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*Original Article*

# Assessment of volatile organic compounds in indoor and outdoor environment – A study on air quality impact assessment

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## ABSTRACT

**Objectives:** Volatile organic compounds (VOCs) are a type of pollutant that causes health risks and can be present in both indoor and outdoor environments. VOCs originate mainly from solvents and chemicals used at home or in offices and also from vehicle emissions. The current research work was aimed at the detection and quantification of VOCs indoor and outdoor at Sri Ramachandra Faculty of Pharmacy, Sri Ramachandra Institute of Higher Education and Research (DU), Porur, Chennai, Tamil Nadu, India.

**Material and Methods:** Air was drawn through an adsorbent tube with a pump at a steady flow rate (100 mL min-1) for an hour to gather samples using the active sampling approach. Thermal desorption in combination with a gas chromatography (GC) analyzer was used to estimate the levels of hazardous VOCs, namely benzene, toluene, ethylbenzene, m-xylene, p-xylene, and o-xylene (BTEX) compounds.

**Results:** VOCs were analyzed using the GC-mass spectroscopy technique. The finding shows the levels of BTEX as benzene (0.05–0.11 $\mu g/m^3$), toluene (0.44–1.27 $\mu g/m^3$), ethylbenzene (0.012–0.03 $\mu g/m^3$), m-xylene (0.009–0.027 $\mu g/m^3$), p-xylene (0.007–0.025 $\mu g/m^3$), and o-xylene (0.003–0.019 $\mu g/m^3$) compounds.

**Conclusion:** The BTEX levels were observed to be well below the maximum acceptable limit. VOC emissions can be reduced by making process changes or by installing air pollution control equipment.

**Keywords:** Volatile organic compounds, Air sampling, Environment, Assessment

## INTRODUCTION

The delicate balance of natural resources, including water, plants, air, and soil, is increasingly threatened by environmental pollution, with profound implications for human health. This study delves into the pervasive issue of volatile organic compounds (VOCs) and their far-reaching impact on both the environment and human well-being.[1]

### VOCs and environmental impact

VOCs, omnipresent in natural and synthetic materials with high vapor pressure, emanate from diverse sources, including both natural processes and human activities such as industrial operations. Their release into the atmosphere has direct and indirect consequences, altering ecosystems and contributing to the depletion of the protective ozone layer. Notably, outdoor sources such as power plants, industrial facilities, and vehicular emissions significantly contribute to the formation of photochemical smog, posing threats to both human health and the environment.[2,3]

### Indoor air quality and health implications

The quality of indoor air, influenced by various factors, plays a crucial role in human health. Particulate concentration, ventilation rate, temperature, and structural design of buildings are key determinants. The detrimental effects of air pollution on health are evident in symptoms ranging from irritation of the nose, eyes, and throat to more severe conditions such as headaches and nausea. Moreover, certain VOCs are implicated as possible carcinogens with long-term effects on vital organs.[4-7]

### Environmental health impacts and legislation

The ramifications of air pollution extend beyond human health, affecting terrestrial and aquatic resources and contributing to global-scale climate change.[8-12] Recognizing the severity of these issues, national and state environmental policies, such as the Environment (Protection) Act and Clean Air Act, have been enacted to address environmental concerns and provide a legal framework for regulation.

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### Analytical techniques and advancements

Environmental analysis demands reliable and efficient methods due to the hazardous nature of VOCs.[13-18] Recent advancements in analytical techniques, such as spectroscopy and chromatography, offer high sensitivity, specificity, and cost-effectiveness. Various detectors, including flame ionization and photo-ionization, are employed for total VOC concentration measurements, providing valuable insights into environmental monitoring.

The study of VOCs as potential cancer biomarkers requires a critical assessment of *in vivo* and *in vitro* approaches, extraction techniques, and detection methods.[16-18] Given the escalating environmental issues due to population growth, industrial processes, and fuel consumption, there is a pressing need for environmental measurements, particularly in densely populated regions such as Chennai, India. Despite Chennai's relatively favorable Air Quality Index, this study aims to comprehensively measure VOCs in both indoor and outdoor environments to gain a nuanced understanding of the local scenario.

The total concentration of various VOCs (TVOCs) can be measured in parts per million (PPM), parts per billion, or milligrams per cubic meter (mg/m$^3$). The following is the level of concern as reported by the Environmental Technology Solutions Group (TECAM). Low level of concern if the TVOC is <0.3 mg/m$^3$. TVOC between 0.3 and 0.5 mg/m$^3$ is an acceptable level, and if it goes beyond 1–3, it will be a great level of concern.

This being the case, the current study aimed for the identification and quantification of VOCs in the indoor and outdoor environments of the Sri Ramachandra Faculty of Pharmacy (SRFOP), Sri Ramachandra Institute of Higher Education and Research (SRIHER) (DU), Porur, Chennai, Tamil Nadu, India. There are numerous laboratories in SRFOP that prepare and analyze pharmaceuticals using VOCs such as benzene, toluene, and xylene. This indicates that there should be a regulation because it puts the staff and students in danger.

## MATERIAL AND METHODS

In pharmacy colleges, students used to spend most of their academic time in laboratories. Hence, the possibility of exposure to chemicals is high especially in chemistry laboratories. Therefore, the following places were selected to collect the samples for VOC measurement.

Entrance of Faculty of Pharmacy, SRIHER,

Pharmaceutics laboratory-1 (I floor),

Instrumentation room (II-floor),

Pharmaceutical analysis laboratory (II-floor),

Pharmaceuticals chemistry laboratory-II (II-floor),

Pharmaceutical chemistry UG laboratory-1 (II-floor),

Computer laboratory (III floor),

Other three places outside the Sri Ramachandra campus Such as the KFC shop entrance, Iyyappanthangal bus stop, and Porur Signal.

A rotameter was used to calibrate the sampler. Air was drawn through an adsorbent tube with a pump at a steady flow rate of 100 mL/min for an hour to gather samples using the active sampling approach. The diurnal variation of BTEX was estimated by sampling four times a day, and for the seasonal variation, sampling was done twice a week. Following the sampling process, parafilm M was used to seal both ends of the tubes. After that, the sealed tubes are stored in plastic bags that are sealed and frozen at or below 4°C until analysis. For BTEX sampling, activated charcoal can be utilized. An excellent adsorbing medium for BTEX, charcoal is an amorphous type of carbon made from animal bones, burned wood, and nutshells. It preferentially absorbs organic gasses and vapors over moisture because of its electrically non-polar nature.

### Adsorbent ATD tube description

ATD tube adsorbent (tenax + carboxen) was used for VOC determination in ambient air.

### Preparation of standard stock solution

VOCs standard (20.0 PPM) was prepared by transferring 1.0 mL of 200.0 PPM standard stock solution into a 10 mL volumetric flask made up of methanol and stored in a refrigerator at 2–8°C

### Calibration standard for gas chromatography-mass spectrometry (GC-MS)

From the above standard preparation, different dilutions were made. The linearity for ATD preparation was measured with concentration varying from 10 ng to 100 ng (2–20 PPM).

### Preparation of sample

VOC samples collected from ambient air were adsorbed on the ATD stainless tube section by passing through the tube. Samples are kept in storage at 4°C when they are received.

### Extraction procedure

The given ATD stainless tube adsorbent sample was directly injected into the GCMS-ATD instrument.

### Quality check

Negative control samples spiked with the analytes to be determined at the beginning of the analytical procedure were used for calibration and quantification of target analytes in the samples. A blank tube of the sample was spiked with VOC analytes before analyzing the sample. The addition of the spike was set at 60 ng. After spiking, the sample was directly injected into GCMS-ATD.

### Injection sequence procedure

The blank, sample, and standard solutions (prepared above) were injected as per the sequence given in Table 1 under the given instrumental conditions [Table 2]. The area of each

**Table 1:** Injection sequence for GC-MS analysis.

| S. No. | Name of the sample | No. of injections |
|---|---|---|
| 1. | Blank tube | 1 |
| 2. | Calibration standards in ATD tubes 2, 4, 6, 8, 12, 16, and 20 PPM | 1 |
| 3. | Blank tube | 1 |
| 4. | Samples batches with one field blank tube and QC check (spiked sample) | 1 |
| 5. | Blank tube | 1 |
| 6. | One standard from the calibration point at the QC check | 1 |
| 7. | Blank tube | 1 |

PPM: Parts per million, GC-MS: Gas chromatography-mass spectrometry, ATD: Automated thermal desorber, QC: Quality check

analyte in the sample was determined and the concentration was calculated and the results were reported as µg/m$^3$.

### Unity thermal desorber method

Thermal desorption is essentially a straightforward expansion of GC technology. Heat and an inert gas flow are utilized in the thermal desorption method to extract volatile organic molecules that are trapped in a sample matrix/on a sorbent bed. The thermal desorption conditions are given in Table 3. The organic compound after desorption is converted into a small, concentrated volume of vapor, mixed with the gas stream, and transported into the column.

The concentration of VOC was calculated in the test sample using the following equation:[18]

$$VOC\left(\mu g/m^3\right) = \frac{Conc.\ of\ sample\ in\ ng}{1000/Volume\ of\ sample\ in\ m^3}$$

## RESULTS

The investigation monitored the presence of hazardous VOCs, specifically benzene, toluene, ethylbenzene, m-xylene, p-xylene, and o-xylene (collectively known as BTEX), across 10 sites in the ambient environment of SRFOP SRIHER (DU) and two additional locations in Chennai, Tamil Nadu, India. The outcomes of this study, conducted within a controlled laboratory setting, are detailed in Table 4.

The concentration of VOC is given in µg/m$^3$ at various locations from L 1 to L 10. L1 entrance of faculty of pharmacy, SRIHER, L2 pharmaceutics laboratory-1 (I floor), L3 instrumentation room (II-floor), L4 pharmaceutical analysis laboratory(II-floor), L5 pharmaceuticals chemistry laboratory II (II-floor), L6 pharmaceutical chemistry UG laboratory-1 (II-floor), L7 computer laboratory (III floor), L8 outside Sri Ramachandra campus (near KFC shop), L9 Iyyappanthangal bus stop, and L10 Porur signal.

**Table 2:** Instrument control method for GC.

| Instrument name | GC – thermo scientific – trace 1310 |
|---|---|
| Column | TG 5MS, 30 m×0.25 mm×0.25 µm |
| Mode | Splitless |
| Inlet temperature | 250°C |
| Split flow | 80 mL/min |
| Splitless time | 1 min |
| Septum purge flow | 5 mL/min |
| Carrier mode | Constant flow |
| Carrier flow | 1.5 mL/min |
| Detector temperature | 300°C |
| Makeup gas flow | 15 mL/min |

GC: Gas chromatography, TG: TraceGOLD

**Table 3:** Thermal desorption conditions.

| | |
|---|---|
| Temperature | 275°C |
| Time for desorption | 5 min |
| Inlet split | 52 (mL/min) |
| Outlet split | 50 (mL/min) |
| Flow path temperature | 120°C |
| Desorb flow | 4 (mL/min) |
| Time for secondary desorption | 3 min |
| **Cold trap** | |
| **Packing** | **Tenax TA** |
| Focusing temperature | −10°C |
| Secondary desorption temperature | 300°C |

TA: Trapping agent

## DISCUSSION

The findings revealed elevated concentrations of toluene and benzene in comparison to other VOCs, such as xylene and ethylbenzene. Benzene exhibited uniform levels across all selected locations except for location 5. Toluene concentrations were notably higher in chemistry laboratory II (associated with experiments involving the use of toluene) and Porur signal (attributed to vehicle emissions). Ambient VOC concentrations at all sites ranged from 0.003 to 1.276 µg/m$^3$. Benzene and toluene levels were predominantly influenced by traffic emissions. Conversely, ethylbenzene and xylenes displayed no discernible variation.

Throughout all locations, BTEX levels remained low, with toluene levels classified as moderate. Importantly, all VOC compounds were found to be below toxic thresholds, as the World Health Organization recommends 0.3 mg/m$^3$ as a permissible limit.

It is important to note that only two places were selected for the outdoor air sampling in the present study, which may have influenced the results to some extent. To address the seasonal variation, sampling should be done in different seasons. Future studies could address these limitations

**Table 4:** Concentration of VOCs in various locations.

| VOC | L 1 | L 2 | L 3 | L 4 | L 5 | L 6 | L 7 | L 8 | L 9 | L 10 |
|---|---|---|---|---|---|---|---|---|---|---|
| Benzene | 0.1 | 0.1 | 0.1 | 0.1 | 0.05 | 0.1 | 0.1 | 0.1 | 0.1 | 0.11 |
| Toluene | 0.034 | 0.781 | 0.447 | 0.747 | 1.050 | 0.738 | 0.631 | 0.774 | 0.653 | 1.276 |
| m-Xylene | 0.012 | 0.028 | 0.026 | 0.030 | 0.023 | 0.019 | 0.028 | 0.018 | 0.012 | 0.030 |
| p-Xylene | 0.010 | 0.018 | 0.017 | 0.017 | 0.019 | 0.013 | 0.019 | 0.013 | 0.009 | 0.027 |
| Ethylbenzene | 0.008 | 0.016 | 0.016 | 0.015 | 0.017 | 0.013 | 0.017 | 0.012 | 0.007 | 0.025 |
| o-Xylene | 0.005 | 0.012 | 0.011 | 0.012 | 0.015 | 0.007 | 0.017 | 0.007 | 0.003 | 0.019 |

VOC: Volatile organic compound

and further refine our understanding of VOCs in outdoor environments.

## CONCLUSION

Human activities have altered the structure of the environment and polluted the ecology, leading to various environmental problems at local, regional, and global levels. Strategies for assessing indoor air quality have been developed and implemented to address environmental concerns. The detection and quantitative assessment of contaminants in environmental samples has been widely accomplished through the application of traditional instrument-based techniques.

The investigation into VOCs conducted in the college laboratory has provided valuable insights into the presence and behavior of these compounds in our experimental setup. Through the use of GC-MS, we were able to detect and quantify the levels of VOCs present in both indoor and outdoor environments. The presence of VOCs in the atmosphere of selected locations in Chennai is emerging as a growing air pollution issue. Future projections suggest that VOC emissions are likely to increase rapidly due to dense industrialization and the rapid growth of the transport sector.

VOCs pose a risk to human health as both indoor and outdoor air pollutants. The main concern lies in the likelihood that VOCs will negatively impact the health of those exposed indoors. Adjusting processes or installing air pollution control equipment can effectively lower VOC emissions.

In summary, this experiment has contributed to our knowledge of VOCs and their impact on indoor and outdoor environments. The findings presented here lay the groundwork for future research endeavors in this field, and the methodologies employed can serve as a foundation for more comprehensive studies. Overall, this investigation enhances our understanding of the intricate nature of VOCs.

### Ethical approval

The Institutional Review Board approval is not required.

### Declaration of patient consent

Patient's consent not required as there are no patients in this study.

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GATE.

### Conflicts of interest

There are no conflicts of interest.

### Use of artificial intelligence (AI)-assisted technology for manuscript preparation

The authors confirm that there was no use of artificial intelligence (AI)-assisted technology for assisting in the writing or editing of the manuscript and no images were manipulated using AI.

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