A FRAMEWORK FOR MONITORING AND MODELLING OF BTEX IN VARIOUS DEVELOPMENT STATUSES IN PENANG, MALAYSIA

WESAM AHMED AL MADHOUN*, NOR AZAM RAMLI, AHMAD SHUKRI YAHAYA, NOOR FAIZAH FITRI MD YUSUF, NURUL ADYANI GHAZALI, , NURULILYANA SANSUDDIN
Clean Air Research Group, School of Civil Engineering, Universiti Sains Malaysia, Penang, Malaysia.
Email: wsah79@yahoo.com

ABSTRACT

The development and urbanization process in Malaysia are believed to contribute to the deterioration of air quality. The rapid growth of the Malaysian economy lead to the increase of motor vehicles ownership, in 2006, there 6.91 million registered cars running on the roads in Malaysia. Benzene, Toluene, Ethylbenzene and Xylene (BTEX) form an important group of aromatic Volatile Organic Compounds (VOCs), emitted mainly from cars, where BTEX is a known carcinogenic. The initial results of a pilot study that was carried out at the engineering campus, USM, to monitor BTEX come out of the motor vehicles, motor bikes and engines, show high concentrations of BTEX (7.5, 6.1, 12.3 and 3.9 ppm respectively).This study aims to propose an a framework to measurer and model BTEX concentrations in two busy places (Penang Bridge, Komtar area) and one rural area in Penang. The results of this research clarify the current status of BTEX concentrations in Penang and pave the way for a suitable action to be taken to reduce BTEX concentrations.

Keywords: BTEX; Emissions; Vehicles; VOC.

INTRODUCTION

Benzene, toluene, ethylbenzene and xylene (BTEX) are elements of an important group of aromatic Volatile Organic Compounds (VOCs), they are emitted from many sources notably from vehicles. BTEX play a vital role in the troposphere chemistry and poses health risk to human [7]. Benzene is known as a carcinogenic compound, which is emitted mainly from petrol-fuelled cars and thus it is found in all urban areas [18].

The relative contributions of light-duty vehicles (LDV) and heavy duty vehicles (HDV) to the total emissions indicated that aldehydes, BTEX (benzene, toluene, ethylbenzene, xylenes), and alkanes are mainly produced by LDV, while HDV dominated emissions of CO, NO_x, SO_2, and PM_{10} [17].

The objectives of the study will be: investigation of the BTEX issues in Penang Roadside, measuring of BTEX concentrations in two busy places (Penang Bridge and Komtar) and a rural area in Penang, development of modeling system of the BTEX concentrations prediction and developing a methodology for prediction of BTEX emission factors from motor vehicles

RESEARCH BACKGROUND

Air pollution is defined as the presence in the outdoor and or indoor atmosphere of one or more contaminants or combinations thereof in such quantities and of such duration as may be or may tend to be injurious to human, plant, or animal life [22].

The rapid growth of the Malaysian economy over the past 27 years, due to the development of industrial estates, free trade zones, thermal power plants and petroleum industries, which could result in the deterioration of the environment if due care is not taken. The severity of the environmental problems associated with air quality degradation may result from, vehicles emissions and industries, particulate matters from stacks and exhaust, dust from quarrying activities, construction projects and open burning [6].

In several large cities, the air pollutants are increasing with time and at times exceed the levels prescribed by the national ambient air quality standards. This has been shown from the monitoring data and studies on ambient air quality. There are three major sources of air pollution viz., mobile, stationary and open burning. Figure 1 illustrates the percentage contribution of each source in Malaysia [1].

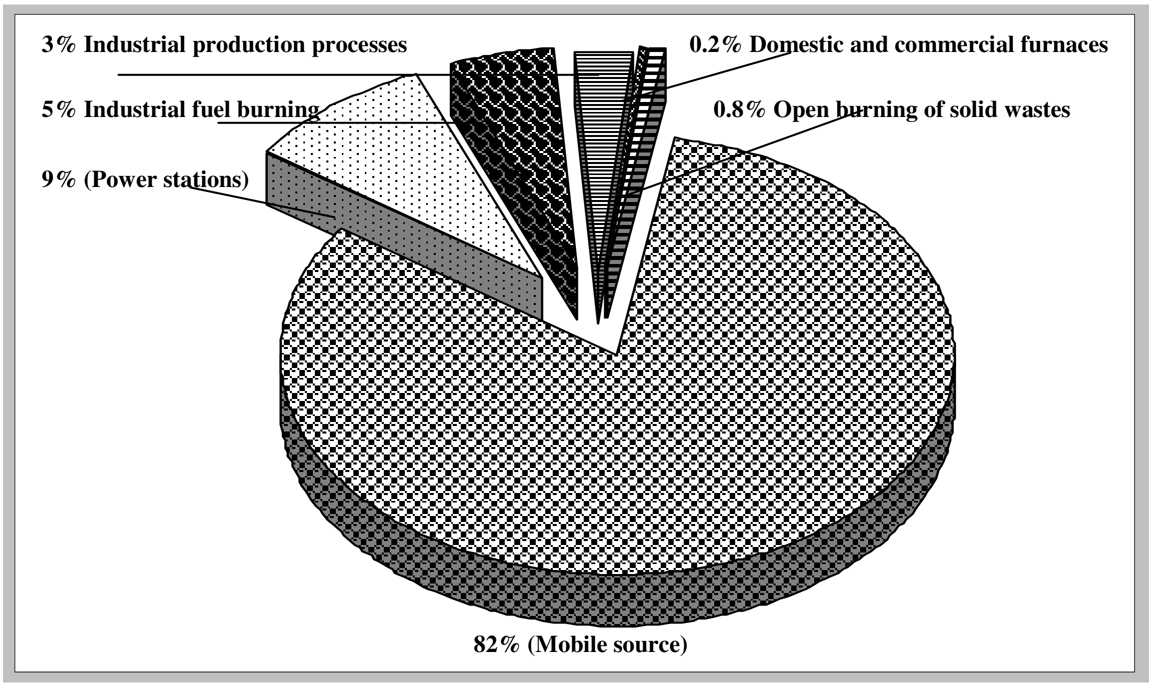

Figure 1: Sources of Air Pollution in Malaysia
Adopted from [1]

There has been marked increase in motor vehicles ownership. In 2006, there are 6.91 million registered cars running on the roads in Malaysia [15]. In motor vehicles fuel, Benzene is the additive. Benzene is mostly produced by chemical reactions occurring during combustion of petrol in the engine.

The EPA Complex Model indicates that benzene emissions account for nearly 70 percent of the total toxic emissions from vehicles using conventional gasoline and that exhaust benzene accounts for nearly 90 percent of the total benzene [23].

In Malaysia reduction of lead content started in July 1985 from the initial of 0.84 grams/liter to 0.5 grams/liter and further reduced to 0.15 grams/liter in January 1990. Benzene levels is limited to 5% by volume (Euro2) by year 2004 and will be further reduced to 1% (Euro 4) by year 2009 [3].

The estimated world-wide average emissions of VOCs are about 1347 million tons (Mt)/year from biogenic sources and 462 Mt/year from anthropogenic sources. Ambient total concentration of airborne VOCs (155 species) in urban and suburban areas have been reported to be in the range 16.2–1033 $\mu g/m^3$. Some VOCs have toxic health effects depending on duration and levels of exposure, even at $\mu g/m^3$ concentrations (e.g., exposure to

BTEX at high levels can cause respiratory, neurological, genetic and excretory system damage) [2].

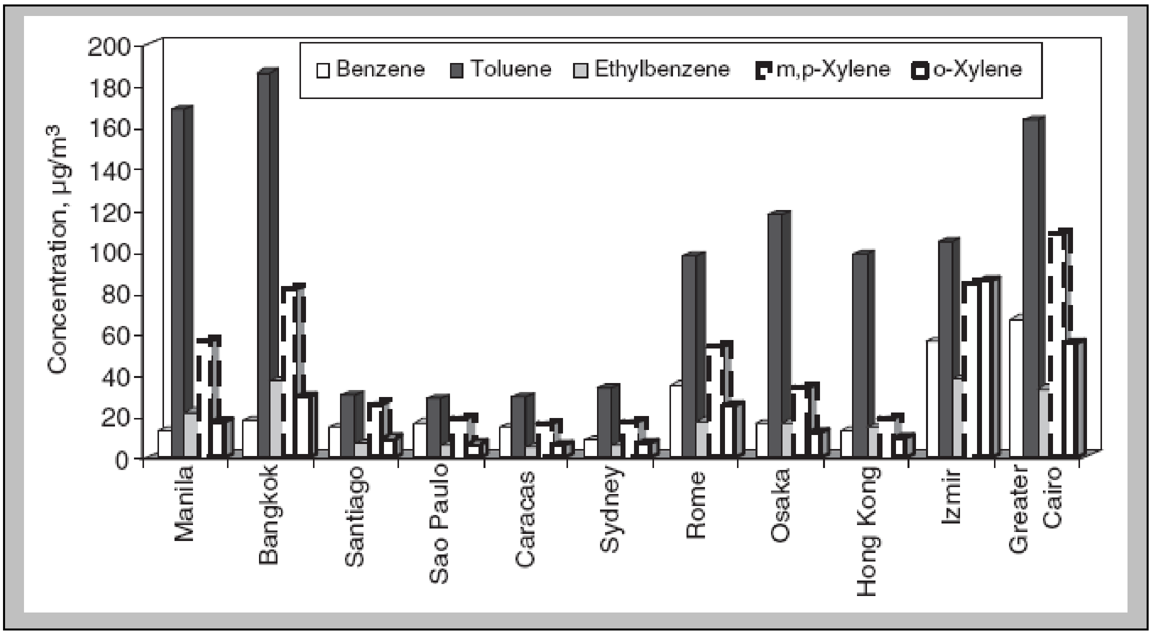

Figure 2: Comparison of BTEX Concentrations for Different Cities Worldwide
Adopted from [8]

Statistics on transport-related pollution death for Penang and Malaysia is yet to be available for reference purposes, figures in London shows that each year, Londoners lose about 34,000 years of life from transport related pollution and this high figure is very much related to the average traffic speed in central London of 16 kmph due to the ever worsening congestion. In addition, soot from diesel pollution also leads to 27,000 non-fatal heart attacks and more than 400,000 emergency room visits in the US annually [19]. Benzene at the busy road was not fully understood.

WHO has estimated that a lifetime exposure of 0.17 $\mu g/m^3$ gives rise to an excess risk of developing leukemia of 1 per 1,000,000 inhabitants based on toxic-kinetic models [19]. In Sweden, relationship between acute myeloid leukemia (AML) and car density was found; the incidence of AML was 5.5 in regions that have more than 20 cars / km^2. Low benzene concentrations in ambient air are likely to be dangerous; other studies have also found an association between traffic density and incidence of leukemia in children [16].

Table 1: Previous Studies on BTEX (Adopted from [5])

Study	**Location**	**Exposure type (duration)**	**Subject or place**	**Pollutants**	**Level ($\mu g/m^3$)**
Wang et al., 2002	China	Urban roadside (30 min)	Guangzhou	BTEX	51.5/ 77.3/ 17.8/ 81.6
Rommelt et al., 1999	Germany	In buses and trams (2-3 hours)	Munich	BTX	15 42.1 / 37.3
Schmid et al., 2001	Austria	Tunnel	Tauerntunnel	BTEX	4.5 / 9.4 / 2 / 6.7
Bae et al.,	Seoul,	Indoor (8 h)	Shoe stall	BTX	732 / 6777 / 5382

2004	Korea		salesperson		
Mukherjee et al., 2003	Kolkata, India	Personal (3–4 h)	Bus driver	Benzene Toluene *o*-Xlyene *p*-Xylene	527.3 472.8 1265.5 402.8
Romieu et al., 1999	Mexico City	Personal (work shift)	Gas station attendant Street vendor Office worker	BTEX BTEX BTEX	310/ 680/ 110/ 490 77/ 160/ 28/ 128 44/ 470/ 17/ 81
Barletta et al., 2002	Karachi, Pakistan	Ambient (4–6 h)	Traffic street	BTX	16.6/ 26.8/ 8.2
Batterman et al., 2002	Detroit, USA	Vehicle/roadway (2–3 h)	Bus	BTEX	4.5/ 10.2/ 9/ 2.1
Gonzalez-Flesca et al., 2000	Rouen, France	Personal (5 days)	Non-smoker	Benzene	10.3

STUDY AREA

The study will be carried out at two busy places in Penang (Penang Brdige and Komtar) and a rural Area (Kampung).

Penang State:

Penang is one of the 13 states of Malaysia and is situated on the north-western coast of the peninsula. It is bounded to the north and east by the State of Kedah, to the south by the State of Perak, and to the west by the Straits of Melacca and Sumatra (Indonesia). Penang consists of the island of Penang (Pulau Pinang) and a coastal strip on the mainland called Province Wellesley (Seberang Perai). Penang has an equatorial climate which is quite uniform throughout the year. The climate is warm and humid where the average minimum 23.3 degree Celsius [13]. The area of Penang state is 1046.3 sq km, latitudes 5° 8' - 5° 35', longitudes 100° 8' - 100° 32' and the population number is 1.4 million [12].

In Penang, there are 1,551,650 registered motor vehicles (MV) averaging to 1.06 cars per person for a population that totals 1,468,800. The MV registration rate is increasing at an average of 9.5 percent per annum – higher than the country's rate of 7.2 percent and the fact that the in 2001, Asian Demographics placed Malaysia second only to Japan in the number of households owning a car indicates the comparatively high level of car ownership in Penang [19].

A survey conducted by Japan International Cooperation Agency (JICA) (1988) identified the main transportation problems in Penang Island, particularly in George Town, as congestion combined with rapid increases in car ownership, high rates of accidents mainly due to lack of traffic safety policies, lack of auto education, inadequate space for pedestrians and a shortage of parking spaces [21].

FRAMEWORK METHODOLOGY

The methodology of the study will be as follows:

1. Conducting a literature review study (Environmental overview, Air components and pollutants, human activities in Penang and air pollution, air pollution monitoring systems and modeling).
2. Locating of the monitoring sites.
3. Determination of the methods and instrument to be used

4. Training on the instrument that will be used in the monitoring and analysis process (GC and multi-Gas PID Meter).
5. Design of the monitoring process
6. Conducting the monitoring, sampling and data collection.
7. Data and sample analysis
8. Data modeling.
9. Thesis finalization

Instruments

Gas Chromatography, which is a well know instrumental method for separation of chemical compounds.

- The Samples will be analyzed using a gas chromatograph equipped with a flame ionization detector (GC–FID).
- FID detects analytes by measuring an electrical current generated by electrons from burning carbon particles in the sample.

Multi-Gas PID Meter

- Probes offer a choice of two different Photo Ionization Detector (PID) sensors optimized for each application.
- PID measures difference in the current flow between two electrodes cause by ionization of the gas by ultraviolet radiation [4].

Sampling

- Hourly samples for BTEX will be collected using SKC_cocnut shell charcoal tubes (6mmX70mm).
- Sampling will be conducted during both the peak and off-peak time periods, which will be determined based on preliminary traffic studies.
- After sampling and during transport, all sampled tubes will be placed in air-tight plastic bags and stored in an icy box.
- The samples will be refrigerated before analysis at the laboratory of USM ([14]; [7]; [20]).

Analysis by GC

- BTEX will be analyzed using the NIOSH method **[**9**]**. The sampled SKC tubes will be desorbed in 1mL carbon disulfide and allowed to stand with occasional shaking for 30min.
- The extract will be analyzed using a gas chromatograph equipped with a flame ionization detector (GC–FID) and a capillary column (F.S.SUPELCOWAX10 30mX 0.32mmX 1.0 μm film thickness).
- A 2 μL of sample extract will be used for one injection. Each sample will be injected twice and the average results are reported. The oven temperature will be set initially at 40 C° for 3min and will be then raised to 88 C° at a rate of 8 C° min^{-1}.Both the auxiliary and detector temperatures will be set at 250 C°.
- Benzene contamination in the carbon disulfide solvent will be removed before it was used for sample extraction by using concentrated sulfuric acid and concentrated nitric acid [10].
- The mixed standard of BTEX (Fluka manufacturer) will be used for quantification of the compounds. ([14] ; [7] ; [20]; [8]).

INITIAL RESULTS AND EXPECTATIONS

A pilot study to measure BTEX concentration was carried out in the engineering campus of Universiti Sains Malaysia (USM) on May, 2008. BTEX concentrations were measured by using Multi Gas PID Meter. The measurements taken place inside a cars petrol tank, cars exhausts and motor bikes exhaust. The results show high concentrations of BTEX as shown in figure 3 and 4.

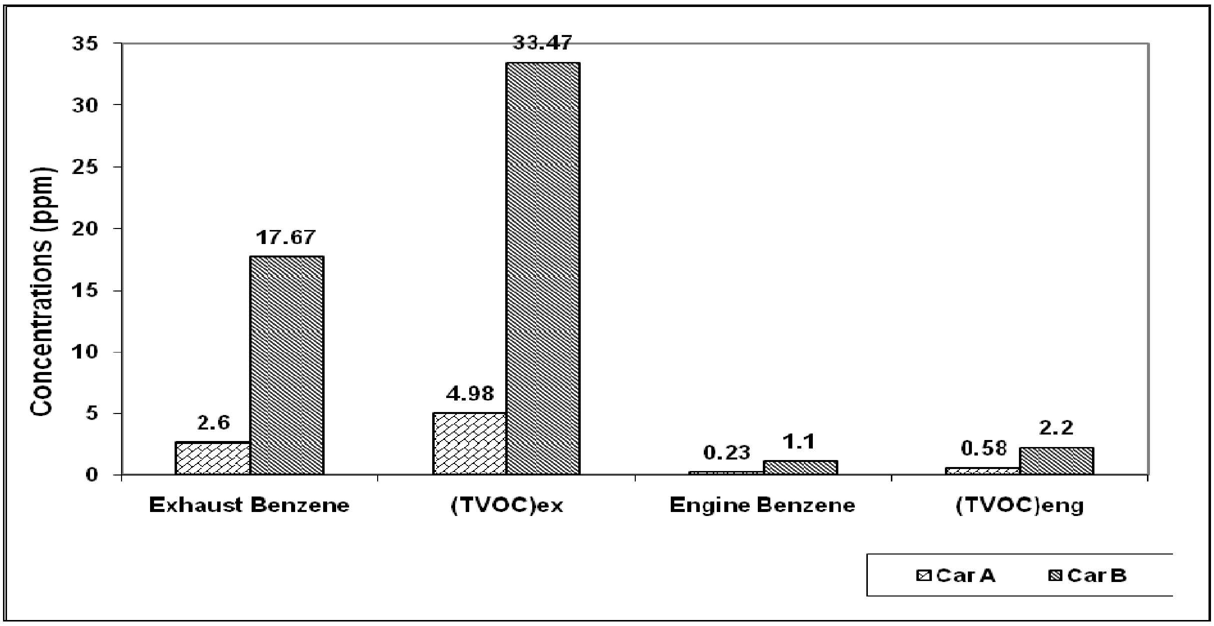

Figure 3: Benzene Concentration in the Engineering Campus, USM

The US Occupational Safety and Health Administration (OSHA) has set a permissible exposure limit of 0.5 part of benzene per million parts of air (0.5 pm) in the workplace during an 8-hour workday, 40-hour workweek. The short term exposure limit for airborne benzene is 5 ppm for 15 minutes [11].

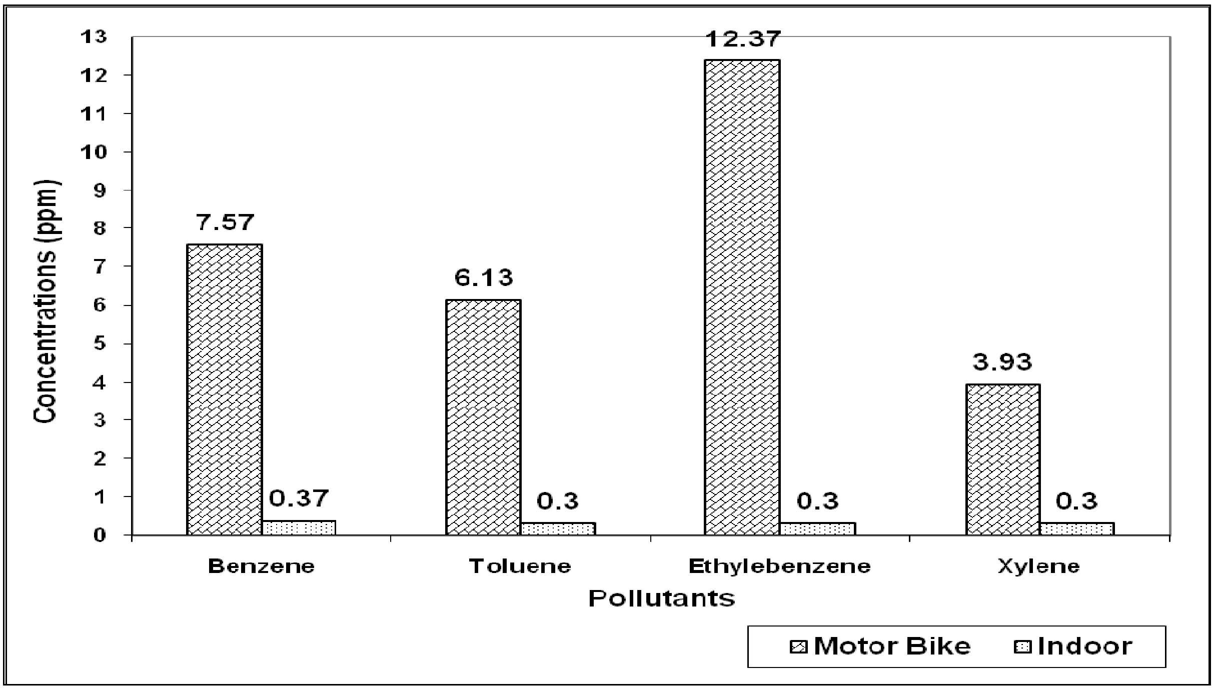

Figure 4: Comparison of BTEX Concentrations

After completing the study, there will be: inventory of spatial BTEX concentrations in Penang and suitable (BTEX) prediction model will be developed. Moreover, this study will have good contribution to the public health sector, where at the end of this research a clear vision of the current concentrations of BTEX will be established which will make it easier to the decision makers to take the suitable actions to reduce the BTEX levels up to the international standards to save the community health from the expected risks.

CONCLUSION

The high BTEX concentrations (7.5, 6.1, 12.3 and 3.9 ppm respectively), that were revealed by the pilot study proved the importance of carrying out a large scale study to measure and model the BTEX trends in the busy places, where the prediction model will act as alert tool to the public and the decision makers.

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