Traffic-related pollutants in roadside environment of Yangon, Myanmar

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Abstract. Roadside environment is a key location responsible for increased exposure to traffic-related air pollutants to people who reside, work and commute on or near the roadside. Although increase in traffic volume and duration of traffic congestion has been significantly recognized in Yangon, research conducted on traffic-related air pollutants is very limited. In this study, we mainly focused on nitrogen dioxide and aromatic hydrocarbons of VOCs; benzene, toluene, ethylbenzene and xylenes collectively known as BTEX. Diffusive air samplers; DSD-CX for BTEX and DSD-TEA for NO₂ were placed at seven sampling sites, S1-S4 located on heavy congested traffic roads of commercial areas and S5-S7 on fast moving traffic roads of residential ones. The BTEX concentrations were measured by gas chromatography/mass spectrometry and NO₂ by ion chromatography. According to the findings, we concluded that roadside NO₂ concentrations reflect the severity of traffic congestion currently encountered in the city. Sources other than vehicle emission could also have contribution to roadside traffic-related pollutants. Appropriate traffic managements and vehicle emission controls are urgently needed for reducing traffic-related air pollution.

1. Introduction
Yangon is situated between Latitude 17.1°N and Longitude 96.1°E, in the southern part of Myanmar, bordered by Bago Region to the North and East, the Gulf of Martaban to the South, and Ayeyarwady Region to the West. The city covers a surface area of 598.75 kilometer square and is the largest city homing over 5 million people. It is also the most densely populated city with 6500 people per kilometer square [1]. It is estimated that by 2040, it will become one of the Asian’s megacities with over 10 million inhabitants [2].

Yangon city, a commercial capital of the country, is growing dramatically which is augmented by continuous immigration of people from other parts of the country usually from rural areas. The dramatic rise of urbanization in the city leads to land-use pattern changes and high dependence on public transport making citizens highly exposed to roadside environment. Roadside environment is a key location...
responsible for increased exposure of traffic-related pollutants to people who reside, work and commute on the roadside.

Currently, many cities in the developing world have to deal with traffic-related air pollution which is drawing increasing concerns from epidemiologists, toxicologists and exposure assessors. It is obviously noted that Yangon streets are suffering from increased heavy traffic and traffic-related pollution becomes a worrying issue. However, information on traffic-related pollutants at the roadside environment is still needed to be explored.

Traffic has been recognized to be dominant source of nitrogen oxides [3], volatile organic compounds (VOCs) [4] and particulate matter [5]. In our study, we focused mainly on nitrogen dioxide and aromatic hydrocarbons of VOCs; benzene, toluene, ethylbenzene and xylenes collectively known as BTEX in roadside environment. In addition to their toxic health effects, these selected traffic-related pollutants are important photochemical precursors for tropospheric ozone and secondary organic aerosols [6] which will again impair urban air quality. Findings of our study will be useful for management of air quality of the city and also for further research on exposure assessment pertinent to commuters and occupants at the roadside environment.

2. Materials and methods

2.1. Sampling sites

Diffusive air samplers; DSD-CX for BTEX and DSD-TEA for NO$_2$ were placed at seven sampling sites; S1 on Pyay road in Kamayut Township, S2 on Insein Road in Hlaing Township, S3 on Yadanar Road in South Okkalapa Township, S4 on Banyardala Road in Tamwe Township, S5 on Shwetharaphyi lane, FMI city of Hlaingtharyar Township, S6 on Pyinoolwin street, 20th ward, Shwepyithar Township, and S7 on Myankanthar street, 14th ward, Hlaing Township respectively. The sampling sites, S1- S4 were located on heavy congested traffic roads of commercial areas and S5-S7 on fast moving traffic roads of residential ones (seen in Figure 1).

The air samplers were suspended at 8-10 feet above the ground within 1 meter from the pavement. The sampling duration was one week in May, 2017. The samplers used in our study are small, light-weighted, do not require a power source and are stable for one month after collection [7]. This study was approved by Ethical Review Committee, Department of Medical Research, Ministry of Health and Sports (Ethics/DMR/2017/130A/2018).

2.2. Methods

The BTEX concentrations were measured by gas chromatography/mass spectrometry (GC/MS) (QP 2010 Ultra, Shimadzu, Kyoto, Japan) and NO$_2$ by ion chromatography (Dionex ICS-2100 Integrated Reagent-free, ThermoFisher Scientific, CA, USA). The detailed procedures of the measurements have been described in our previous publication [8].
3. Results and Discussion

NO$_2$ is a product of combustion process and its main source in urban atmosphere is exhaust emission from vehicles with either diesel- or gasoline-powered engines [3]. In the presence of hydrocarbons and ultraviolet light, NO$_2$ is the main source of tropospheric ozone, thus playing an important role in determining ambient ozone concentrations. Moreover, NO$_2$ is also a key precursor of nitrate particles which are major fraction of ambient particulate matter [9]. The current WHO guideline value of ambient concentration of 40 μg m$^{-3}$ (annual mean) is set in order to protect the adverse health effects [9]. Figure 2 shows roadside NO$_2$ concentrations of the sampling sites. It is noted that during the sampling period, the roadside environment of three sampling sites (S1, S2 and S4) with heavy traffic congestion showed NO$_2$ concentrations above 40 μg m$^{-3}$.

Many studies have used NO$_2$ as a marker for the mixture of combustion-related pollutants particularly emitted from road traffic. Ambient concentration of NO$_2$ is found rising sharply at high traffic volume and has been used as surrogate of congestion impact [10]. Janssen et al. (2001) also reported that traffic density was highly correlated with ambient NO$_2$ concentration [11]. In 2008-2009, it was reported that annual mean value of ambient NO$_2$ of Yangon city was 18 μg m$^{-3}$ in residential and 14 μg m$^{-3}$ in commercial sites [12]. In our study, mean NO$_2$ (one week duration) of commercial sites is 54 μg m$^{-3}$ whereas in residential sites, 16 μg m$^{-3}$. Comparison of these findings highlights that during one decade, dramatically increased in traffic congestion has been occur in the commercial areas rather than the residential areas. According to Road Transport Administration Department (2018), number of the registered vehicles in Myanmar has been arose from 480,000 in 2013 to 870,000 in 2018 and the percentage of vehicles in Yangon is 60% of total vehicles registered in the whole country [13].
Except S3, the roadside NO$_2$ concentrations exhibited by sampling sites of high traffic congested roads showed higher NO$_2$ concentrations (about 3 times) than concentrations detected from the samplers set on roads of residential areas (S5, S6 and S7) (seen in Figure 2). This finding reflects the nature of sampling sites; busy large roads in commercial areas versus small roads in residential ones. The S3 showed lower NO$_2$ concentration compared with other sampling sites on large roads and this also coincides with the real situation of lesser traffic jam on the road of the sampler located.

Traffic congestion lowers the speed of vehicles and changes the driving patterns such as increased numbers of speedups, slowdowns, stops and restarts leading to increase exhaust emission compared to congestion-free conditions [14]. In our study, the highest NO$_2$ concentration was noted at S4. Very high traffic congestion on this large road could be due to the presences of (1) a famous wholesale centre which is always overcrowded with a lot of cars parking, with pedestrians and customers (2) two-three intersections within a short distance and (3) bus-stops on both sides of the road. All these conditions favour frequent idling of many vehicles for a considerable long period on the road of S4 located.

![Figure 2](image_url)

Figure 2. Roadside concentrations of NO$_2$ at seven sampling sites.

The BTEX provides a well-rounded picture of volatile organic compounds (VOCs) and the primary man-made release of BTEX compounds is through emissions from motor vehicles [15]. Comparison of roadside total BTEX concentrations of the sampling sites is shown in Figure 3. The total BTEX concentration ranged from 9.3 μg m$^{-3}$ to 40 μg m$^{-3}$. The highest BTEX concentration (40 μg m$^{-3}$) is noticed at S4, which is mentioned earlier as the most traffic congested site based on ambient NO$_2$ value. Congestion itself does not generate new pollutants but could have impact on traffic-related pollution by reducing these pollutants dispersion [16]. However, compared with S4, roadside BTEX concentrations of other three sampling sites of traffic-congested large roads are found relatively lower. This inconsistency may be due to the difference in density of buildings surrounded. The S1, S2 and S3 are surrounded by lower density of buildings whereas S4 is enclosed by a compact locality with multi-storeyed buildings resulting in canyon effect that can limit traffic pollutants dispersion.
Figure 3. Roadside BTEX concentrations at seven sampling sites.

Vehicle emission is an important source for ambient benzene concentrations in urban area. Benzene is carcinogenic to humans, and no safe level of exposure can be recommended and is classified as carcinogenic to humans (Group 1) and the life risk of chronic leukemia is 4.4 to 7.6 x 10^{-6} when atmospheric benzene is 0.17 μg m^{-3} [17]. In our study, roadside benzene concentrations of all sampling sites with seven day duration ranged from 1.2 to 3.9 μg m^{-3} (Table 1) with mean concentration, 2.4 μg m^{-3}. According to EPA QS (1994), a target value of annual mean of ambient benzene concentration has been set at 3.29 μg m^{-3} [18]. Two of four sampling sites on large congested roads, S2 (3.9 μg m^{-3}) and S4 (3.4 μg m^{-3}) exhibited ambient benzene levels higher than this set value. The benzene concentration with the same duration of sampling (one week) at the Pathumwam Junction area, one of the most traffic congested area of Bangkok, is 12.7 μg m^{-3} [19] and this concentration is higher than the sampling site S4 with similar environment.

As a weekly average concentration, the guideline value of ambient toluene level is set as 260 μg m^{-3} and this value is derived from LOAEL (Lowest-Observed-Adverse-Effect Level) of 332 mg m^{-3} for central nervous system effect seen in occupational exposure [20]. In our study, roadside toluene concentrations ranging from 4.3 to 22 μg m^{-3} are found far below the weekly guideline value. However, at all sampling sites, toluene is found as the major contributor to total BTEX concentrations (Figure 3) and percentage of contribution is from 39% to 52% suggesting that toluene is abundantly emitted to the roadside environment. Unleaded fuels widely used in Asian cities contain high aromatic compounds to increase the octane index. A major use of toluene is addition to gasoline to improve octane ratings [21]. Therefore, common use of RON (Research Octane Number) 92 and RON 95 in Yangon could partly explain the consistent finding of the highest concentration of toluene among BTEX pollutants detected at the sampling sites. Moreover, unlike benzene, toluene has other non-traffic sources such as workplace using solvent, paint, paint thinner and polish [21, 22] construction sites and industries [21].
Table 1. Roadside concentrations of BTEX species at the sampling sites.

| BTEX species (μg m⁻³) | S1 | S2 | S3 | S4 | S5 | S6 | S7 |
|-----------------------|----|----|----|----|----|----|----|
| Benzene               | 2.3| 3.9| 1.5| 3.4| 1.4| 3.0| 1.2|
| Toluene               | 4.3| 7.5| 9.4| 22 | 7.7| 11 | 5.1|
| Ethylbenzene          | 1.1| 1.6| 1.6| 5.3| 1.23| 2.6| 1.1|
| m,p-Xylene            | 2.3| 3.2| 2.6| 6.3| 1.6| 4.1| 1.5|
| o-Xylene              | 0.90| 1.3| 0.83| 2.3| 0.52| 1.5| 0.50|
| T/B ratio             | 1.9| 2.0| 6.3| 6.5| 5.6| 3.7| 4.3|
| X/E ratio             | 2.8| 2.8| 2.2| 1.6| 1.6| 2.1| 1.9|

The ratio of toluene to benzene (T/B) is frequently used to evaluate the samplers are under the influence of mobile source (traffic emission) or of point source (non-traffic source) [15, 23]. The ratio between 1.5-3.0 indicates the predominance of vehicular emission on BTEX concentration at a give site [24-26]. In our study, T/B ratio of S1 and S2 fell within this range (Table 1) indicating that there is a strong contribution of traffic source to BTEX concentrations at these sites. For the remaining sampling sites, the ratios are above 3.0 revealing that there could be possibility of sources beyond vehicle emissions. Presence of a newly painted building near S3 and of many furniture shops at the vicinity of S4 could explain the ratio above 3.0 at the sites. For sampling sites of the residential area, there could be local stationary sources such as garage attached to residential building.

Ethylbenzene is naturally present in petroleum. It is also used in the manufacture of dyes, rubber adhesives, paints and varnishes [27]. Similarly, mixed xylenes (meta-, para-, and ortho-isomers) are blended into gasoline and used in the production of industrial solvents, solvents in commercial products such as paints, coatings and adhesive removers [28]. However, these two pollutants have dissimilar rates of degradation in the air; xylenes are high reactive species while ethylbenzene is low reactive species [29]. With concentration of hydroxyl radicals at 10^6 rad cm⁻³, ethylbenzene, m-xylene, p-xylene and o-xylene have lifetimes 1.6 days, 11.8 h, 19.4 h and 20.3 h respectively [23]. Based on their different degradation rates, the ratio of xylenes to ethylbenzene (X/E) reflects the photochemical age of air mass [23] and is frequently used to evaluate the air pollutants are freshly emitted (from automobile source) or aged (transported from regional or point source).

High X/E ratio is commonly observed in traffic congested area and low ratio suggests that the sampled air masses are photochemically aged, not freshly emitted and transported from point sources [24]. The ratio recorded by traffic exhaust were between 2.8-4.6 [23]. In addition, Miller et al. study (2011) in Canada reported high traffic area showed the ratio above 2.8 and low traffic area (background area) exhibited the ratio below 2.8 [23]. Therefore, at the sampling sites, S1 and S2, road traffic emission could contribute as a main source of BTEX. Apart from these sites, other sites exhibited the ratio below 2.8 indicating that pollutants are transported from pointed sources in addition to fresh emission from automobile sources.

Table 2 shows Pearson’s correlation coefficients among individual BTEX species. A weak positive correlation (r=0.49) between benzene and toluene is also suggestive of different sources of emission at the sampling sites. Both ethylbenzene and xylenes exhibit significant strong positive correlations (r>0.9, p<0.01) with toluene and this finding can be attributed that like toluene, both ethylbenzene and xylenes have non-traffic emission sources as well as traffic source.
Table 2. Correlation between individual BTEX species.

| BTEX species | Benzene | Toluene | Ethylbenzene | Xylenes |
|--------------|---------|---------|--------------|---------|
| Benzene      | 1       | 0.49    | 0.58         | 0.77    |
| Toluene      | 0.49    | 1       | 0.98*        | 0.91*   |
| Ethylbenzene | 0.58    | 0.98*   | 1            | 0.95    |
| Xylenes      | 0.77    | 0.91*   | 0.95*        | 1       |

* Correlation is significant at the 0.01 level (2-tailed, Pearson’s correlation)

4. Conclusion
Traffic-related emissions are important factors in determining air quality of urban areas. The results of roadside NO₂ concentrations of our study reflect the severity of traffic congestion currently encountered in the city. The highest concentrations of both NO₂ and total BTEX at the sampling site S4 could be linked to restricted effect of compact surrounding on air pollutants dispersion. Low T/B and high X/E ratios at S1 and S2 are suggestive of the dominant source of vehicle emission on roadside BTEX concentrations. However, sources other than vehicle emission could also have contribution to roadside traffic-related pollutants detected at other sampling sites of both commercial and residential areas. Most of the megacities in the developing countries are currently experiencing serious ambient pollution. Findings of our study could be useful for management of air quality of the Yangon, a potential Asia’s megacity. It is recommended that appropriate traffic managements and vehicle emission controls are mandatory for reducing traffic-related pollution. Future exposure assessment studies on the residents living near the roads with heavy traffic are also suggested.

Declaration of interests
The authors declare that they have no competing interests.

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