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Volatile Organic Compounds in Ambient Air: Potential Sources, Distribution and Impact

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Abstract

The present review study focuses on Volatile Organic Compounds (VOCs) monitoring, source identification and their negative impact on the environment and human health. In most studies, it was found that the concentration of VOCs is increasing at an alarming rate in urban areas compared to rural areas due to extensive use of vehicles, industries, biomass burning, gas leakage etc and an increase in population in rural areas due to burning of biomass for cooking. An increase in VOCs emission affects human health and climate change. Natural sources such as biogenic sources constitute higher VOCs emission worldwide. Most of the studies have reported that the VOCs concentration was found to be higher in the winter season in indoor environments as compared to outdoor environments. Most people spend their maximum time in indoor climatic conditions, and they have possible cancer risk and other health effects. Therefore, it is required to set emission standard limits and some remedial measures for the indoor environment.

Introduction:

In pre-historical times, living beings had created different kinds of shelter to protect themselves from the harsh conditions of the environment. For comfort, they start living a lot in an indoor environment. After discovering fire, humans began cooking food on fire inside their homes during winter. In the winter season, when the temperature decreased, they started using wood fire to maintain room temperature. Consequently, we can say that indoor pollution has been part of our life since ancient times (Weschler *et al*., 2009; Yin *et al*., 2020). With the increase in population, industrialization and urbanization, air pollution increases day by day. In developed countries, natives spend around 87% of their time indoors (Huang *et al*., 2019). There are different kinds of air pollutants in indoor and outdoor environments. The concentration of air pollutants is several times higher in indoors than in outdoor environments.

Volatile Organic Compounds (VOCs) are an influential group of air pollutants in indoor as well as the outdoor environment. Volatile organic compounds are organic chemicals with high vapour pressure and quickly form vapours at average temperature and pressure. Volatile organic compounds (VOCs) have a boiling point below 250°C at ambient atmospheric pressure (Adamova *et al*., 2020; Kumar *et al*., 2018). United States Environmental Protection Agency (USEPA) identified 189 hazardous air pollutants (HAPs), of which 97 are volatile organic compounds (Ward *et al*., 2009). Volatile organic compounds in the air consist of hydrocarbons of C and H only as well as partially oxidized hydrocarbons such as ketones, organic acids, aldehydes and organics containing nitrogen, and chlorine, sulfur or other atoms in the molecule (Kumar *et al*., 2017). Volatile organic compounds (VOCs) are important precursors to secondary organic aerosols and ozone, which cause adverse health effects on human beings. A high level of volatile organic compounds can decrease radical hydroxyl concentration and increase peroxy radical formation and organic nitrates such as peroxyacetyl nitrate formation (Yadav *et al*., 2019).

VOCs are important air quality parameters in the indoor environment because of their ubiquitous nature and impact on human health. The wide variety of indoor VOCs sources is building materials and consumer products, which include perfumes, ink, ceiling tiles, carpets, paints, solvents, air fresheners, cleaning products and furniture etc. Emissions from the transportation sector and cigarette smoking also contribute to the presence of volatile organic compounds in indoor air (Gulia *et al*., 2018 Kumar *et al*., 2017). Recent epidemiological studies have established that VOCs are coupled with disorders of many

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of the body's organs (Cheng *et al*., 2012). A large number of VOCs such as benzene, formaldehyde and 1, 2-butadiene are toxic, mutagenic and carcinogenic (IACR, 2011; WHO, 2010; Buczynska *et al*., 2009; Kumar et al., 2019); toluene harms the human central nervous system and could cause vertigo symptoms (Kumar *et al*., 2014, Hogie *et al*., 2009). The National Ambient Air Quality Standards set by the Central Pollution Control Board (CPCB) for annual time-weighted average benzene limits is 5µg/m³ (Brancher *et al*., 2019). Till now, the CPCB has not set any standard for other photochemical active VOCs like Toulene, Ethylbenzene and Xylene.

Natural source of VOCs

Earth's natural vegetation releases many organic gases when plants do photosynthesis by assimilating carbon dioxide into biomass and releasing carbon in highly reduced form as isoprene and terpenes. Plants emit different volatile organic compounds due to climate change, such as terpenes, alcohols, aromatic compounds, and aldehydes (Copolovivi *et al*., 2020). Robinia pseudoacacia and Platanus orientalis emit large amounts of isoprene (Khedive et al., 2017). Isoprene is also emitted by spruce, oak, citrus and eucalyptus plants, whereas monoterpenes are from pine, hickory, maple, spruce and fir trees, respectively (Gilbert *et al*., 2017). Ocean and microbial communities also contribute to VOCs (Bruggemann *et al*., 2018).

Sindelarova *et al*. (2014) studied the emission of biogenic VOC from 1980 to 2010 for 30 years every month by using the MEGANv21 (Model of Emissions of Gases and Aerosols from Nature) collectively with the MERRA (Modern-Era Retrospective Analysis for Research and Applications) meteorological data also used for estimating global emission. The global emission data set was developed by using the MACC (Monitoring Atmospheric Composition and Climate project). The MEGAN estimated that total biogenic VOC emission was 760TG(C) yr-1 from terrestrial vegetation consisting of 70% isoprene, 11% monoterpenes, 6% methanol, 3% acetone, 2.5% sesquiterpenes and less than 2% was constituted by other species (Liu *et al.*, 2018; Sinderlarova *et al.*, 2014)..

Biogenic volatile organic compound (BVOC) emission calculated in China using the MEGAN in 2018 based on vegetation was 58.89Tg with 63.60% isoprene, 11.35% monoterpenes, 2.18% sesquiterpenes and 22.87% was from other sources (Liu *et al*., 2018). BVOC emissions increased by 20.18% from 2008 to 2018 with an annual growth rate of 2.03%, and the highest increase in isoprene, around 32.67%, due to an increase in leaf biomass and increase in temperature as a result of global warming also enhance the emission of BVOC (Li *et al*., 2020).

Anthropogenic source of VOCs

Painting a house, driving a car, cooking food, glass processing, making fires and even breathing cause emission of volatile organic compounds. The total anthropogenic emission of non-methane volatile organic compounds (NMVOCs) in 2010 was estimated at 9.81Tg (Teragram) based on different studies (Kumar *et al*., 2017). Residential combustion of biomass for cooking contributes to 60% of total emissions, 12% by transportation, 7% by open burning, and 20% by oil production, distribution and solvent use (Sharma *et al*., 2015). Landfills contribute to NMVOCs emission from burning landfill material and their decomposition (Dave *et al*., 2020). Vehicular-based total VOC emission in China during the year 2015 was found to be 4.21Teragram, and intermediate-volatile organic compounds emission was 200.37 Gigagram (Liu *et al*., 2017). Vehicular tailpipe emissions include passenger vehicles, trucks and motorcycles as predominant contributors to VOCs, and vehicular evaporation emissions contribute to 39.20% of volatile organic compounds emissions (Liu *et al*., 2017). From 1990 to 2017, anthropogenic non-methane VOC emissions increased continuously in China from 9.76 to 28.5Tg due to the constant growth of the industrial sector and solvent use (Li *et al.*, 2019). The ozone-forming potential of non-methane volatile organic compounds increased from 38.2Tg to 99.7Tg from 1970 to 2017 (Li *et al*., 2019). Non-methane VOCs emission from petrol pumps in Delhi was found to be around 3190 tons per year in Delhi city (Gulia *et al*., 2018).

Impact of VOC on the environment and human health

Biogenic and anthropogenic VOC emission leads to the occurrence of different photochemical reactions and results in tropospheric ozone formation. Ozone formation was observed to be higher in urban areas due to a higher concentration of oxides of nitrogen (NOx) than in rural areas. Atmospheric ozone formation requires photolysis of NO2 at <424nm wavelength. VOCs act as a precursor for ozone production through OH radical initiated oxidation and consequent reaction with NOx in the presence of sunlight and led to the production of other secondary oxidant pollutants. The primary source of the emission of NOx is vehicles and industries. Photochemical reactions include the following reactions where R is an alkyl group, hv stands for photon, and M is a third body molecule (Kansal, 2009).

$$RH + OH \rightarrow R + H_2O \quad (1)$$
$$R + O_2 \rightarrow RO_2 \quad (2)$$
$$RO_2 + NO \rightarrow NO_2 + RO \quad (3)$$
$$NO_2 + h\nu \rightarrow NO + O \quad (4)$$
$$O_2 + O + M \rightarrow O_3 + M \quad (5)$$

Peroxyacyl Nitrate (PAN) is a secondary pollutant found as a constituent of photochemical reactions. $RC(O)OONO_2$ is the chemical formula for peroxyacetyl nitrate, in which $RC(O)OO$ stands for peroxyacetyl and NO_2 for nitrate. The first compound of this series is peroxy acetyl nitrate $CH_3C(O)OONO_2$. PAN behaves as stable species in the atmosphere because it is not soluble in water and does not photodissociate in the atmosphere. The following reactions show PAN formation in which carbonyl compounds such as aldehyde react with OH radical present in the atmosphere and form peroxy acyl and then react with NO and form PAN.

$$RCHO + OH \rightarrow RCO + H_2O \quad (6)$$
$$RCO + O_2 + M \rightarrow RC(O)OO + M \quad (7)$$
$$RC(O)OO + NO_2 + M \rightarrow RC(O)OONO_2 + M \quad (8)$$

Peroxy acetyl nitrate dissociates at high temperatures, but due to low temperature in the upper troposphere, it remains for an extended period, and PAN acts as phototoxic in higher concentrations. It causes skin cancer and acts as an eye irritant (Kumar *et al*., 2017). VOC affects the growth of plants during different stages. Chlorinated hydrocarbons were found as harmful to plants. Proteus Vulgaris is most sensitive to VOCs, which decreases the harvested pod weight (Cape, 2003). The higher level of ozone causes a decrease in crop production and plant growth along with a reduction in the nutrient content of vegetables (Ashmore, 2005; Sharma *et al*. 2907).

Carbonyl and aromatic compounds such as benzene, xylene, toluene, HCHO and CH_3CHO are proven human carcinogens. VOCs play an essential role in photochemical smog formation, causing eye, nose and skin irritation. Direct exposure to VOC in the long term causes carcinogenicity, teratogenicity and mutagenicity in humans. Short-term exposure to VOC in newly constructed building cause dizziness, sickness, headaches, irritation in the eye, nose and skin, sick building syndrome, atopic dermatitis, asthma, *etc*. (Soni *et al*. 2018). Terpenes cause skin, eye and respiratory system irritation. VOCs concentration up to 25000µg/m3 cause headaches and other neurotic diseases. International Agency for Research on Cancer (IARC) classified formaldehyde as a group 1 human carcinogen and causes eye and upper respiratory tract irritation (Adamova *et al*., 2020). IARC classified benzene as a group 1 carcinogen, and it causes neurotoxicity by neurobehavioural function impairment, aplastic anaemia and acute myeloid (Xuan *et al.*, 2021).

Monitoring and measurement of VOCs

VOCs are often present in low concentrations at ppb (part per billion) levels in the atmosphere and are considered trace gases. In some polluted areas, the concentration of VOC has been detected at higher levels which are in ppm (part per million). Different approaches have been used for VOC sampling, such as active, passive and whole air sampling. Usually, active sampling requires air samplers connected with a pump for a regular flow rate of air for a specific period as the air passes through absorbing media and VOCs are adsorbed on activated charcoal or Tenax tubes. The researchers mostly use Tedlar bags and Summa Canister (Polished Stainless Steel canister) for air sampling worldwide. Air samples were taken per the procedure based on the National Institute for Occupational Safety and Health (NIOSH) Manual of Analytical Method 1501; Gas chromatography with Mass Spectrophotometry and Gas chromatography with flame ionization detector was used for further analysis of VOCs (Hazrati *et al*., 2016).

Study of VOCs monitoring and their health assessment

Kumar *et al*. (2013) studied total VOC and BTEX emissions in the library of Jawaharlal Nehru University, New Delhi, from 2011 to 12 summer and winter. Indoor Total VOCs mean concentration was 465.8µg/m³ and 31.8µg/m³ in winter and summer, respectively. The outdoor mean concentration of Total VOCs was 187.4µg/m³ and 113.3µg/m³ in winter and summer, respectively. Indoor concentration was found to be higher in the library due to emissions from office equipment, insulating material, adhesive and building material. The indoor concentration of BTEX (Benzene, Toluene, Ethylbenzene, Xylene) was 7.2, 94, 10.1 and 20.9µg/m³ in winter and 12.2, 66.7, 13.9 and 15.8µg/m³ in summer season respectively. Lifetime Cancer Risk for women was 1.40*10-5and 1.04*10-5 in winter and summer seasons, respectively, and LCR was found to be higher in women due to low body weight, and it was 5.27*10-6 and 8.93*10-6 respectively for men.

Total BTX concentration was measured in biomass burning kitchen having openness of <25%, 25-50%, 50-75% and >75% respectively and it was observed that kitchen with openness of <25%, 25-50%, 50-75% and >75% has total BTX concentration of 148.51, 76.98, 34.91 and 13.34 µg/m³ respectively. Total BTX concentration was found to be higher in winter as compared to summer. A kitchen with a more open area has less concentration of BTX in biomass burning kitchens in rural areas of West Bengal, India. The Lifetime Cancer Risk of Benzene at 2.2 * 10-6 to 7.8 *10-6 per µgm-3 exceeds the standard limits of 1*10-6 (USEPA, 2009), posing a possible risk of cancer to women working in the kitchen (Nayek & Padhy, 2020). The hazard quotient of benzene was 0.51, xylene 0.47, and the Lifetime Cancer Risk of Benzene was 125*10-6 and 75*10-6 in indoor and outdoor environments, respectively, due to the use of natural gas appliances and heating systems in residential buildings of Iran (Hazrati *et al*., 2016).

Bari & Kindzierski (2018) studied the mean total VOC concentration in Calgary, which was 41.99µg/m3, while the mean BTEX concentration was 0.59, 1.79, 0.26 and 0.30µg/m³. Significantly, a higher concentration of BTEX was found during winter compared to other seasons and influenced by 17% fumigative evaporation emission, 17% industrial, 20% natural gas and 40% by the transportation sector, respectively. Dominating compounds at Calgary were observed to be alkanes, halogenated, aromatics,

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alkenes, alkynes and terpenes. Lifetime Cancer Risk (LCR) of naphthalene, carbon tetrachloride and benzene were above the acceptable limit of 1*10-6.

Hajizadeh *et al.* (2017) studied the VOCs level in Iran, the concentration of total VOCs varied from 8 to 560μg/m3, benzene varied from 38 to 42 μg/m3 and toluene from 41 to 45μg/m3, respectively. Ozone forming potential (OFP) was 720μg/m3 and 375μg/m3 in the summer and winter seasons, respectively. Xylene has the highest OFP, followed by toluene, ethylbenzene and benzene. There was a potential cancer risk in exposure to benzene, and the LCR of benzene was observed to be 1.64*10-4, whereas non-carcinogen risks were found to be under the permissible limits. Mojarra *et al.* (2020) studied BTEX concentration in Iran and found that the concentration of BTEX in winter was 15.2, 22.49, 5.69, 12.38μg/m3 and in spring, it was 19.84, 32.05, 9.49, 15.56μg/m3 respectively. Principle component analysis identified that the major source of pollution was from industries in spring and traffic sources during the winter season. Hazard quotient of BTEX were 0.25, 0.002, 0.003 ando.06 respectively.

Rastaman *et al.* (2021) studied BTEX levels in photocopy and printing shops in Iran, and the concentration of BTEX was influenced by printing, copying machines and ventilation systems. BTEX concentration was found to be 93.6, 150.6, 34.3 and 29.5μg/m3, respectively. Lifetime cancer risk in photocopy and printing shops caused by benzene, and ethylbenzene were 44.4*10-6 and 153.3*10-6 with laser print and 23.4*10-6, 54.2*10-6 with an inkjet printer, which was higher than the permissible limit prescribed by USEPA (US Environmental Protection Agency) and WHO (World Health Organization).

Ari *et al.* (2020) observed the concentration of BTEX at 6.57, 31.3, 1.19 and 1.08μg/m3 in a restaurant in Turkey. VOCs pollutants emitted from the kitchen and restaurant were influenced by the following factors such as ventilation, temperature, material type and fuel type. Lifetime cancer risk varied from 3.4*10-8 to 1.1*10-5, which causes possible cancer risk to people working in a restaurant. Cooking emissions and cooking fumes cause cancer risk and affect the indoor air quality of restaurants (Dai *et al.*, 2018).

An indoor and outdoor VOCs concentration from different studies is presented in Table-1 during different seasons. All the selected case studies are related to long-term exposure spanning from weeks to years because they represent actual personal exposure more accurately. A study performed by Kumar *et al.* (2018) at three locations, two urban (Connaught Place and Jawaharlal Nehru University, New Delhi) and one rural area during the study period of 2013-14 found that the concentration of VOCs was higher in urban areas (CP than JNU) as compared to a rural area. VOCs concentration was observed to be significantly higher in winter, followed by summer and autumn. The indoor concentration of total VOCs was higher (456.8μg/m3) compared to the outdoor (187.4 μg/m3) environment in the winter season. The concentration of toluene and Xylene was higher in the winter season, accounting for 94μg/m3 and 20.9 μg/m3 respectively, in indoor environments (Kumar *et al.*, 2014). Many international studies shown in Table 1 are also depicting that the mean value of total VOCs was higher in Saudi Arabia in printing shops (Hashemy *et al.*, 2019) because the solvent used in ink was the primary source of VOC and photocopy machine and ventilation system also affect VOCs emission (Rastami *et al.*, 2021, Barrese *et al.*, 2014). Benzene concentration in an indoor environment (gym) was observed to be higher (75.1 μg/m3) in Iran (Dehghani *et al.*, 2019). A study performed in salons by Baghani *et al.* (2018) observed high concentrations of benzene, toluene, ethylbenzene and Xylene at the levels of 32.40μg/m3, 16.10μg/m3, 62.38μg/m3 and 13.82μg/m3 respectively. Different studies performed on school and university campuses also revealed a significant amount of VOCs emission and their health impacts (Tarn *et al.*, 2020; Raysoni *et al.*, 2017; Kumar *et al.*, 2014).

VOCs Source Apportionment

VOCs are hazardous indoor/ outdoor air pollutants that cause different kinds of health risks, so to reduce their risks; it is required to identify their sources. Therefore, there are various studies related to source apportionment. Mainly four different kinds of receptor models are used for source apportionments such as Positive Matrix Factorization (PMF), Principle Component Analysis (PCA), UNMIX and Chemical Mass Balance (CMB) (Bari *et al.*, 2018; Song *et al.*, 2019). PMF model is primarily used in recent VOCs source apportionment studies worldwide. PMF was a model used for source identification in Alberta in two sand communities and identified four sources of VOCs at Fort McKay as oil sands fugitives, ethylbenzene/ Xylene rich, unburned fuel and petroleum processing. The contribution of oil sand-related emissions to total VOCs was 70% at Fort McKay. Six different sources were identified at Fort McMurray such as oil sand fugitives, toluene wealthy, aged air mass, ethylbenzene/ benzene rich, liquid or unburned fuel and petroleum processing and 30% contribution to total VOCs at both sites was contributed by age air mass transportation including emission from biomass burning (Bari *et al.*, 2018). UNMIX receptor model identified sources of BTEX compounds in Tehran city with higher traffic and industries. Mainly three sources were identified such as painting and solvent used in vehicle manufacturing units, motorized road vehicles and mixed sources. UNMIX model identified that painting and solvent industries contribute 41% toluene and 27% of o-Xylene; motorized road vehicles contribute 40% benzene and 31% ethylbenzene. The mixed origin source industry includes plastic, rubber, leather and other industries, and their contribution to total BTEX was 66%. In comparison, the

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Table 1:- Indoor and outdoor VOCs concentrations measured in different studies (unit= μg/m³)

Location & (Year of study)	Season/ period	TVOC Indoor	TVOC Outdoor	Benzene Indoor	Benzene Outdoor	Toluene Indoor	Toluene Outdoor	Ethylbenzene Indoor	Ethylbenzene Outdoor	Xylene Indoor	Xylene Outdoor	Location type	References (Year)
JNU, New Delhi, India (2011-12)	Summer	321.8	113.3	12.2	14	66.7	39.3	13.9	10.9	15.8	8.9	Library	Kumar *et al.*, 2014
	Winter	465.8	187.4	7.2	11.9	94	34.9	10.1	6.5	20.9	7.8		
JNU, New Delhi, India (2013-14)	Summer				6.3		23.1		8.8		21	Campus	Kumar *et al.*, 2018
	Winter				11.7		42.2		2.9		11.5		
	Autumn				8.2		28.8		4.5		9.4		
CP, New Delhi, India (2013-14)	Summer				8		53.3		10.5		20.5	Market CP	Kumar *et al.*, 2018
	Winter				17.1		33.7		5.4		13.8		
	Autumn				10.4		30.3		3.9		13.7		
DP, New Delhi, (2013-14)	Summer				3.8		34.1		3		2.7	Rural areas	Kumar *et al.*, 2018
	Winter				8.4		22.8		5.7		4.2		
	Autumn				6		19.3		1.9		1.1		
South Africa (2018)	Annual	167	21									University campus	Mundackal *et al.*, 2020
Gorakh-pur, India	Summer			3		5.48				0.30		Residen-tial areas	Masih *et al* ., 2017
	Monsoon				6.11		9.28		0.19		0.88		
	Winter			14.8		30.20		0.35		1.86			
Turkey (2008)	1-month			2.29	1.23	26.55	6.11	0.73	0.26	0.82	0.38	School	Demirel *et al.*, 2014
Iran (2015)	Winter			53.2	43.5	21.5	26.2	14.4	10	21.1	19.1	Home	Hadei et al., 2018
Turkey	Annual	40	22	10.30	11.72	20.30	12.69	1.83	0.72	0.50	0.55	School	Sofaoglu et al., 2011
Iran (2018-19) 2019	5-months				75.1		34.1		54.8		19.5		GymDehghani et al.,
Saudi Arabia (2016)	4-weeks	145.78-1141.54	12.5-26.89	2.45-14.46	1.79-2.73	81.59-955.65	6.18-16.56	11.19-97.35	1.15-3.86	3.9-28.39	1.06-2.20	4 Printing shops	Hashemy *et al.*, 2019
Iran (2017)				32.40		16.10		62.38		13.82		Salons	Baghani *et al.*, 2018
Iran	Summer			15.18	8.65	69.70	40.56	12.07	4.92	48.08	7.44	Residences	Hazrati *et al.*, 2016
Vietnam (2017)	2- months				8.75	5	133.86	132.7		619.47		436.1	HomeHa *et al.*, 2017
Louisiana (2013-15)				1.14		2		0.74		0.81		Home	Wickliffe *et al.*, 2020
Texas, Mexico (2010)	1- Week			0.34	0.52	0.92	1.16	0.30	0.27	0.26	0.28	School	Raysoni *et al.*, 2017
Vietnum (2017-18)	4-Months			3.49	2.59	13.7	19.8	3.12	1.69	1.81	1.28	Classroom	Tran *et al.*,2020
USA (2000)	Winter			0.6		2.9		0.6		0.8		School	Adgate *et al.*, 2003
	Spring			0.6		1.6		0.3		0.4			

remaining 34% was contributed by vehicle manufacturing and vehicles in Tehran (Dehghani *et al.*, 2017). Vehicular exhaust sources significantly contributed to VOCs (Guo *et al.*, 2017; Dehghani *et al.*, 2017). Source apportionment by CMB, CMT (Chemical transport modelling) and PMF at different four sites in Seoul during 2013-15 identified vehicles, solvent use, coating, non-electric generating utility combustion, electric generating utility combustion, wood combustion and biogenic sources were significant contributors to VOCs emission (Song *et al.*, 2019). VOCs sources were also identified at the photochemical assessment monitoring station in Taichung, Taiwan, by using the PMF model were identified as industrial emissions from northwest to south, traffic emission, including vehicular emission and fuel evaporation, came from the southwest (Huang *et al.*, 2019).

Conclusion

The extensive review focused on monitoring, health risk assessment and source identification. The concentration of VOCs is increasing quickly in urban areas in India due to anthropogenic activities, vehicular emission, biomass burning and industrial exhaust. In rural areas, the concentration of VOCs is higher mainly due to biomass burning for cooking food. High concentrations of NOx and OH radicals in the presence of sunlight and VOC precursors initiate the formation of ozone and photochemical smog. Many studies show that VOCs have high ozone-forming potential, and this tropospheric ozone act as an air pollutant and has carcinogenic properties. Many national and international studies conducted in restaurants, universities and schools show possible cancer risks. Some studies reveal that an efficient ventilation system improves indoor air quality and reduces VOCs exposure. It is concluded that as humans spend most of their time indoors and are exposed to different kinds of VOC pollutant exposure which poses higher cancer risk and other health impacts, it is required to formulate remedial measures, prevention and control strategies to regulate VOCs emission.

Recommendation

1. The nation's development in terms of industrialization and urbanization will be achieved with proper preventive measures such as age and type limit of vehicles, vehicular emission and the fuel used.

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2. In India, there is only a NAAQS limit for benzene and benzo [a] pyrene. At the same time, other VOCs air pollutants have no standard limit, so the government has to formulate a new standard for the rest of the VOCs parameters.
3. Government has to renew existing policies and formulate new policies in the public domain, such as the use of low pollution emitting fuel as CNG and four-stroke engines and rules for the use of mass transport services.
4. Proper training and workshop facilities for public awareness will help reduce the level of VOCs emission.

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