CHEMICAL ENGINEERING TRANSACTIONS
VOL. 68, 2018
A publication of AIDIC
The Italian Association of Chemical Engineering
Online at www.aidic.it/cet
Guest Editors: Selena Sironi, Laura Capelli

ISBN 978-88-95608-65-5; **ISSN** 2283-9216
DOI: 10.3303/CET1868080

Determination and Distribution of Indoor off-Odor Pollutants

Zhanguo Hao, Xiaoming Su*

School of Architecture, Inner Mongolia University of Technology, Hohhot 010051, China
SXMARC@126.com

This paper aims to study the indoor off-odor determination and distribution law using literature analysis, experiment detection and inductive generalization. With reference to literature on relevant VOCs at home and abroad, the concentrations and pollution properties of contaminants such as benzene series, formaldehyde and TVOC are analyzed against their sources and classification of odd odors often given off from the indoor air by tracking detection on samples, for example, in the Shenzhen's houses newly renovated or for more than two years. On this basis, the study traces the distribution law of odd odor pollutants indoors in decoration and life pollution phases.

1. Introduction

With the constant improvement of living standards, people have already started to pursue high quality of life, and indoor air quality has also aroused widespread concern of scholars and ordinary residents. Today, the odd odors in the room mainly derive from formaldehyde and Total Volatile Organic Compounds (TVOC) emitted by fixture and decoration materials and daily activities of residents. Due to its long emission period and high concentration, the above two pollutants are used as the main indicators for indoor off-odor monitoring and determination (Ngundi et al., 2006).

There are so far more than 500 types of Volatile Organic Compounds (VOCs) determined in the air, but due to the low concentration of single VOC, many studies quote the TVOC as an indicator (Kim et al., 2013). As a typical pollutant in VOCs, formaldehyde is also regarded as an important indicator for determining indoor air quality thanks to its high content and great impairment to human eyes and respiratory tract (Gottschalk et al., 2008). As early as the 1980s, foreign scholars attempted to shift the focus of air pollution from outdoors to indoors and probed into the concentration of VOCs in different types of rooms and public places in the house, in conjunction with their harm to human health. Some studies reveal that (Takeuchi et al., 2014) the concentration of indoor VOCs is higher than the outdoor. In the field of indoor air environment, China starts relatively late, but involves basically consistent areas with foreign countries, for example, the establishment of indoor air quality prediction model, typical pollution sources analysis, etc. (Tennakoon, 2010). The indoor air quality is subjected to many factors. In general, there are two classes of them, i.e. pollution sources and environmental factors. The pollution source location and nature, and the pollutant generation mechanism are three common classification modes for VOCs in indoor air (Montesinos et al., 2015). While ventilation conditions, temperature, humidity, etc. are the environmental factors that affect the concentration of indoor VOCs (Davenport et al., 2016).

Based on the above analysis, this paper samples the two types of houses, i.e. newly decorated houses and houses decorated for more than two years, randomly for tracking and determination. The focus rests on the concentrations and pollution law of benzene series, formaldehyde and TVOC, followed by the induction on principal sources and classifications of indoor odors. Based on the study results, the distribution law of indoor off-odors is also analyzed by stages. Study shows that the indoor air pollution in the newly renovated houses are heavy with some pollutants seriously exceeding the standards. After two years of renovation, the concentrations of air pollutants decrease significantly, the air pollution in the life stage goes up with the subsistence of pollution sources and down with the disappearance of pollution sources (Vilar et al., 2018; Mezzanotte et al., 2018).

Please cite this article as: Hao Z., Su X., 2018, Determination and distribution of indoor off-odor pollutants, Chemical Engineering Transactions, 68, 475-480 DOI: 10.3303/CET1868080

2. Determination of indoor off-odor pollutants

2.1 Method

This paper randomly samples the Shenzhen's houses for tracking determination on the frequently hunted odors TVOC and formaldehyde concentrations in the room. The samples are collected and tested in accordance with the national standards (Daisey et al.,2003). The doors and windows in each sample house are in daily routine state before sampling, if necessary, they should be closed in advance. When sampling, it is ensured that all of them are closed. Dynamic adsorption tester is used to conduct VOC adsorption/desorption experiments on indoor materials (Doi et al., 1994). After the test, DPS software will perform data analysis to discuss the contaminants in the houses roughly divided into two types, i.e. newly decorated houses (renovation time 1-2 years, a total of 30 households) and those decorated for more than 2 years (15 households).

2.2 Status analysis of TVOC and formaldehyde pollution

As shown in Fig. 1, the experiment results show that, in relation to those houses decorated for more than two years, the indoor air pollution in the newly renovated house is heavier, where, at 100% determination rate of TVOC and formaldehyde, the over-standard rates of TVOC and formaldehyde in the newly renovated houses are respectively 68.3% and 52.8%, while the two parameters in the houses decorated for more than two years are 15.4% and 19.3%, respectively. The concentrations of the remaining benzenes in the two types of houses fall below the national standards.

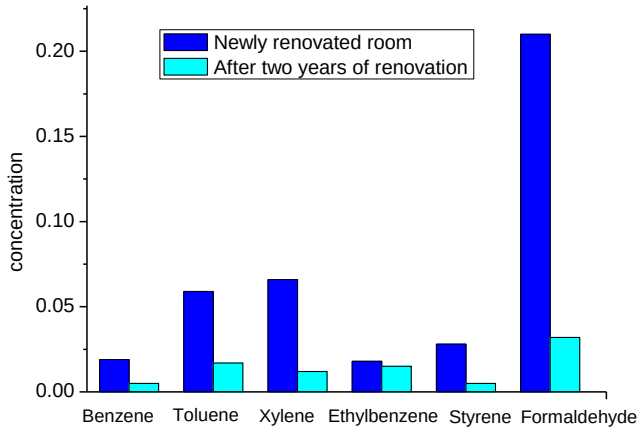

Figure 1: Indoor air VOCs concentration levels

2.3 Distribution law of VOC pollutants

As shown in Fig. 2 and Fig. 3, the concentration levels of VOCs in various rooms in two house types are given. obviously, in the newly renovated houses. the TVOC and formaldehyde concentrations in the schoolroom and bedroom are higher than that in the parlor and kitchen because the airtightness of two are relatively better, and there is furniture mostly made of the wood-base home decoration materials. While the kitchen decoration is relatively simple, so that the pollutant concentration is the minimum. Among all benzene pollutants, the toluene content tops off, but the average concentrations of benzene and styrene are the minimum. In the houses decorated for more than two years, the concentration levels of pollutants in the bedroom, parlor and kitchen differ a little. Although the concentration of formaldehyde is significantly reduced when compared with the newly renovated room, it is still one of the highest concentration compounds.

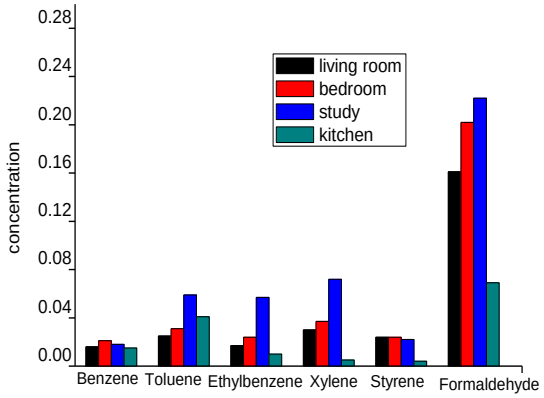

Figure 2: Newly renovated room VOCs concentration levels in various rooms

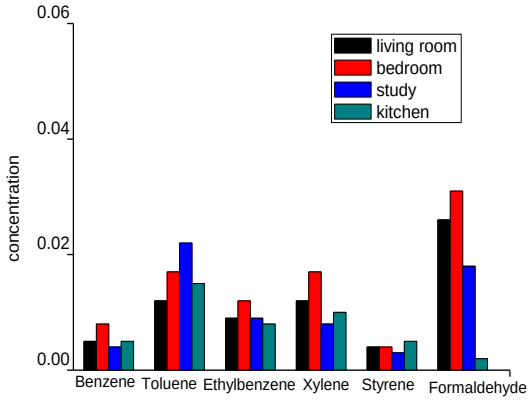

Figure 3: Renovation VOCs Concentration Levels in Various Rooms in the Room over Two Years

3. Distribution law of indoor off-odor

As above, odd odor determination results show that the concentrations of indoor air contaminants vary over time after the renovation. Now we analyze the distribution law of the indoor off-odor from two perspectives of the decoration and life pollution phases (Jin et all, 2005).

The principal sources of odd odors in the room include volatile, combustion and composite types. See Table 1 for the principal sources and classes of indoor off-odors concluded herein (Hollender et all, 2002).

Table 1: The main source and classification of abnormal indoor odors

Classification	Decoration Materials	Daily necessities	human activity
Volatile source	Coatings, adhesives, artificial boards, wallpapers, carpets, etc.	Daily chemicals (cleaners, fragrances, etc.), furniture	/
Burning source	/	/	Cigarette smoke, incense, heating stove, water heater
Composite source	/	Computers, copiers, printers, fax machines	Cooking

3.1 Decoration pollution phase

As shown in Table 2, after the renovation of the two types of households, the concentrations of formaldehyde and TVOC in each phase (month) are determined. It can be seen that the concentrations of air pollutants in the two houses within the first month after the renovation all exceeds the national standards (Saito et all,2004), but gradually decrease over time, and even basically fall below the national standards after 6 months.

Table 2: Formaldehyde and TVOC concentrations at various times (months) after renovation

Pollutants	Living room				Bedroom			
	1	2	3	6	1	2	3	6
Room A								
Formaldehyde	0.721	0.532	0.391	0.111	0.523	0.338	0.225	0.127
TVOC	0.849	0.678	0.485	0.430	1.224	0.881	0.555	0.425
Room B								
Formaldehyde	0.343	0.238	0.199	0.092	0.718	0.438	0.399	0.144
TVOC	0.688	0.523	0.438	0.435	2.299	1.254	0.752	0.650

3.2 Domestic pollution phase

The odd smell indoors given off from interior decoration materials will gradually lessen over time, but the indoor off-odor (such as smoking, cooking, etc.) air pollutants prouduced by various activities of residents will fluctuate within a certain range, that is, rise up with the subsistence of pollution source and decrease with the disappearance of pollution sources (Lee et al., 2002).

3.2.1 Comparison between the intensities of typical life pollution sources

As shown in Fig. 4, the emission intensities of benzene series in typical indoor combustion sources are compared (Björklund et al., 2004). It can be seen from the figure that among the benzene-based pollutants from various combustion sources, the emission of moxa is the maximum, next to the cigarettes. Two emissions after 1 h combustion are 39863ug and 22590ug, respectively, while the emissions of candles is the minimum, only 19ug after 1 h combustion.

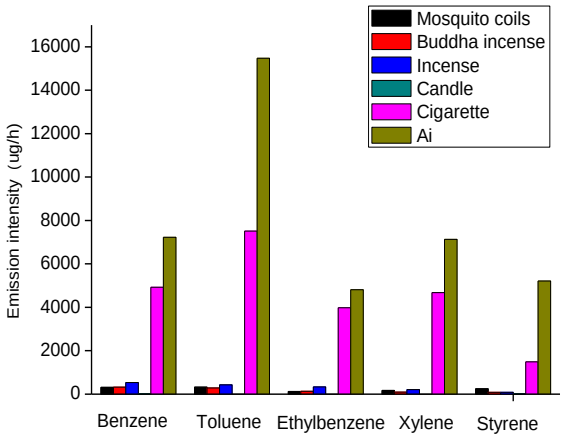

Figure 4: Comparison of emission intensity of benzene series in typical indoor combustion sources

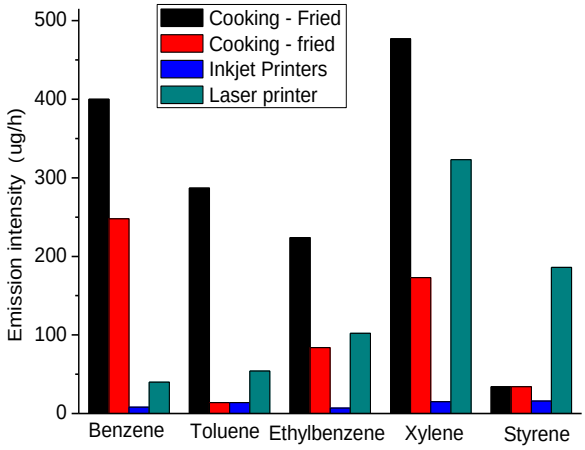

Figure 5: Comparison of Emissions of Benzene Compounds from Indoor Typical Compound Sources

Based on the comparison between the emission intensities of benzene series from typical composite sources indoors. the emissions of benzene series are subjected to change with source types, e.g. cooking mode and printer. Among them, the benzene series discharged during cooking-fry has the maximum intensity, as shown in Fig. 5, but the emission intensity of benzene series from the composite source is far less than that from indoor combustion source.

3.2.2 Distribution law of domestic pollutants

Various activities launched by residents can trigger pollution sources. When the activity is ended, the pollution intensity will also decrease either it. See Table 3 for the concentrations of indoor pollutants in the case when there is no activity launched and in the ventilation of 1 h after relevant activity is over (Zhu et all, 2008). Obviously, smoking and moxibustion can cause a significant increase in benzene in indoor air. There is a little difference in the concentration levels of other pollutants, but in the families where there are smoking and moxibustion, frequent window ventilation may be required to increases the indoor air circulation and reduces the level of indoor pollution.

Table 3: Various activities cause changes in indoor pollutant levels

Activity	No related activities		Related activities		Ventilation 1h	
	Formaldehyde	TVOC	Formaldehyde	TVOC	Formaldehyde	TVOC
Smokes	40.1	380	97.6	671	46.1	417
Moxibustion	32.0	208	107.8	723	51.3	376
Mosquito Coils	22.4	242	44	646	35.1	331
Cooking	24.0	197	22.1	321	27.4	210
Use a printer	11.6	124	20.0	356	22.0	207

4. Conclusion

Based on the Introduction of studies on relevant VOCs at home and abroad, this paper discusses the determination and distribution law of odd odor components that arouse people's wide concern in the indoor air, and traces the indoor air samples in the houses newly renovated or for more than two years in Shenzhen. Analysis results reveals the following conclusions:

(1) The TVOC and formaldehyde in the newly renovated house are relatively high, all of which exceeds the national standards as specified by more than 50%, while in the house decorated for more than two years, two parameters significantly drop off, and the over-standard rate falls within 15% ~ 20%.

(2) In the newly renovated houses, TVOC and formaldehyde concentrations are higher in the study room and bedroom; while in the houses renovated for more than two years, there are four classes of rooms where TVOC and formaldehyde concentrations differ a little. Formaldehyde is the compound with top concentration, while the methylbenzene has a top content in all benzene series. Benzene and styrene have the lowest concentrations.

(3) Decoration pollution type, TVOC and formaldehyde have higher concentrations in the decoration phase, and their pollution sources derive from construction materials. They weaken as the day wears on; for domestic pollution type, compared with typical composite source, typical combustion source benzene pollutant has a higher emission intensity. Moxa and cigarettes are two pollution sources which discharge more benzenes in the combustion source. For typical composite sources, the intensity of benzene-based pollutants discharged during cooking is relatively high.

Acknowledgement

The study was supported by the General fund of Inner Mongolia Education Department 2016" Quantitative Control on Energy Saving Reconstruction Technology of Buildings Thermal Environment in Inner Mongolia Universities" (Fund No. NJZY16088); The General Fund of Inner Mongolia Natural Science Department 2017"Research on Space Model of Low energy Education Building in Inner Mongolia" (Fund No. 2017MS0504); The Key fund of Inner Mongolia University of Technology 2015 "Research on envelope thermal performance optimization of low energy consumption buildings in Inner Mongolia " (Fund No. ZD201513).

Reference

Björklund J., Isetun S., Nilsson U., 2004, Selective determination of organophosphate flame retardants and plasticizers in indoor air by gas chromatography, positive-eion chemical ionization and collision-induced

dissociation mass spectrometry, Rapid Communications in Mass Spectrometry, 18(24), 3079, DOI: 10.1002/rcm.1721

Daisey J.M., Angell W.J., Apte M.G., 2003, Indoor air quality, ventilation and health symptoms in schools: an analysis of existing information, Indoor Air, 13(1), 53-64, DOI: 10.1034/j.1600-0668.2003.00153.x

Davenport J.J., Hodgkinson J., Saffell J.R., Tatam R.P., 2016, A measurement strategy for non-dispersive ultra-violet detection of formaldehyde in indoor air: spectral analysis and interferent gases, Measurement Science & Technology, 27(1), 015802, DOI: 10.1088/0957-0233/27/1/015802

Doi M., Fujimoto K., Kobayashi S., Yonehara H., 1994, Spatial distribution of thoron and radon concentrations in the indoor air of a traditional japanese wooden house, Health Physics, 66(1), 43-9, DOI: 10.1097/00004032-199401000-00006

Gottschalk C., Bauer J., Meyer K., 2008, Detection of satratoxin g and h in indoor air from a water-damaged building, Mycopathologia, 166(2), 103-107, DOI: 10.1007/s11046-008-9126-z

Hollender J., Sandner F., Möller M., Dott W., 2002, Sensitive indoor air monitoring of monoterpenes using different adsorbents and thermal desorption gas chromatography with mass-selective detection, Journal of Chromatography A, 962(1), 175-181, DOI: 10.1016/s0021-9673(02)00511-3

Jin Y., Zhou Z., He G., Wei H., Liu J., Liu F., 2005, Geographical, spatial, and temporal distributions of multiple indoor air pollutants in four chinese provinces, Environmental Science & Technology, 39(24), 9431, DOI: 10.1021/es0507517

Kim H.J., Yoon J.W., Choi K.I., Jang H.W., Umar A., Lee J.H., 2013, Ultraselective and sensitive detection of xylene and toluene for monitoring indoor air pollution using cr-doped nio hierarchical nanostructures, Nanoscale, 5(15), 7066, DOI: 10.1039/c3nr01281f

Lee S.C., Li W.M., Chio H., 2002, Investigation of indoor air quality at residential homes in hong kong: case study: asia, Atmospheric Environment, 36(2), 225-237, DOI: 10.1016/s1352-2310(01)00435-6

Mezzanotte V., Marazzi F., Sá Mesquita Da Silva Cristovao M.B., Bellucci M., Ficara E., 2018, Phycoremediation to reduce the pollution load of piggery wastewater: results of semi-continuous lab tests using chlorella and scenedesmus spp., Chemical Engineering Transactions, 64, 679-684. DOI: 10.3303/CET1864114

Montesinos V.N., Sleiman M., Cohn S., Litter M.I., Destaillats H., 2015, Detection and quantification of reactive oxygen species (ros) in indoor air. Talanta, 138, 20-27, DOI: 10.1016/j.talanta.2015.02.015

Ngundi M.M., Qadri S.A., Wallace E.V., Moore M.H., Lassman M.E., Shriverlake L.C., 2006, Detection of deoxynivalenol in foods and indoor air using an array biosensor, Environmental Science & Technology, 40(7), 2352-2356, DOI: 10.1021/es052396q

Saito I., Onuki A., Seto H., 2004, Indoor air pollution by alkylphenols in Tokyo, Indoor Air, 14(5), 325-332, DOI: 10.1111/j.1600-0668.2004.00250.x

Takeuchi S., Kojima H., Saito I., Jin K., Kobayashi S., Tanakakagawa T., 2014, Detection of 34 plasticizers and 25 flame retardants in indoor air from houses in sapporo, japan, Science of the Total Environment, s491–492, 28-33, DOI: 10.1016/j.scitotenv.2014.04.011

Tennakoon M., 2010, A fuzzy inference system prototype for indoor air and temperature quality monitoring and hazard detection, Journal of Environmental Informatics, 16(2), 70-79, DOI: 10.3808/jei.201000179

Vilar D.A., Ngilangil L.E., Andrada J.C., Lucena J.J., 2018, “bantay tambutso” project implementation for reducing air pollution: the dmmmsu-nluc, philippines experience, Chemical Engineering Transactions, 63, 97-102, DOI: 10.3303/CET1863017

Zhu J., Hou Y., Feng Y., Shoeib M., Harner T., 2008, Identification and determination of hexachlorocyclopentadienyl- dibromocyclooctane (hcdbco) in residential indoor air and dust: a previously unreported halogenated flame retardant in the environment, Environmental Science & Technology, 42(2), 386-91, DOI: 10.1021/es702272s