Monitoring of Benzene in an Ambient Air on the Roadside at Udon Thani of Thailand

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Abstract. Vehicles of Transportation in the urban area was the major source of benzene emission that caused to effect on human health and air quality. A monitoring air quality in an ambient air was designed and sampling of benzene level on the roadside in Udon Thani province from May 2018 to October 2018. The samples of the air were collected at different five sites from the roadside of a traffic jam, namely hospital, university, shopping mall, park, and market. Benzene was sampling by activated charcoal tubes and analyzed by GC-FID. Total Benzene concentration at roadside sites ranged in our study from 0.004±0.0017 to 2.120±2.519 mg/m³. The higher traffic volume and traffic congestion on the roadside of the university leads to remarkably higher benzene concentration (1.260±2.418 mg/m³) than that of other sites indicating the stronger contributions from benzene emissions. The results of source apportionment were highly consistent with the vehicles compositions, strongly evidenced that the precise characterization of the vehicles emission sources. The market and park roadside were clean with daily benzene concentrations below 0.001mg/m³. The daily benzene concentrations in the shopping mall and hospital roadsides were 0.939±0.298 mg/m³ and 0.739±1.808 mg/m³, respectively. The average benzene was 0.588±0.862 mg/m³ that was higher than the range reported in other cities. This indicates that the benzene on roadsides was equivalent and acceptable for daily outdoor benzene monitoring. The information of this study complements the air pollution database regarding the vehicle emission sources in Udon Thani of Thailand.

1. Introduction

Benzene is wildly known a part of type from volatile organic compounds (VOCs) that are generally caused to air pollution from the vehicle emission. Vehicle emission is one of the important air pollution sources for an ambient air level benzene pollutant in urban areas. Benzene is commonly generated by a vehicular traffic which attributed to the largest composition of gasoline fuel vehicles on the road. The pollutants such as benzene gaseous and particulate matters that generated from the vehicle exhaust on the roadside, caused contaminate of air quality and their effect on human health [1, 2]. The International Agency for Research on Cancer, classified benzene as a carcinogenic compound. Several studied were reported that benzene is well known that emitted from the petrol fuel vehicles, and thus, it is mostly found in the traffic jam of the big city [3]. In Asian countries, the annual average concentration of benzene on the roadside in Mumbai, India was found to be 14.7 µg/m³, while the benzene concentration was measured at 11.8 µg/m³ in Manila, Philippines [4]. Furthermore, a high
concentration of benzene has also been observed in Guangzhou, China at 51.5 µg/m³. They conclude that the air quality on the roadside, especially benzene pollutants, caused by the high of traffic jam in the urban city [5].

In Thailand, VOCs concentration on the roadside was reported at 73.0 µg/m³ in Bangkok [4]. The reported identified the VOCs pollutants caused to be discharged from vehicle in transportation. However, the concentration of benzene in an ambient air on the roadside has a few studied. Therefore, the concentration of benzene gaseous on the roadside was an important information for monitoring of the air quality in the urban city that can be investigated for the risk assessment for human health [6]. For Udon Thani province, it is well known as a big city in Thailand. It has never been reported for the concentration of benzene emission in ambient air. Udon Thani is located in a center of the northeast in Thailand and near Laos and Vietnam, which includes several major shopping mall, market, school, hospital, university, hotels, banks, and restaurants. It was a big city and high population within the residential areas that settled on a busy road including the construction of transportation. Along the roadside in Udon Thani, there are many houses and restaurants which have been settled on the roadside. Generally, we have a high traffic throughout the day with heavy motorbike vehicles on these roads. The reason for increasing of the vehicular that caused to be produced benzene concentration was rapidly increased population in Udon Thani. In some developed countries, they mostly reported that the air pollutants in an urban were found from a high of vehicles on the density of traffic on the roadside, and effect to the population living in this area that was a risk of their health from the exposure of high benzene pollutant from vehicles emission [7].

According to the above, benzene is important gaseous to air pollutants not only because they caused to air pollution in the ambient air but also because some have toxic health effects. Therefore, benzene monitoring in ambient air should be investigated for the air quality management in urban areas. This study was determined the concentration of benzene gaseous at a roadside in a high of the traffic jam at Udon Thani city, Thailand. In addition, the correlations between the concentration of benzene and vehicle types have been interpreted with the potential source of fuels.

2. Experimental Procedure

2.1 Sampling sites area

Air samples were collected in ambient air on the roadside from five locations that located in Udon Thani province. The roadside monitoring sites were selected with the traffic density of high namely hospital (17°22'12.4"N, 102°48'45.2"E), university (17°39'82.1"N, 102°79'53.5"E), shopping mall (17°39'76.4"N, 102°80'57.8"E), park (17°41'89.1"N, 102°77'88.1"E), and market (17°40'84.5"N, 102°78'38.7"E). The map of the sampling sites area in Udon Thani is shown in Figure 1.

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Figure 1. Map of the sampling sites on the roadside in Udon Thani.
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2.2. Benzene analysis

Benzene was monitored for ambient air quality on five roadside area, which was selected a busy road with a high traffic density in Udon Thani city from May 2018 to October 2018. The sampling was done on working days from Monday to Fridays illustrated in Table 1. The samples were collected from five sites per month and a total of 30 samples were collected from 6 months. In order to study the level of benzene, air samples were also collected at the different place namely hospital, university, shopping mall, park, and market, respectively, from the roadside. The air samples were also collected by coconut charcoal tubes (CSC, 8 mm x 110 mm, 600 mg, SKC Inc.). It was separated by urethane foam and using the flow rate of 0.02 ml/min for 1 h by Gillian model sampling pump (Gillian, Model LFS 1130C). The benzene sampling was settled from the road at the high 1.5 meters and distance from the roadside at 1.0 meter, respectively. Benzene was sampled and analyzed using a methodology based on the National Institute for Occupational Safety and Health (NIOSH) method 1501 (USEPA, 2012). After collecting the samples, the obtained charcoal tubes were extracted by adding 1.0 ml of carbon disulfide (CS₂) and transferred to 2.0 ml vials for 30 min. The concentration of benzene was then analyzed with gas chromatography-flame ionization detector (Shimadzu, GC-2010). The benzene concentration results were checked by analyzing duplicated samples for reproducibility.

3. Results and Discussion

3.1. Meteorological in Udon Thani

A monitoring air quality in an atmosphere was designed and sampling of benzene level on the roadside in Udon Thani province from May 2018 to October 2018. The meteorological conditions during the sampling period at Mueang Udon Thani city as illustrated in Table 1. In addition, the level of benzene emission also depended on the emission type sources of each vehicle, car speed, the position of the road in the beginning and the end, and meteorological information including wind direction, atmospheric temperature, and humidity. The total mean of wind speed, air temperature, and relative humidity in this study were 10.38± 2.0 m/s, 30.30±0.8°C, and 66.80± 10.2%, respectively.

Table 1. The condition of meteorological measured in the period studied at Udon Thani.

| Parameter                  | Month 2018      |
|----------------------------|-----------------|
|                            | May  | Jun  | Jul  | Aug  | Sep  | Oct  | Mean     |
| Wind speed (ms⁻¹)          | 10.1±2.2 | 7.4±2.7 | 12.6±2.9 | 12.6±5.0 | 10.2±2.7 | 9.4±1.7 | 10.38±2.0 |
| Air Temperature (°C)       | 30.6±1.3 | 30.0±1.4 | 28.8±3.3 | 30.4±2.1 | 31.0±1.7 | 31.0±1.7 | 30.30±0.8 |
| Relative humidity (%)      | 67.2±10.1 | 70.8±10.4 | 79.2±13.7 | 69.2±10.4 | 66.2±10.3 | 48.2±3.5 | 66.80±10.2 |

3.2. Monthly variation of benzene at roadside

The monthly variation of benzene in Udon Thani was measured at five sites from 6 months from May to Oct 2018. The concentration of benzene at roadside all sites ranged from 0.004±0.0017 to 2.120±2.519 mg/m³ is illustrated in Figure 2. The average concentration of benzene the entire samples collected was found to be 0.588±0.862 mg/m³ and the median was 0.112 mg/m³. The high concentration of benzene showed the temperature minimum and humidity maximum. The concentration of benzene was the highest as 2.120±2.967 mg/m³ in Jul, to as the lowest as 0.004±0.0017 mg/m³ in Oct, respectively. This is because of the concentration of benzene along the roadside differs significantly from the high concentration at the low atmospheric temperature. Monthly variations are mostly dependent on emission with meteorological information, sources strength, and quantitative of vehicles [3, 4]. The lower temperature including high humidity and wind speed might be effective to a variation of benzene concentration [5]. When compared with other sites country, it could be found that the levels of benzene in Udon Thani of Thailand was higher than other megacities.
Figure 2. Monthly variation of benzene concentration.

Figure 3 depicts that higher a total car volume was observed on monthly having the benzene concentration of high. The results showed that a total car volume rang in 5,747-7,038 in traffic congestion in Udon Thani. It clearly illustrates the total car volume during Jul and Oct as compared to the respective levels for benzene and the meteorological. The higher benzene concentration as 2.120±2.967 mg/m³ in Jul had the total car volume of the highest (7,038), while the lower benzene concentration as 0.004±0.0017 mg/m³ in Oct had a total car volume of the lowest (5,757). Furthermore, the temperature in Jul was the lower (28.8±3.3°C) compared with the temperature in Oct (31.0±1.70°C). This might be probably because benzene was slowly evaporated in low temperature, hence, the concentration of benzene was high. In another factor, benzene was constituents of gasoline and is emitted into the atmosphere by many car exhausts from these roadsides [2, 3]. Therefore, the comparatively higher concentrations of Benzene might be due to more total car volume and hence greater exhaust emissions. In addition, benzene concentrations in this study were compared with other roadside studies reported from different countries of Asia. It indicates that the concentrations of benzene were higher than those reported in China (51.5 µg/m³), Philippines (11.8 µg/m³), and India (14.7 µg/m³) [4].

Figure 3. Monthly variation of a total car volume on the roadside.

3.3 Comparison of benzene concentration with difference sites
High levels of benzene were investigated in various sites with a high traffic density on the weekday. The reason for the enhanced concentration was slowly attributed to the increase of the vehicular population. Benzene concentration was found on the roadside from discharged of vehicles at 1.260±2.418 mg/m³ in roadside of the university, 0.939±0.298 mg/m³ in roadside of the shopping mall, 0.739±1.808 mg/m³ in roadside of hospital, 0.001±0.0017 mg/m³ in roadside of the market, and 0.001±0.0015 mg/m³ in roadside of the park, respectively. The concentration of benzene at the roadside in Udon Thani is illustrated in Figure 4. Vehicular emissions were many reported to be responsible for benzene emissions [1, 7]. Moreover, the high of traffic jam might be a major source of ambient benzene in many urban areas.
The trends of benzene concentration at all the roadside sites observed in this study found that the university was the maximum of benzene concentration on a roadside. This is because of the highest number of vehicles caused to increase benzene emission from fuel. For comparison another factor, the total car volume at various sites from the roadside is presented in Figure 5, which shows that the highest total cars at the university from the road and benzene increases with increasing number of vehicles from the road. It could be concluded that the concentrations of benzene increased considerably with the high of the number vehicles on roads. Although the air in Udon Thani was collected and determined at various sites the concentration of benzene was stilled high in some area. This is because the level of benzene depended on the traffic density on the roadside. In addition, benzene caused motorbike emission or car repairing works, cigarette smoking or evaporation from the cars near the roadside were contributed to the higher benzene concentration.

The higher concentration of benzene might be probably due to their emission from gasoline (major fuel of vehicles) which is known to contain a high proportion of these compounds and their long lifetime [5]. The various type of vehicle emission obtained in this study has identified the type of fuel with various emission rate such as motorbike (0.08 g/kg/car), gasoline (0.023 g/kg/car), and diesel (0.001 g/kg/car), respectively [6]. It had a report that benzene emission can be calculated by an emission rate for each type of fuel. Generally, benzene decreased with the number of a vehicle by diesel by 53%, while benzene caused by benzene of vehicle decreased at almost similar rates around 51% [7]. As results, it could be observed that the increasing trend of benzene concentrations in the urban city was mainly caused by the high of total cars on the roadside. Thus the rate of benzene emission can be used to estimate the proximity of vehicular emission source as shown in Figure 6. The results could be observed that the percentage of the motorbike was the highest as 81% that caused to be the emission exhaust from a motorcycle. Gasoline from a personal car was shown at 18%, while diesel emission from a truck was found at 1%. It could be concluded that benzene pollution is the main problem of developing countries especially the country of Thailand. Therefore, the correlations between the concentration of benzene and vehicle types were the main source of fuels caused to contribute the air pollutant on roadsides.
Figure 6. Roadside sites variation of a total car volume.

4. Conclusion
Vehicles are the major cause for the high roadside benzene concentration along the high traffic density of roads at Udon Thani, Thailand. The monitoring of benzene was investigated at five locations, which difference places. The total mean concentration of benzene for the entire samples collected was found ranged from 0.004±0.0017 to 2.120±2.519 mg/m$^3$. The average concentration of benzene was found to be 0.588±0.862 mg/m$^3$. The concentration of benzene reduced significantly with the number of a vehicle from the different roadside. Benzene remained high concentration from traffic that was a high exposure for people living along the main roads. Higher concentration of benzene was observed in Jul as compared to the respective levels on another month. This is a temperature effect by meteorological in Udon Thani. They concluded that traffic emissions were the main source of benzene in the urban area. A high level of benzene emission was depended on the number and type of vehicle including a composition of fuels. Therefore, the risk of cancer through benzene exposure from vehicles emission was the main effect for the population who live near the heavy traffic on the roadside.

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