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# Level of Gaseous Pollutants, Particulate Matters and Lead: The Case of Roof Top of Dhaka Buildings

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*The aim of the study was to find out the level of pollutants at the roof of a seven-storied building and the values were compared with ground level pollutants. The gaseous pollutants ($SO_2$, $NO_2$ and $O_3$), particulate matter (2.5 and 10 micron) and lead in SPM were determined by UV-visible, AAS spectrophotometer and gravimetric methods respectively. For all the criteria pollutants, the concentration of pollutant was lower than ground level at Kallyanpur, Dhaka and also lowers than Bangladesh acceptable limit (DOE). High rise buildings are considered to be greener with lesser amounts of pollutant compared to ground level.*

**Keywords:** ambient, air pollution, roof top, gaseous pollutants, particulate matters, Dhaka city

**Field of Research**: Air Pollution

## 1. Introduction

According to the guideline of Environmental, Health, and Safety Guidelines (2007), the ambient air means the space within 3.0±0.5-meter height from the ground level. The values of air quality parameters at higher elevation will have different values compared to ground level (Zhongchao Tan 2014). The smaller and lighter a particle is, the longer it will stay in the air. Larger particles (greater than 10 micrometers in diameter) tend to settle to the ground by gravity in a matter of hours whereas smaller particles (less than 1 micrometer) can stay in the atmosphere for weeks and are mostly removed by precipitation. The above statement may not be valid for the gaseous pollutants. However, gaseous pollutants have tendency to stay near the ground due to the ambient atmospheric pressure (Wallace et al, 2006). The roof has an advantage of not receiving higher amounts of air pollutants than the ground level (Chatterjee, M, 2009). High rise buildings can be considered not only for providing accommodation to a large number of firms and families but also for saving precious land which can be utilized for agricultural and industrial purposes and for lowering the cost of facilities like water supply, transport, electrification, drainage etc. High rise buildings are also environmentally safer compared to the low-rise buildings.

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The ambient air pollutants partly affect the indoor air quality, too. The pollutants enter into living room through window (Solis, HL, 2011). As a result, people suffer from various diseases like Asthma, bronchitis, heart disease, allergic rhinitis etc. (Stankovic, *et al,* 2011). Increased concentrations of $PM_{2\cdot5}$ and traffic-related air pollution within metropolitan areas commonly encountered worldwide are associated with progression in coronary calcification, consistent with acceleration of atherosclerosis (Kaufman, *et al,* 2016). Dhaka is the capital city of Bangladesh and has come to be known as one of the mega cities of the world. The rapid growth of population in Dhaka city is due to high rate of migration, territorial expansion and natural growth. The traditional urban housing in Dhaka has undergone many radical transformations over the past few decades. Thus, increasing housing demands are being fulfilled essentially by multi-storied apartments. The dwelling culture has also been changed gradually over a short span of time. The ministry of Housing under Government of Bangladesh has given permission for high rise buildings in Dhaka metropolitan area. The building height ranges from 18 to 24 meters from ground level (Kamruzzaman, *et al, 2006)*.

Many people from different parts of the country come to Dhaka in search of work, education purpose, business purpose and many more reasons. The population concentration in different areas also influence the environment and the over population is harmful for the environment. It creates pollution of the air, water and environment. The environment is getting polluted, the people are getting fewer facilities, there are transportation problems and many more problems are happening because of population concentration of Dhaka. As per World Bank report 2007 to be published, Dhaka will have a population of 197 million by 2015. The number of such vehicles rare to 741,547 by 2012, a growth of 145%. During the period, the number of private cars increased by 121%. Traffic congestion in the capital and smoke from brick kilns are the main reasons for air pollution in Dhaka city, according to the World Bank and the Bangladesh government. According to the Department of Environment official's faulty vehicles, smoke from brick kilns, dust from construction sites and toxic fumes from industries are main sources of particulate matter and gaseous pollutants. Around 60 percent of city air pollution is caused by thousands of unfit and faulty vehicles, especially from those that run-on diesel. These vehicles add to city traffic, congestion and ambient air pollution, too. The combination of meteorological conditions, long–range transport during the winter and local sources result in PM concentrations much higher than the Bangladesh National Ambient Air Quality Standard (BNAAQS). However, the gaseous pollutants (CO, $SO_2$, $NO_2$ and $O_3$) are lower than the acceptable limit of ambient air quality in the Dhaka city, Alam, *et al,* 2008. Hitchins, J, showed that at high rise buildings the concentration of fine and ultra-fine particles decreased in most cases to about 50-60% from the approximate ground level readings (between heights of 0 to 6 m), to full building height (from 24 to 33 m above the ground). Ambient air is generally absorbed by silencer pipe of air sampler at 1.2-2 m above from the ground. The objectives of the present work are basically to determine the concentration of certain criteria of pollutants in ambient air on the roof of a seven-storied building at Kallyanpur, Dhaka and to compare with the published data of the ground level. Studies on variation of criteria air pollutants at the roof top of high-rise buildings at Dhaka city have so far been not reported. In this context, the research work was undertaken to study the following pollutants; carbon monoxide (CO) nitrogen-dioxide ($NO_2$), Ozone ($O_3$), particulate matters ($PM_{2.5}$, $PM_{10}$ and SPM) and lead (Pb) in particulate matters. The present work is carried out between January 2015 to July 2015. Furthermore, the present work is also to initiate studies on air pollution states at roof top which could provide indicator to roof top gardening. The results obtained could not be compared with other studies, since such

studies at the roof top of a 7-storied building in Dhaka was not available. The findings should certainly contribute to air quality of a height between 24 to 33 m from ground level.

The current study has been carried out at the roof of 7-storied building at Kallyanpur, Dhaka. The values of roof level for air pollutants and the level of ground level has been compared. These values also have compared the value of DOE, Bangladesh. The level of pollutants decreased with increasing height of building (Jung, *et al* 2011). Consideration of the relationship between residential floor level and concentration of traffic-related airborne pollutants may predict individual residential exposure among inner city dwellers more accurately. A few studies conducted on vertical gradients of traffic-related airborne pollutants have been reported in urban area. Researchers have shown that amount of pollutants at higher elevation of sampling site was lower than ground level. Alam, *et al* (2008), has used high volume air samplers with gaseous attachment and some electronic devices for the determination of carbon monoxide (CO) nitrogen-dioxide ($NO_2$), Ozone ($O_3$), and gravimetric method for determination of particulate matter. The above-mentioned samplers and devices for the determination of air pollutants were being used by the present study.

The section 2 illustrates literature review. Section 3 discusses methodology including site selection, sampling method, principle of methods for air pollutants. The result and discussion are presented in section 4. Conclusion has been presented in section 5. References have been included in section 6.

## 2. Literature Review

*Tan and Sia* (2005) showed in a study that the level of sulphur dioxide was reduced by 37% after installation of the green roof but the concentration level of nitrogen dioxide showed variable results. The data collected from air borne particulate matter showed that the mass concentration for $PM_{2.5}$ had increased by 16% and $PM_{10}$ had increased by 42% after sampler installation of the green roofs.

*Alam, et al (2013) illustrated in his paper* that higher concentration (63.5 µg/m$^3$) of $NO_2$ was found in Industrial area (Tejgaon) and the lower concentration (16.2 µg/m$^3$) was found in tannery area (Hazaribagh). The sampling was carried out for eight hours. The concentration of $NO_2$ found in different locations is much lower than the guideline values of WHO and US standard. Higher concentration (38.0 µg/m$^3$) of $O_3$ was found in selected area (Khondokar Mokarram Hossain Bhaban, DU) and the lower concentration (7.4 µg/m$^3$) was found in tannery area (Hazaribagh) for eight hours sampling.

*Alam, et al*, (2008) also reported in his study that the average concentration of SPM in ambient air (ground level) of Dhaka city was 262.6 µg/m$^3$. The World Bank and Department of the Environment of Bangladesh found SPM concentrations 665–2456 µg/m$^3$ at Farmgate, Dhaka (Core 1998) based on 8 hours sampling at several locations near busy roads in Dhaka city. $PM_{10}$ and $PM_{2.5}$ had average concentration of 75.5 and 66.2 µg/m$^3$, respectively. The average mass concentrations varied from 62.0 to 91.2 µg/ m$^3$ for $PM_{10}$ at the five sampling locations in Dhaka.

*C. Alves, at el (2013) showed* that the $PM_{10}$ levels ranged from 6.73 to 20.8 μg/$m^3$ in schools farthest from the road and from 9.20 to 32.8 μg/$m^3$ in schools nearest from the road. *Lee and Chang (2000)* found $PM_{10}$ concentrations in 5 schools in Hong Kong above the 24-h average value (180 μg/$m^3$) stipulated by the local legislation. *Diapouli, et al* (2011) determined air particulates in seven primary schools in Athens (Greece) and have reported the higher value of $PM_{10}$ (229 μg/$m^3$) higher indoor than outdoor levels (166 μg/$m^3$).

Gilbert D, *et al* (2002) showed that in low rise buildings the pollution concentration (sub-micrometer particles and $PM_{2.5}$) did not change significantly at different points (front, back, and sides) around the building. Therefore, it was suggested that the measurement of pollution concentration on one side of a low-rise building can be used as an indicator of concentration level for all sides of the building. Pollution concentrations (submicrometer particles) decreased by about 50-60% between the ground level and the building's full height from measurements taken at the front of the high-rise buildings.

The results of the above-mentioned finding indicated that pollutants levels are always lower than the ground level. We assume that the concentration of gaseous pollutants (CO, $NO_2$, $SO_2$ and $O_3$) lead, $PM_{10}$, and $PM_{2.5}$ may decrease with higher elevation and the vertical gradients of these compounds would be affected by height of the building and surrounding environment.

## 3. Methodology

### 3.1 Site Selection

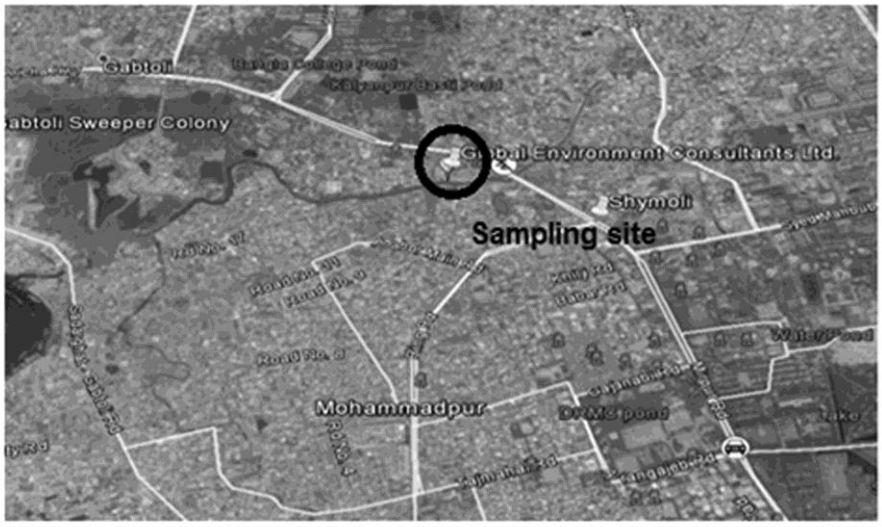
Dhaka, (23˝ 76° N, 90˝38° E, 8m a.s.l) is the capital city of Bangladesh. Dhaka is growing rapidly with all the problems of a megacity. The sampling locations were selected near the busy bus stand, *Gabtoli* with a mixed residential area. Sampling instruments were set up on the roof ($6^{th}$ floor) of *Kallyanpur*, Dhaka. The roof of the building is about 75 feet above the ground. Dhaka-North Bengal highway passes through the northern side of the sampling location; other sides being residential area. *Gabtoli* bus stand is around 1-km away from the sampling location. Vehicles which release air pollutants are trapped by the 8 hours' static air sampling on the roof.

### 3.2 Sampling Method

A high-volume air sampler (ECOTECH –INDIA) is used for collecting air. SPM and $PM_{10}$ were measured by respirable dust sampler (model Ecotech AAS 217 NL). This sampler has gaseous sampling attachment (Ecotech AAS 109) for the determination of $NO_2$, $O_3$ and $SO_2$. Ambient air laden with suspended particulates enters the respirable dust sampler through an inlet pipe. As the air enters the cyclone, coarse, non-respirable dust is separated from the air by centrifugal forces acting on the solid particles. These coarse particulates fall through the cyclone and are collected in the sampling bottle fitted at the bottom. The air stream passing through the glass micro-fiber filter (Whatman, Maidstone, UK; size: 20.3 ×24.4 cm,) paper, which was clamped between the top cover and filter adapter assembly, carries the fine dust forming the respirable fraction ($PM_{10}$). The flow rate of PM collection was determined from the difference of the initial and final flow rate of the instrument manometer reading. The $PM_{2.5}$ and $PM_{10}$ were deposited on micro-fiber filters (Millipore, Bedford, MA), and those larger than $PM_{10}$ were collected in the dust cup vial. Total SPM was calculated from the sum of the $PM_{10}$ and

PM larger than $PM_{10}$. Air has been trapped by respective absorbing solutions in impingers for measuring $NO_2$, $O_3$ and $SO_2$. A separate machine for measuring $PM_{2.5}$ (model Ecotech AAS 127 mini 2.5 sampler) has been used for the determination only $PM_{2.5}$. The reading of CO value is seen from the sensor type device at the sampling spot.

**Figure 1: Satellite Map of Sampling Location**




### 3.3 Principle of Methods for Air Pollutants

#### 3.3.1 $PM_{2.5}$, $PM_{10}$ and SPM

The calibrations were done directly by the manufacturer (Envirotech Instruments, New Delhi, India) in every year. The filter papers of $PM_{10}$, $PM_{2.5}$ and dust cup vial before and after were weighted by 4-digit analytical balance.

#### 3.3.2 Sulphur Dioxide

Sulphur dioxide from air is absorbed in a solution of potassium tetrachloro-mercurate (TCM). A dichlorosulphitomercurate complex, which resists oxidation by the oxygen in the air, is formed. Once formed, this complex is stable to strong oxidants such as ozone and oxides of nitrogen and therefore, the absorber solution may be stored for some time prior to analysis. The complex is made to react with pararosaniline and formaldehyde to form the intensely colored pararosaniline methyl sulphonic acid. The absorbance of the solution is measured by means of a suitable spectrophotometer of 560 nm.

#### 3.3.3 Nitrogen Dioxide

Ambient nitrogen dioxide ($NO_2$) is collected by bubbling air through a solution of sodium hydroxide and sodium arsenite. The concentration of nitrite ion ($NO_2$) produced during sampling is determined colorimetrically by reacting the nitrite ion with phosphoric acid, sulfanilamide, and N-(1-naphthyl)-ethylenediaminedihydrochloride (NEDA) and measuring the absorbance of the highly colored azo-dye at 540 nm.

### 3.3.4 Ozone

Micro-amounts of ozone and the oxidants liberate iodine when absorbed in a 1%solution of potassium iodide buffered at pH 6.8 +0.2. The iodine is determined spectrophotometrically by measuring the absorption of tri-iodide ion at 352 nm.
The stoichiometry is approximated by the following reaction:

$$O_3 + 3KI + H_2O \rightarrow KI_3 + 2KOH + O_2$$

### 3.3.5 Carbon Monoxide

With metal oxide semiconductor (MOS) detector technology, a tin dioxide semiconductor is heated by an electric current at periodic intervals. When tin dioxide reaches its operating temperature, it is capable of changing its resistance in the presence of carbon monoxide. Once the resistance change reaches its threshold, an alarm sounds. MOS detectors have a long-life span and can respond quickly to CO.

### 3.3.6 Lead

One fourth of the glass fiber filter for $PM_{10}$ is cut into small pieces and taken into beaker. The filter is placed in 30 ml concentrated nitric acid (70%) and 10 ml hydrogen peroxide (30%) solution in a beaker. The beaker is placed in a hot plate and heated to 180°C for about 1 h. Upon cooling of beaker, 60 ml water is added and agitated carefully. The SPM which was collected in dust cup vial, $PM_{2.5}$ and$PM_{10}$ were deposited on filter paper. Both were separately digested in the above-mentioned procedure. All solution was filtered into a 100-ml volumetric flask, diluted to the mark with de-ionized water, and used for lead analysis with AAS. The unexposed filter papers of $PM_{2.5}$ and $PM_{10}$ were separately digested as a blank using the same procedure.

### 3.3.7 Method of Analysis of air Pollutants

A Shimadzu UV visible model UV-160A was used for the measurement of $SO_2$, $NO_2$ $O_3$ with standard calibration curve. The red color for $NO_2$ solution of wave length 540 nm and violet color of $SO_2$ with wave length 540 nm measured by visible range. Only $O_3$ is measured at wave length 352 nm. A sensor type device of model (Model – Uniphos -6xx, Origin -India) was used for the determination of CO at the roof of building. First a suitable calibration was made by the Analar Grade chemicals and reagents. Finally, concentration of unknown samples was determined from absorbance-concentration calibration curve for $SO_2$, $NO_2$ and $O_3$. For the determination of the lead concentrations, a calibration curve for lead was prepared using five standard solutions at different concentrations. AAS (Shimadzu 6800) with Air-acetylene flame was used for the determination of lead in $PM_{10}$, $PM_{2.5}$ and SPM.

## 4. Results and Discussion

Assessment of the concentrations of ambient air $PM_{10}$ and $PM_{2.5}$, trace gases ($SO_2$, $NO_2$, CO and $O_3$), and lead were determined by $PM_{2.5}$, $PM_{10}$ and SPM size fractions at the roof of the 7-storied building in Dhaka, Bangladesh in January, March and July 2015. Among gaseous

pollutants, CO was measured by a sensor type device which is shown in the table-1. It has been observed that the value of CO was significantly lower than the DOE and EPA acceptable limits (10 mg/$m^3$). Incomplete combustion of biomass and fossil fuel might produce CO in the ambient air. After the withdrawal (2003) of two stroke engines, the amount of CO has been decreased in the Dhaka city air. Values of CO were 210 μg/$m^3$, 200 μg/$m^3$ 310 μg/$m^3$ in January, March and July 2015 respectively

**Table 1: Results of Gaseous Air Pollutants and Particulate Matters with Standard Values (EPA, WHO & DOE)**

| Sl NO | Parameters | WHO μg/$m^3$ | EPA μg/$m^3$ | DOE μg/$m^3$ | January μg/$m^3$ | March μg/$m^3$ | July μg/$m^3$ |
|---|---|---|---|---|---|---|---|
| 1 | CO | 10000 | 10000 | 10000 | 210 | 200 | 310 |
| 2 | $NO_2$ | 100 | | 150 Annual | 16.11 | 13.56 | 20.21 |
| 3 | $SO_2$ | 40-60 annual 100-150 (24 h) | - | 80 (annual) | 10.56 | 15.65 | 11.78 |
| 4 | $O_3$ | - | - | 235 (1 h) 157 (8h) | 22.7 | 18.56 | 13.84 |
| 5 | $PM_{10}$ | 20 (Annual) | 50 (Annual) | 150 (24 h) | 117.79 | 100.97 | 97.87 |
| 6 | $PM_{2.5}$ | 10 | 15 (annual) | 65 | 49.99 | 44.14 | 36.17 |
| 7 | SPM | 150-230 (24 h) | 150(24 h) | 200 (8 h) | 278.98 | 244.32 | 235.98 |

The standard limit of EPA, DOE is 10000 μg/$m^3$. The CO values of this study lie well below the acceptable value of EPA and DOE (Department of Environment, Bangladesh). Azad and Kitada (1998) reported that the primary source of $SO_2$ in Dhaka is fuels (55.8%) followed by industry (10.5%), and others (about 5%). $SO_2$ concentration of this study shows the values of 10.56 μg/$m^3$, 15.65 μg/$m^3$ and 11.78 μg/$m^3$ during the month of January, March and July 2015.

**Figure 2: Comparison of CO in Different Sampling Time with Standard Limit**

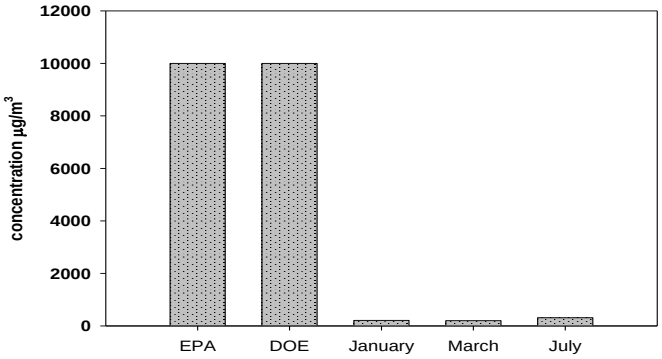


**Figure 3: Comparison of $NO_2$ in Different Sampling Time with Standard Limit**

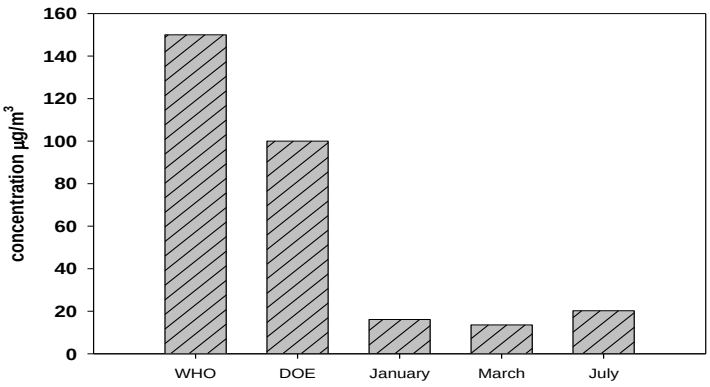
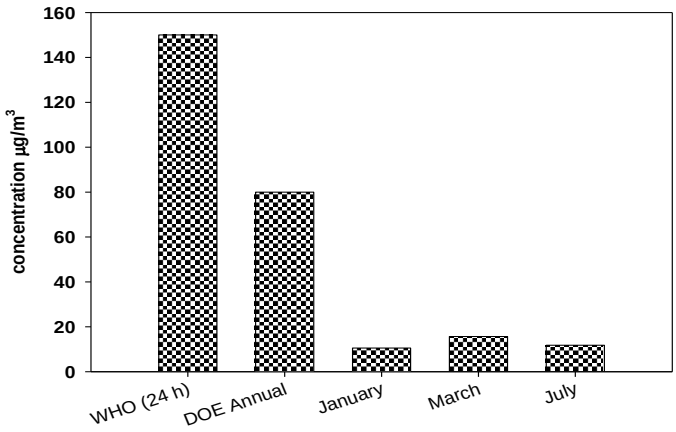


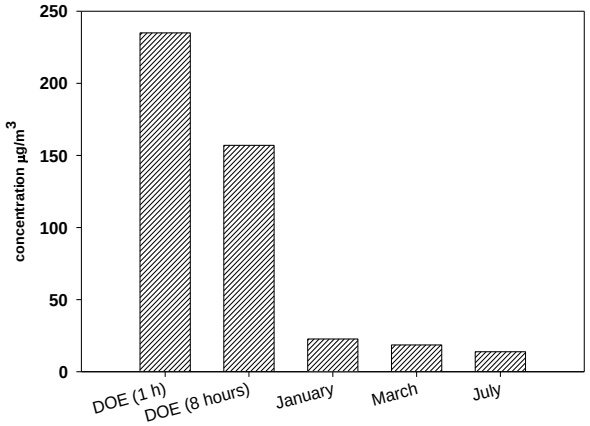

**Figure 4: Comparison of $SO_2$ in Different Sampling Time with Standard Limit**




The $NO_2$ enters the atmosphere from various natural and anthropogenic sources including lighting, action of microorganisms on nitrogen-based fertilizer but the most important and major anthropogenic source is the combustion of fossil fuel. Higher values of $NO_2$ was found in the month July (20.21 $\mu g/m^3$) compared to relatively lower values (13.56 $\mu g/m^3$) in the month of March. Comparatively higher values, 20.21$\mu g/m^3$ was found in July. These values are also lower than the value of DOE and EPA.

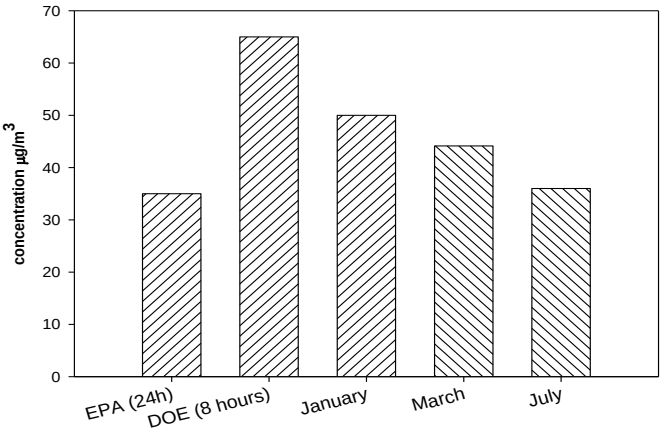
Breathing ground-level ozone can trigger a variety of health problems including reduced lung function and inflamed lining of the lungs. There are two limits set by the DOE, 235$\mu g/m^3$ for 1 hour and 157$\mu g/m^3$ for 8 hours limit. The concentration of ozone was found to be 22.7$\mu g/m^3$, 18.56 $\mu g/m^3$ and 13.84 $\mu g/m^3$ in January, March and July respectively. These values are lower than the acceptable standard values of DOE and EPA.

**Figure 5: Comparison of $O_3$ in Different Sampling Time with Standard Limit**



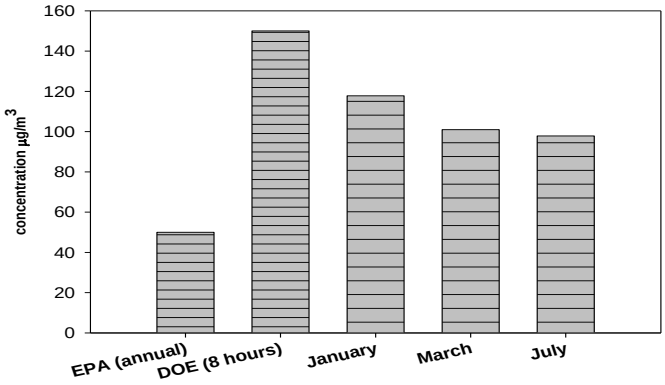

Ozone is a secondary standard pollutant and it is formed due to interaction of volatile hydrocarbon and $NO_2$ in the presence of light. The introduction of compressed natural gas (CNG) in the vehicles of Dhaka city has minimized the criteria pollutants significantly including the formation of ozone. Particle pollution (also known as "particulate matter") in the air includes a mixture of solids and liquid droplets. Some particles are emitted directly and others are formed in the atmosphere when other pollutants react. Particles come in a wide range of sizes and produced by crushing or grinding operations, cutting, finishing, printing sections of garments factory and dust stirred up by vehicles traveling on roads. The $PM_{10}$ is set in units of micrograms of $PM_{10}$ per cubic meter of air ($\mu g/m^3$) for each of two averaging periods. The current 24-hours $PM_{10}$ standard (for which concentration levels are averaged over one day) is 150 $\mu g/m^3$. The current annual $PM_{10}$ standard (for which concentration levels are generally averaged over three years pursuant to an EPA protocol) is 50 $\mu g/m^3$. The WHO and DOE (Department of Environment), Bangladesh also have standard limit of $PM_{10}$ as 20 $\mu g/m^3$ (annual) and 150 $\mu g/m^3$ (24 h) respectively. $PM_{2.5}$ is emitted directly by combustion sources such as open burning, trucks, automobiles, boilers and wood stoves and by a variety of non-combustion sources.

**Figure 6: Comparison of $PM_{2.5}$ in Different Sampling Time with Standard Limit**




Chuersuwan et al, (2008) reported that mass concentrations of 57.6–108.1 µg/$m^3$ for $PM_{10}$ and between 69.0 and 37.9 µg/$m^3$ for $PM_{2.5}$ at four sampling sites in Bangkok, Thailand. Sharma, Maloo (2005) also reported that the average $PM_{10}$ concentration was 211 µg /$m^3$ ranging from 80 to 281 µg /$m^3$ at three sampling locations in Kanpur, India. The average $PM_{2.5}$ mass concentration at the same locations was 101 µg /$m^3$ ranging from 65 to 146 µg /$m^3$.

**Figure 7: Comparison of $PM_{10}$ in Different Sampling Time with Standard Limit**




The observed $PM_{10}$ values were 117.79 μg/$m^3$,100.97 μg/$m^3$ and 97.87 μg/$m^3$ and $PM_{2.5}$ values were 49.99 μg/$m^3$, 44.14 μg/$m^3$ and 36.17 μg/$m^3$ in the month of January, March and July, respectively. The result of $PM_{10}$ which has been found on 7-storied building roof is greater than EPA and WHO (annual) standard but below the Bangladesh standard limit and the average value observed in Bangkok (Thailand) and Kanpur(India). The value of $PM_{2.5}$ is also higher than EPA and WHO (annual) limit but below the Bangladesh standard limit set by DOE with 24 hours limit of sampling. More than 500,000 deaths per year have been reported worldwide due to $PM_{2.5}$ pollutions. $PM_{10}$ and $PM_{2.5}$ concentrations are related since most of the $PM_{10}$ is contributed by $PM_{2.5}$. In samples, the value of $PM_{10}$ was always greater than the value of $PM_{2.5}$.

The suspended particulate matter (SPM) having the larger size of $PM_{10}$ was determined by the different mass of final and initial mass of dust vial. The limits of EPA, WHO and DOE are 150 μg/m$^3$ (24 h), 150-230 μg/m$^3$ (24 h) and 200 μg/m$^3$ (8-hour) respectively. The observed value of SPM is 278.90 μg/m$^3$ in January, 244.32 μg/m$^3$ in March and 235.98 μg/m$^3$ in July 2015 which exceeded the EPA, WHO and DOE standard.

**Figure 8: Comparison of SPM in Different Sampling Time with Standard Limit**

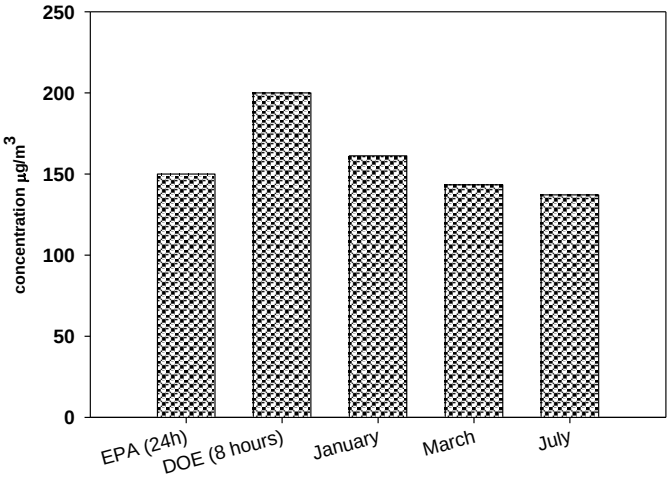
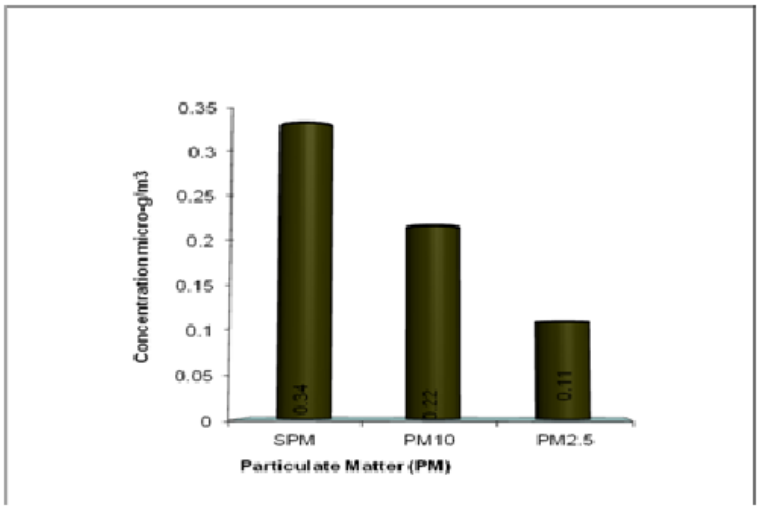



**Table 2: Results of Lead Concentration in Particulate Matters Collected on the Roof of a 7-Storied Building.**

| Sl No | Month of Sampling | Lead concentration in particles matter | | |
|---|---|---|---|---|
| | | SPM μg/m$^3$ | PM10 μg/m$^3$ | PM2.5 μg/m$^3$ |
| 1 | January | 0.41 | 0.31 | 0.14 |
| 2 | March | 0.38 | 0.18 | 0.11 |
| 3 | July | 0.24 | 0.17 | 0.09 |
| | **Average** | **0.34** | **0.22** | **0.11** |

There is a relationship between the lead content of the soil and the atmospheric deposition as it consists of re-suspended soil particles originating from short- and mid-range transport. At a deposition rate of about 13 Kg Pb/km$^2$/a, more than half of the lead accumulated by leafy vegetables is of airborne origin (Temmerman & Hoenig, 2004). Actually, guidelines for lead in air will be based on the concentration of lead in blood. The median blood lead level should not exceed 54 μg/L. On this basis, the annual average, lead level in air should not exceed 0.5 μg/m$^3$.

**Figure 9: Variation of Lead Concentration in Different Particulate Matters**




The higher value of lead concentration in SPM compared to $PM_{10}$ and $PM_{2.5}$, however these values are below the EPA, WHO and DOE standard limit. Prior to 2003, Bangladesh was used leaded gasoline. But after 2003, the concentration of lead decreased gradually due to the use of compressed natural gas (CNG) in most of the vehicles.

**Figure 10: Variation of Gaseous Pollutants**

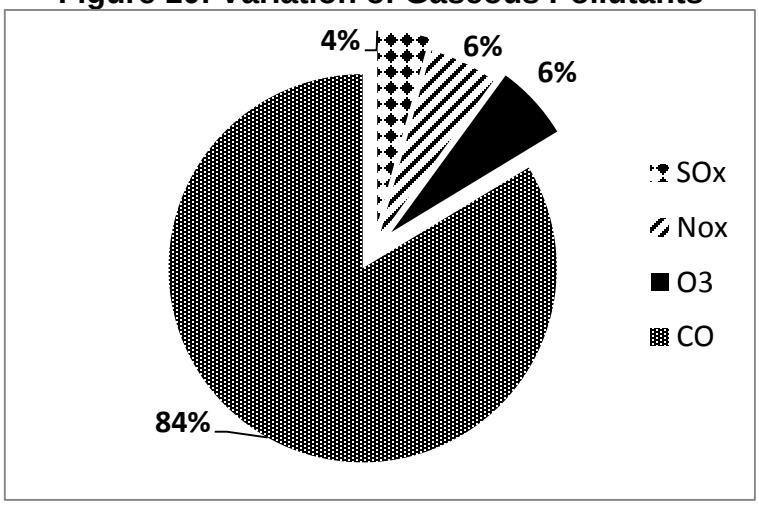


**Figure 11: Variation of Particulate Matters**

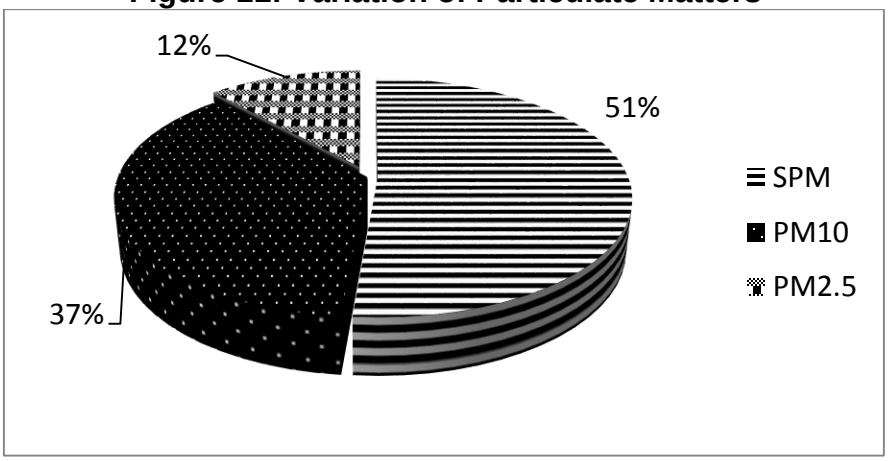



Fig-9 and fig-10 shown, the variation of gaseous and PM pollutants. CO represents 84% of the total gaseous air pollution, $NO_2$ and $SO_2$ represent 6% each and $O_3$ represents while 4% of the total gaseous pollutants. SPM represents 51%, $PM_{10}$ and $PM_{2.5}$ represents 37% and 12% respectively among all particulate matters. The average value of lead in SPM, $PM_{10}$ and $PM_{2.5}$ correspond to 0.34 µg/m$^3$, 0.22 µg/m$^3$ and 0.11 µg/m$^3$ for the month of January, March and July (2015) respectively. These values are considerably lower than the values of ground level (0.5 µg/m$^3$). According to Begum et al, [Aerosol and Air Quality Research, 12: 1062–1072, 2012] the average value of $PM_{2.5}$ in January 2011 was 256 µg/m$^3$, 67 µg/m$^3$ in March 2010 and the observed value was 49.99 µg/m$^3$ in January and 44.14 µg/m$^3$ in March in 2015 at sampling locations. Philip K Hopke, et al, [Air Qual Atmos Health (2008) 1:125–133] was showing that the average value of $PM_{10}$ varied from 124 µg/m$^3$ to 170 µg/m$^3$ from 2000 to 2006 whereas values was at the 7-storied building varied from 97.87 µg/m$^3$ to 117.79 µg/m$^3$. Tanvir Ahmmed KM, et al, has been showing that the values of $PM_{10}$, $NO_2$, and CO were 167 µg/m$^3$,113 µg/m$^3$ and 572 µg/m$^3$ respectively at Dhannmondi, Dhaka in 2010 but the value of $SO_2$ was in trace level. The average finding values of CO, $NO_2$ and $SO_2$ were 240, µg/m$^3$ 16.62 µg/m3 12.63 µg/m$^3$ respectively.

In all case, the values of pollutants at 7-storied building were lower to the reference values. these results indicated that the values of ambient air quality both standard [ DOE] and reference were higher than our current study values.

## 5. Conclusion

The value of CO has been found to be much lower than limit of Department of Environment (DOE) at ground level. This is expected because of the withdrawal of two stock engines and also the use of compressed natural gas in most vehicles. The observed values of $SO_2$ and $NO_2$ have also been found to be lower than the annual limit of DOE. The lower value of $SO_2$ and $NO_2$ suggest that the concentration of gaseous pollutants tend to decrease with increasing elevation. The concentration of SPM, $PM_{10}$ and $PM_{2.5}$ were also found to be lower than the ground level. The values of $PM_{10}$ and $PM_{2.5}$ were higher than the EPA and WHO limits (24 hours' limit) but lower than the acceptable limit of DOE. However, the values of particulate matters were higher in January compared to March and July. This trend follows similar pattern

when compared to the pattern shown by DOE at the ground level. The value of lead concentration in particulate matters are found to be similar when compared to other published results at ground level.

Some important ideas emerged from this study are relevant to both urban farming practice, living at high rise flats and our understanding of ecosystem service attributed to green roofs. We state these as the following hypothesis; 1) human exposure to particulate matters and gaseous air pollutants arising from street level will be lower on a roof than at street level. 2) Vegetables grown on roof tops will receive a reduced air pollutant load than crops grown in the ground level than the crop grown in the ground level near road side. Therefore, high rise buildings are greener to live compared to ground level buildings.However, the variation may be significantly different between ground and roof top level if the sampling point would be higher than 7-storied building. Significant variation will not be widely understood on the 7-storied building. It needs further studies for the collection of samples at high rise roof top. Moreover, the results of present study can provide positive indicators to the roof top gardaning in high rise building.

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