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Ambient Air Pollution Status of Addis Ababa City; The Case of Selected Roadside

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Abstract: The Objective of the present study was to determine the concentration level, spatial and temporal variation of air pollutants (Carbon monoxide, Volatile organic carbon, Nitrogen dioxide, and Sulfur dioxide) from vehicular emission in ambient air of Addis Ababa city. Measurements were taken at sixty five roadsides sites for all the above selected pollutants. The overall (mean ± SD) of Addis Ababa city roadsides Carbon monoxide, Volatile organic carbon, Nitrogen dioxide, and Sulfur dioxide concentration level were 4.82 ± 3.60 ppm, 317.52 ± 221.52 $\mu g/m^3$, 0.12 ± 0.16 ppm and 0.23 ± 0.20 ppm respectively. Spatial variation were observed for all the pollutants; the highest Carbon Oxide, Volatile organic carbon, Nitrogen dioxide, and Sulfur dioxide concentration were recorded at SS16, SS34, SS39 and SS6 sites whereas the lowest at SS6, SS36, SS6 and SS19 respectively. At most of the sites high Carbon Oxide and volatile organic carbon concentrations were also observed at early in the morning and late afternoon. The temporal variation of Nitrogen dioxide and Sulfur dioxide were not significant at all sites under the study at $p<0.05$. The morning and the late afternoon peaks indicate that those pollutants were emitted where vehicular traffic was high. The roadside concentrations of all the pollutants under the study were high and needs continuous monitoring and exploring of mitigation techniques.

Keywords: Ambient Air Pollution, Roadsides, Air Pollutants, Addis Ababa, Volatile Organic Carbon

1. Introduction

Air pollution generated from vehicles has become a major cause of worldwide scientific and public concern. The estimate of the air pollution to global mortality based on World Health Organization (WHO) indicates even million deaths worldwide in the year 2012. However, 3.7 and 4.3 million are only due to Ambient Air Pollution (AAP) and Indoor Air Pollution (IAP) respectively [1, 2]. Population growth, limited emission control technology, substantial scale of urbanization, increased demand of transportation service, land use without planning, low quality fuels, age of vehicles, increased road congestion and lack of effective transport are among the factors contributing to enhanced vehicular urban air pollution [2-6]. The combined effects of urban air pollution factors create adverse air pollution by forming traffic air pollution. If it is not controlled or monitored effectively and timely, the deterioration will increase continually in cities of developing countries [6, 7].

Therefore, air pollution is one of the leading global public health threats. The following health problems like cardiovascular disease (stroke and ischemic heart disease), respiratory disease (asthma, lung cancer, acute respiratory infections in children and chronic obstructive pulmonary disease) are mainly linked with traffic air pollution exposure. The impact of air pollution is severe for sensitive population subgroups (children and elders), pedestrians who walk along busy roads, traffic police and street retailer who spend their time on and along congested roads, work or occupations like taxi and truck drivers [1, 8, 9].

Urban environment of both developed and developing countries like Ethiopia, vehicular emission pollution are a major source of emissions of ultrafine particles in ambient/outdoor air both at national and local level [3, 4, 5, 9, 10]. Ninety (90%) urban air pollution is rapidly growing and expanding in cities like Addis Ababa is due to motor vehicle emission.

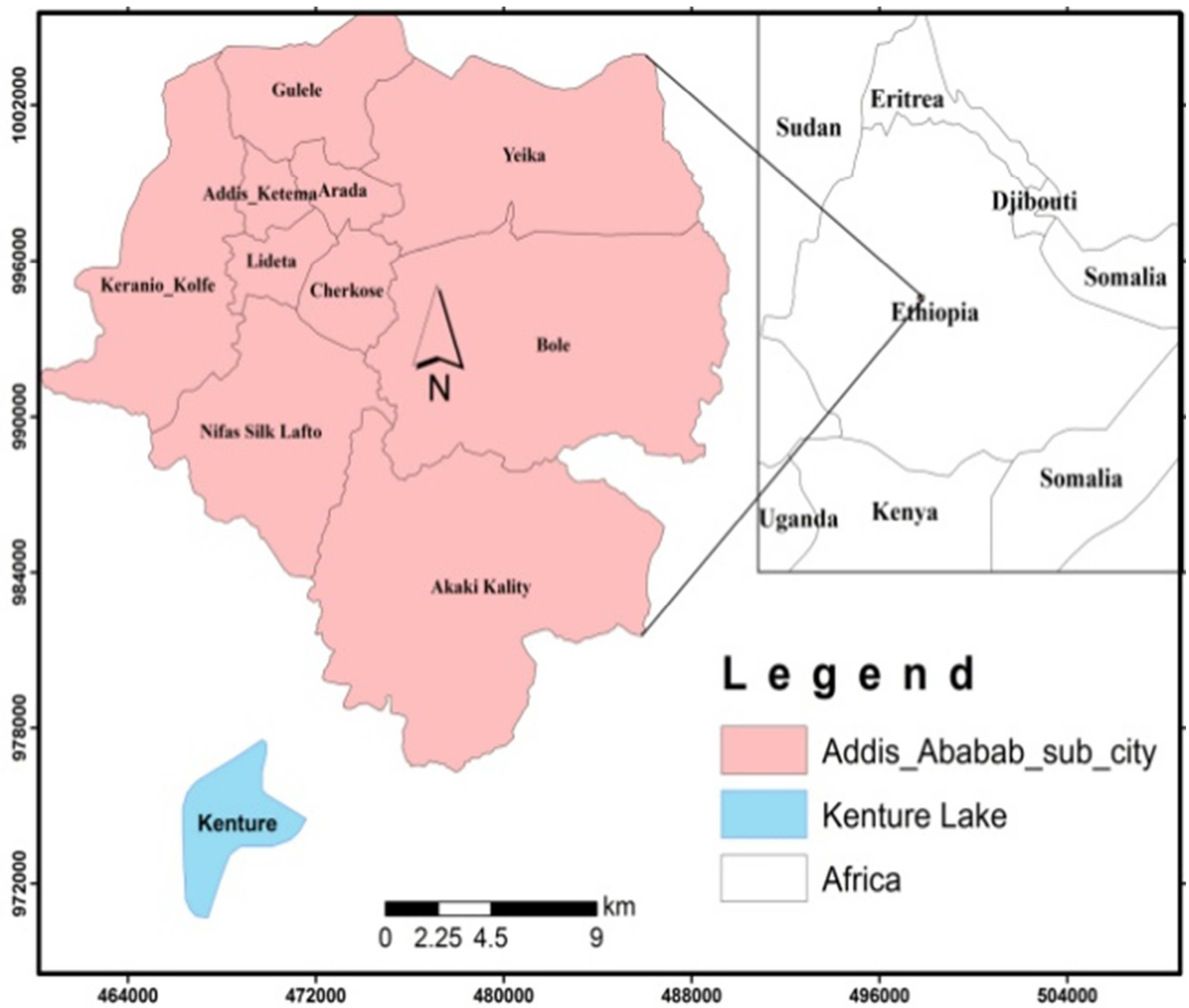
WHO identified range of pollutants such as particulate matter (PM), Carbon Monoxide (CO), Sulfur dioxide (SO_2), Nitrogen dioxide (NO_2) and Ozone (O_3) air pollutants that have a greatest human health importance and The United States (US) National Ambient Air Quality Standard (NAAQS) also include airborne lead (Pb) to the above mentioned air pollutants although more than three thousand substances are known to potentially contaminate urban ambient air [11, 12, 13].

Addis Ababa is among the cities currently undergoing rapid urbanization having considerable investment on buildings, road and transport sectors [14]. The number of vehicles is increasing annually without an expansion of roads in the city which is the main possible factor of the traffic congestion, therefore increasing in traffic pollution level of Addis Ababa. According to NMA, the air quality data of Addis Ababa is not available and data is provided based on the request [15]. Though this subject was extensively studied in cities of developed countries, to the best of our knowledge there are limited research conducted on vehicular pollution level and status in cities of developing countries like Addis Ababa. Therefore, there is a need to set information on the status and level/concentration of vehicular air pollution on roadside of Addis Ababa. Therefore, the present study was undertaken to fill the knowledge gap mentioned above aiming at exploring the concentration level of CO, VOC, SO_2, and NO_2, their spatial and temporal variation at selected sites of Addis Ababa main roadsides.

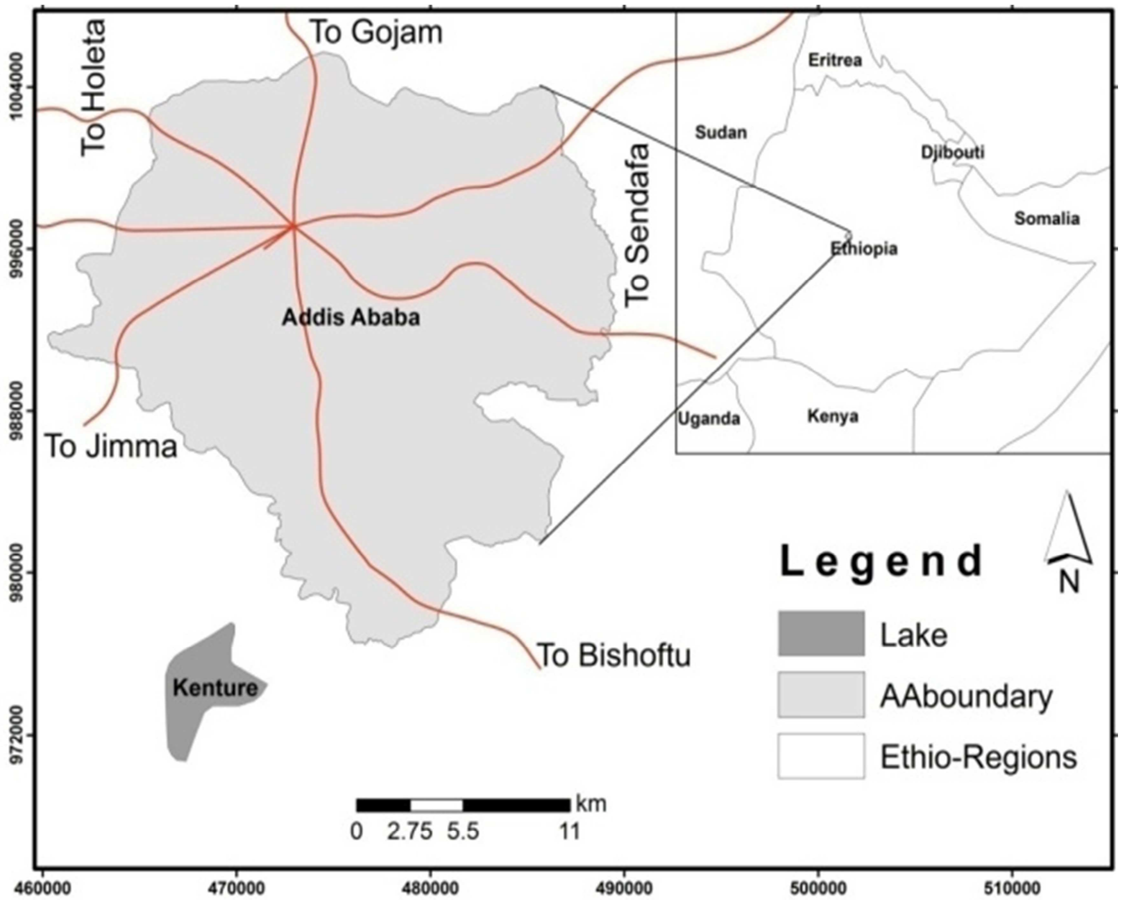
2. Materials and Methods

2.1. Study Area Description

Present study was conducted in Addis Ababa, a capital city of Ethiopia and working center of African Union. Geographically, Addis Ababa has a total land of over 54,000 hectares and of more than four million populations. Addis Ababa, a heart of the country having an altitude ranging between 2,200 - 2,800 meter above sea level with latitude of 9.0300 degree north and longitude 38.7400 degree east. It has 10 sub-cities and 116 woreda's. The sampling sites under the study touch the corridors of the 10 sub-cities corridor.



a)



b)

Figure 1. *Geographical location of the study Area map a) Sub-cities and b) Main roads of Addis Ababa rooting to different parts of the Country.*

2.2. Study Approach

Cross-sectional, environmental ambient air sampling approach was followed for the measuring the roadside pollutants gases mainly due vehicles (traffic congestion); CO, VOC, SO_2 and NO_2 at Addis Ababa city main roadsides from 03 June - 30 August, 2016.

2.3. Sampling Method

The sampling sites were selected by a walk through survey on the main roads of the City to assess the vehicle flow from 7:30 - 8:30 am (peak busy hours), 12:00-1:30 pm and 05:30-06:30 pm (peak busy hours) on working days of the week. Based on the survey sixty five (65) relatively busy roadside sites were selected. Then ambient air measurement was carried out at one hour interval from 7:00 am - 6:00 pm to quantify the concentration of the pollutants (CO, VOC, SO_2, and NO_2) at each selected sites. Real time measurement of VOC, SO_2, NO_2, and CO_2 were done using digital aeroqual instrument (portable gas sensor model 500 series, made in USA). GPS (GPS 60 Garmin, made in Taiwan) was used to take the x, y and z coordinates of the sampling/measuring points.

Table 1. *Sampling Site Code/ID.*

Sampling Sites	Sampling Site Code/ID	Sampling Sites	Sampling Site Code/ID
Arat kilo Commercial bank Selassie branch	SS1	Kality Meseltegn adebabey	SS34
Piassa Hermon Hotel	SS2	Kality KAFDEM	SS35
Megenegna square	SS3	Legehar, around Medin insurance	SS36
Saltemiret Mariam Square	SS4	Ethio-post office main branch	SS37
Summit Yetebaberut fuel station	SS5	Taklehaimanot bruk photo	SS38
Summit Condominium last	SS6	Merkato big bus Station	SS39
Arat kilo Minilik School	SS7	Merkato Near Telle, small (Taxi and Bus Station)	SS40
Sidist kilo Dibab Café and Restaurant	SS8	Mesalemia (Yekatit 23 Secondary School)	SS41
Shiromeda Condominium	SS9	Kolfe Taxi Station	SS42
Red Terror, Flamingo	SS10	Sebategna (Cross Road)	SS43
Shoa super market	SS11	Ayer Tena Taxi Station	SS44
Bole millennium taxi station	SS12	Kara Kore (Absiniya bank)	SS45

Sampling Sites	Sampling Site Code/ID	Sampling Sites	Sampling Site Code/ID
KazanchisHanan Bakery	SS13	Kera Mezoria Adebabay (Near Kera org. Station)	SS46
Bole Medehanialem	SS14	SarbetAdebabay Pushkin (Commercial Bank of Ethiopia)	SS47
Bole Brass, Dashin bank	SS15	Karl Square (Arcobalrnd)	SS48
Shola Traffic Light	SS16	Ethiopia medihanit Fabrica Square	SS49
Kotebe 02	SS17	German Square (Commercial bank)	SS50
Karalo	SS18	Jemo Cross Road, Taxi Station, NOC	SS51
Tafo Square	SS19	Lemberet square Near public Toilet	SS52
Stadium Admass College	SS20	Lemberet Bus Station	SS53
Agona Gotera (Color Furniture)	SS21	Torhailoch taxi station	SS54
Saris Dawi Building	SS22	Lideta Mariam	SS55
Ras Desta Hospital	SS23	Abnet square, tinsaebirahan pharmacy	SS56
Paster Square	SS24	Autobistera near children cloths	SS57
Asco Square/Winget	SS25	Addis ketama, Awash bank	SS58
Stadium Infront of Lalibala Hotel	SS26	Addis ketama school at center	SS59
Hayahulet (Industrial building)	SS27	Yirga Haile	SS60
Gerjimebrat hail vision school	SS28	Burayu city Admn. Bereket school	SS61
Semen Hotel, Nafyad Café	SS29	Burayu Keta (infront of Sifan pharmacy)	SS62
Addisu Gebaya, Commercial Bank	SS30	Asco Taxi Station	SS63
Tsion Hotel	SS31	Goro Alemayo Ketema building	SS64
Mexico taxi station	SS32	Goro square (Riyan car spare part shop)	SS65
Kality Bus station	SS33		

2.4. Data Collection and Analysis

From all sampling sites all the pollutants i.e parameters under the study were collected in one hour interval starting from 7:00 am in the morning to 6:00 pm in the evening to maximize presence of high vehicular activities on road during the study period. All measurements were made at a range of 0.5-2.0 meter distance from the main road and 1 m height. The collected data entered to Microsoft excel database for further analysis and interpretation. The graphs were drawn using Origin Pro 8 software. For summarizing all the pollutant concentrations descriptive statistics was used. Mean pollutant concentrations were compared between selected sampling sites by t-tests and a p-value of 0.05 was considered for the statistical significance.

3. Result and Discussion

Measurements were taken for parameters under study at sixty five (65) sampling sites during the study period 03 June - 30 August, 2016 which falls in the wet season. The average (mean ± SD) concentrations of all parameters under study are presented in Table 1. The daily variation patterns of the pollutants (CO, VOC, SO_2 and NO_2) at (SS42) Merkato; busy business center and country cross Bus Station site of particular day was also indicated in Figure 2.

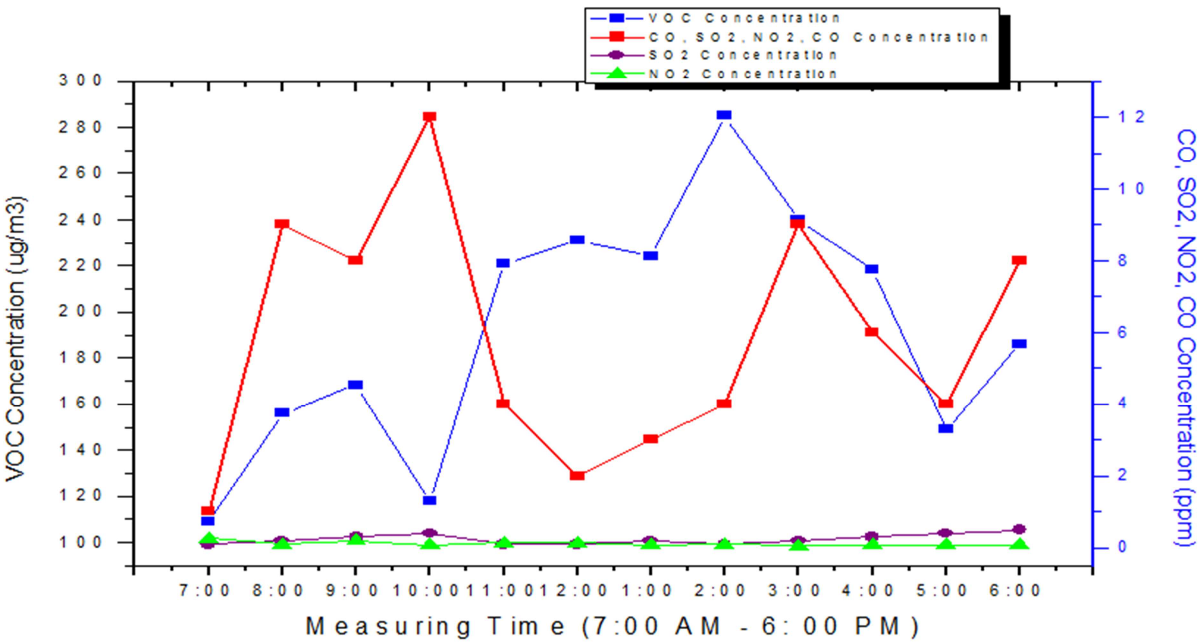


Figure 2. *The daily variation patterns of the pollutants (VOC, SO_2, NO_2 and CO) at Merkato big Bus Station (SS39) of particular day.*

3.1. Roadsides CO Concentration

The arithmetic mean and standard deviation (mean ± SD) concentrations of CO at all the sampling site of roadside presented in the Table 2. The overall mean ± SD CO concentration during the sampling period was 4.82 ± 3.60 ppm. The overall trends of CO concentration at all sites during the study period were similar. All the sites (SS16, SS40, SS3, SS41, SS33, SS39, SS38, SS26 and SS35) with high CO concentration (mean ± SD) are sites located in the high congestion traffic zones of Addis Ababa. The finding of this study is higher than the value reported (2.8 and 2.1 ppm in dry and wet seasons respectively) by [3] which was studied in the same city (Addis Ababa) and lower than the one reported by [16]. The higher concentration of CO recorded in this research work was may be due to the indirectly increased vehicle congestion in the city. Figure 3 below indicate the trends of CO concentration at site with highest and lowest roadside CO concentration.

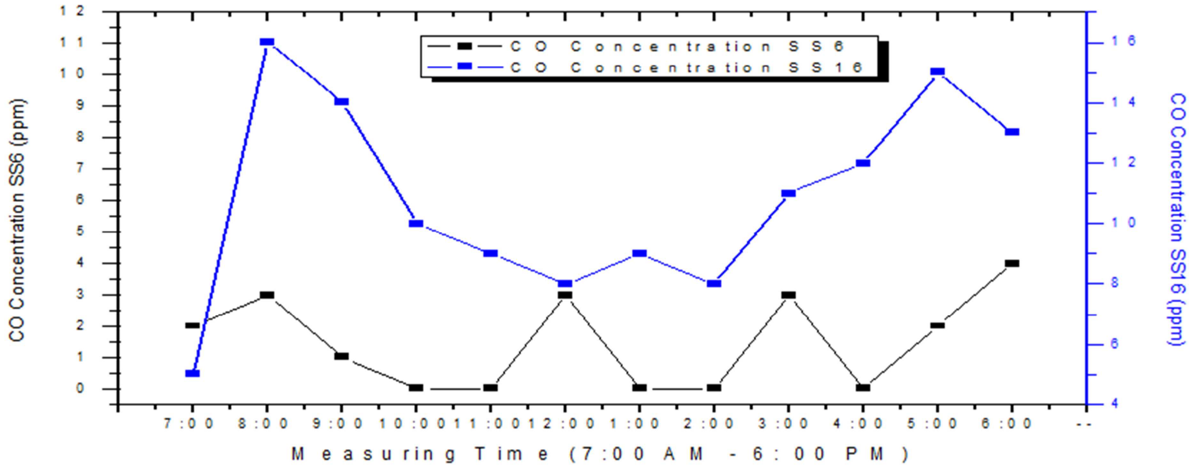


Figure 3. *Typical daily CO concentration trends at sites with highest and lowest concentration.*

The results obtained from the present study revealed that there is a spatial (site to site) variation ($p<0.05$) of CO concentration even though the overall concentration trend of CO concentration at all sites was analogous [Figure 2, 3& 4]. The highest and lowest CO concentration was recorded at Merkato, which is very busiest business center and country cross bus Station (10.83 ± 3.3.27 ppm) and Summit Condominium square; south-eastern peripheral of Addis Ababa city (1.20 ± 1.40ppm) sampling sites respectively. It was indicated in recent study [1] that there is a spatial variation of CO concentration in Addis Ababa City. Lowest (0.2 ppm) and highest (23.2 ppm) CO concentration in Addis Ababa city at Entoto St. Mary Church and Teklehaimanot square respectively were reported [17].

Table 2. *Geographical Location of Sampling site and Average (mean ± SD) n= 12 Concentration of all the parameters under study at all study sites.*

Sampling Site Code/ID	UTM (X)	UTM (Y)	Elevation	VOC (µg/m^3)	CO (ppm)	SO_2 (ppm)	NO_2 (ppm)
SS1	474186	998409	2431	560.17± 137.08	5.29± 5.50	0.28± 0.09	0.08± 0.04
SS2	472997	998487	2456	598.25±78.68	7.83±5.62	0.23±0.08	0.14±0.20
SS3	478054	997288	2391	697.33±293.16	9.92±5.23	0.29±0.11	0.08±0.14
SS4	480720	996972	2369	809.92±233.36	3.75±3.89	0.24±0.10	0.08±0.01
SS5	483798	997276	2390	574.02±120.31	3.58±2.81	0.24±0.11	0.07±0.02
SS6	484043	992991	2320	629.91±72.36	1.20±1.40	0.21±0.01	0.05±0.02
SS7	473941	998823	2442	377.28±159.88	7.92±2.97	0.23±0.11	0.12±0.14
SS8	473807	1000042	2505	221.15±43.88	5.58±4.54	0.18±0.10	0.06±0.03
SS9	473819	1001585	2569	207.42±30.38	3.42±2.91	0.18±0.09	0.07±0.01
SS10	474196	995768	2355	255.73±145.07	5.08±2.94	0.24±0.13	0.11±0.04
SS11	474949	994487	2338	196.97±51.97	3.50±1.98	0.23±0.13	0.10±0.03
SS12	476908	993584	2332	208.98±42.35	3.57±1.59	0.28±0.12	0.22±0.31
SS13	474867	996734	2369	363.63±160.37	4.17±2.21	0.28±0.14	0.11±0.10
SS14	476457	994679	2361	305.08±132.08	6.25±5.93	0.26±0.15	0.08±0.03
SS15	477253	993821	2332	264.58±145.10	5.58±5.09	0.20±0.25	0.32±0.31
SS16	477536	997525	2402	375.41±84.46	10.83±3.27	0.37±0.24	0.18±0.17
SS17	484110	998745	2451	270.11±75.36	2.83±1.53	0.23±0.23	0.07±0.02
SS18	472301	993299	2280	277.84±78.85	1.58±0.67	0.26±0.10	0.07±0.02
SS19	486713	1001113	2448	206.83±34.21	1.67±0.78	0.01±0.03	0.02±0.02
SS20	473555	996064	2334	247.89±79.74	7.92±6.26	0.29±0.16	0.14±0.83
SS21	473609	993529	2306	185.94±22.35	4.58±1.78	0.30±0.13	0.12±0.08

Sampling Site Code/ID	UTM (X)	UTM (Y)	Elevation	VOC (μg/m^3)	CO (ppm)	SO_2 (ppm)	NO_2 (ppm)
SS22	474039	990518	2261	210.58±43.30	4.83±1.8	0.33±0.16	0.09±0.03
SS23	471838	999838	2500	391.09±102.55	3.08±2.11	0.18±0.12	0.09±0.03
SS24	470585	1000002	2521	311.20±70.14	3.25±2.22	0.12±0.06	0.07±0.02
SS25	468515	1001055	2549	247.33±46.71	2.17±1.19	0.36±0.83	0.07±0.01
SS26	473193	996168	2333	402.76±89.33	8.25±3.79	0.20±0.18	0.14±0.07
SS27	476149	996476	2362	323.05±84.74	6.83±2.08	0.37±0.17	0.13±0.86
SS28	479187	995344	2356	275.42±101.64	2.67±1.56	0.27±0.11	0.11±0.18
SS29	472357	979826	2504	159.59±110.61	5.17±2.33	0.13±0.10	0.11±0.11
SS30	471014	1001606	2602	95.01±38.66	4.08±1.78	0.12±0.06	0.10±0.03
SS31	473220	996175	2346	95.89±27.93	4.25±2.01	0.10±0.04	0.08±0.01
SS32	472104	995943	2358	332.24±74.41	6.75±2.14	0.71±0.20	0.44±0.37
SS33	474779	983302	2162	342.49±66.14	5.67±2.81	0.08±0.05	0.33±0.33
SS34	474268	987576	2184	752.88±121.36	9.75±2.60	0.74±0.31	0.67±0.30
SS35	475113	983168	2152	330.63±73.79	7.33±3.11	0.60±0.23	0.56±0.30
SS36	472845	996203	2351	157.73±39.79	8.00±4.31	0.33±0.21	0.10±0.08
SS37	472772	997208	2366	192.26±53.26	5.83±3.35	0.24±0.14	0.12±0.06
SS38	471872	997973	2428	192.15±53.26	6.42±3.60	0.24±3.60	0.12±0.06
SS39	470515	998677	2469	308.75±90.50	8.75±2.99	0.25±0.09	0.64±0.01
SS40	470575	998672	2465	256.25±50.08	8.83±3.16	0.20±0.14	0.07±0.01
SS41	469959	998589	2348	295.08±57.87	10.50±3.06	0.19±0.12	0.12±0.17
SS42	468373	999542	2402	292.48±50.32	9.83±2.37	0.17±0.12	0.07±0.02
SS43	470632	998067	2452	200.17±50.01	4.17±2.55	0.18±0.13	0.09±0.06
SS44	466676	993044	2321	207.09±57.40	4.33±2.77	0.16±0.13	0.09±0.06
SS45	465051	992182	2340	295.94±54.73	2.67±1.61	0.16±0.13	0.06±0.02
SS46	472301	993299	2280	225.19±45.51	4.25±1.66	0.23±0.11	0.06±0.02
SS47	471299	994304	2320	231.45±82.97	3.58±1.83	0.23±0.18	0.07±0.02
SS48	470372	994596	2324	250.83±49.80	2.42±1.56	0.17±0.12	0.11±0.15
SS49	469564	993626	2315	252.53±77.92	3.40±2.64	0.19±0.14	0.06±0.01
SS50	470616	990975	2224	227.36±83.37	3.08±1.62	0.23±0.10	0.06±0.01
SS51	468230	990470	2241	216.45±84.97	3.92±2.19	0.12±0.11	0.07±0.02
SS52	480163	997515	2395	216.08±81.03	3.92±2.19	0.12±0.11	0.07±0.02
SS53	480281	997633	2404	303.42±49.77	2.42±1.00	0.16±0.11	0.06±0.01
SS54	469389	996070	2355	218.79±69.75	3.75±2.05	0.18±0.11	0.09±0.03
SS55	471047	996121	2363	220.50±87.87	3.67±2.10	0.20±0.14	0.09±0.02
SS56	470680	997173	2400	200.17±50.01	3.58±1.93	0.20±0.14	0.09±0.06
SS57	471145	998288	2454	334.05±75.67	7.75±3.14	0.18±0.17	0.08±0.02
SS58	470855	998598	2464	303.42±49.71	4.83±2.72	0.17±0.12	0.09±0.02
SS59	471352	998587	2453	406.75±74.82	4.75±2.63	0.26±0.14	0.08±0.03
SS60	471369	998572	2410	388.50±185.04	3.50±2.32	0.21±0.16	0.06±0.01
SS61	463174	1002325	2611	196.67±59.54	4.17±2.37	0.18±0.10	0.07± 0.02
SS62	464939	10002640	2603	182.58±44.06	2.75±1.82	0.18±0.09	0.07±0.01
SS63	466389	1002171	2563	195.00±59.07	3.25±1.76	0.18±0.09	0.07±0.02
SS64	480280	994818	2335	212.50±72.51	2.92±1.68	0.18±0.11	0.07±0.01
SS65	481250	993917	2320	249.65±93.50	3.92±2.02	0.16±0.12	0.06±0.01

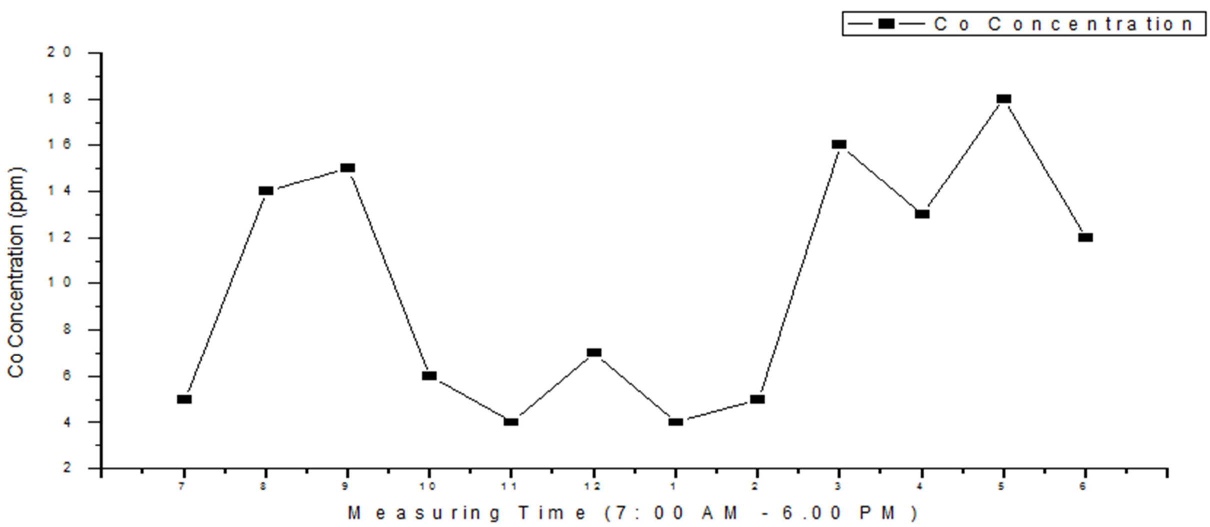


Figure 4. *Typical day CO concentration trends at SS3 (Megenagna train ticket sell).*

The result of this study shows there was temporal variation of CO concentration at all sites under study and the variation was significant ($p<0.05$). Figure 4 below shows the patterns of CO concentration on particular measuring day at Megenagna; thickly crowded road part in Addis Ababa (SS3). There was high CO concentration during the rush hours in the morning (8:00 am- 9:00 am) and early afternoon (04:00-06:00 pm) and lower at 10:00 am -03:00 pm [18, 19, Figure 4). The daily (hourly) maximum CO concentration recorded during the study period was 18 ppm for SS14 and SS3 sampling sites on rushing hours of the day on 9:00 am and 5:00 pm respectively [Figure 4]. The high CO concentration in the early morning and late afternoon was due to the congested vehicular staging and stagnation of temperature in the city [3, 16]. The low concentration of CO at mid-day was because of the photochemical reaction taking place by sunlight in the presence of hydrocarbons as CO is converted to carbon dioxide [3].

3.2. VOC Concentration

The overall VOC concentration mean ± SD during the sampling period was 317.52 ± 221.52 μg/m^3. The arithmetic mean and standard deviation concentrations of VOC at all the sampling site of roadside presented in the Table 2, SS1, SS2, SS3, SS4, SS5, SS6, SS26, SS34 and SS59 are sites with VOC concentration of above the overall mean ± SD [Table 2]. Scholar [20] also reported lower total VOC concentrations of 129 μg/m^3 on roadsides of Philippines. The VOC concentration found in this study was higher than the value reported for Ghent city (54 μg/m^3), similar with that of Addis Ababa (318 μg/m^3) and lower than that reported for Hanoi city (507 μg/m^3) [15].

The finding of the present study is indicating that, there is a spatial variation of VOC concentration over the selected study sites. The highest and lowest VOC concentration during the sampling period was 752.88 ± 121.36 μg/m^3 and 157.73 ± 39.79 μg/m^3 at SS34 and SS36 sampling sites respectively. More than ten (10) sites under study have VOC concentration above mean ± SD and most of the sampling sites have VOC Concentration below mean ± SD [Table 2]. The study by [22] also reported the spatial variation of VOC in urban areas of Dhaka city of Bangladesh.

Temporal variation of VOC concentration during the study period at the entire study site was not significant as such even though the overall concentration trend of VOC concentration at all sites was similar. The pattern of particular measuring day, Megenagna site (SS3) shown in Figure 2. There was high VOC concentration at most sampling sites during the rush hours in the morning (8:00- 9:00 am) and early afternoon (04:00 pm) and lower 10:00 -03:00 pm [Figure 2, 5]. Temporal variation of VOC; low in mid night and high at early in the morning continuously increasing up to 10:00 am was reported in [23].

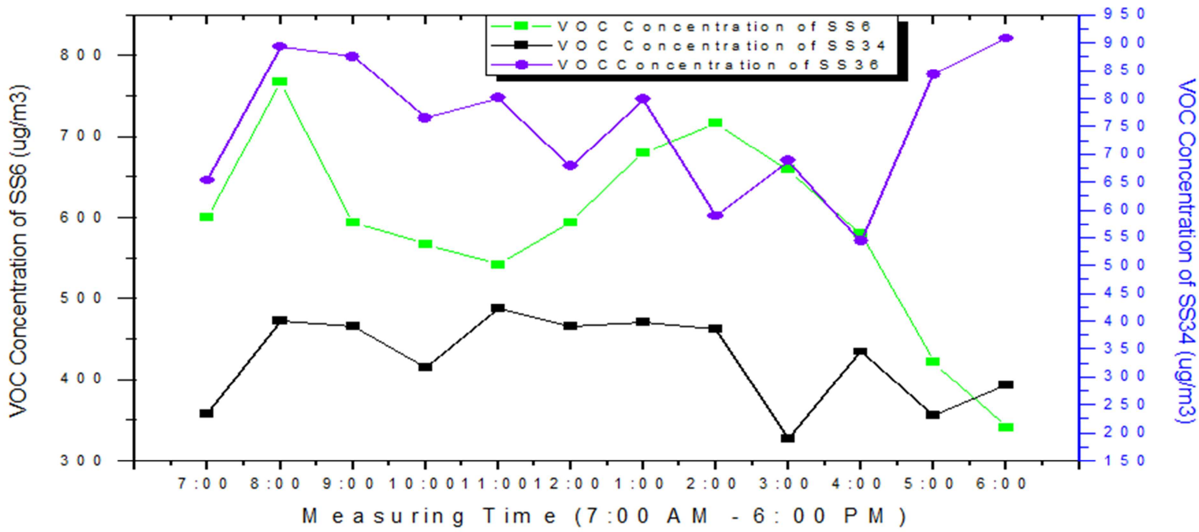


***Figure 5.** The daily VOC concentration patterns on particular day of sites SS6, SS34 & SS36 sites.*

3.3. NO_2 Concentration

The overall mean ± SD NO_2 concentration during the sampling period was 0.12 ± 0.16 ppm [Table 2]. The highest and lowest NO_2 concentrations were recorded at site SS34 (0.67 ± .30 ppm) and SS6 (0.05 ± 0.02 ppm). The study conducted in two Ugandan cities also reported 0.025 ppm NO_2 concentration [1]. Furthermore, the study by [17] conducted in Addis Ababa city, reported that the NO_2 concentration at the sites under their study was not detectable.

The arithmetic mean and standard deviation (mean ± SD) concentrations of NO_2 at all the sampling site of roadside presented in the Table1. The result of this study shows that there is a spatial variation of NO_2 concentration. The overall NO_2 concentration trend at all sampling sites were similar [Figure 6]. Sites such as; SS2, SS26, SS34, SS35 and SS39 have high concentration of NO_2 then mean ± SD and are located in the high congestion of traffic zones in Addis

Ababa [Table 2]. The highest and lowest NO_2 concentrations were recorded at sites SS39 and SS6 respectively [Table 2]. Figure 6 below shows the trends of NO_2 concentration of SS6 and SS39 during particular day during the study period, which shows directly proportional to traffic and congesting of traffic.

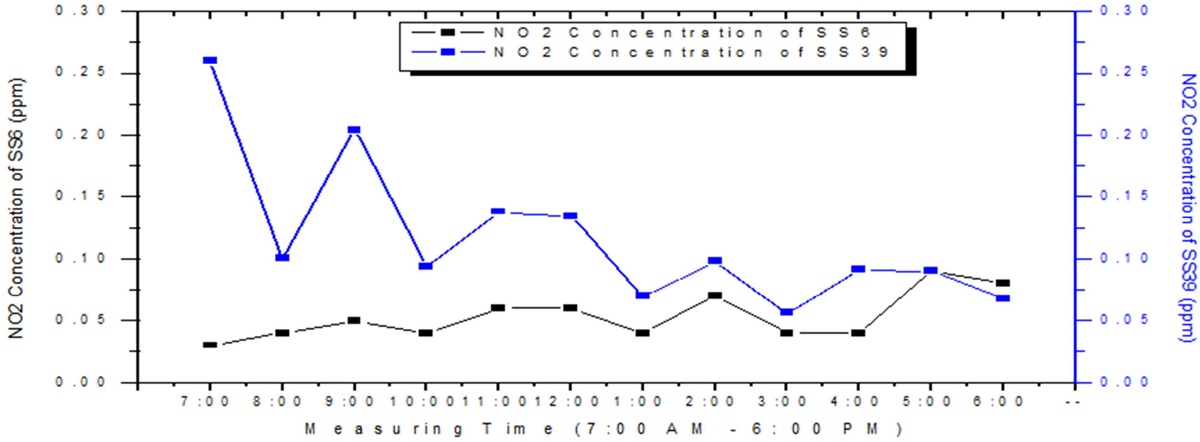


Figure 6. *The daily NO_2 concentration Trends in particular day of sites SS6 (Summit Condominium last gate) & SS39 (Merkato big bus Station).*

Temporal variation of NO_2 concentration at all sites under study was observed. The trend of NO_2 concentration at all sites was similar [Figure 6]. There was high NO_2 concentration during the rush hours in the morning (8:00 - 9:00 am) and early afternoon (04:00-06:00 pm) and lower 10:00 am -03:00 pm [Figure 6].

3.4. SO_2 Concentration

The arithmetic mean and standard deviation (mean ± SD) concentrations of SO_2 at all the sampling site of roadside presented in the Table 1. The overall arithmetic mean and standard deviation (mean ± SD) concentration of SO_2 during the study period was 0.23 ± 0.20 ppm perhaps the climatic condition of Addis Ababa may facilitate the adsorption of the gaseous pollutants such as SO_2 on particulate matter [1]. As reported by [17] the SO_2 concentration at the sites under their study in Addis Ababa city was not detectable.

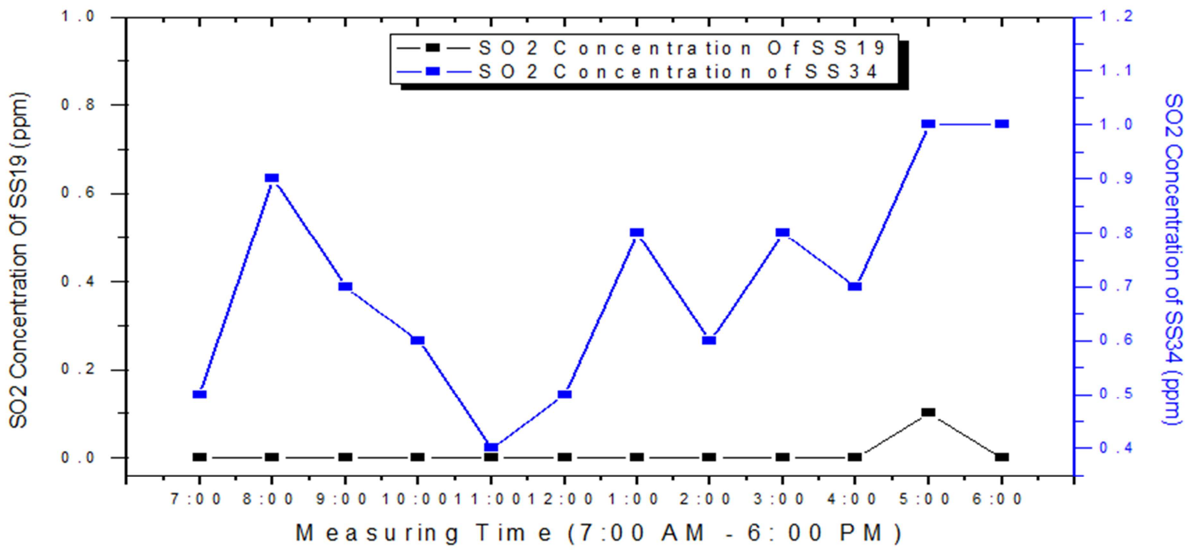


Figure 7. *Trends of SO_2 at sites with highest and lowest concentration.*

The highest and lowest SO_2 concentrations were recorded at site SS33 (0.74 ± 0.31 ppm) and SS19 (0.01 ± 0.03 ppm) respectively [Table 2]. The roadside SO_2 concentration of the site with highest and lowest is indicated in figure 7. The results shows that no remarkable spatial and temporal variation of SO_2 concentration (not significant at $p<0.05$), but the overall concentration trends of SO_2 concentration at all sites were similar [Figure7].

4. Conclusion

The current study was carried out to assess the concentration of four ambient air pollutants in Addis Ababa City focusing on the road side to understand their distribution and provide the overview of the pollutants concentration. The roadsides concentration (mean ± SD) of CO, VOC, NO_2 and SO_2 found were 4.52 ± 3.60, 317.52 ± 221.52, 0.12 ± 0.16

and 0.23 ± 0.20 respectively. The result of this study for all air pollutants under study were higher than the previous studies result reported by different researchers. Therefore, air pollution in the city needs to be monitored continuously and exploring mitigation mechanisms should be put in place by concerning government bodies or non-government organization.

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