMBIENT AIR QUALITY IN 2017 – AT PUTTALAM URBAN AREA

The sample locations description is given in table 6.10.1 and figure 6.10.1 shows the locations map. The figure 6.10.2 presents the overview of each location in the Puttalam urban area.

Table 6.10.1: Selected Sampling Locations in Puttalam Urban area

Urban Area	No of Points	Sampling Location	Location Description
Puttalam	10	PT1	Palavi Junction
		PT2	North East direction to the Holcim Cement Plant
		PT3	Close to the Hindu Temple (Good Shed Road)
		PT4	Service Road – Close to the RDA Office
		PT5	Puttalam Town Area
		PT6	Chenakudiyirippu Junction (Kurunegala Road)
		PT7	Periyavillu Junction (Anuradhapura Road)
		PT8	Near Puttalam Salt (Mannar Road)
		PT9	1 km to the South direction from the Coal Power Plant
		PT10	1.5 km to the North-East direction from the Coal Power Plant

Sample Locations at Puththalam Urban Area



Legend

- Sample Location
- Main Road
- Divisional Secretariat



Figure 6.10.1: Sampling Locations Map in Puttalam Urban area

Table 6.10.2: Overview of each location in the Colombo urban area



Location No: PT1
 Location Name: Palavi
 Junction
 GPS Coordinates:
 7°58'44.94"N
 79°50'0.48"E



Location No: PT2
 Location Name: North East
 direction to the Holcim Cement
 Plant
 GPS Coordinates:
 7°59'40.50"N,
 79°52'28.26"E



Location No: PT3
 Location Name: Close to the Hindu
 Temple (Good Shed
 Road)
 GPS Coordinates: 8° 1'3.38"N,
 79°50'5.62"E



Location No: PT4
 Location Name: Service Road
 – Close
 to the RDA Office
 GPS Coordinates:
 8°1'31.59"N,
 79°50'7.64"E



Location No: PT5
 Location Name: Puttalam
 Town Area
 GPS Coordinates:
 8°1'49.24"N,
 79°49'51.57"E



Location No: PT6
 Location Name: Chenakudiyirippu
 Junction
 GPS Coordinates:
 8°1'33.71"N,
 79°50'50.63"E



Location No: PT7
 Location Name: Periyavillu
 Junction
 GPS Coordinates:
 8°1'48.94"N,
 79°51'13.23"E



Location No: PT8
 Location Name: Near Puttalam
 Salt
 GPS Coordinates:
 8°3'40.17"N,
 79°49'27.73"E



Location No: PT9
 Location Name: 1 km to the South
 direction from the Coal
 Power Plant
 GPS Coordinates: 8° 0'41.37"N,
 79°43'31.53"E



Location No: PT10
 Location Name: 1.5 km to the
 North-East direction from
 the Coal Power Plant
 GPS Coordinates: 8° 1'23.28"N,
 79°44'14.94"E

Monthly average NO₂ and SO₂ exposure levels at each measuring location within Puttalam urban area for the year 2017 is summarised in table 6.10.2 and 6.10.3 respectively.

Table 6.10.3: Monthly Average Exposure Levels of NO₂ at each location in Puttalam Urban Area

Urban Area	Location	NO ₂ Concentration (µg/m ³)		
		Oct	Nov	Dec
Palavi Junction	PT1	27	15	24
North East direction to the Holcim Cement Plant	PT2	19	12	13
Close to the Hindu Temple (Good Shed Road)	PT3	22	12	17
Service Road – Close to the RDA Office	PT4	10	14	19
Puttalam Town Area	PT5	25	20	25
Chenakudiyirippu Junction (Kurunegala Road)	PT6	18	21	27
Periyavillu Junction (Anuradhapura Road)	PT7	9	8	13
Near Puttalam Salt (Mannar Road)	PT8	10	6	13
1 km to the South direction from the Coal Power Plant	PT9	14	14	16
1.5 km to the North-East direction from the Coal Power Plant	PT10	11	8	18

Table 6.10.4: Monthly Average Exposure Levels of SO₂ at each location in Puttalam Urban Area

Urban Area	Location	SO ₂ Concentration (µg/m ³)		
		Oct	Nov	Dec
Palavi Junction	PT1	39	26	35
North East direction to the Holcim Cement Plant	PT2	39	27	38
Close to the Hindu Temple (Good Shed Road)	PT3	47	42	39
Service Road – Close to the RDA Office	PT4	43	38	30
Puttalam Town Area	PT5	35	38	31
Chenakudiyirippu Junction (Kurunegala Road)	PT6	28	33	31
Periyavillu Junction (Anuradhapura Road)	PT7	39	28	24
Near Puttalam Salt (Mannar Road)	PT8	26	22	23
1 km to the South direction from the Coal Power Plant	PT9	43	29	53
1.5 km to the North-East direction from the Coal Power Plant	PT10	42	26	31

The figure 6.10.2 and 6.10.3 presented the monthly variation of NO₂ and SO₂ in each location within the year 2017 in Puttalam. It indicates that at the levels are highly subjective to the local wind condition.

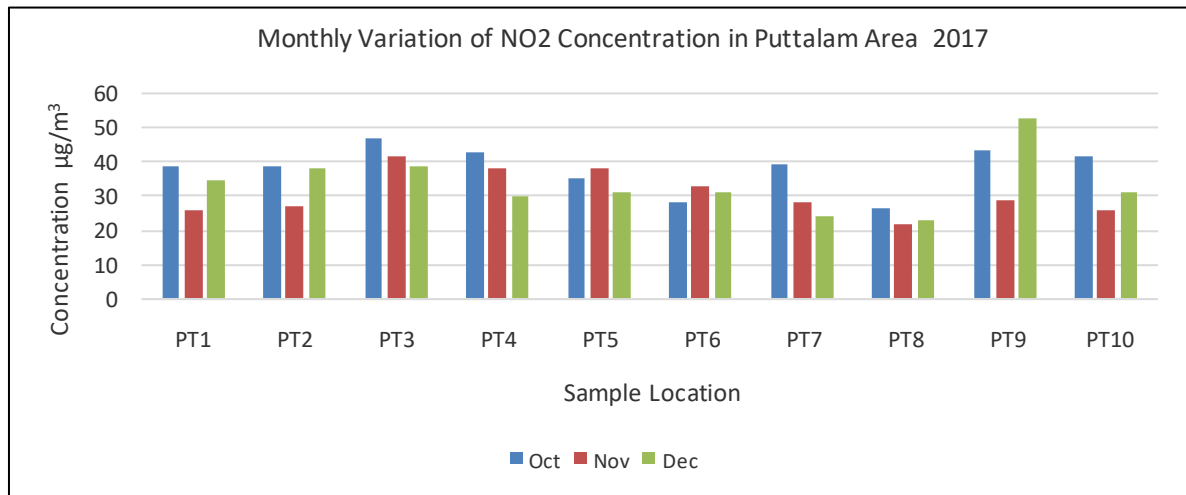


Figure 6.10.2: Monthly Variation of NO₂ concentration within Puttalam Urban Area in 2017

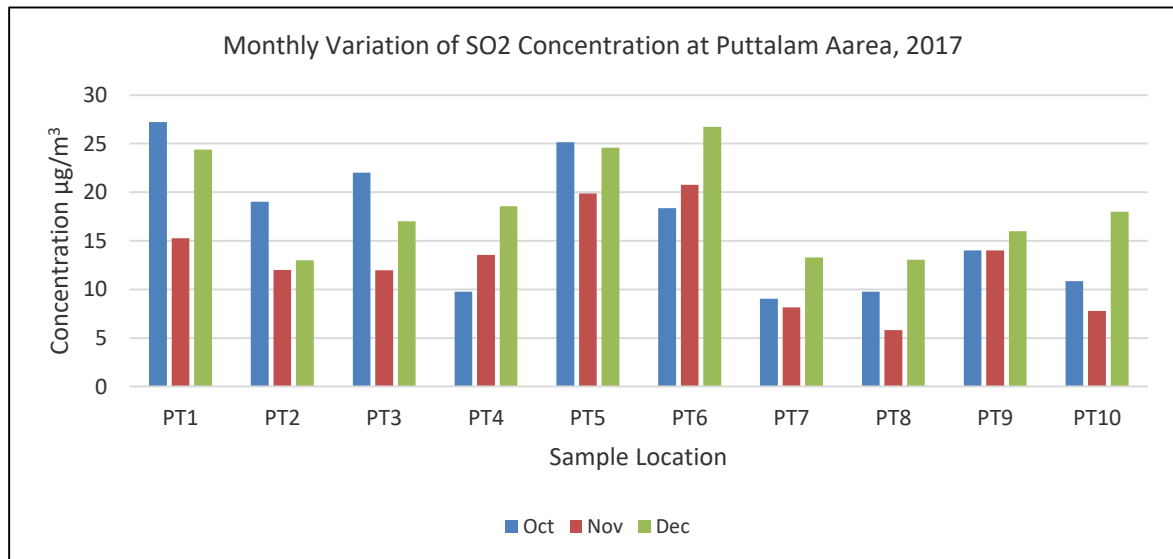


Figure 6.10.3: Monthly variation of SO₂ concentration within Puttalam Urban Area in 2017

Figure 6.10.3 and 6.10.4 represent the monthly average NO₂ and SO₂ concentration levels at each sampling location in Puttalam urban area during the year, 2017. Also, representative maps for NO₂ and SO₂ from October to December are shown in figure 5.2.10 and 5.2.11 respectively. The annual average NO₂ and SO₂ levels for relevant months in year 2017 within Puttalam are in between 10µg/m³ - 23µg/m³ and 24µg/m³ – 43 µg/m³ respectively. The high levels are representing highly urbanised areas with high traffic such as Hindu Temple (PT2) and Puttalam Town (PT5) while low levels are recorded at locations away from the city area such as Periyavillu Junction (PT7) and near Puttalam Salt (PT8) etc.

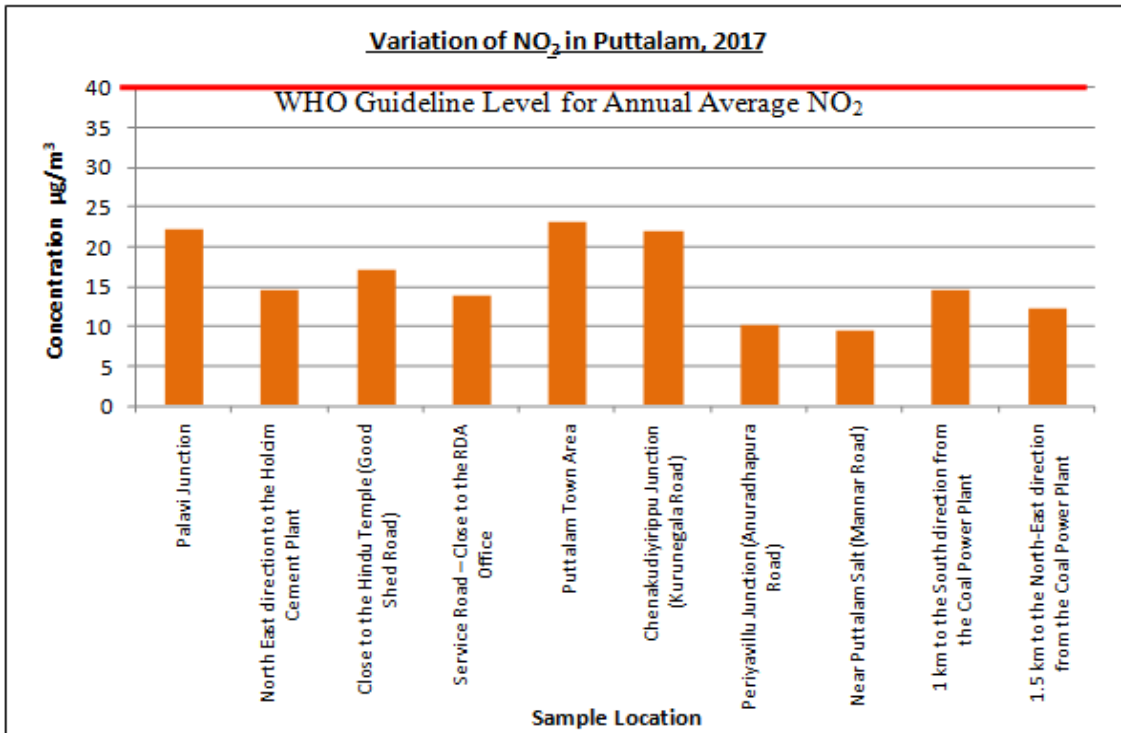


Figure 6.10.4: Average NO₂ concentration within Puttalam Urban Area in 2017

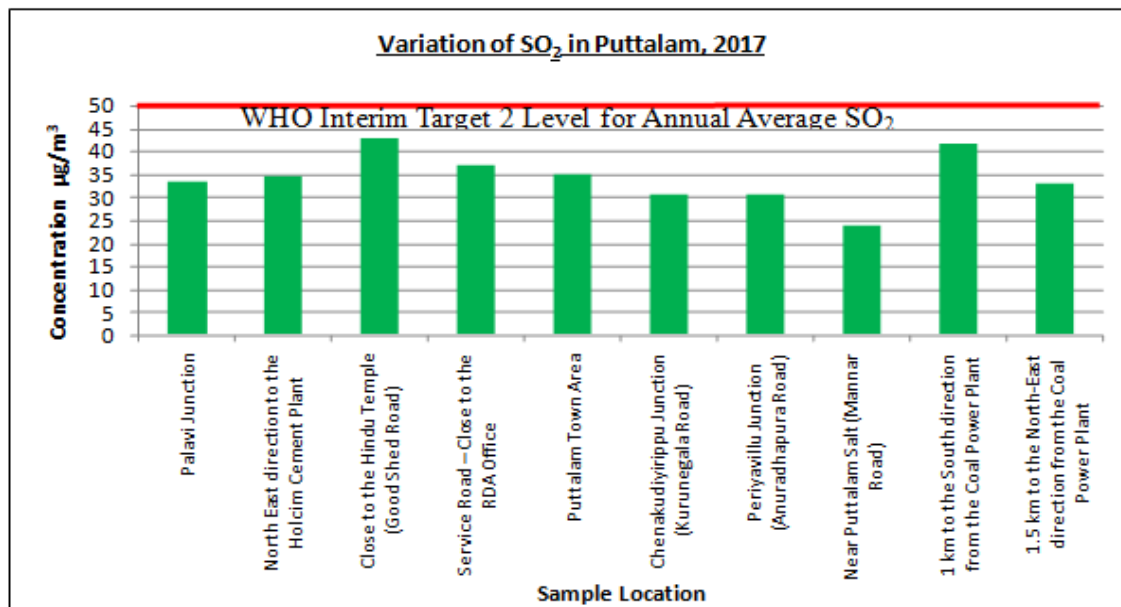


Figure 6.10.5: Average SO₂ concentration within Puttalam Urban Area in 2017

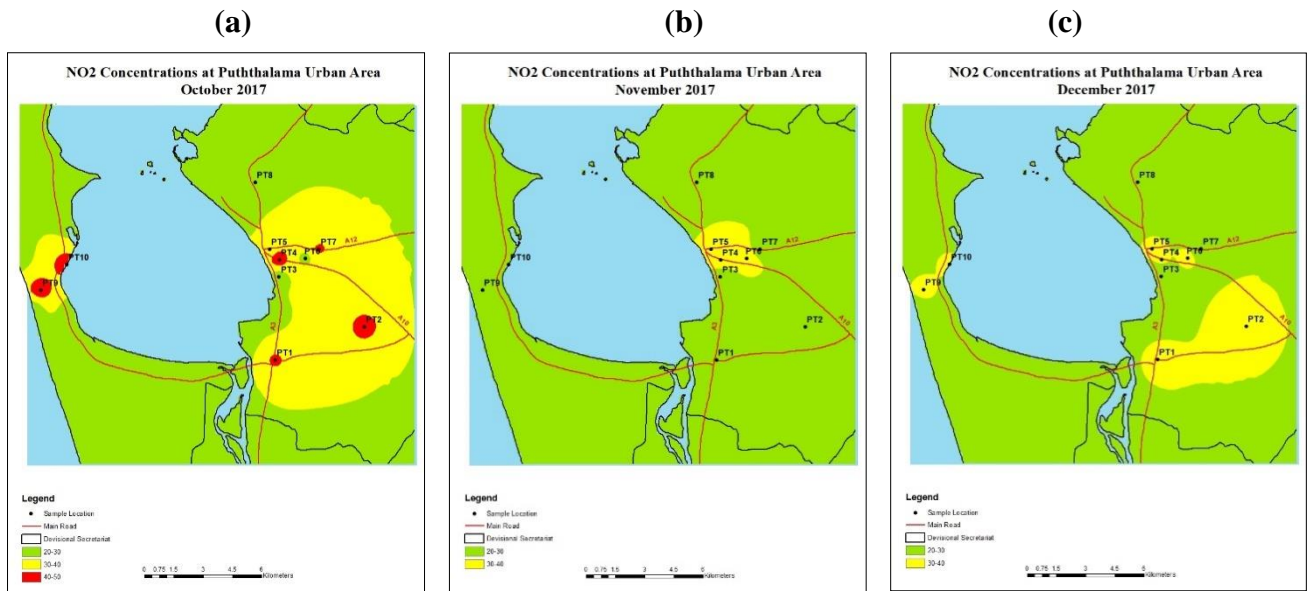


Figure 6.10.6: Average NO₂ Concentration within Puttalam Urban Area Oct-Dec, 2017.
 (a)Oct, (b)Nov and (c)Dec

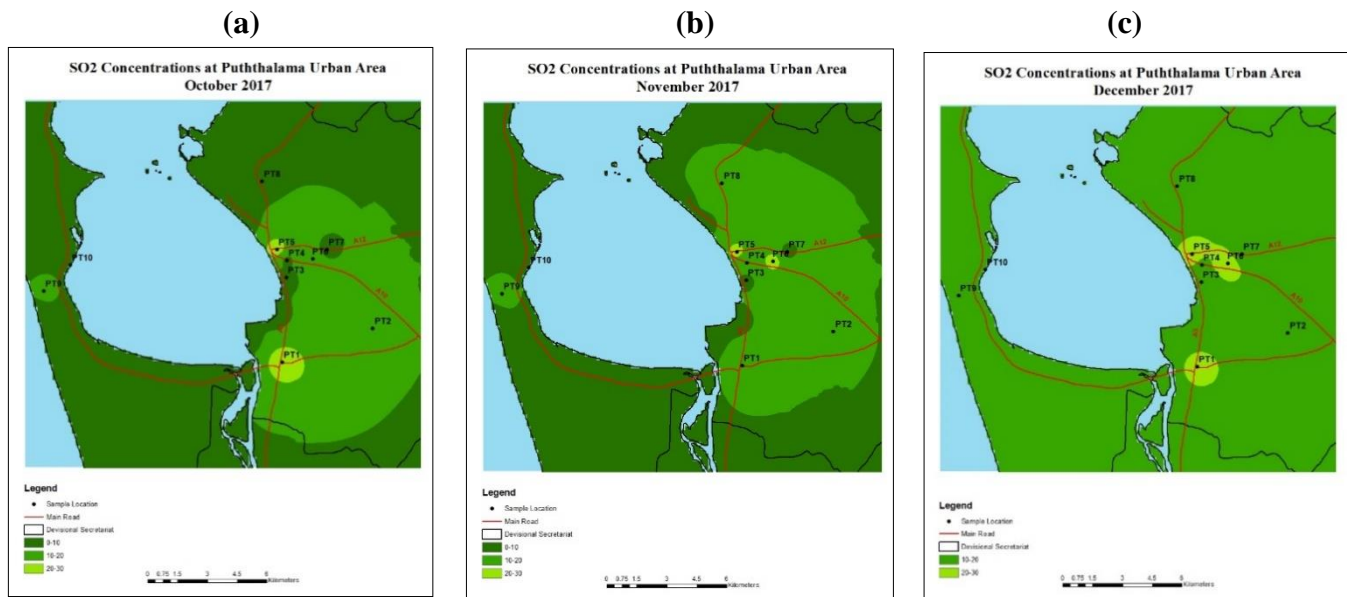


Figure 6.10.7: Average SO₂ Concentration within Puttalam Urban Area Oct-Dec, 2017.
 (a)Oct, (b)Nov and (c)Dec

6.11 COMPARISON OF AVERAGE EXPOSURE LEVEL IN EACH CITY - 2017

Annual average NO₂ concentration levels of each selected urban area in 2017 are represented in figure 6.11.1. According to the results, maximum average NO₂ level in the year 2017 was recorded in Kurunegala urban area. Kandy urban area has next highest average NO₂ level among other urban areas. Out of 10 urban areas Anuradhapura urban areas shows lowest average pollution with respect NO₂. According to the results on average the Kurunegala Urban area has reach to the WHO Annual Guideline Level NO₂. Colombo and Kandy urban areas were also marginal to the WHO Annual Guideline Level NO₂. However, at high traffic area in all these three-urban areas exceeded WHO Annual Guideline Level NO₂. This may be due to the high vehicular population and dense commercial activities in these urban areas.

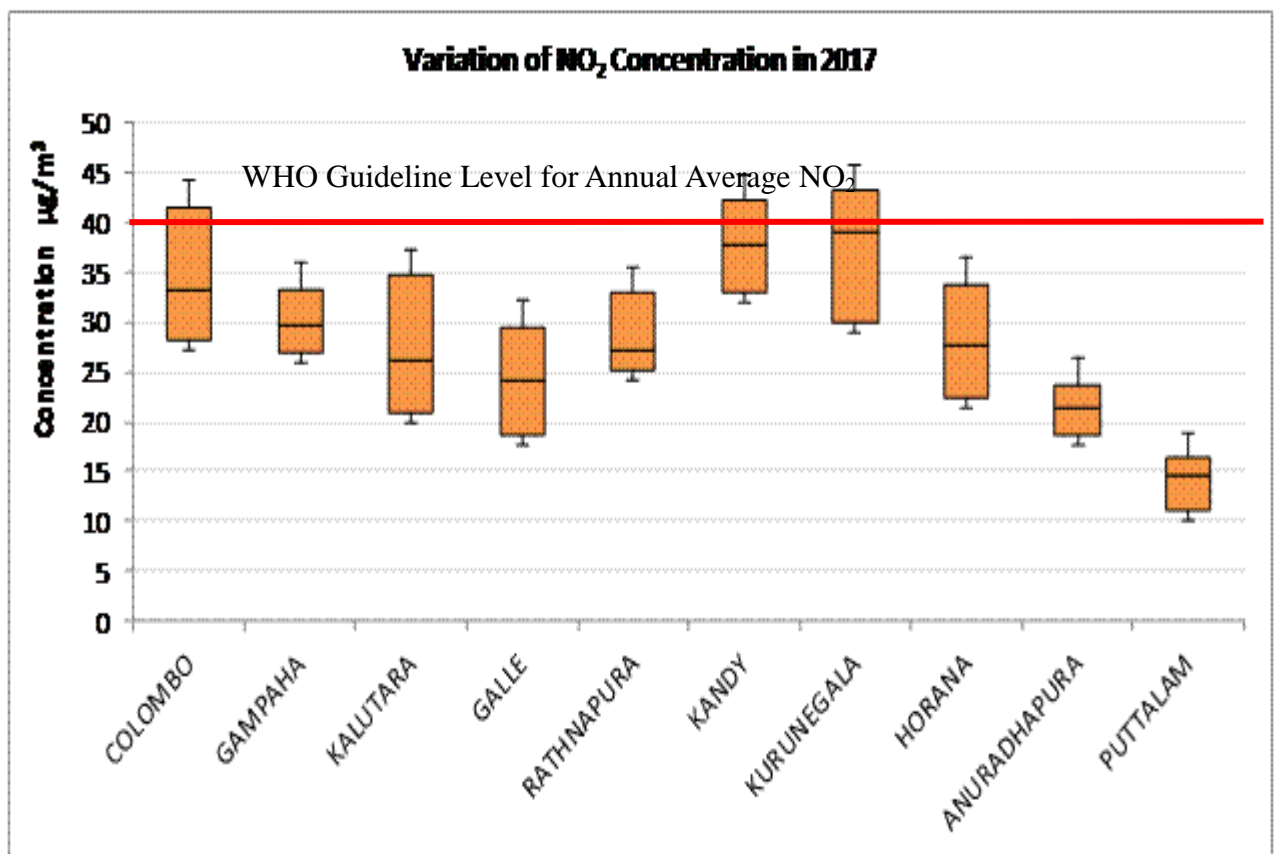


Figure 6.11.1: NO₂ Concentration in each urban area during year 2017

Annual average SO₂ concentration levels of each selected urban area in 2017 are represented in figure 6.11.2. According to the results, maximum SO₂ level in the year 2017 was recorded in Colombo urban area where as the minimum SO₂ level was recorded in the Kalutara urban area. The measuring data also indicate that the annual average SO₂ levels in Colombo Urban area have exceeded the WHO Interim Target 2 Level of SO₂. Colombo, Gampaha, Galle and Kurunegala were marginal to the Interim Target 2 Level of SO₂. This may be due to the high diesel driven vehicular population in these urban areas.

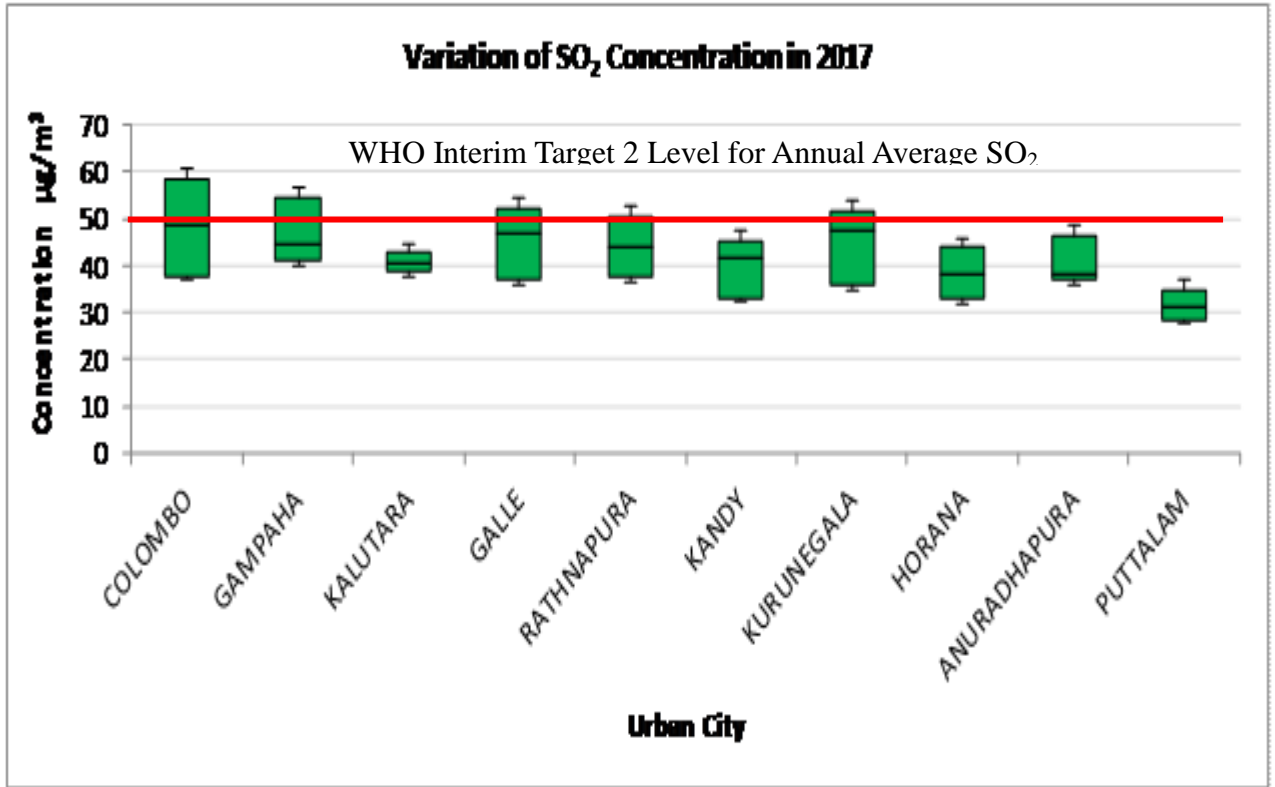


Figure 6.11.2: SO₂ Concentration in each urban area during year 2017

The maximum 24-hour average PM_{2.5} exposure levels within November and December months of 2017 are given in figure 6.11.3. Accordingly, the highest PM_{2.5} levels are recorded in Horana urban area while Colombo, Rathnapura, Galle and Anuradhapura urban areas also have relatively high PM_{2.5} levels. Only the Horana urban area has exceeded the National Ambient Air Quality Standard Levels for PM_{2.5} stipulated Ministry of Environment, Sri Lanka.

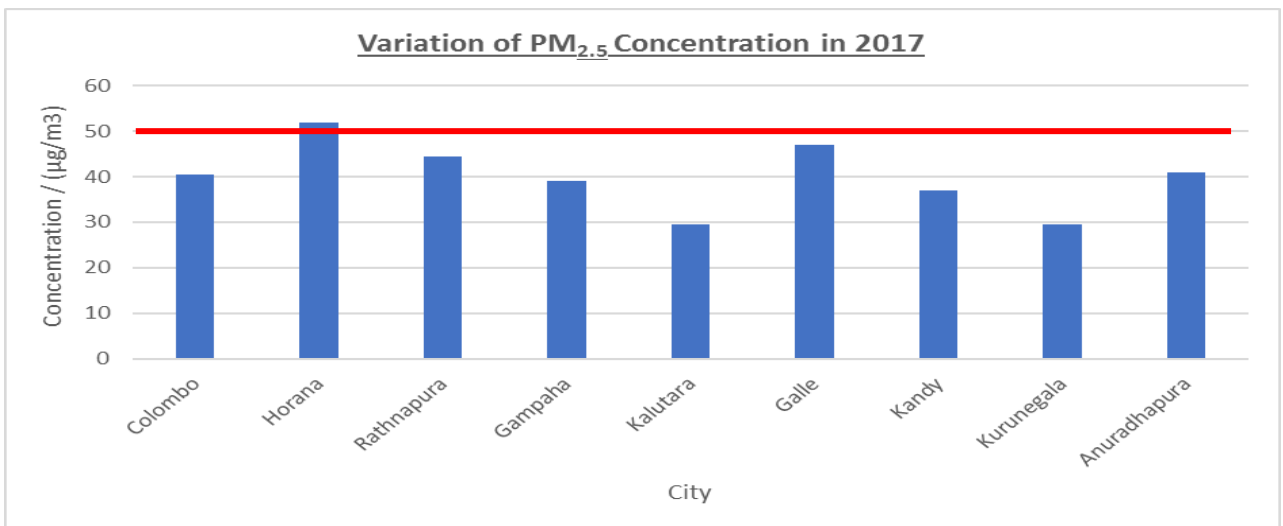


Figure 6.11.3: 24-hour maximum average PM_{2.5} Concentration in each urban area (during the period of November – December 2017)

In general, ambient air pollution levels of all above urban environments rise from a spectrum of different sources, which are broadly classified as vehicular, commercial & domestic and stationary emission sources. All above cities have high traffic congestion where large numbers of vehicles are operated within small area. Therefore, the main source of ambient air pollution in those urban areas is the vehicular emissions, which contribute more than 60% of total emissions. The majority of remaining 40% is contributed by commercial and domestic sources except in Colombo in which the contribution from industrial emission are also significant due to the availability of several industries, thermal power plants, harbour etc. around the city area.

In addition, source emissions, the other factors that affect the urban air pollution levels are meteorological, climatic, geographical and terrain factors. Although these factors do not contribute to emissions, they play a major role in air pollution dispersion. Continuous air quality monitoring data in each of these cities indicates that the pollutant levels are highly subjective to the seasonal climatic conditions and wind pattern of the area. Review of scientific literature on past studies in Sri Lanka analysing influence of climatic and geographical factors on air pollution are rather limited emphasising a gap in information vital for urban air quality management. Therefore, the measured pollutant levels are being analysing to study the influence of climatic and geographical faction on urban air pollution in major cities in Sri Lanka.

7. CONCLUSION, REMARKS AND RECOMMENDATION

Based on the results in 2017 of the monitoring program, in each and every urban area, high traffic congested areas shows relatively high pollutant levels and pollutant levels are decrease when goes away from the city centers and where available pollution sinks such as water bodies, green areas, elevated lands etc. This could reveal that vehicular emissions are the main pollutant source in urban air pollution. Also, past few year data in most of urban areas shows that action taken to reduced vehicular emission by improving fuel quality, VET and road surface improvements etc. could positively affect to manage urban air pollution in Sri Lanka.

However, the results indicate that the pollutant levels in most urban area is slight increase in 2016 as well as 2017 than that of 2015. This could be due to the increase of vehicular fleet. Urban development programs, weakness of traffic management, fuel quality and draw away or negative aspects of VET program would also significantly contribute this situation.

The measuring data also signified that the local as well as country climatic conditions and the geographical setting and natural topographical etc. have a strong influence on the ambient air pollutant levels in urban areas. Therefore, it indicates the need of study the local wind pattern and thermal variations alone with the air quality to find real situation and to implement better air quality management system.

The PM_{2.5} monitoring data clearly indicates different scenes compared to the gaseous pollutants such as SO₂ and NO₂. This could highlight the requirement of measurement of particulate matter (PM₁₀ / PM_{2.5}) continuously along with the other pollutants.

Following action are recommended to improve the monitoring network and program.

1. It is recommended to continue the monitoring programme to obtain more continuous data that would be needed to identify pollution trends, the impact of urbanization and other studies such as health impacts and environmental impacts etc.
2. Measured data should be validating by comparison with the automated air quality data. For this operation of one automated monitoring unit by the same organisation (NBRO) is recommended.
3. The same methodology should be applied to monitor other critical urban areas in Sri Lanka and an air pollution status database should be developed which could be used for decision makers to take management actions as well as in urban designing etc.
4. Monitoring of particulate matter (fine particulate PM_{2.5}) which is an important parameter in each urban area along with above parameters in continuous basis.
5. Disseminate of data in monthly basis to use for general public and other interested parties, researches etc.

8. MAKE USE OF DATA

Following three research papers and two abstracts were published during the period of 2015 to September 2016 by analysing data obtained through this project.

- Premasiri H.D.S., Kumarapeli H.D., Perera N.K.P.M.M., Navaratne R.P., (2016) **“Influence of Climatic and Geographical Conditions on Urban Air Quality of Major Cities in Sri Lanka”** 7th NBRO International Symposium on Risk Awareness and Future Challenges, 2016, Colombo.
- Premasiri H.D.S., Rathnayake, R.M.A.S, Navarathne, R.P., Mallawa, S.D., **“Interventions to Urban Air Pollution Management and Their Impacts on Ambient Air Quality in Sri Lanka”** National Symposium on “Innovation for Resilient Environment” 22th December 2015. (161-165).
- Premasiri H.D.S., Jayawardhane N.L, Jayarathne R.V.K, Rajapaksha K.M.S.K., **“Air pollution levels in major urban cities in the Western province in Sri Lanka”** National Symposium on “Innovation for Resilient Environment” 22th December 2015. (161-165).
- Premasiri H.D.S, Kumarapeli H.D, Dissanayake M, Kudagoda U.D., **“Variation of urban air quality with the Climatic and geographical condition of the urban cities in Sri Lanka”**, Abstract submitted and accepted, 17th IUAPPA World clean air Congress and 9th CAA Beret Air Quality Conference, 29th August to 2nd September 2016 at Busan, South Korea.
- Premasiri H.D.S, Kumarapeli H.D, Rathnayake R.M.A.S, Kudagoda U.D., **“Urban Air Pollution Management in Colombo, Sri Lanka by Fuel Quality Improvement and Physical Interventions”**, Abstract submitted and accepted, 17th IUAPPA World clean air Congress and 9th CAA Beret Air Quality Conference, 29th August to 2nd September 2016 at Busan, South Korea.

The data collected by this study has given to following students/researchers to use their research studies.

1. Dr. H.I.U.Caldera, Senior Lecturer – Department of Plant Sciences, University of Colombo., undergraduate assignment on *“Air pollution in Western Province – Causes and Solutions”* carried out by M.D.Piyumi Pramoda Premadasa.
2. R. Siriwardhane, National Coordinator / Consultant, MCC Sri Lanka Project, J. Charitha Ratwatte, Chief of Party MCC Project, Senior Adviser to the Prime Minister, Head of Policy Development Office., For evaluating the possibilities of funding *inter alia* to establish Advanced Traffic Management System (ATMS) in Colombo Metropolitan Area.
3. Ms. Madumi Perera Ginigaddarage, Deputy Registrar – Establishment and Student Affairs, IESL College of Engineering., *“Feasibility study of the construction of an additional bridge along with New Kelani Bridge”*.
4. Mr. A.K.M. Kulasekara, Lieutenant Commander (E), Sri Lanka Navy., *“Sri Lankan VET procedure and future challenges”*.
5. Mr. Manjula Ranagalage, Senior Lecturer, GIS & RS Specialist, Department of Environmental Management, Rajarata University of Sri Lanka., *“Analysis of Urban built and green volume for air pollution dynamics in Colombo Municipal Council (CMC) area – A remote sensing and GIS approach”*.
6. Ms. Elizabeth Moir MBE, Head of School., Mr. Sunila Ganhewa, Head of Science., Elizabeth Moir School., Student project on *“Air Quality of Sri Lanka”*.