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Indoor VOCs from Religious and Ritual Burning Practices in India

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ABSTRACT

Measurements of selected volatile organic compounds (VOCs), known as markers of emissions resulting from burning practices using natural- and synthetic biomaterials, have been carried out in major religious/ritual-indoors in India. Four different religious/ritual-indoors were selected for monitoring purposes: 1) Hindu Marriage Places (MP), 2) Muslim Holy Shrines (MG), 3) Buddhist Temples (BT), and 4) Hindu Temples (HT). One pure residential-indoor (RESID) site was also examined for comparison studies. Indoor VOCs sampling was carried out throughout the three seasons of summer, fall and winter of the calendar year of 2012–2013 in Raipur, India. VOCs samples, collected by passive sampling over a 48-h period, were analyzed using thermal desorption (TD), followed by high-resolution gas chromatographic separation and mass spectrometric detection (GC/MS). A total of 14 volatile organic compounds (n-hexane, cyclohexane, n-heptane, n-octane, n-nonane, n-decane, n-undecane, styrene, o-xylene, m,p-xylene, 1,2,4-trimethyl benzene, ethylbenzene, benzene, and toluene.) were quantified. The annual mean concentrations for total VOCs (TVOCs) were 216.61 ± 75.15, 656.34 ± 220.82, 681.75 ± 219.83, 129.51 ± 45.24 and 82.67 ± 40.96 $\mu g/m^3$ for MP, MG, BT, HT and RESID respectively. The results were found to be higher than the prescribed standards and earlier reported indoor VOCs levels. Indoor/outdoor ratios (I/O), correlation analyses, seasonal variations and indoor/outdoor contributions to the measured levels are also investigated.

Keywords: VOCs; Indoor air quality; Religious and ritual places; Indoor/Outdoor ratio; Seasonal variation.

INTRODUCTION

Volatile organic compounds (VOCs) have now been identified as one of the major indoor air contaminants due to construction of well-sealed houses using various types of insulators (Berk *et al.*, 1980), usage of painting materials in indoor-houses (Srivastava *et al.*, 2000), household cooking fuels (Liquid petroleum gas, kerosene, solid fuels etc.) (Sinha *et al.*, 2006; Huang *et al.*, 2011), adhesive- bonded material use in plywood/ PVC flooring (Low *et al.*, 1998; Wilke *et al.*, 2004; Jarnstom *et al.*, 2008; Choi *et al.*, 2010; Kang *et al.*, 2013) and house furniture's (Fisher *et al.*, 1962; NRC, 1980; USDHUP, 1980; Franklin, 1981). Furthermore, Selected VOCs emission over the building materials has also been reported by Molhave (Molhave, 1980). High lipid solubility character of these VOCs explained that they are rapidly absorbed through the lungs and enter organs having high content of lipids. VOCs are also reported that they rapidly cross the blood-brain barrier and commonly depress central nervous system and cardiac functions (Beall and Ulsamer, 1980). Human exposure to one of the VOCs namely n-hexane causes demyelination and degeneration of peripheral nerves (Paulson and Wylonis, 1976; Spencer *et al.*, 1980). Similarly toluene which was observed to be present in more than 50% of indoor air samples, causes fatigue, muscle weakness, and confusion in humans exposed for eight hours to atmospheric concentrations of 200 to 300 ppm (Berk *et al.*, 1980; Benett and Forman, 1980; Konietzko *et al.*, 1980). Benzene and toluene vapors have been reported to cause central nervous system depression, psychosis, and liver and kidney damage (Aruffo and Escobar, 1979; Tarsh, 1979); benzene also damages the hematopoietic system, causing first a decrease in the number of white blood which manifests themselves as anemia, leukopenia, thrombocytopenia, and leukemia (Beall and Ulsamer, 1980).

Most of air quality studies on VOCs status conducted in Indian sub-continent are mainly focused on ambient-outdoor environment (Rao *et al.*, 1996; Chattopadhyay *et al.*, 1997; Srivastava, 2004; Srivastava *et al.*, 2004, 2006; Dutta *et al.*, 2009) and fewer indoor air quality studies were reported, specifically for residential cooking activity emissions (Raiyani *et al.*, 1993; Mishra, 2003; Pandey *et al.*, 2005;

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Saha *et al.*, 2005; Sinha *et al.*, 2005). Selective studies on indoor VOCs were conducted and reported for commercial activity centers in India; described the quantification of 40 VOCs and most of these were found to be below the prescribed limits, except higher concentration of benzene and carbon tetrachloride compared to the permissible limits (Srivastava and Devotta, 2007). Synthetic and natural bio-materials usage in combustion activities during religious and ritual performances has also been reported to be the major source of various VOCs with major constituents namely benzene, toluene, ethylbenzene, m,p_xylene and styrene (Dewangan *et al.*, 2013). VOCs emission during incense burning and candle in temples has been described earlier (Lau *et al.*, 1997; Jetter *et al.*, 2002; Lee and Wang, 2004; Wang *et al.*, 2007; Navasumrit, 2008; Derudi *et al.*, 2012). VOCs concentration at emission plume of incense/candle burning practices involved with temples located in different east-Asian countries were found to be: 870 ± 63 and 1260 ± 17 $\mu g/m^3$ in Hong Kong, 4508.8 ± 472.0 $\mu g/m^3$ (non-smoke incense), 6992.6 ± 1638.8 $\mu g/m^3$ (reduced smoke incense) 18474.0 ± 673.8 $\mu g/m^3$ (standard smoke incense) in Taiwan, 3810 $\mu g/m^3$ respectively (Madany and Crump, 1994; Wang *et al.*, 2007; Yang *et al.*, 2007). Season variation and outdoor infiltration of VOCs were also determined for selected indoor environments: 1) residential, 2) classrooms, 3) office buildings, 4) photocopy centers in Germany (Rehwagen *et al.*, 2003), Spain (Esplugues *et al.*, 2010), Japan and China (Ohura *et al.*, 2009), Thailand (Ongwandee *et al.*, 2011), Turkey (Pekey and Arslanbas, 2008), Izmir, Turkey (Sofuoglu *et al.*, 2011), Taiwan (Lee *et al.*, 2005), and Hong Cong (Lee *et al.*, 2001).

The work being presented here is focused on quantification of selected VOCs, potentially known markers of indoor sources, in major religious and ritual centers of central India. Outdoor infiltration and indoor/outdoor relationship along with seasonal & temporal variation of indoor VOCs has been investigated. Comparison of these VOCs measurements with those measured in pure-residential indoors along with prescribed standards has also been described. In addition, this study will provide a useful database for further risk assessment or health-related studies as well as regulatory agencies to set up guidelines or standards for indoor religious and ritual places.

MATERIALS AND METHOD

Study Area

Raipur, the capital city of Chhattisgarh, India, is located in global scale of 21°14′22.7″N latitude and 81°38.1″E longitude (Fig. 1). According to 2011 Census (Census, 2011), population of Raipur Municipal Corporation was about 10 million. Raipur has a tropical wet and dry climate; temperature remains moderate throughout the year, except from March to June, which can be extremely hot. Annual average temperature is 32.8°C. The temperature in April–May sometimes rises above 48°C (118°F).These summer months also have dry and hot winds. The city receives about 1,300 millimeters (51 in) of rain, mostly in the monsoon season from late June to early October. Winters last from November to January and are mild, although lows can fall to 5°C (41°F) (IMD, 2012; RDP, 2012). A survey to determine numbers of different religious and ritual places along with statistics of clerics working in religious-indoors and pilgrims visited to these religious places has been conducted using questionnaire study. Results of survey study has shown that about > 1200 religious and ritual places, belongs to different religions namely Hindus (> 1100), Muslims (~30), Buddhist (~10) and Christians (~15), are located within the periphery of the city. About 5000 religious clerics are exposed daily to these religious-indoors for more than 8 hrs/day and > 20 thousand pilgrims are visited and exposed to their respective religious-indoors for > 1 hr/day (average).

Sampling and Chemical Analysis

A stratified random sampling plan using longitudinal study design was adopted for monitoring of indoor air VOCs in selected community activities (Gilbert, 1987; Delmas *et al.*, 1995; USEPA, 2003). VOCs monitoring was carried out in four different types of religious and ritual activity centers along with pure residential-indoors and one ambient-outdoor site located in Raipur City, District Raipur, Chhattisgarh during March 2012 to February 2013. Selected religious and ritual places, known for performing different types of burning practices, were: Hindu Marriage Places (MP), Muslim Holyshrines (MG), Buddhist Temples (BT) and Hindu Temples (HT). Details of sampling sites, characteristics of burning materials and combustion characteristics have been presented in Table 1. Normally, all windows and ventilators of these sites are kept closed 24-h a day except residential home in which windows are opened morning, evening and cooking times. Three centers for each of four different religious and ritual activities have been chosen for the VOCs monitoring. Sampling of indoor VOCs has been carried out in each month from March 2012 to February 2013. A total of 180 samples were collected comprising of 36 samples from each type of five different indoors. These 36 samples have contained 12 samples from each of three sites belongs to a specific religious/ritual-indoors during all three seasons (Fall, winter and summer). VOCs samples were collected during a 48-h period (except residential-indoors for 4-days sampling period) using Radiello VOC passive samplers (Supelco Analytical), containing stainless steel mess tubes (3 × 8 µm mesh, 4.8 mm diameter × 60 mm length) packed with Carbograph4 (350 mg) (Radiello, 2010). A passive sampler was designed as portable and noiseless devices without a power supply, suitable for measurement of indoor air pollution (Son, 2003). Passive samplers were placed at 1.5–2 m above the ground in the middle of a room in which the mostly worshipping activities occurred. The samplers were carefully placed to avoid any type of possible contamination. Simultaneously, outdoor measurements were also carried out on the same sites and sampler was placed at a rain protected position directly on the outer site (Rehwagen *et al.*, 2003). After collection of samples, the tubes were then covered with aluminium foil, packed in Ziploc bag and stored at 4°C until analyzed (Ongwandee *et al.*, 2011).The cartridges were deployed in

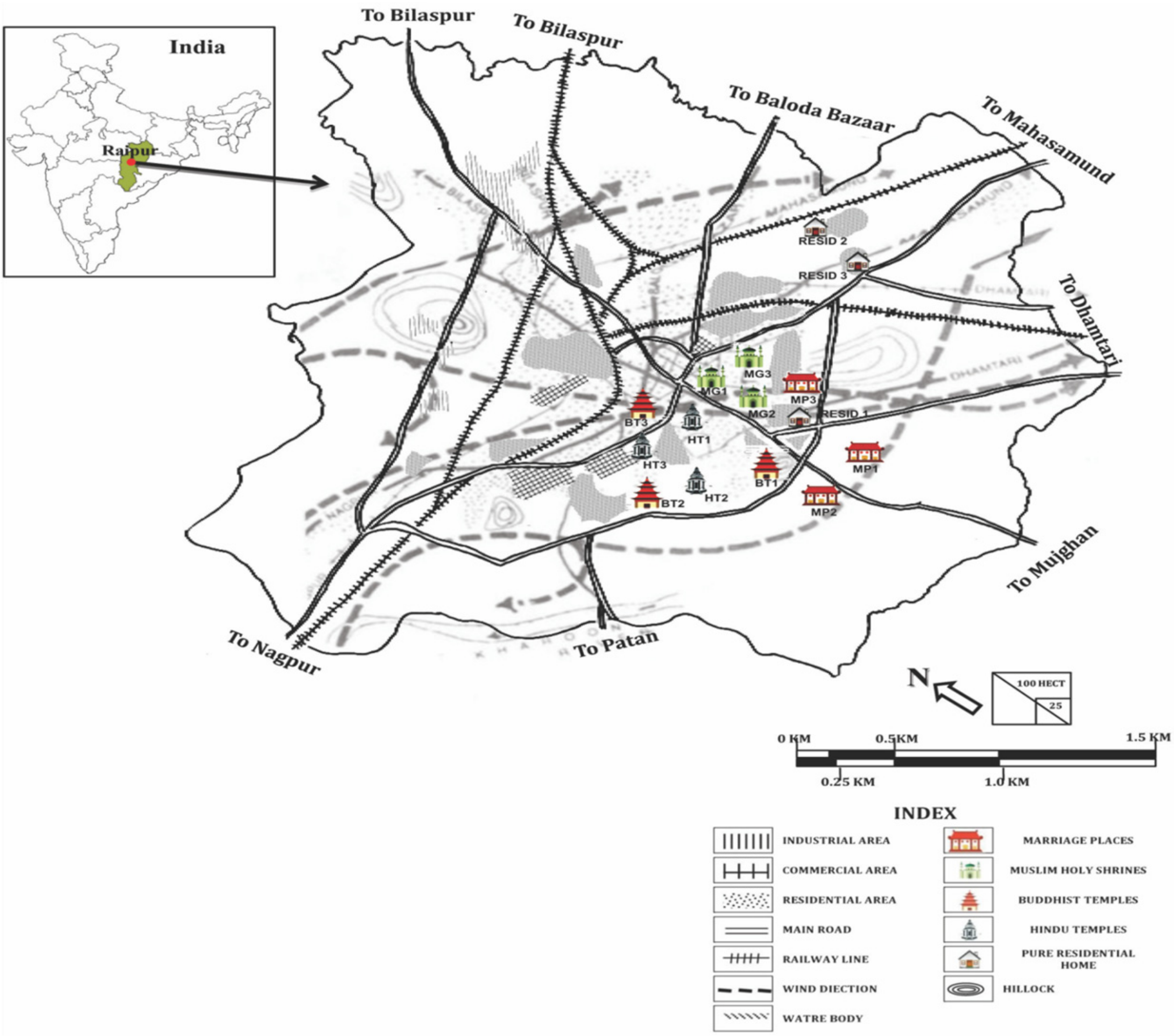

Fig. 1. Location map of religious/ritual-indoor sites designed on the background map of wind channel over Raipur India.

the diffusive sampling bodies according to manufacturer's instructions (Radiello, 2010). All samples were then quantitatively analyzed for n-hexane (n_hex), cyclohexane (cyhexa), n-heptane (n_hept), n-octane (n_oct), n-nonane (n_non), n-decane (n_dec), n-undecane (n_unde), styrene (stry), o-xylene (o_xyl), m,p-xylene (mp_xyl), 1,2,4-trimethyl benzene (bz124m), ethylbenzene (etbz), benzene (benze), toluene (tolue). The quantification of VOCs was done by the thermal desorption-cryogenic pre-concentration method, followed by high-resolution gas chromatographic separation and mass spectrometric detection (GC/MS) of individual compounds. Details of analysis procedure were described elsewhere (Mason *et al.*, 2011; Dewangan *et al.*, 2013).

Statistical inferences of longitudinal measurements of fourteen VOCs in selected religious and ritual-indoors along with pure residential-indoors and local ambient-outdoor site have been documented in statistical box-plot diagrams (Fig. 2). Relative concentration strength of each VOCs across the five different activity centers has also been presented in Fig. 3. Seasonal and temporal variations of indoor VOCs along with variation in local meteorological parameters have also been assessed graphically and presented in Table 2 and Figs. 4 and 5. Outdoor infiltration and contribution from indoor activities to VOCs measurements in all selected religious/ritual/residential-indoors has also been evaluated using regression analysis between longitudinal measurements of VOCs of ambient-outdoor and respective indoors and regression data along with indoor/outdoor ratios (I/O) have been presented in Table 3.

RESULTS AND DISCUSSION

Annual Average of VOCs in Religious/Ritual-indoors

High emission factors of VOCs from burning practices involved with religious and ritual activities in India (Dewangan *et al.*, 2013) are attributed to significance of indoor air quality assessment of religious and ritual-indoors in relation to quantify indoor VOCs level. The 14 target VOCs

Table 1. Characteristics of indoor sampling sites located at Raipur.

S. No.		Indoor Sites	Type	Area volume covered (M^3)	Visitors /day /sites	Combustion Characteristics	Ventilation Properties	Activity period	
								Morning	Evening
1.	Marriage Places (MP)	Puzari Park, Tikarapara, Raipur (MP1)	Indoor	5120	20	Hawan Material# A, B	Exhaust fan & Windows Moderate	7:00am–12:00noon	5:00pm–11:00pm
		Kundan Palace, Pensionbada, Raipur (MP2)		5513	12	Hawan Material A, B	Exhaust fan & Windows Moderate	7:00am–12:00noon	5:00pm–11:00pm
		Katora Talab, Raipur (MP3)		3600	15	Hawan Material A, B	Exhaust fan & Windows Moderate	7:00am–12:00noon	5:00pm–11:00pm
2.	Muslim Holyshrines (MG)	Aliya Chowk, Raipur (MG1)	Indoor	1080	2000	Incense Sticks & Styrax Benzoin A	Windows Moderate	6:00am–11:00pm	
		Mantralaya, Raipur (MG2)		225	100	Incense Sticks & Styrax Benzoin A	No Poor	7:00am–12:00noon	5:00pm–10:00pm
		Civil Line, Raipur (MG3)		210	50	Incense Sticks & Styrax Benzoin A	NO Poor	7:00am–12:00noon	5:00pm–10:00pm
3.	Buddhist Temples (BT)	New Rajendra Nagar, Raipur (BT1)	Indoor	95	10	Incense Sticks & Candles A, B	NO Poor	7:00am–12:00noon	5:00pm–9:00pm
		B Lakhe Nagar, Raipur (BT2)		90	25	Incense Sticks & Candles A, B	NO Poor	7:00am–12:00noon	5:00pm–9:00pm
		Old Bus Station, Raipur (BT3)		92	20	Incense Sticks & Candles A,B	NO Poor	7:00am–12:00noon	5:00pm–9:00pm
4.	Holy Hindu Temples (HT)	Kali Mandir, Akhashwani Chowk, Raipur (HT1)	Indoor	500	1000	Incense Sticks, Vegetable oil & Cotton A, B	Exhaust fan & Windows Moderate	7:00am–12:00noon	5:00pm–10:00pm
		Sidhivinayak Mandir, Budapara, Raipur (HT2)		500	200	Incense Sticks, Vegetable oil & Cotton A, B	Windows Moderate	7:00am–12:00noon	5:00pm–10:00pm
		Sai Mandir, Azad Chowk, Raipur (HT3)		210	300	Incense Sticks, Vegetable oil & Cotton A, B	Window Poor	7:00am–12:00noon	5:00pm–10:00pm
5.	Residential Homes (RESID)	Katora Talab, Raipur (RESID 1)	Indoor	288	5	Incense Sticks, Vegetable oil, Cotton & LPG A, B	Windows Cross Ventilation	8:00am–10:00am*	7:00pm–9:00 pm*
		Shankar Nagar Raipur (RESID2)		300	6	Incense Sticks, Vegetable oil, Cotton & LPG A, B	Windows Cross Ventilation	8:00am–10:00am	7:00pm–9:00pm
		Telibhandha Raipur (RESID3)		310	5	Incense Sticks, Vegetable oil, Cotton & LPG A, B	Windows Cross Ventilation	8:00am–10:00 am	7:00pm–9:00pm

A = Smoldering, B = Flaming, * Cooking Time.

Hawan (worship of fire), material (Wood, cow dung cakes, cow urine, clarified semifluid butter rice, barley, sesame, vermillion powder, turmeric powder, camphor, cardamom, betel nut, betel leaf, clove, etc.).

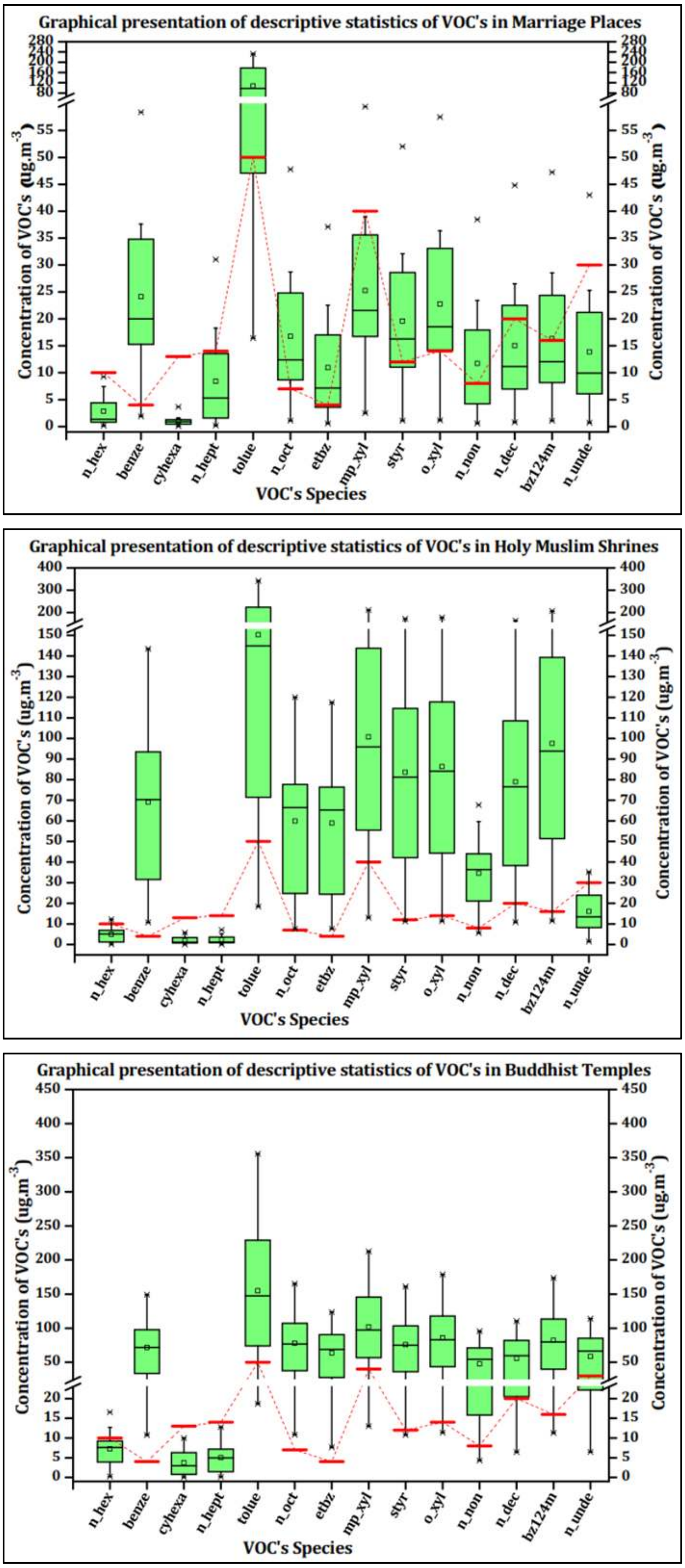

Fig. 2. Box-plots of longitudinal measurements of selected VOCs with prescribed limit (▬) in selected religious/ritual-indoors, pure residential-indoor, and common ambient-outdoor site located in Raipur.

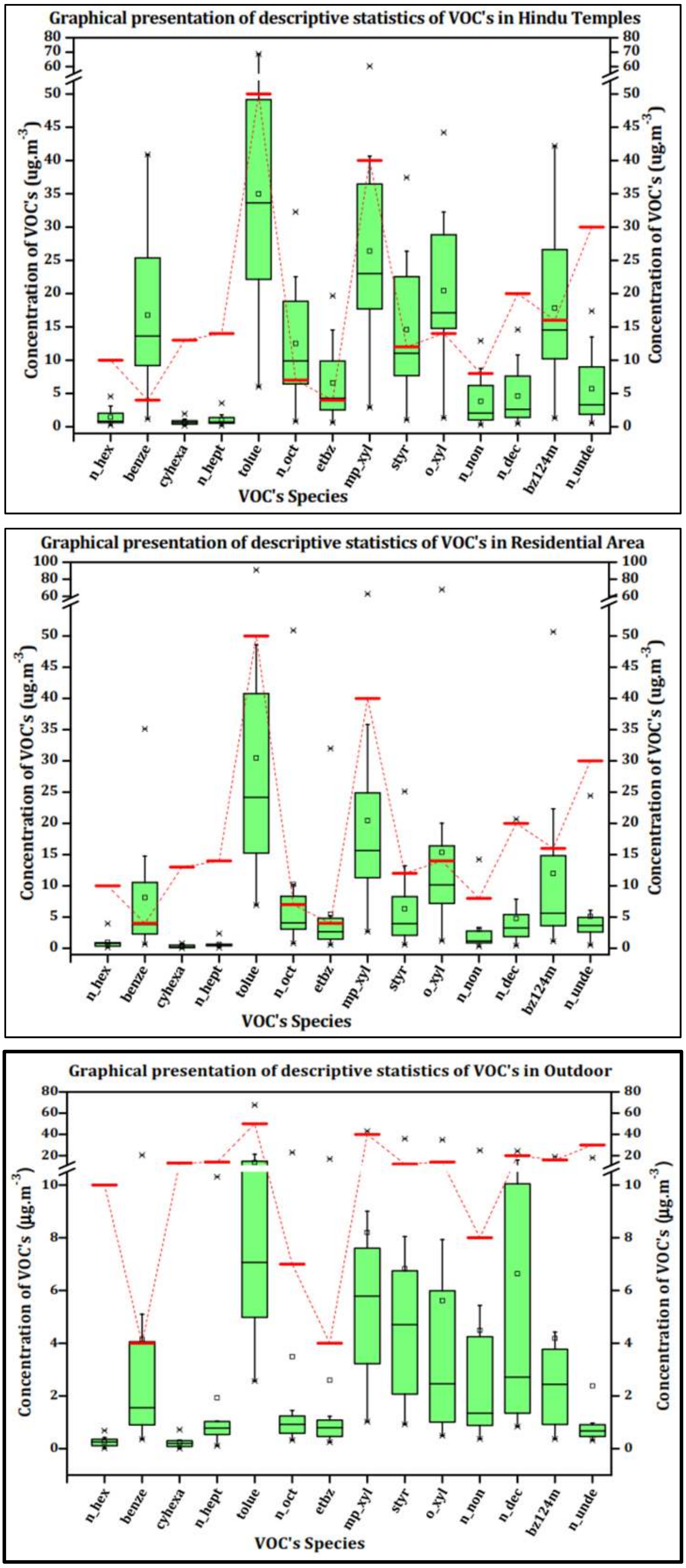

Fig. 2. *(continued).*

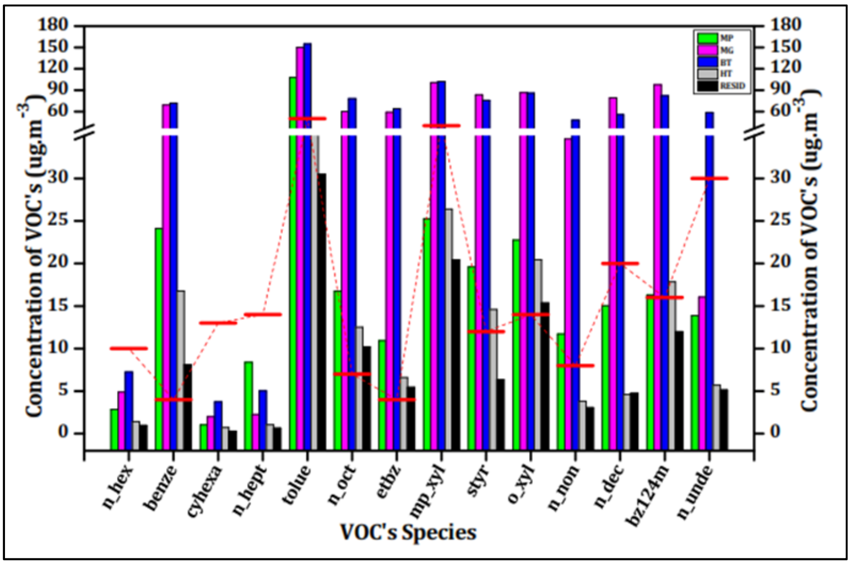

Fig. 3. Comparison of indoor level of VOCs concentration with prescribed limit (▬) in selected religious/ritual-indoors including pure residential-indoors located at Raipur.

Table 2. Seasonal Variation of TVOCs (µg/m^3) observed in selected religious/ritual-indoors including pure residential-indoors located at Raipur.

TVOCs	Summer	Fall	Winter	Annual
MP	110.97 ± 27.68	228.49 ± 57.39	549.32 ± 140.37	216.61 ± 75.15
MG	290.59 ± 76.05	824.87 ± 213.45	1419.87 ± 372.94	656.34 ± 220.82
BT	286.82 ± 71.13	886.65 ± 217.06	1503.46 ± 371.32	681.75 ± 219.83
HT	75.22 ± 20.02	132.18 ± 35.30	295.19 ± 80.39	129.51 ± 45.24
RESID	47.11 ± 15.63	83.89 ± 27.79	238.99 ± 79.47	82.67 ± 40.96

were investigated in this study. These all are categorized as Hazardous Air Pollutants in USEPA Air Toxic Programme. (USEPA, 1994; Srivastava *et al.*, 2006). Annual average of Total VOCs (TVOCs) (sum of 14 identified VOCs) in all four different religious and ritual places along with one type of representative residential site are found to be (µg/m^3): Hindu Marriage Places- 216.61 ± 75.15; Muslim Holyshrines- 656.34 ± 220.82; Buddhist Temple- 681.75 ± 219.83; Hindu Temple- 129.51 ± 45.24 and Pure residential-indoors- 82.67 ± 40.96. Out of four different religious sites, two sites (MG and BT) have shown eight-fold higher TVOCs concentration compared to residential-indoors; whereas comparable TVOCs levels found in HT and MP sites. Specific VOCs were found in different concentration levels across the selected sites; depending on the combustion temperature and type of material burnt. All VOCs, except n-heptane, were found higher in BT-Indoors compared to other sites. n-heptane was found higher in MP-Indoors with annual mean of 8.394 ± 3.332 µg/m^3. Toluene and m,p-xylene have been observed to be most abundant in all religious and ritual-indoors compared to other VOCs due to their emission-marker characteristics from combustion of synthetic and natural biomaterials (Symanski *et al.*, 2009; Esplugues *et al.*, 2010; Ongwandee *et al.*, 2011; Dewangan *et al.*, 2013). The annual indoor toluene and m,p-xylene concentration were found to be in the ranges of 30.48–154.84 and 20.45–102.02 µg/m^3, respectively; higher than reported values of 13.03 µg/m^3 in commercial indoor site (Srivastava and Devotta, 2007), 16.2–31.81 µg/m^3 in residential-indoors (Rehwagen *et al.*, 2003; Son *et al.*, 2003; Esplugues *et al.*, 2010).

Statistical inferences from box-plots of individual VOCs were compared with indoor air quality standards of VOCs developed by AGOF, Germany shown (AGOF, 2008); Indian indoor air quality standards are yet to be developed. Annual mean of most of the VOCs have shown projection above 50th percentile and also above than prescribed limits. In case of MP-indoors, toluene, benzene, n-octane, ethylbenzene, styrene, o-xylene, n-nonane have shown high annual mean compared to their respective prescribed limits. Except n-hexane, cyclohexane, n-heptane and n-undecane, all other VOCs have shown high annual mean compared to prescribed standards in MG-indoors. In case of BT-indoors, n-hexane, cyclohexane and n-heptane have shown their annual mean within the prescribed limits. HT-indoors have shown most of measured VOCs annual mean within the prescribed limits, except benzene, n-octane, ethylbenzene, styrene, o-xylene and 1,2,4-trimethyl benzene. In case of pure residential-indoors, except benzene, n-octane, ethylbenzene and o-xylene, all other VOCs have shown lower concentration compared to prescribed limits. In case of MP-, HT- and Residential-indoors, upper outliers were observed to be far away from 95th percentile compared to lower outlier closeness with 5th percentile; attributed to higher occurrence of most of

VOCs during the sampling period. Indoor concentration strength of specific VOCs across the selected religious/ritual-indoors including pure residential-indoors has been shown in Fig. 3. Specific VOCs wise, highest concentration site was (site code in parenthesis): n-hexane (BT), benzene (BT), cyclohexane (BT), n-heptane (MP), toluene (BT), n-octane (BT), ethylbenzene (BT), m,p-xylene (BT), styrene (MG), O-xylene (MG), n-nonane (BT), n-decane (MG), 1,2,4 trimethyl benzene (MG), n-undecane (BT).

Seasonal and Temporal Variation of VOCs

Seasonal and temporal variation of VOCs across three major seasons, winter (November to February), summers (March to June) and monsoon, also called fall, (July to October) has been investigated using reported Indian climatic conditions (Kulshreshra *et al.*,2009) and trends of local meteorological parameters (Fig. 4). The order of occurrence of all individual and total VOCs in all religious/ritual-indoors are found as: Winter > Fall > Summer; inversely related to climate temperature: Summer > fall > winter (Fig. 5). Seasonal ratios (Summer/winter and Fall/winter) of TVOCs are evaluated to be in the range of 0.19–0.25 and 0.34–0.59 across the sites and comparable to reported values (Rehwagen *et al.*, 2003; Pekey and Arslanbas, 2008); whereas these seasonal ratios for climate temperature and relative humidity were evaluated to be in the ranges of 1.4–1.7, 1.1–1.6 and 0.8, 1.5 respectively. All the religious/ritual-indoor sites have shown uniform trend of seasonal variation in most of individual VOCs except cyclohexane and n-hexane which implies similar source origin of these VOCs (Dewangan *et al.*, 2013). In other side, o & m,p-xylene, 1,2,4-tri methylbenzene have shown uniform seasonal variation in pure residential-indoors. Temporal variation of each VOCs has been graphically presented in Fig. 5. Temporal variation (March 2012 to February 2013) of VOCs measurement in selected indoor environments has been evaluated by mean difference between monthly measurements of selected VOCs using statistical t- and f-test at the confidence level of 95%. Significant variation with highest t-value of 2.74 and f-value of 116.97 at the degree of freedom of 26 has been observed between May 2012 and February 2013 in the case of MP-indoors. Other significant variation has been observed during April 2012-February 2013 (t-value: 2.34 and f-value: 37.02); June 2012–February 2013 (t-value: 2.12 and f-value: 18.45) in MP-indoors. Similarly in MG-indoors, significant variation with highest t-value of 4.41 and f-value of 165.10 at the degree of freedom of 26 has been obtained during May 2012–February 2013. In case of BT-indoors, significant variation with highest t-value of 5.31 and f-value of 148.85 at the degree of freedom of 26 has been obtained during May 2012–February 2013. In HT-indoors significant variation with highest t-value of 4.19 and f-value of 96.38 at the degree of freedom of 26 has been obtained during May 2012–February 2013. Lower trend in variance in average VOCs between the monthly measurements has been observed in residential-indoors with highest t-value of 1.98 and f-value of 49.91 at the degree of freedom of 26 has been obtained during May 2012–February 2013.

Indoor/Outdoor Relationship

To study relationship between site specific-indoors and corresponding outdoor VOCs, regression analysis and indoor/outdoor VOCs ratio have been computed (Geller *et al.*, 2002). The intercept and slope of regression analysis between independent outdoor VOCs levels with site specific-indoor VOCs levels (dependent variables) describes the infiltration factor and decay constant of pollutant indoors in relation to explain outdoor infiltration (USEPA 2003). It has been reported that intercept values of regression analysis have shown clear agreement with concentration of specific pollutant generated indoor itself and slope values have

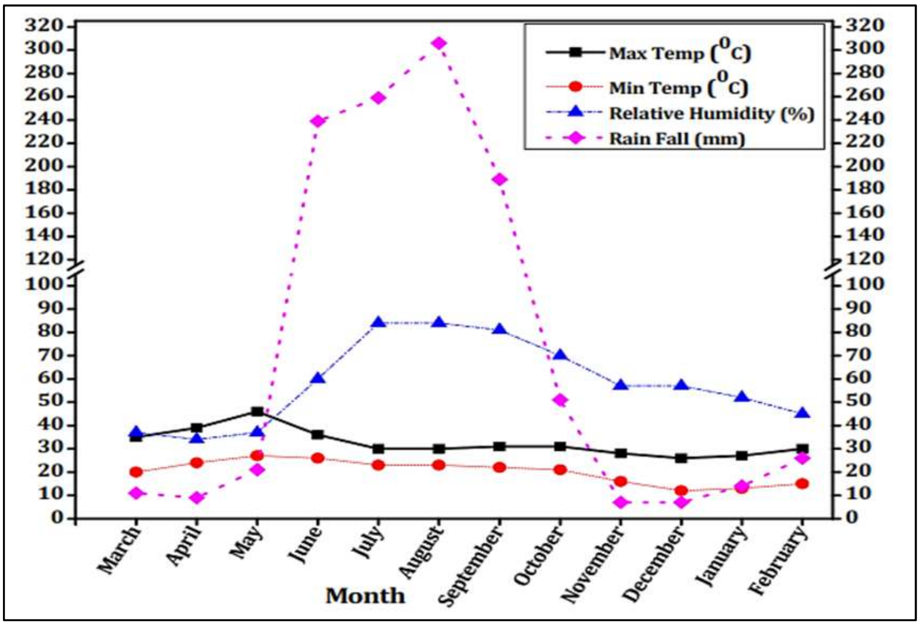

Fig. 4. Monthly variation in temperature, rainfall and humidity during the study period (March 2012–February 2013).

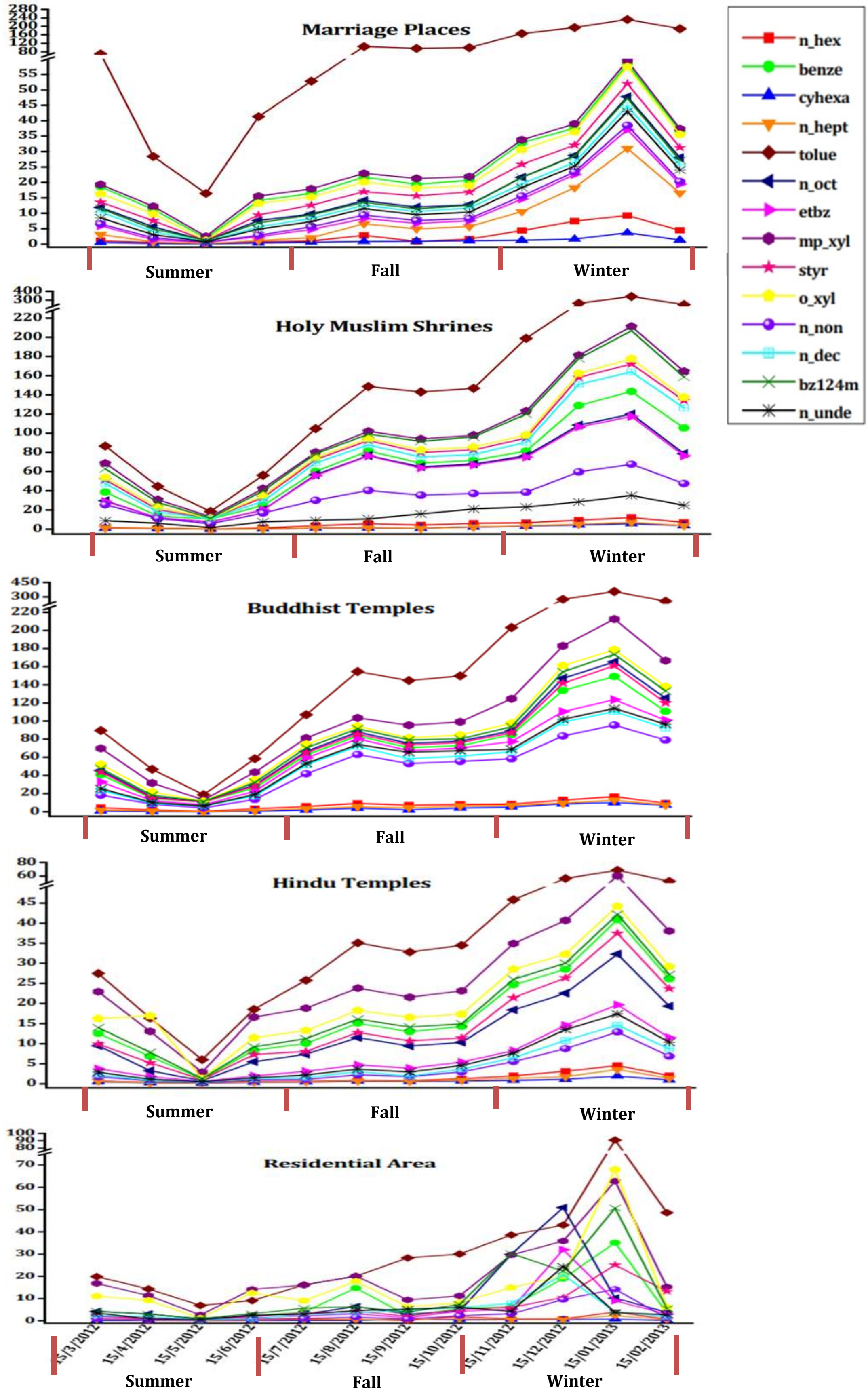

Fig. 5. Temporal Variation of individual VOCs in selected religious/ritual-indoors including pure residential-indoors located at Raipur.

shown removal of pollution concentration from indoors (Geller *et al.*, 2002). Religious/ritual-indoor VOCs have been regressed with respective outdoor VOCs to investigate outdoor infiltration and indoor generated VOCs within site-specific indoors. The indoor/outdoor VOCs ratio (I/O) and intercept and slope values of regression analysis have been presented in Table 3. MP- and HT-indoors have shown I/O ratios in unit range, whereas MG- and BT-indoors have shown tens of those occurred in earlier; contrast observations compared to residential-indoors and earlier reported values of < 1 (Srivastava *et al.*, 2000; Son *et al.*, 2003; Srivastava and Devotta, 2007). Regression data are clear evident of dominance of indoor itself in VOCs levels in religious/ritual-indoors. In case of MP-indoors, nine VOCs have shown major contribution (55.8–75.3%) from indoor sources, which are mainly religious burning practices. Similarly, in case of HT-indoors, nine VOCs have shown major contribution (56.9–75.9%) from indoor activities. In the cases of MG- and BT-indoors, religious burning practices have shown dominant contribution in the ranges of 59.59–80.9% for more than ten VOCs. In contrast to the results of this religious/ritual-indoors, only two VOCs in residential-indoors

Table 3. Correlation statistics and I/O ratio of individual VOCs in selected religious/ritual-indoors including pure residential-indoors located at Raipur [*(M-Slope (μg/m^3); C-Intercept (μg/m^3)].

Indoor Sites	Regression Parameters*	n_hex	benz	cyhex	n_hept	tolue	n_oct	etbz
MP	*M**	6.452	2.191	1.819	2.698	3.605	1.183	1.428
	*C**	1.169	15.059	6.299	3.186	65.711	12.614	7.234
	R^2	0.163	0.798	0.1354	0.809	0.5815	0.392	0.425
	I/O	10.923	5.828	4.651	4.350	7.873	4.795	4.215
MG	*M*	1.169	5.788	2.566	0.620	4.441	3.463	4.659
	C	1.541	45.144	1.431	1.060	89.554	47.814	46.810
	R^2	0.861	0.683	0.072	0.786	0.657	0.421	0.415
	I/O	18.668	16.691	8.999	1.170	10.993	17.154	22.693
BT	*M*	15.442	6.022	5.795	1.009	4.641	4.950	4.691
	C	3.208	46.796	2.449	3.076	91.403	60.816	51.582
	R^2	0.392	0.687	0.105	0.669	0.668	0.469	0.363
	I/O	27.711	17.324	16.809	2.604	11.328	22.364	24.563
HT	*M*	3.232	1.618	0.878	0.277	0.799	0.863	0.848
	C	0.587	10.078	0.525	0.512	24.081	9.499	4.389
	R^2	0.213	0.789	0.122	0.864	0.618	0.425	0.512
	I/O	5.476	4.052	3.237	0.542	2.560	3.583	2.539
RESID	*M*	1.612	1.548	1.239	0.158	1.211	1.785	1.722
	C	0.554	1.699	0.024	0.349	13.93	3.975	0.991
	R^2	0.081	0.866	0.801	0.716	0.872	0.660	0.953
	I/O	3.729	1.959	1.346	0.340	2.230	2.293	2.104

Indoor Sites	Regression Parameters*	mp_xyl	stry	o_xyl	n_non	n_dec	bz124m	n_undec
MP	*M*	1.127	1.269	1.323	1.376	1.245	2.086	1.154
	C	16.011	10.931	15.328	5.532	6.775	7.589	11.117
	R^2	0.714	0.761	0.711	0.818	0.714	0.834	0.235
	I/O	3.079	2.871	4.052	2.608	2.265	3.900	5.819
MG	*M*	3.969	3.912	3.802	1.951	4.643	8.991	1.079
	C	68.154	56.858	64.983	25.868	48.120	59.941	13.476
	R^2	0.538	0.518	0.479	0.585	0.617	0.707	0.277
	I/O	12.277	12.242	15.374	7.711	11.893	23.316	6.734
BT	*M*	3.976	3.724	3.845	2.885	3.052	7.672	3.653
	C	69.399	50.329	64.312	34.903	35.373	50.060	49.842
	R^2	0.533	0.546	0.486	0.456	0.522	0.697	0.255
	I/O	12.435	11.097	15.297	10.657	8.381	19.635	24.568
HT	*M*	1.123	0.921	0.935	0.488	0.476	1.780	0.665
	C	17.177	8.325	15.208	1.634	1.465	10.399	4.108
	R^2	0.702	0.692	0.630	0.818	0.766	0.773	0.386
	I/O	3.217	2.140	3.644	0.852	0.697	4.266	2.389
RESID	*M*	1.291	0.685	1.763	0.586	0.422	2.420	1.187
	C	9.854	1.670	5.461	0.431	1.986	1.865	2.318
	R^2	0.824	0.849	0.944	0.968	0.421	0.827	0.907
	I/O	2.492	0.929	2.735	0.682	0.721	2.866	2.160

have shown slightly higher contribution (53.2–56.8%) from indoor sources compared to outdoor ones. As far as indoor/outdoor contribution to specific VOCs is concern, n-hexane and n-heptane have shown lower contribution (31.5–48.9%) from indoor sources compared to outdoors, which can also be justified by higher R^2 values. Benzene, toluene, styrene, 1,2,4 trimethyl benzene and m,p-xylene have shown moderate contribution (55.8–68.8%) from indoor sources compared to outdoor source; this might be due to infiltration of their major outdoor source emissions viz. automobile exhaust and municipal waste burning (Pagans *et al.*, 2006; Srivastava *et al.*, 2006; Chiriac *et al.*, 2011; Hsieh *et al.*, 2011) Cyclohexane, n-octane, ethylbenzene, o-xylene and n-undecane have shown major contribution (60.8–85.1%) from indoor sources compared to outdoor sources. In case of residential-indoors, n-hexane has shown major contribution from indoor sources; this might be due to: 1) LPG use for cooking purposes and 2) solvent use for cleaning purposes in homes (Srivastava *et al.*, 2000; Huang *et al.*, 2011).

CONCLUSION

The present study has found information for the level of VOCs in religious/ritual-indoors in Raipur, Central India. Concentrations of all individual VOCs were found higher in all indoor religious and ritual places compared to residential-indoors. This might be due to the fact that all selected religious and ritual centers have reported to carryout burning practices using mainly synthetic and natural bio-materials such as incense, candles, benzoin styrax, cotton, vegetable oils, semi-clarified butter milk and wood. Most of burning practices are occurred in both flaming and smoldering phases; emits a large amount of VOCs (Dewangan *et al.*, 2013). Emissions of these VOCs were, generally, accumulated inside due to poor ventilation system in most of the religious and ritual places. In residential site, sources of the VOCs were cooking, cleaning activities and hardware materials used in houses (Srivastava *et al.*, 2000; Lee *et al.*, 2001; Rehwagen *et al.*, 2003; Son *et al.*, 2003; Sinha *et al.*, 2006; Huang *et al.*, 2011) but concentration of VOCs were higher during the burning in temple than indoor residential. Consequently the data derived from this study is likely to be significant for the purposes of associated health risk assessment and management.

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