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Address for correspondence:
Alka Gupta, Assistant Professor, Department of Chemistry, Brahmanand College, CSJM University, Kanpur, India
Email: alkagupta2575@gmail.com

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Mysterious World of Volatile Organic Compounds and Mitigate its Effect for Environmental Sustainability and Human Health

Dr. Alka Gupta
Assistant Professor, Department of Chemistry, Brahmanand College,
CSJM University, Kanpur, India

Abstract

Volatile Organic Compounds (VOCs) are hazardous substances that pose risks to both environmental sustainability and human health. Volatile organic compounds (VOCs) are the compounds that have a diverse class of chemicals contaminants that are emitted from the certain liquid and solids. The human exposure to VOCs(carbons) occurs predominantly through inhalation of air particularly indoor air. These are the compounds which are present in the atmosphere and having a highly volatile nature either they are emitted by the solid and liquid. There are many indoor sources of VOCs. Some VOCs have high level can be detected by smell but the other VOCs have no odour. So, the odour is not a good indicator for the indication of the overall level of VOCs. VOCs are the chemicals including benzene, xylene, toluene, benzopyrene than some poly aromatic hydrocarbons gasoline, formaldehyde and many more volatile organics is considered or comes under the category of volatile organic compounds. The wide variety of VOCs, along with their differing physical and chemical characteristics, complicates the establishment of standardized sampling and analytical methods. Most techniques are contingent upon the specific compounds being analyzed and the necessary sampling duration. The category of very volatile organic compounds (VVOCs) is gaining attention in the analysis of indoor air, particularly in light of ongoing international and European regulations aimed at improving indoor air quality and protecting human health. Currently, there is no validated method for the identification and quantification of VVOCs in indoor environments. The VOCs are release by a wide area of sources within the home for example – household products and building materials and also migrate indoors from the outdoor sources e.g. industrial and mobile sources. The residential VOCs exposure is associated with the verity of health outcomes especially in young children. To lower the VOCs borden in your home there are a number of simple step that can be taken from choosing products that reliefs fewer VOCs to helping to capture VOCs by using air purification as well as increasing ventilation in the home when products are used. This study aims to develop an analytical technique to capture the maximum possible amount of VVOCs from indoor air using solid sorbents, followed by analysis through thermal desorption coupled with gas chromatography/mass spectrometry (TDS-GC/MS). To achieve this, it was essential to evaluate the effectiveness of various sorbents and optimize the parameters for GC/MS analysis.

Keywords: *Volatile Organic Compounds, human health, GC/MS analysis, contaminants, environmental sustainability.*

Introduction

Many curious mind have looked Into the mysterious world of volatile organic compounds, or VOCs as they like to call them these compounds are quite the troublemakers, contributing to air pollution and posing risks to our well- being. VOCs comes from all sorts of places- some are the result of human activities like cars puffing out exhaust, factories humming away, and even the use of cleaning solvents. Others, however, just stroll in from nature, courtesy of our friendly vegetarian. To better understand these mischievous molecules, scientists have employed various methods. They often turn to gas chromatography with mass spectrometry- now that's a mouthful! There is also flame ionization detection and proton transfer reaction- mass- spectrometry- each technique brings it's own flair to the table, the air with remarkable precision. In their quest for knowledge, researchers have also kept a keen eye on how VOC levels fluctuate over time and across different cities, quiet suburbs, or serene countryside. They have discovered that being around too many VOCs can lead to the formation of ground-level ozone and those pesky secondary organic aerosols. We may know these by their more common name: smog, which tends to hang around and cause a ruckus in our Lungs. Recently, there have been exciting developments in VOC tracking. Portable sensors and real – time monitoring technologies are making easier than ever to keep an eye on these vapours.

Sources of VOCs **in the home**

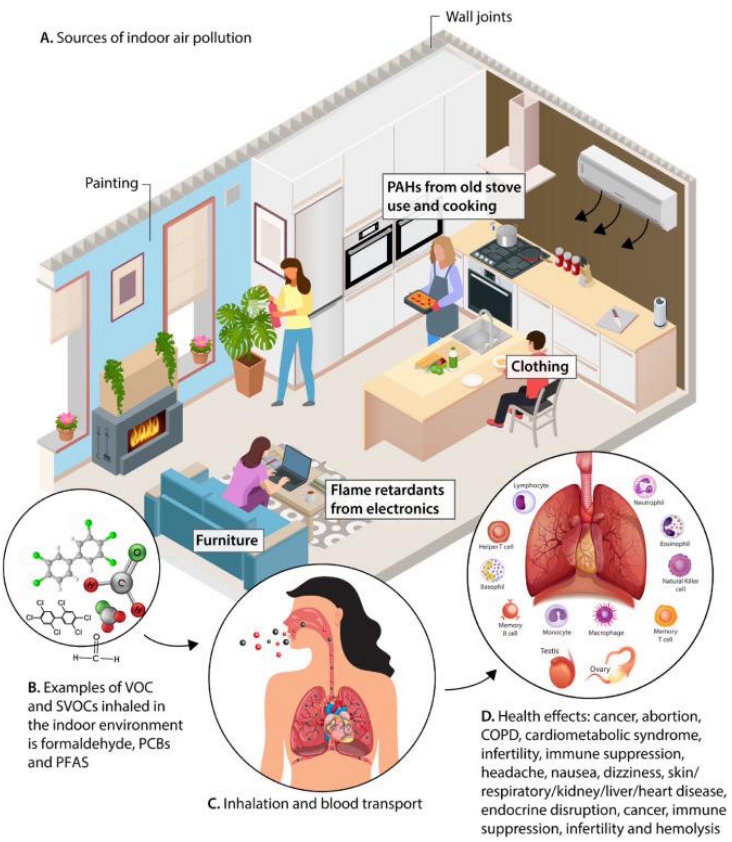
The most common indoor VOCs emission sources include consumer products e.g. cleaner, solvent,

- Building materials e.g. insulation, paint, wood finishing products are VOCs into the atmosphere.
- Combustion processes like smoking, cooking, are also responsible for the presence of VOCs in the home. Personal care products e.g. shampoo, soap, and the other compounds dry cleaning, clothing and the municipal take water are the other sources of VOCs in home.

Each method exhibits varying levels of specificity and sensitivity. As of now, no single method has been universally recognized as the most precise. This review presents an overview of the most frequently utilized methods for VOC determination, drawing from international literature [1]. Children are particularly susceptible to indoor pollutants due to their significant time spent in homes and schools. The presence of organic air pollutants in these environments can negatively affect their health and academic performance. A study was conducted to assess the exposure to volatile organic compounds (VOCs) in nine schools across various regions of Kuwait [2]. These schools, which provide formal education to different age groups, were chosen from diverse urban settings identified as industrial, vehicular, and residential. Air samples were collected from the schools over periods of 8 and 24 hours during both weekdays and weekends [3].

Health Effects of VOCs Exposure

- The risk of health effects from inhaling any chemical depends on how much is in the air, how long and how often a person breathes it in.
- Breathing in low levels of VOCs for long periods of time may increase some people's risk of health problems.



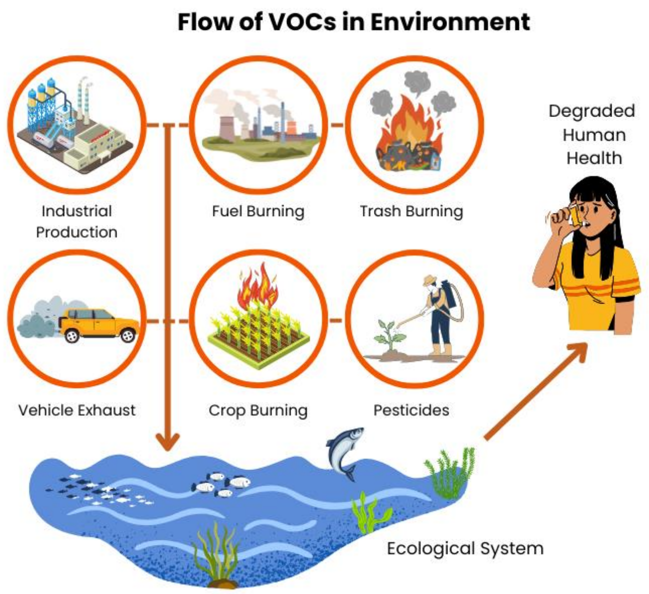
The several studies suggest that Exposure to VOCs may make symptoms worst for people with asthma or who are particularly sensitive to chemicals. These are much different exposure than the occupational exposure. VOCs were captured using canister passive sampling and subsequently analyzed with an Entech pre-concentrator coupled with gas chromatography and flame ionization detection. A total of seventy-two VOCs were examined and categorized into four groups: aliphatics, aromatics, oxygenated, and halogenated compounds. The concentrations of VOCs were measured both indoors and outdoors, and the indoor-to-outdoor (I/O) ratio was calculated to evaluate the indoor air quality of the monitored schools. Generally, the concentration of the oxygenated group was found to be higher indoors compared to outdoors [4]. The variation in VOC concentrations was influenced by the specific characteristics of the sampled areas, with some schools exhibiting a significant indoor contribution while others showed a dominant outdoor influence [5]. Now, let's talk about those pesky little things known as volatile organic compounds. These are a varied bunch of carbon-based chemicals that act a bit like the sky person at a party, they evaporate easily at room temperature and it can be found hiding in all sorts of places. Whether it's from factories, cars, buildings, or even your favourite household cleaner, VOCs are popping up everywhere, much to our chagrin. They cause quite a stir regarding human health and the environment, especially when they go on to form ground-level ozone [6].

Common symptoms

Common symptoms of exposure to high levels of VOCs include:

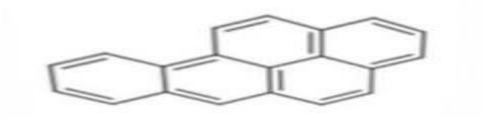
- Acute/ short term exposures (years to a lifetime) including the effects of VOCs e.g. eye, nose, throat irritation, headache, nausea/ vomiting damage, dizziness, worsening of asthma symptoms.
- Chronic exposures (hours to days) including the effects of VOCs e.g. liver, kidney damage, cancer, central nervous system.

Researchers have done quite a bit of digging and have neatly categorized VOC sources into two camps: the natural (or biogenic) and the man – made (or anthropogenic). Biogenic VOCs, such as isoprene and monoterpenes, come mainly from our leafy friends, the plants [7]. In some places, these plant emissions even outdoor the emission from our bustling human activities. On the flip side, anthropogenic VOCs are what your had find bubbling up from vehicle exhaust, solvents, factories, and good old consumer products [8]. VOCs are not just harmless visitors; they significantly add to air pollution. In the presence of sunlight and together with nitrogen oxides (NOx), these compounds create troposphere ozone, a major culprit in smog formation. The crucial role of VOCs play in the chemistry of our atmosphere, particularly in the hustle and bustle of urban settings. They also contribute to making of secondary organic aerosols (SOAs), which can affect our Climate and visibility.



Volatile organic compounds includes Polycyclic Aromatic Hydrocarbon (PAH) compounds

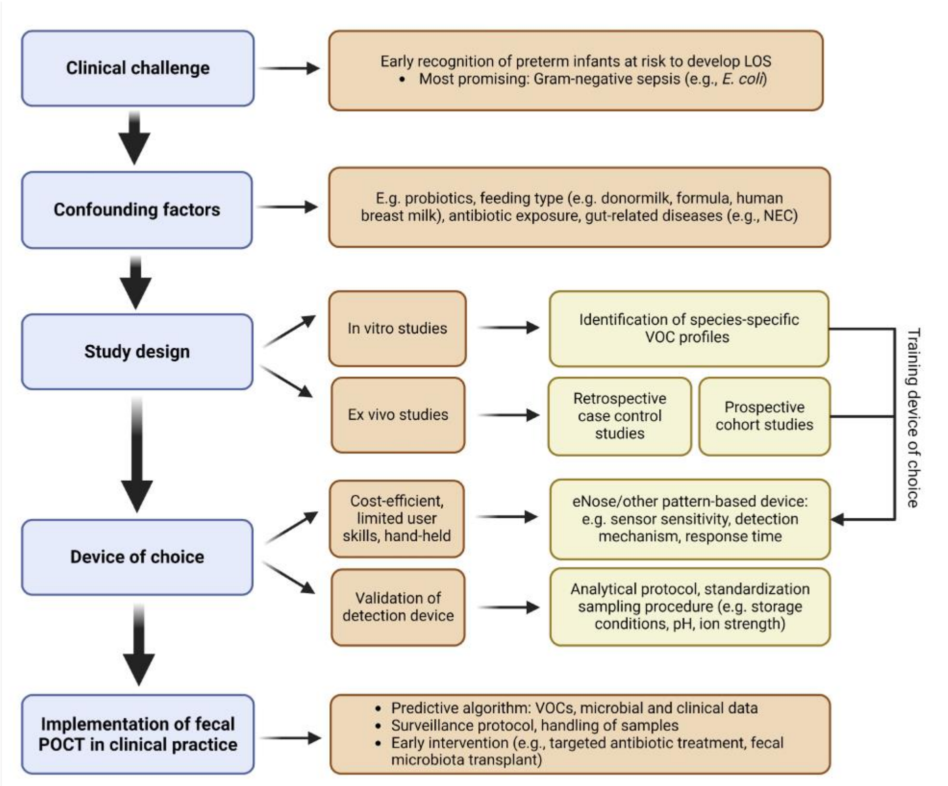
- Benzo(a)pyrene is one of the most important constituent of PAH compound and also one of the most potent carcinogenic.
- This can be measured in both particulate phase and vapour phase.
- PAH is significantly less than the particulate phase. Therefore, more care to be taken for the measurement of benzo(a)pyrene.



Benzo(a)pyrene

When it comes to health, VOCs can be a mixed bag. The effects depend on the particular compound and how long you're exposed. Short -term effects might leave you with a bit of irritation in your eyes or throat, perhaps a headache, or even a touch of nausea. Long -term exposure, however, can lead to more serious troubles like damage to the liver, kidneys, and even the

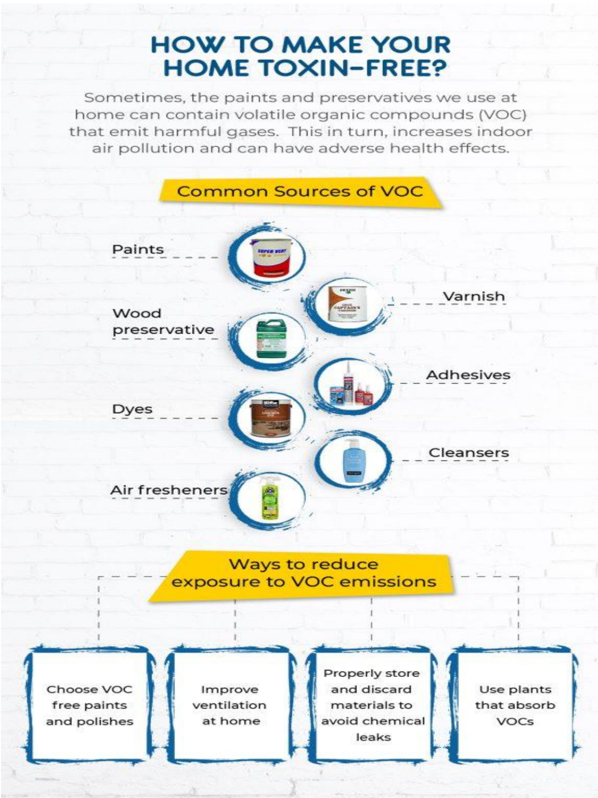
nervous system. Some VOCs, like benzene and formaldehyde, have earned the unfortunate badge of being carcinogenic. Research into indoor air quality shows us that our household products can lift indoor VOC levels and come with their own set of health risks. Now, recognizing the trouble that VOCs can cause, various regulations have been set up to keep them in check. The U.S. Environmental Protection Agency (EPA) and the European Union have rolled out standards to limit VOCs levels both outdoors and indoors. There are also some nifty technological solutions, like activated carbon filters and thermal oxidized, which help clean things up a bit [9]. In the world of research, there have been exciting advances, particularly in detecting VOCs in real – time. Techniques such as gas chromatography -mass spectrometry (GC – MS) and electronics noses are making waves. Moreover, the pursuit of sustainable materials and green chemistry aims to lower the use and release of these tricky compounds from commercial products [10].
This research utilized specific ambient volatile organic compounds (VOCs) as indicators of pollution to examine the influence of meteorological conditions on air quality. A remote coastal location was selected as a monitoring site to observe pollutants carried from urban traffic and industrial activities. Significant variability in VOC concentrations was noted at the coastal site, attributed to rapid meteorological changes that led to periodic exchanges of air masses between land and sea [11]. To ensure the accuracy of the online measurements, consistent concentrations of chlorofluorocarbon-113 (CFC-113) were used as an internal benchmark for assessing the stability of the instrument and the quality of the data obtained [12]. A VOC-speciated air quality model was utilized to simulate the temporal and spatial distributions of VOC plumes. The model effectively represented the general characteristics of toluene as a pollution tracer, indicating that both emissions and meteorological factors were adequately simulated. Through validation against observational data, the model demonstrated the ability to depict the dynamic temporal and spatial distribution of air pollutants[13]. Consequently, this approach provides a deeper understanding of how local air quality is influenced by meteorological conditions. In summary, VOCs are quite the important topic. They are everywhere and carry a hefty load of implications for our health and environment. Continued research is crucial to untangle their sources and effects, setting the stage for more effects, setting the stage for more effective solution to minimize their Impact[14]. The findings from the continuous online measurement of 62 volatile organic compounds (VOCs) at the Air Quality Monitoring Station located at the School of Engineering in Bilbao, Northern Spain, are presented[15].This monitoring system was operational from 1997 to 2001 in an area affected by urban and industrial emissions. The text begins with a description of the measurement methodology and the data validation process, followed by an exploration of combined statistical analysis techniques used to identify the sources of mixed organic compounds affecting the monitoring site. Furthermore, a straightforward meteorological analysis of prevailing winds, along with pollution roses, has corroborated these statistical findings, enabling the differentiation of each compound's origin as either urban—primarily from traffic—or industrial[16].
This paper provides a comprehensive review of the literature concerning the behavior of semivolatile organic compounds (SVOCs) within indoor environments, along with the primary sources of their emissions[17]. It outlines the sequential analytical procedures employed for monitoring SVOCs indoors. The document highlights the prevalent methods for collecting samples from both gas and particulate phases. Furthermore, it examines and contrasts various types of sorbents and filters utilized in dynamic, passive, and denudational techniques, as well as the methods for extracting SVOCs, including Soxhlet extraction, sonication, and microwave extraction[18].



The paper discusses the key advantages and disadvantages of each technique, while also considering potential future developments. Additionally, it presents the commonly employed methods for final determination, such as gas chromatography and liquid chromatography, addressing their limitations and proposing solutions to mitigate these issues[19]. The review briefly touches on the implications of human exposure to SVOCs found in house dust and elaborates on the main aspects of the analytical procedures used to detect SVOCs in this context[20]. To evaluate indoor air quality (IAQ), two separate one-week monitoring campaigns focused on volatile organic compounds (VOCs) were conducted in various sections of a multistorey shopping mall[21]. High-resolution spatial monitoring took place at 32 indoor locations, including two storage areas and different sections of a supermarket. Concurrently, VOC levels were measured in the mall, parking lot, and outdoor environments. VOCs were collected over 48-hour intervals using diffusive samplers designed for thermal desorption, with subsequent analysis performed using gas chromatography-mass spectrometry (GC- MS)[22]. The analysis of the data and the resulting chromatic maps revealed that the two storage areas exhibited the highest concentrations of VOCs, primarily consisting of terpenes. These elevated total VOC levels may be attributed to the inefficiency of the air exchange and intake systems, along with the significant volume of items stored in these confined spaces[23]. Conversely, within the supermarket, the food department emerged as the area with the most concerning VOC levels. To pinpoint potential sources of emissions in this section, a continuous VOC analyzer was employed. The results indicated that the highest total VOC concentrations occurred during cleaning operations, which were frequently conducted in the food department[24].This study underscores the necessity of implementing both high-spatial-resolution and high-temporal-resolution monitoring. The former effectively identified critical issues in environments characterized by complex emission scenarios, while the latter facilitated a better understanding of the dynamics associated with each emission source[25].

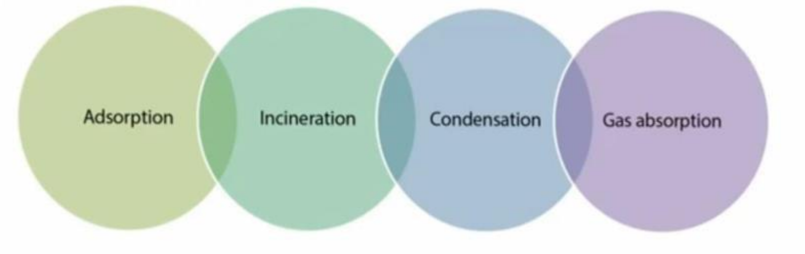
Result & Discussion

- **While VOCs are consistently identified in residential air. The concentration of the individual VOCs and work specific VOCs identify in many, one vary considerately.**
- This variation suggests that there are steps that can be taken to reduce VOCs levels within homes.
- Effective strategies to lower indoor VOCs levels are removed, replace, or relocate existing products are materials that release VOCs.



- Remove as many sources of the VOCs as possible, for example, using less cleaning products, buying smaller volumes of cleaning products or storing them in a location outside the home for example garage.
- Help remove VOCs from the air by increasing ventilation and By using a air purification with a air cleaning system that's include a carbon filter.
- Then replace typical consumer products and building materials with certified " green" products that generate lower VOCs or no VOCs for example no VOCs paint. When considering these products care should be taken evaluate than carefully as many green claimed a largely question.

- Relocate products that release VOCs to the areas that are not inhabited like detached garages and sheds. Also Relocate the use of these products are those for example painting furniture outside to home in the garage.



Control and Treatment of VOCs and hydrocarbons
Control and treatment of VOCs and organic hazardous air pollutant emission are generally accomplished by adsorption, incineration, condensation, gas absorption and bio filters. The mythology is usually chosen depending upon temperature, composition and volumetric slow rate of the emission stream space constraints and allowable installation and operational constant.

Adsorption
It is the method for controlling the emission from small sources. It can be Physical absorption and chemic absorption. Later, it is use for VOCs emission of control because it involves a less reversible chemical bonding of the absorbent that is pollutant and the absorbing solid that is packing and is relatively expansive then the physical absorption uses a wander Waal force giving the advantage of reversibility regeneration due to the weaker bonding of gas and absorbent material.

Incineration
The complete combustion or the oxidation of pure hydrocarbons products in carbon di oxide and water. The sulphur and nitrogen compounds produce acid gases and limited air supply result in the formation of carbon mono oxide. The complex organic compounds may not be oxidised completely in the residence time and ass may form. For most of the VOCs oxidation must be done at high temperature unless the catalyst is involved.

Condensation
Condensation and gas absorption are most commonly used for highly concentrated VOC streams. That are advantageous to recover and the relatively large expenses is warranted. It employs a drop in temperature and increase in pressure to cause the VOCs in the emission stream to condense. The cleaned air steam is separated from the condensate containing target pollutants.

Gas Absorption
Gas absorption involves the absorption of a gas into a liquid. Water can be used for recovery Of water soluble compounds such as acetone and low molecular weight alcohols. Additives are often used to increase the effective mass transfer rate of the pollutant from the gas phase into the liquid phase.

Conclusion
The research paper centred on VOCs for air quality monitoring can peel back the layers of understanding about air pollution sources and their potential impact on our health. With a mix of sampling methods, real-time monitoring, and advanced data analysis, it's possible to measure VOC concentrations, track their sources, and at the end of the day, help shape policies to better our air and keep the public healthier and happier. Indoor air quality and VOCs emission room building and household materials have been a major challenge for scientists, industry and consumers protection. Much research has been contacted regarding VOCs Determination in indoor air because of their effects to human health. A series of protocols and methodologies have been developed from national and international research schemes in order to achieve common indoor air sampling strategies and VOCs quantitative analysis. To accomplish this task, the European commission established the European Collaborative Action on urban air, indoor environment and human exposure and for more than 22 years. Now the European Collaborative Action (ECA)"Indoor Air Quality and it's Impact on Man" has been implementing a multidisciplinary adoration of European scientists.

In parallel, a number of techniques have been incorporated into formal methods that have developed for identification and quantified pollutants in the air. The EPA compendium of methods referred to as "TO" and "IP" methods corresponding to the quality of ambient and indoor air. Additionally, a number of existing standards for indoor products emission testing are available. The selection of the appropriate methodology is a function of the analytes of interest and the required specificity and Sensitivity, while many factors must be considered in order to achieve reliable and reproducible results on indoor air VOCs Determination. The selection of the appropriate methodology is a function of the analytes of interest and the required specificity and Sensitivity. In additional, the selection of a sampling method is dependent on the Objectives of the study, the contaminants of concern and the required sampling duration, while many factors must be considered in order to achieve reliable and reproducible results on indoor air VOCs Determination.

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Conflicts of interest
The authors declare that there are no conflicts of interest regarding the publication of this paper.

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