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BTEX Profile in Ambient Air of in and around Gangtok (Sikkim) – North-East Himalayan Region

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ABSTRACT

The present study aims to provide an indication of ambient levels of BTEX, a group of VOCs in and around Gangtok (Sikkim) for the first time in the history of North-East Himalayan Region of India. The study on VOCs particularly BTEX are important because they can present a health risk to humans, animals, and vegetations. Benzene is classified as a "Group A, known human carcinogen of medium carcinogenic hazard" by the United States – Environmental Protection Agency (Beim et al, 1998). Chronic (long-term) exposure to benzene is associated with haemotoxicity, genotoxicity, and carcinogenicity. For monitoring of BTEX levels, five sites were selected based on land use pattern i.e. Remote area, Commercial area, Residential area, Traffic Intersection area and Industrial area. The BTEX levels were observed for two years on monthly basis at these sites using passive sampling. The levels of pollutants were highest in the winter season, at traffic Intersection area and lowest in monsoon season, at remote area. The annual average concentration of benzene was slightly higher at traffic Intersection area in Gangtok (Sikkim) during June-2015 to May-2016 (II year) of measurement than its prescribed limit i.e. 5 µg/m³ as per National Ambient Air Quality Standards 2009 (NAAQS) of Central Pollution Control Board, Delhi. So, this is an alarming situation to ecosensitive and fragile environment of Gangtok (Sikkim).

1. Introduction

A part of the Eastern Himalaya, Sikkim is a northeastern state of India which is surrounded by Tibet (China), Bhutan, Nepal and the Indian state of West Bengal in its north & northeast, east, west and south respectively. Sikkim is the least populous with a total population of 6,10,577 as per Census 2011 and second smallest among the Indian states with total area 7,096 km^2. Sikkim, which is one of the most beautiful and peaceful state of India, is a world famous tourist place, and also notable for its biodiversity and subtropical climates. Mount Kanchenjunga is the highest peak in India and third highest on Earth also lies in this region. Sikkim is the most environment-friendly state of India, which has come forward to ban plastic water bottles and Styrofoam products **(1-2)**. Sikkim has been ranked as top performing state in a Swachhta (cleanliness) survey conducted by the National Sample Survey Office (NSSO) in 2016.

Therefore, due to development of industries, means of transportations, population, and deforestation etc, Sikkim is also facing the effects of global warming and air pollution. Industrialization & urbanization is bound to increasing air pollution. With the use of fossil fuel & petroleum products organic compounds BTEX are emanated into the environment, whether outdoors or indoors. By inhaling such polluted air human health is jeopardized **(3-5)**. BTEX (Benzene, Toluene, Ethylbenzene, and Xylene) are volatile, monocyclic and aromatic compounds present in coal tar, petroleum products, and various organic chemical product formulations **(6)**. These are the most soluble of the major gasoline compounds and, therefore, are common indicators of gasoline contamination **(7)**.

We, all are responsible for producing BTEX into the environment by emissions from different categories of vehicles. Very often, when we carry on petroleum products from one place to another, they also pollute the environment due to leakage, mishandling etc. Smoking of cigarette also increases the concentration of these pollutants in the air. The refineries are also responsible for creating BTEX during its process. The consumer products like paints, lacquers, plastics, nylon, insecticides, dyes, thinners, rubber products, adhesives, inks, detergents, cosmetics and pharmaceutical products **(8-12)** etc are also responsible to increase the amount to BTEX during their productions and the chemical reactions they undergo for their formations.

BTEX chemicals vapourise easily i.e. they change from a liquid to a gas form. Their vapours can pollute the air, groundwater, soil and harm nearby communities. Almost everyone to some degree or other is exposed to BTEX in their environment, whether outdoors by breathing in vapours from autos on the streets to pumping gasoline or indoors through house furnishing (paints, carpets), personal care products (perfumes, room fresheners), water by drinking (ingesting), bathing or laundering (inhaling), or doing laundry (exposure through the skin).

The main concern of VOCs/ BTEX is the role they play in the formation of Ozone, photochemical smog **(13)** and Global warming by Intergovernmental Panel for Climate Change (IPCC). Besides their environmental effects, VOCs also have many harmful effects to human health even at lower concentrations. They affect different target organs e.g. central nervous system, respiratory system, liver, kidney, reproductive system etc **(14-15)** as well as to vegetation **(16)**.

The VOCs/ BTEX in general, have a positive correlation with severe symptoms of asthma among children **(17)**. BTEX have long been an object of study in occupational epidemiology; thus, the health effects of these compounds among highly exposed populations are well–known, especially those caused by chronic exposure to benzene, which is considered to have more serious consequences than exposure to other compounds of this type. Indeed, there is scientific evidence that benzene exposure is one of the risk factors for leukemia **(18)** and other types of cancers **(19)** and that it has immuno-toxic effects **(20)**. In this context, one study found a significant amount of liver damage or hypertransaminasemia, among workers at a petrochemical plant **(21)** while an increase in chromosomal aberrations was noted among workers in petrol refinery plants **(22)**. Toluene is less toxic and causes drowsiness, impaired co- ordination, liver and kidney damage **(23-24)** less than Benzene.

Volatile organic compounds (VOCs) include a large group of chemicals containing carbon and hydrogen atoms that can react quickly to form other chemicals in the atmosphere and BTEX is an important group of VOCs.VOCs can also react with oxides of nitrogen (NOx) to form ozone (O_3), a health hazard and major contributor to smog. Because of the extensive use in industries and the presence of these compounds in fossil fuels, their emission resources are very diverse. In order to make our environment safe, it is our prime duty to study VOCs and also due to the inclusion of these parameters in the new notification November 2009 by "Ministry of Environment and Forests, India."

The study on VOCs particularly BTEX are important because they can present a health risk to humans, animals and vegetation. Benzene is a known carcinogen causing blood leukemia. So, it may be an emerging area for the research work on air pollution. There is no study on BTEX levels in Gangtok (Sikkim) till date. So, this study will generate baseline data on BTEX first time for Eastern Himalayan region. As BTEX are carcinogenic and tumorigenic to human and also have an impact on the ground level ozone generation, hence data will provide useful information along with compliance level of National Ambient Air Quality Standard laid down for the Benzene by MoEF & CPCB.

2. Materials and Methods/ Methodology

2.1) Study area

In and Around Gangtok (Sikkim) area has been selected for this study as shown in Figure 1. Gangtok with Coordinates 27.33°N 88.62°E, is the capital and the largest town of the Indian state of Sikkim as well as the headquarters of the East Sikkim district with area 35 km^2. In East Sikkim district, more than one-third of the state population i.e. 283583 out of total population of 610577 lives with approximately 35000 registered vehicles. Gangtok is located in the eastern Himalayan range, at an elevation of 1,650 m (5,410 ft). The town's population is 98658 as per 2011 Census with population density 5675/km^2.Gangtok is at the centre of Sikkim's tourism industry. It features a monsoon-influenced subtropical highland climate and due to its elevation and sheltered environment, Gangtok enjoys a mild, temperate climate all year round. Temperatures range from an average maximum of 22 °C in summer to an average minimum of 4 °C in winter. Gangtok is connected to the rest of India by a National Highway 10, earlier known as National Highway 31A, which links Gangtok to Siliguri, located 114 km away in the neighbouring state of West Bengal.

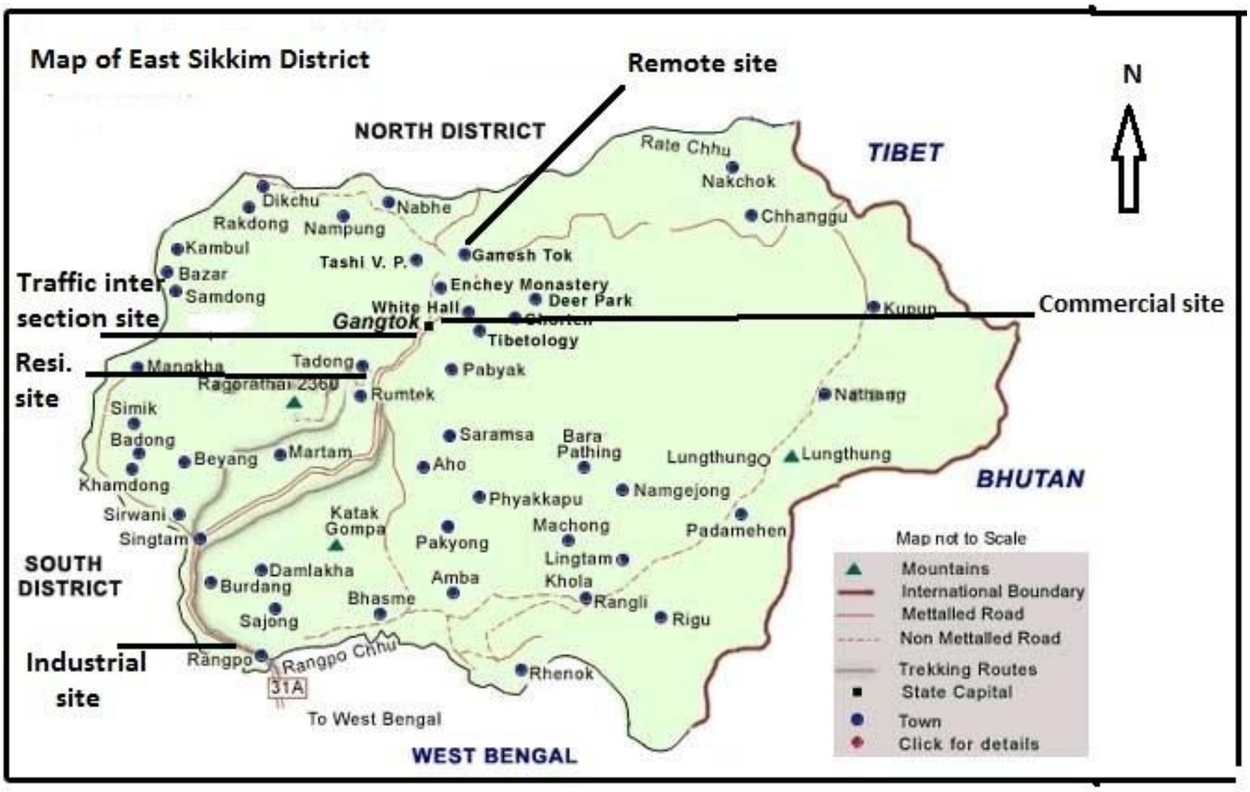

Fig-1, sampling sites in and around Gangtok (Sikkim)

2.2) Study Site

For monitoring of BTEX levels, five sites were selected based on land use pattern i.e.

I. **Remote area –** this site was selected at Bulbuley, near Sikkim Himalayan Zoological Park, Gangtok. It is at a distance of about 05 km from Mahatma Gandhi Marg with a lot of greenery and almost the least polluted area of Gangtok.

II. **Commercial area –** it was at Mahatma Gandhi Marg, Gangtok. This area is town centre and the best shopping destination for tourists. Mahatma Gandhi Marg in Gangtok is close to National Highway 10.

III. **Residential area –** this site was at Tadong, near NHPC complex, Gangtok, which is about 06 km from Mahatma Gandhi Marg.

IV. **Traffic intersection area -** At Indira Byepass, Gangtok was selected for this area. This site is situated on NH 10. This site is one of the busiest traffic area & about 04 km from Mahatma Gandhi Marg, Gangtok.

V. **Industrial area -** due to absence of industrial area in Gangtok city, Majitar of East Sikkim district was selected as Industrial area (semi Industrial area) for this study. This is situated at NH 10 and about 34 km from Gangtok.

The study period of the BTEX profile was observed for two years i.e. **from June-2014 to May-2016** on monthly basis at these sites.

2.3) Sampling Procedure/ Experiment and Instrumentation

A **SKC, USA passive sampler (catalogue No. 575-001) using charcoal sorbent 350 mg** was used for sampling of ambient air on monthly basis. The sampler was located at height of 2.0 to 3.0 meter above the ground level at the sampling sites. After completing the sampling period, the sampling charcoal tubes were sealed by wrapping with aluminium foil in an opaque, clean and airtight container immediately in order to prevent further adsorption of compounds on the tubes and also by storing them below 4^{0}C before analysis. Samples collected through passive sampling technique (activated charcoal tube method) were desorbed by conventional solvent using CS_2, 2ml in an ultrasonic bath for half an hour twice. Carbon disulphide desorbed samples were analyzed using Gas Chromatograph (GC) fitted with a capillary column and Mass Spectroscopy (GC-MS) with model no. **Agilent Technologies 7890 A GC system (Agilent Technologies 5975 C) inert MSD with Triple Axis Detector (Germany make).**

3. Results and Discussions

3.1) BTEX Concentration

Benzene Concentration- The annual average concentration of Benzene was found 0.95, 2.87, 2.29, 4.63 and 3.23 µg/m³ during May-2014 to June-2015 (I year) and 1.07, 3.16, 2.52, 5.17 and 3.45 µg/m³ during May-2015 to June-2016 (II year) at Remote, Commercial, Residential, Traffic intersection and Industrial area respectively as shown in Fig-2 & 3. The annual average concentration of Benzene was the highest i.e. 5.17 µg/m³ at Traffic intersection area in winter season (Nov – Feb), which was slightly higher than its prescribed limit i.e. 5 µg/m³ as per National Ambient Air Quality

Standards 2009 (NAAQS) of Central Pollution Control Board, Delhi. This concentration was the lowest at Remote area in monsoon season (Jul- Sep). There was an increase in annual average concentration of Benzene during II year in comparison to I year and it was 11%, 9%, 7%, 8% & 10% for Remote, Commercial, Residential, Traffic intersection and Industrial area respectively.

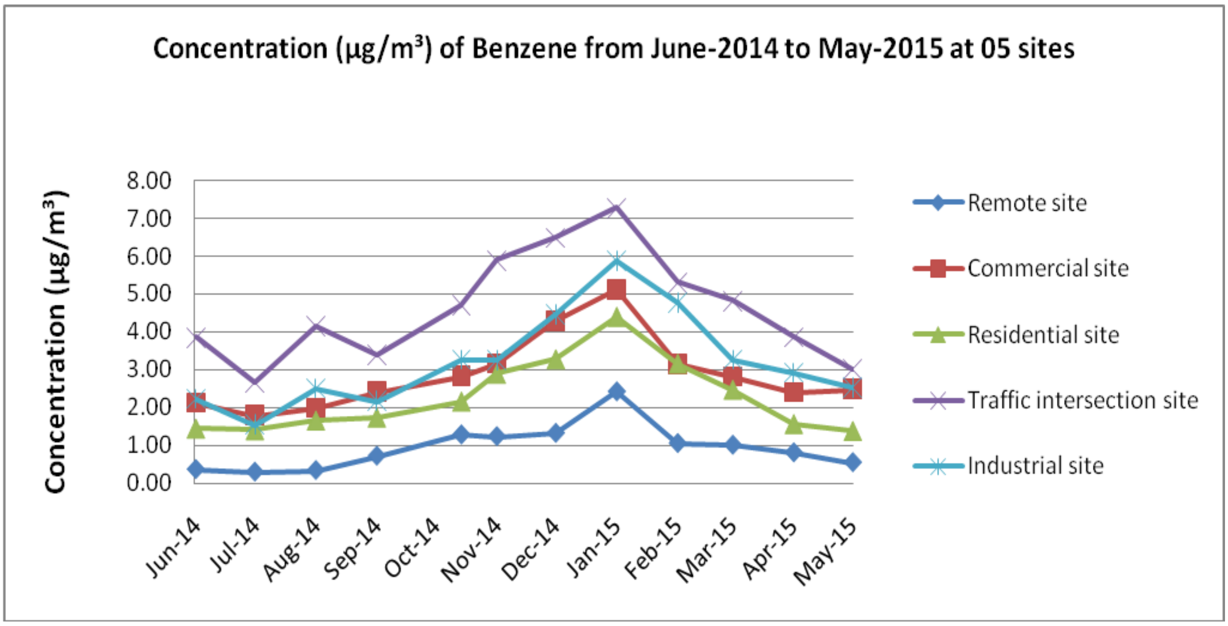

Fig-2, Concentration (µg/m³) of Benzene from June-2014 to May-2015 at 05 sites

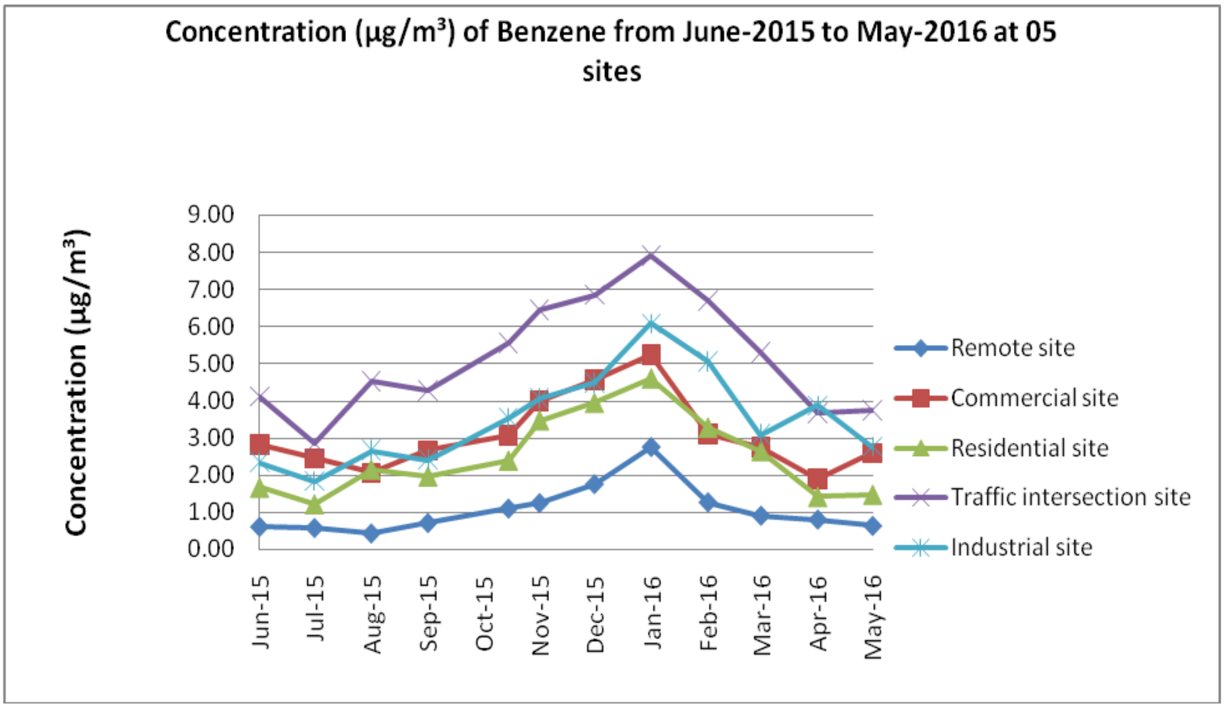

Fig-3, Concentration (µg/m³) of Benzene from June-2015 to May-2016 at 05 sites

Toluene concentration- On the other hand, the annual average concentration of Toluene was found 3.11, 7.55, 6.64, 15.76 and 9.38 µg/m³ during May-2014 to June-2015 (I year) and 3.46, 8.48, 7.22, 16.95 and 10.86 µg/m³ during May-2015 to June-2016 (II year) at Remote, Commercial, Residential, Traffic intersection and Industrial area respectively as shown in Fig-4 & 5. The concentration of Toluene was the highest at Traffic intersection area in winter and the lowest at Remote area in monsoon season. According to several studies, Toluene was found to be the most abundant compound in the urban environment of India **(25-29)**, Iran **(30)**, Spain **(31)** and Mexico **(32)**.

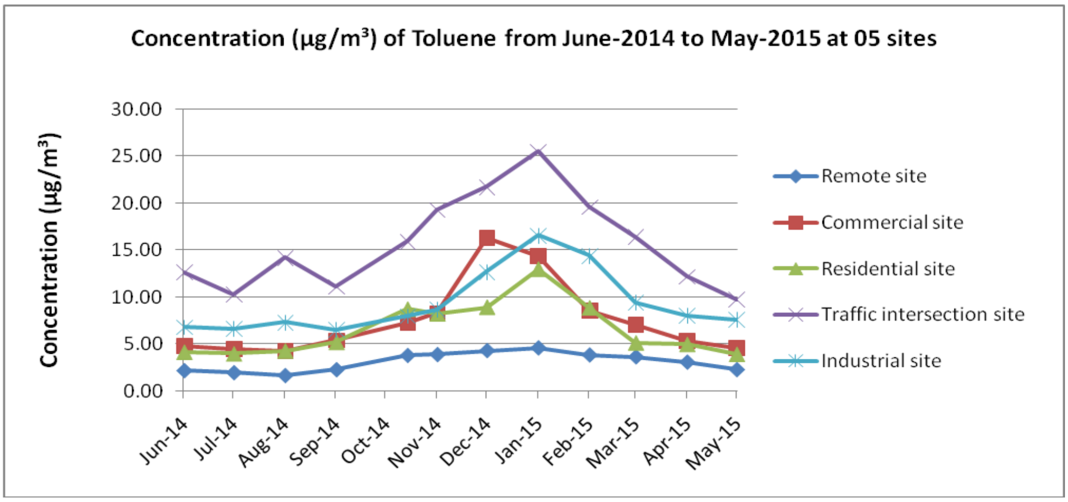

Fig-4, Concentration (µg/m³) of Toluene from June-2014 to May-2015 at 05 sites

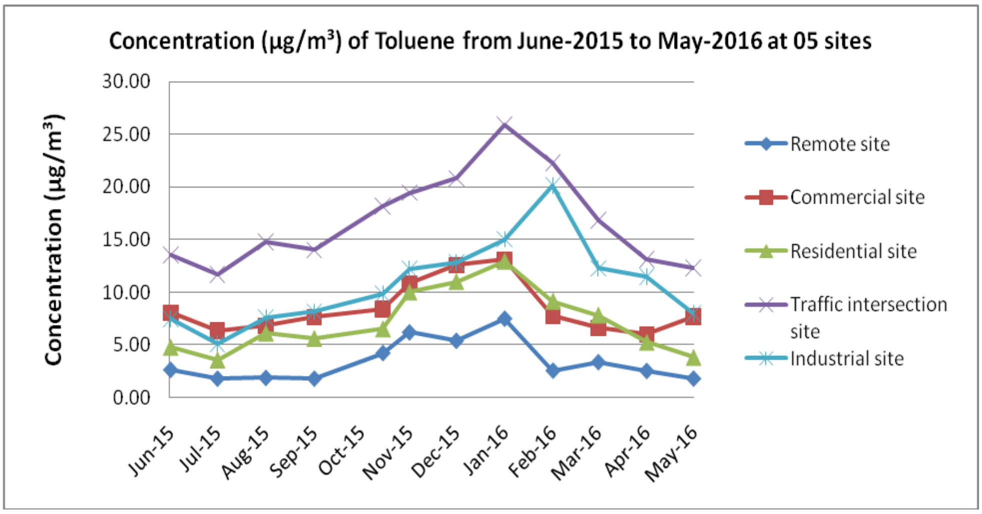

Fig-5, Concentration (µg/m³) of Toluene from June-2015 to May-2016 at 05 sites

Ethyl Benzene concentration – in case of Ethyl Benzene, the annual average concentration was found 0.74, 2.21, 1.58, 4.05 and 2.90 µg/m³ during May-2014 to June-2015 (I year) and 0.84, 2.43, 1.76, 4.40 and 3.26 µg/m³ during May-2015 to June-2016 (II year) at Remote, Commercial, Residential, Traffic intersection and Industrial area respectively as shown in Fig-6 & 7. The concentration of Ethyl Benzene was the highest at Traffic intersection area in winter and the level was lowest at Remote area in monsoon season.

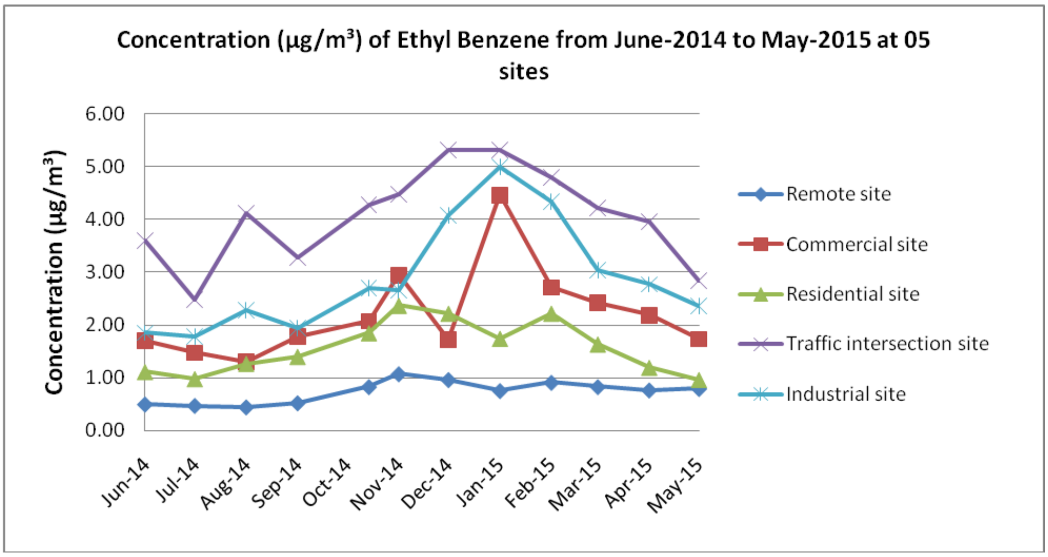

Fig-6, Concentration (µg/m³) of Ethyl Benzene from June-2014 to May-2015 at 05 sites

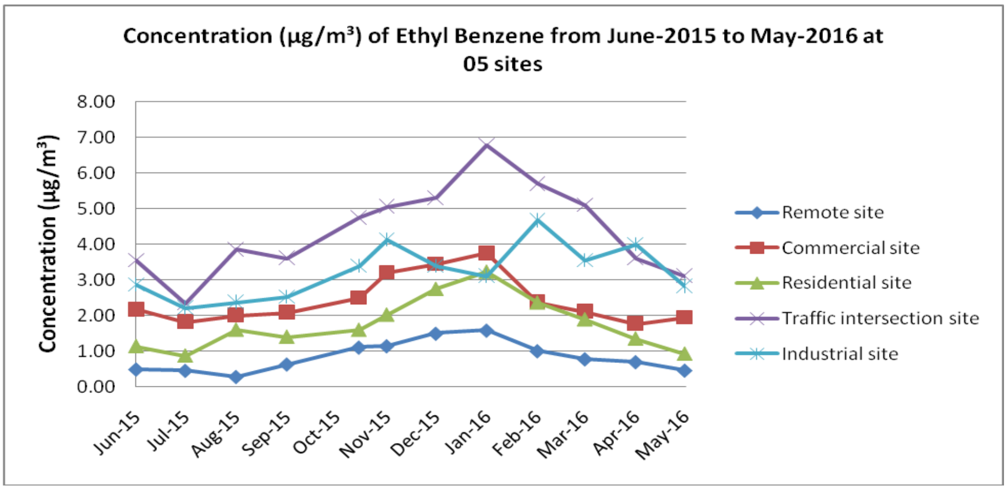

Fig-7, Concentration (µg/m³) of Ethyl Benzene from June-2015 to May-2016 at 05 sites

o- Xylene concentration- The annual average concentration of o-Xylene was found 0.56,1.78, 1.47, 2.10 and 2.05 µg/m³ during May-2014 to June-2015 (I year) and 0.61,1.93, 1.65,2.33 and 2.20 µg/m³ during May-2015 to June-2016 (II year) at Remote, Commercial, Residential, Traffic intersection and Industrial area respectively as shown in Fig-8 & 9. The concentration of o-Xylene was also the highest at Traffic intersection area in winter and the level was lowest at Remote area in monsoon season. O-Xylene was minimum in level among all the 04 pollutants.

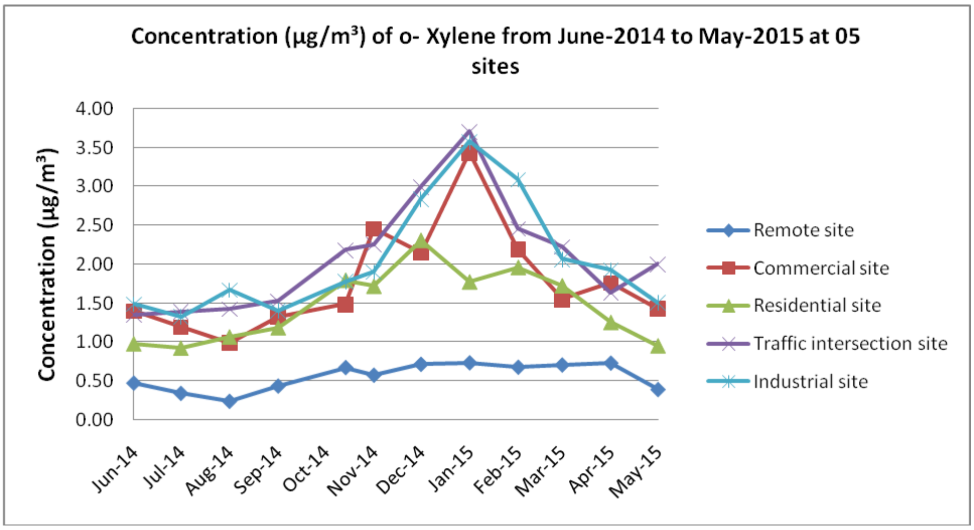

Fig-8, Concentration (µg/m³) of o- xylene from June-2014 to May-2015 at 05 sites

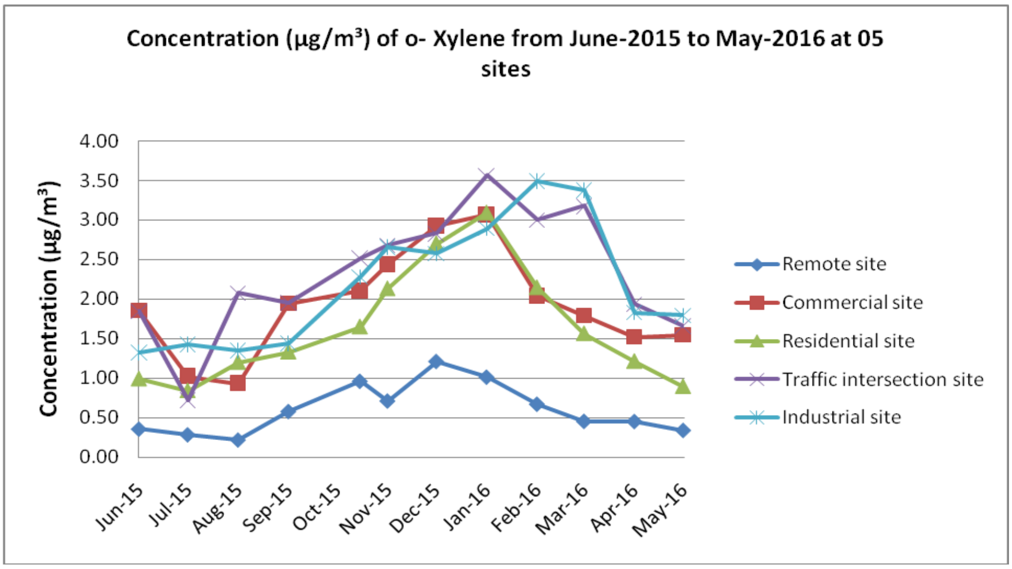

Fig-9, Concentration (µg/m³) of o- xylene from June-2015 to May-2016 at 05 sites

4. Conclusion

This study provides an indication of ambient levels of BTEX, a group of VOCs in and around Gangtok (Sikkim) for the first time in the history of North-East Himalayan Region of India. Benzene is classified as a “Group A, known human carcinogen of medium carcinogenic hazard” by the United States – Environmental Protection Agency. Chronic (long-term) exposure to benzene is associated with haemotoxicity, genotoxicity, and carcinogenicity. The annual average concentration of benzene was found slightly higher i.e. 5.17 µg/m³ in winter season at traffic Intersection area only out of five areas in Gangtok (Sikkim) during June-2015 to May-2016 (II year) of measurement than its prescribed limit i.e. 5 µg/m³ as per National Ambient Air Quality Standards 2009 (NAAQS) of Central Pollution Control Board, Delhi. The levels of all the pollutants were highest in the winter season, at traffic Intersection area and lowest in monsoon season, at remote area. Toluene was found to be the most abundant compound in the environment of Gangtok (Sikkim) followed by Benzene, Ethyl Benzene and o-Xylene. Further, BTEX levels were found to be increased from 7% to 12% during Jun-2015 to May-2016 (II year) in comparison to Jun-2014 to May-2015 (I year) of their measurements. The main reasons for this increment are-increased vehicular traffic, improper tuning of engines, industrial pollution, agricultural waste burning in winter season, solvent handling and fuel adulteration by mixing Toluene, Ethyl Benzene and Xylene etc. So, in order to save the ecosensitive and fragile environment of this beautiful and peaceful place, it is an alarming situation and also the right time to implement all the preventive measures at all levels.

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