EVALUATION OF VOC EMISSION AT MUNICIPAL SOLID WASTE TRANSFER STATIONS SITUATED IN RESIDENTIAL URBAN AREA

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Abstract : The process of Municipal Solid Waste Management is associated with the control of generation, collection, storage, transfer and transport, processing and disposal of solid wastes. Concentration of VOC emissions were measured at major transfer stations of Surat city located in residential areas due to human health and environmental effects as well as on sire vehicular activities. A VOC meter was used to carry out VOC measurement, a simple handy tool is becoming popular nowadays. VOCs are hazardous to human health and also contribute to ozone formation at ground level, responsible for climatic changes as well. VOC emissions were measured considering the temporal variations at Pal and Anjana Transfer Stations. The VOC levels measured in Post-Monsoon were Benzene: 0-22 ppm, Toluene: 0.1-24.6 ppm, Ethyl benzene: 0-5.5 ppm, Xylene: 0-13.2 ppm and TVOC: 0-20.8 ppm. Compared to the Post-Monsoon monitoring, the VOCs level in Post-Winter were much lower due to lower temperature and high relative humidity and thus less gas generation occurred through continuous compaction process.

***IndexTerms* - Municipal solid waste management, VOC meter, Temporal variations, Meteorological parameters.**

1. INTRODUCTION

Industrialization and rapid urbanization has brought serious air pollution problems and has impacted human health in major developing countries. Among the gaseous air pollutants, VOCs are the key components both in polluted and remote regions of the troposphere. In tropospheric photochemistry, VOCs play a key role due to the high abundance of water vapor and intense solar radiation flux (*Md. Aynul Bari, et al, 2017*). Volatile Organic Compounds have considerable roles as the secondary precursors of air pollutants and bad influences on human health. Several VOCs such as alkanes, alkenes, aromatic hydrocarbons, oxygen and nitrogen including materials as well as terpenes can contribute to produce the tropospheric ozone and secondary organic aerosols (SOAs), which are the key components to increase PM2.5 pollution (*Neha Gupta, et al, 2015*). However, several VOCs categorized as class 1 carcinogens, including benzene, formaldehyde and acetaldehyde, have resulted in cancer. In addition, exposure to other VOCs including toluene, Ethyl benzene and trichloroethylene, may have bad impacts on human health. During past recent decades, broad studies have been conducted on the VOC levels and scenarios such as atmospheric and industrial environment as well as vehicle sources, but only a few studies are available about reactivity contributions of VOC spreaded from waste transfer stations (WTS).

Cities are expanding fully and the issues of municipal solid waste (MSW), is becoming critical due to the increase in quantity and complexity of generated waste (*V. Devadas and H. Zia, 2008*). Municipal solid waste management is an essential function of Municipal Corporation and urban local bodies. A viable solid waste framework is expected to better human health and safety. It is estimated that about 10% of each person's production life is lost as a result of waste related disease. There are uncontrolled sector for disposal of solid waste in developing country like India. Municipal solid waste management is an important issue in today's world as it deals with budget allocation of local community, public acceptance and adverse impacts on environment. The most widely recognized issues that related with improper management of solid waste include fire risks, odor nuisance, environmental and water contamination.

Transfer station is a facility which stores waste temporarily in regions nearby urban areas. WTS causes bad impacts on neighborhoods and personnel like noise and emissions of bad odors relating to solid waste and oil of the transfer vehicles. The aim of this research is to assess VOCs emission from WTS in Surat City. The current research has the goal to achieve presentation of quantitative information on the VOCs concentrations in WTS due to very limited researches in a WTS site ambient air with no information about the dispersion of VOCs. Another goal is to provide the knowledge about distribution of emitting VOCs from WTS. The VOCs dirspersion in landfill or waste treatment plants has already been conducted in the earlier studies, but not t the WTS (*Neha Gupta, et al, 2015*).

Indian Scenario of SWM:

In modern-day society, industry will become a crucial part. Developing nations like India is in industrialization segment, which also make contributions to urbanization. Large population is migrating closer to town area for higher opportunities. Uncontrolled urbanization and improved residing standards thereby lead to accelerated charge of per capita waste era. presently, 1,27,486 tons per day of municipal solid waste is being generated due to various family activities and other business & institutional activities (CPCB, 2012). Municipal waste and certain commercial waste have relatively substantial impact on environment. It may downgrade groundwater quality through leachate percolation and also cause air pollution through emission of greenhouse gases via various paths of remedy. Nowadays, E-waste and nuclear waste are different waste streams which might be requiring attention because of fastest growing electronics & nuclear area. Environmental protection agency (U.S. EPA) followed hierarchy of waste control practices the elements of hierarchy are:

- Source reduction
- Recycling of materials
- Combustion
- Landfilling

In India, initially there has not been a lot attention about solid waste management and its hierarchy. However, since previous few years, the situation of solid waste management has been changing constantly. Still, there's a long way to enforce an effective solid waste Management practices. Even these days, most effective few part of solid waste generated is disposed via proper treatment. Loss of waste segregation is the most important obstacle in enforcing powerful solid waste management.

House → Dustbin → Municipal Vehicle → Dumping Ground.

Sources of VOCs:

VOCs are emitted from a variety of sources, including motor vehicles, chemical manufacturing facilities, refineries, factories, consumer and commercial products, and natural (biogenic) sources (mainly trees).

Anthropogenic sources emit about 142 teragrams of carbon per year in the form of VOCs (*Wen-Yi Deng, et al, 2008*).VOC emissions from traditionally inventoried anthropogenic source categories:

- "Fuel combustion," which includes emissions from coal-, gas-, and oil-fired power plants and industrial, commercial, and institutional sources, as well as residential heaters and boilers;
- "Other industrial processes," which includes chemical production, petroleum refining, metals production, and processes other than fuel combustion;
- "On-road vehicles," which includes cars, trucks, buses, and motorcycles;
- "Nonroad vehicles and engines," such as farm and construction equipment, lawnmowers, chainsaws, boats, ships, snowmobiles, and aircraft.

The biological sources emit an estimated 1150 teragrams of carbon per year in the form of VOCs. The majority of VOCs are produced by plants, the main compound being isoprene. The remainders are produced by animals and microbes. Microbial volatile organic compounds (mVOCs) can also be beneficial, when used to control plant pathogens, for instance.

Environmental Impacts of VOCs:

VOCs have numerous direct and indirect impacts on humans and the environment. The main issues of concern are:

- Harmful effects on human health and on natural ecosystems through toxicity, carcinogenicity and other adverse physiological effects
- Damage to materials
- Tropospheric photochemical oxidant formation
- Stratospheric ozone depletion
- Global climate change
- Odour

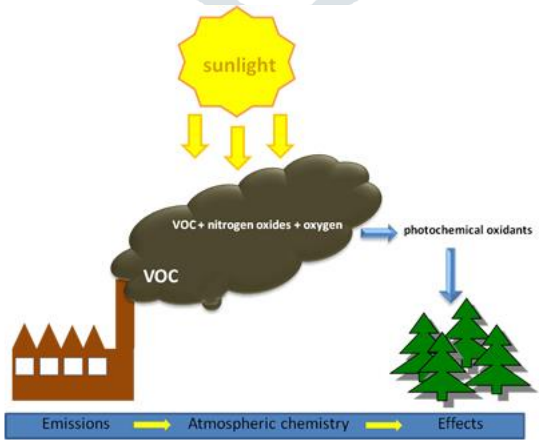

Fig.1 Tropospheric photochemical oxidant formation

(Source: tle.westone.wa.gov.au)

2. VOC MEASUREMENT

VOCs can be measured in two ways. They are as follows:

a) Through VOC meter/ analyzer

b) Through Gas Chromatography method.

VOC Meter :

Fig.2 Tiger VOC Meter

The Tiger VOC detector is a revolutionary handheld gas detection instrument for the rapid, accurate detection of volatile organic compounds (VOCs) within the harshest of environments.
Tiger incorporates Ion Science patented photoionization detection (PID) sensor technology with humidity resistance and anti-contamination design, proven to dramatically extend run time in the field.
A robust VOC detector Tiger provides a dynamic detection range of 0 to 20,000 parts per million (ppm) with a minimum sensitivity of 0.001ppm (1 ppb).
Tiger has been designed for the safe replacement of batteries in hazardous environments. Long-life rechargeable Li-ion batteries give up to 24 hours of use. Fast battery charging allows the instrument to be fully charged in 6.5 hours, while 8 hours of use can be achieved from 1.5 hours charge.
Low-cost filters and lamps can be easily changed in seconds, minimizing instrument downtime. Inexpensive disposable parts mean the Tiger VOC detector has the lowest running costs.
Tiger offers simple, one-handed operation for easy VOC detection. Its rugged design and protective, removable rubber boot withstand the harshest environments.
The large, clear back-lit display allows for easy viewing in any light condition. An integrated torch is designed for directing the instrument's probe into dimly lit areas.
Ready to use on start-up the Tiger VOC detector needs no complex set up procedures via a PC to perform basic functions. Its simple-to-use software features require minimal user training.

Applications include:

- Environmental monitoring
- Soil contamination detection
- VOCs in landfill
- IAQ measuring industrial volatiles
- Leakage in fuel and chemical storage
- Health & Safety
- STEL & TWA monitoring
- Confined space entry
- Screening tool for First Responders
- VOC leak detection
- Wing tank entry
- Medical gases within Hospitals
- Fumigation gases
- Fugitive emissions

3. METHODOLOGY

Study Area : Surat covers 326.515 sq. km of area. Surat had a population of 4.6 million at the 2011 census. It is the eighth largest city and ninth largest metropolitan area of India. Surat has a density of 13681 persons/sq.km. in Surat City, 1575 MT MSW (in year 2015) generates per day, out of which 1499.44 MT/day waste is collected by Surat Municipal Corporation (SMC).
There are 7 zones in the Surat city namely North, East, West, South, Central, South-East and South-West. Each zone has a municipal solid waste transfer station. All six transfer stations are regularly in operation and few modern transfer stations are

planned to be constructed at four places (namely Dindoli, Kosad, Gaviyar and Simada) for newly merge of SMC to cater the day to day need.

Daily Activities carried out at transfer stations :

- Primary collecting vehicles travel through ramp to reach the Elevated platform.
- Unloading of MSW from primary collection vehicles through chutes provided at Elevsted platform.
- Secondary transport vehicles are placed underneath the chutes having hopper bottom.
- Transfer of MSW unloaded from primary collection vehicles into the closed container provided with compactor system.
- The chute portion of transfer station is covered on the top with FRP sheet and whole structure is kept closed with concrete louvered blocks.
- Hook lifting vehicles are available for the transportation of loaded containers.
- Containers are fully closed with leak proof door opening system.

VOC Monitoring Sites

The major solid waste transfer stations have different localities surrounding it. Based on the localities the major transfer stations are selected that are Pal and Anjana transfer stations as majority of transfer stations are surrounded by residential and concentrated areas within Surat City.

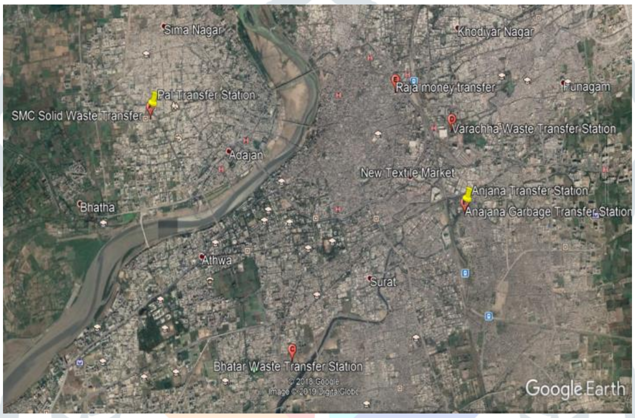

Fig.3 Location of VOC Monitoring Sites

Pal transfer station is located purely in residential area and surrounded by residents all around and a school from one side. Anjana transfer stations has surroundings of both residential as well as industrial areas. The activities included at this site are as follows:

- Entry of primary waste collecting vehicle at weight bridge
- Unloading of primary vehicle at elevated platform through chutes provided with hopper bottom and compaction system at the end.
- Compaction of solid wastes in Compaction Unit with the help of piston.
- Loading of secondary vehicle with compacted waste.
- Lifting of loaded vehicles with hook system after it is completely filled, for further transportation of waste to the landfill disposal site.

Table 1 Sampling Schedule for VOC Emissions

Location of Transfer Station	**Peak hours of activities at WTS**	**Sampling Period**	**Sampling location at site**	**Parameters to be measured**
Anjana Transfer Station (Round 1)	10am-12:30pm	Post-Monsoon season	-Vehicle entry time -Unloading of vehicle	-Benzene -Toluene -Total VOC -Meteorolgical Parameters (Relative
Pal Transfer Station (Round 1)				

Anjana Transfer Station (Round 2)	10am-12:30pm	Post-Winter season		Humidity, Temperature, Wind Speed and Wind Direction
Pal Transfer Station (Round 2)				

Parameters Measured:
The parameters measured at major municipal solid waste transfer stations of Surat City are as follows:

Table 2 List of parameters to be measured and its instrumentation

Sr. No.	Parameters measured	Permissible Limits (as per NAAQS)	Instrumentation
1	Benzene (B)	5 ppb	VOC Meter
2	Toluene (T)	NE	
3	Ethyl benzene (E)	NE	
4	Xylene (X)	NE	
5	Total VOC (TVOC)		
6	Meteorological Parameters-Temperature Relative Humidity Wind Speed and Direction		IMD

NAAQS: National Ambient Air Quality Standards
NE: Not Established
IMD: Indian Meteorological Department

IV. RESULTS AND DISCUSSIONS

The monitoring of VOCs emissions were carried out at Pal and Anjana Transfer Station using a VOC meter at different sampling locations based on the activities being carried out at the transfer stations daily. The localities surrounding the transfer station varies with different transfer stations of Surat City.

Post-Monsoon Monitoring of VOCs emission:
The following are the emissions of different VOCs i.e. Benzene, Toluene, Ethyl benzene, Xylene and total VOCs at Pal and Anjana transfer stations during Post-Monsoon season.

The concentrations of BTEX and TVOC at Pal Transfer Station were monitored during Post Monsoon period between the peak hours of activities i.e. 10:00 AM to 12:30 PM.
The highest concentration of Benzene, Toluene and Ethyl benzene found was 0.9 ppm. Also the concentration of Xylene and TVOC were 6 and 14 ppm respectively. These values were recorded at the compaction section of the transfer station. The meteorological parameters also affect the VOC emission. With increase in temperature, BTEX and TVOC concentration also increases.

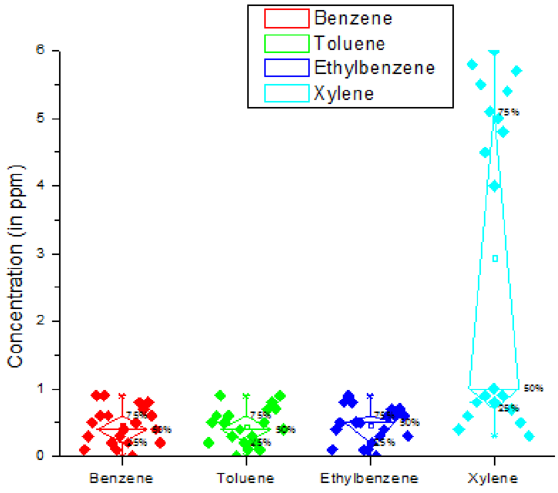

Fig.4 Graphical representation of variation in concentration of BTEX at Pal transfer station (Round 1)

The above graph is created using Origin software and it represents range of variation in concentrations of BTEX. It depicts the 75th, 50th and 25th percentile of VOCs emission. The 25th percentile is the value at which 25% of the data values are below this value i.e. 0.25 ppm for Benzene, Toluene and Ethyl benzene and nearly 0.8 ppm for Xylene.

The middle 50% of the data values fall between the 25th percentile and 75th percentile. A line is drawn inside the box at the median (the 50th percentile). The median is a popular measure of the variable's location. For Benzene, Toluene, Ethyl benzene and Xylene 50th percentile is 0.4, 0.4, 0.5 and 1 ppm respectively.

The 75th percentile is the value at which 75% of the data values are above this value i.e. 0.6, 0.6, 0.55 and 5 ppm respectively for Benzene, Toluene, Ethyl benzene and Xylene.

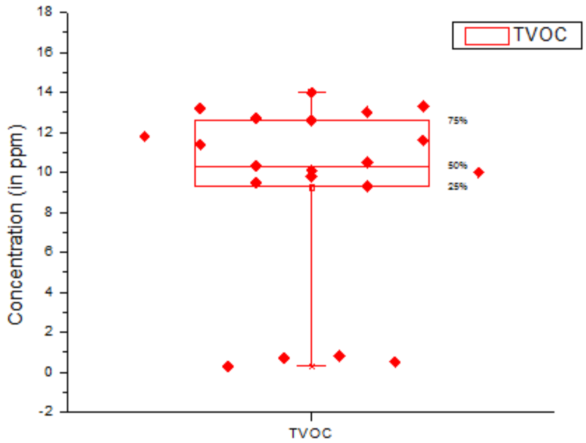

Fig.5 Graphical representation of variation in concentration of TVOC at Pal transfer station(Round 1)

The above graph depicts that 75th percentile of TVOC is 12.5 ppm, 50th percentile is 10 ppm and 25th percentile is 9 ppm.

The concentrations of BTEX and TVOC at Anjana Transfer Station were monitored during Post Monsoon period.

The highest concentration of Toluene, Ethyl benzene and Xylene found was 0.9 ppm. Also the concentration of Benzene and TVOC were 22 and 20.8 ppm respectively. These values were recorded at the compaction section of the transfer station during the peak activity time of loading of vehicles i.e. 10:00 AM to 12:30 PM.

The meteorological parameters also affect the VOC emission. With increase in temperature, BTEX and TVOC concentration also increases.

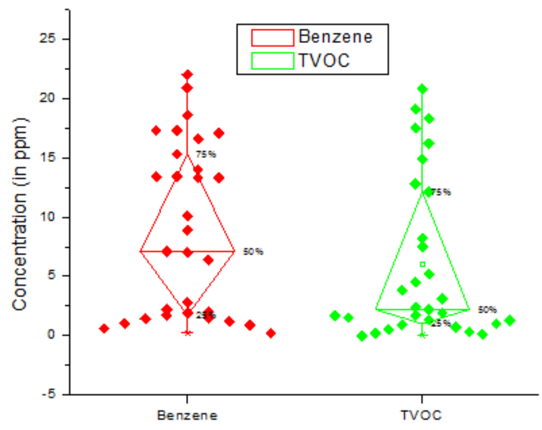

Fig.6 Graphical representation of variation in concentration of Benzene and TVOC at Anjana transfer station (Round 1)

The above graph represents 75th percentile of Benzene and TVOC are 15 and 13 ppm respectively. The median value is 7 and 4 ppm respectively for Benzene and TVOC. The 25th percentile is 4 and 2.5 ppm respectively for the same.

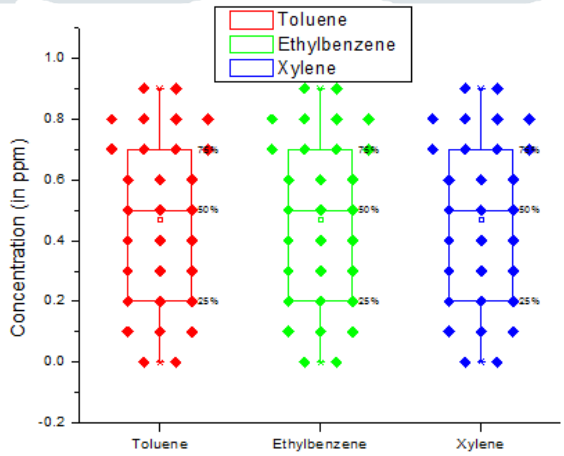

Fig.7 Graphical representation of variation in concentration of Toluene, Ethyl benzene and Xylene at Anjana transfer station (Round 1)

The above graph depicts that the concentration of toluene, ethyl benzene and xylene are 0.7, 0.5 and 0.2 ppm respectively as 75th , 50th and 25th percentile values.

Post-Winter Monitoring of VOCs emission:

The following are the emissions of different VOCs i.e. Benzene, Toluene, Ethyl benzene, Xylene and total VOCs at Pal, Anjana and Varachha transfer stations during Post-Winter season.

The concentrations of BTEX and TVOC at Pal Transfer Station were monitored during Post Winter period.

The highest concentrations of Benzene as 4.4 ppm, Toluene as 4.2 ppm and Ethyl benzene as 5.2 ppm, Xylene as 4.1 ppm and TVOC as 11 ppm were recorded. The meteorological parameters also affect the VOC emission. With increase in temperature, BTEX and TVOC concentration also increases.

These values were observed at the compaction section of the transfer station during the peak activity time of loading of vehicles i.e. 10:30 AM to 2:00 PM.

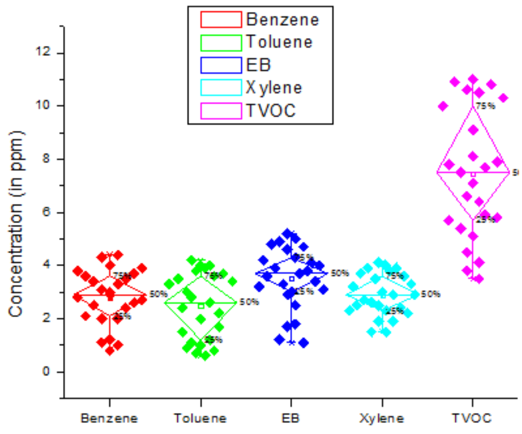

Fig.9 Graphical representation of variation in concentration of BTEX and TVOC at Pal transfer station (Round 2)

The above graph depicts the 75th, 50th and 25th percentile of VOCs emission.
The 75th percentile of BTEX and TVOC are 3.5, 3.5, 4, 3.5 and 10 ppm respectively. The median values of BTEX and TVOC are 3, 2.7, 3.5, 3 and 7.5 ppm respectively. The 25th percentile is 2, 1, 3, 2 and 5.5 ppm respectively for BTEX and TVOC.

The concentrations of BTEX and TVOC at Anjana Transfer Station were monitored during Post Winter period between the peak hours of activities i.e. 10:00 AM to 2:00 PM.
The highest concentrations of Benzene as 4.4 ppm, Toluene as 3.4 ppm, Ethyl benzene as 3.5 ppm, Xylene as 3.2 ppm and TVOC as 7.6 ppm were recorded. The meteorological parameters also affect the VOC emission. With increase in temperature, BTEX and TVOC concentration also increases. These values were observed at the compaction section of the transfer station.

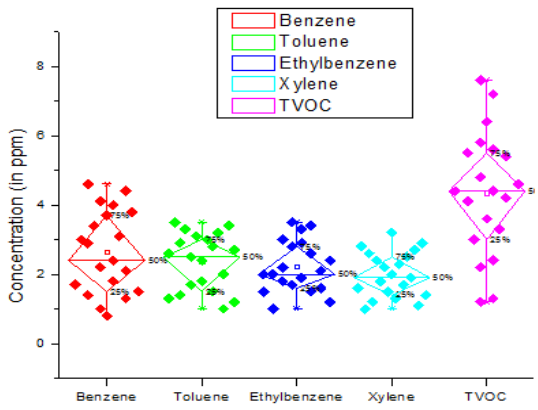

Fig.10 Graphical representation of variation in concentration of BTEX and TVOC at Anjana transfer station (Round 2)

The above graph represents that 75th percentile of BTEX and TVOC is 3.7, 3, 2.8, 2.5 and 5.3 ppm respectively. And 25th percentile is 1.5, 1.5, 1.7, 1.5 and 3 ppm respectively for BTEX and TVOC.

Variations in Concentrations of BTEX and TVOC with Meteorological Parameters

The following Table 9 shows the meteorological parameters noted through the weather forecasting application for the day of VOCs monitoring.

Table 3 Meteorological Parameters

Sampling Period	Time Interval	Temperature	Relative Humidity	Wind Speed	Wind direction
Post-Monsoon	10:00am–12:00pm	30.4 °C	65%	6 km/hr	SW
	12:00pm – 2:00pm	31.0 °C	61%	8 km/hr	SSW

Post-Winter	10:00am–12:00pm	25°C	35%	8 km/h	WNW
	12:00pm – 2:00pm	27°C	40%	9 km/h	WNW

The above data were obtained from the site of Indian Meteorological Department of India.

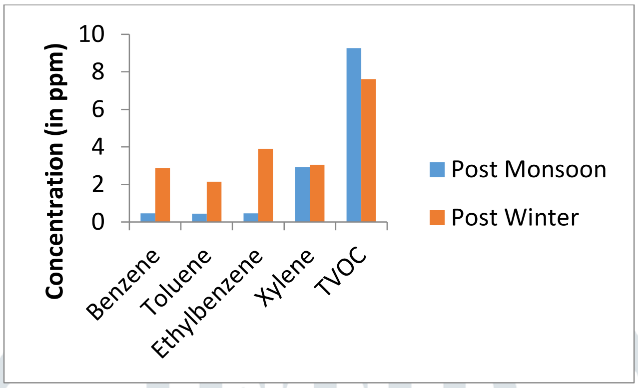

Fig.12 Bar Chart representing variations in concentration (in ppm) of BTEX and TVOC at Pal transfer station

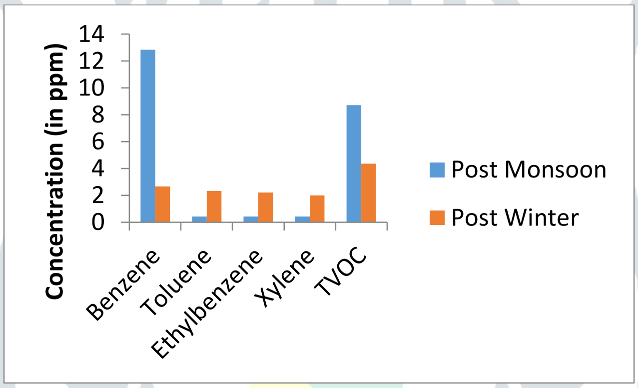

Fig.13 Bar Chart representing variations in concentration (in ppm) of BTEX and TVOC at Anjana transfer station

Thus from the above graphs it can be concluded that the concentrations of BTEX and TVOC increases with increase in temperature and decrease in relative humidity. Thus the VOCs concentration is mostly higher in Post-Monsoon season compared to Post-Winter season. Also, more the wind speed more will be the dispersion of VOCs.

V. CONCLUSIONS

Volatile Organic Compounds concentrations along with meteorological parameters were measured at transfer stations (Pal and Anjana) nearby residential areas of Surat City during Post-Monsoon and Post-Winter season. The conclusions made from the analysis of measured parameters are discussed below:

- The volatile organic compounds were positively correlated with meteorological parameter Temperature and negative correlation was found with Relative humidity and Wind speed.
- The highest VOCs concentrations were obtained during Post-Monsoon season due to high temperature and low relative humidity effect compared to Post-Winter season having high humidity and low temperature.
- The VOC levels measured in Post-Monsoon were Benzene: 0-22 ppm, Toluene: 0.1-24.6 ppm, Ethyl benzene: 0-5.5, Xylene: 0-13.2 ppm and TVOC: 0-20.8 ppm.
- The VOCs levels measured in Post-Winter were Benzene: 0.8-4.4 ppm, Toluene: 0.5-4.2 ppm, Ethyl benzene: 1-5.2 ppm, Xylene: 1-4.1 ppm and TVOC: 1.2-11 ppm.
- The concentration of Benzene was exceeding the standard limit as per NAAQS (i.e.5 ppb) given by Central Pollution Control Board (CPCB). It is due to high temperature effect as well as gas generation from continuous compaction process being carried out at the transfer station.

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