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Survey on Indoor Air Pollution by Formaldehyde in Some Newly Residential District in Wuhan City

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Abstract: This study aimed to investigate factors influencing formaldehyde pollution in the air, with a particular focus on the effects of house decoration. Several new residential areas in Wuhan were chosen, from which, 100 houses that had been decorated for 1 year or less were selected. A portable meter was utilized to measure the concentration of indoor formaldehyde. At the same time, a questionnaire on the topic of formaldehyde concentration influence factors was carried out with residents living in the selected houses. In the 100 houses selected, different types of rooms were found to have different formaldehyde concentrations. Formaldehyde concentration was found to be highest in the master bedroom while levels decreased in the study room, guest bedroom and living room, respectively. Formaldehyde concentration in the wardrobe was significantly higher than that detected in any area of the other rooms ($p<0.05$). Differences in the time of decoration were shown to significantly influence formaldehyde concentration ($p<0.01$). Different ventilation systems were also seen to affect the formaldehyde concentration in the air; the average formaldehyde concentration of regular ventilation was significantly lower than in occasional ventilation ($p<0.05$). The results suggested that formaldehyde pollution in new residential houses is significant. The main factors influencing indoor formaldehyde concentration were the level of decoration, time since decoration and the type of ventilation system used.

Key words: House decoration, indoor air pollution, formaldehyde, detection

INTRODUCTION

With rising living standards in China, residential decoration has become an important way for people to personalize and improve their living environment. However, indoor air pollution resulting from improper decoration has become an increasing problem. The subsequent impact seen on human health has received a large amount of attention in recent years (Wang, 2007; Fu, 2007; Chen, 2007; Lu and Yang, 2010). Harmful substances from decoration materials and furniture are a key factor influencing indoor air pollution. In particular, formaldehyde which often results from these materials, has been shown to pose a significant risk to human health (Liu and Zhang, 2007).

The level of indoor formaldehyde pollution of newly decorated houses was investigated to understand the extent of the problem in several residential areas in Wuhan from May 2011 to June 2012. 100 of the houses which had been decorated less than a year before, were randomly selected. They were measured for the pollutant and investigated for factors influencing its indoor air pollution. We aimed to raise awareness concerning formaldehyde pollution during housing decoration, to adequately understand the source of indoor air formaldehyde, to correctly recognize its health risks and to provide a scientific method to decorate a house free from this pollutant.

OBJECTS AND METHODS

Survey subjects: Living room, master bedroom, guest bedroom, study room and internal wardrobe of 100 houses were studied. The decoration and its use in these houses had numerous characteristics. They mainly were different decoration complexity degree, use of variety of artificial boards and adhesives as material composition, use of brushed paint or pasted wallpaper on indoor walls, laid ceramic tiles or wood as indoor floors, use of on-site made furniture and other purchased furniture by some residents, decoration completion time with a range of 1-12 month and an occupancy rate of 60%.

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Survey methods: In accordance with "Code for Indoor Environmental Pollution Control of Civil Building Engineering (GB 50325-2001, 2001), all the bedroom doors and windows were initially opened for 2 h to fully exchange the indoor air and later were closed for 12 h. The sampling was then started. Sampling points were located in the center of the room, away from air ducts and vents and the inner wall which was less than 0.5 m away at the height of 0.8-1.5 m from the floor. Sampling points were individually set up for each household according to the building room layout. In the morning and at the afternoon, a total of 500 monitoring points were monitored using a PPM400ST handheld direct-reading formaldehyde fast tester, an average of twice measured indoor formaldehyde concentration was taken as valid data, sampling samples data were processed with SPSS13.0 software package, at the same time, a questionnaire was carried out with residents living in the selected houses about factors influencing formaldehyde concentration such as vacant duration after house decoration, housing ventilation frequency etc.

Evaluation standard: In accordance with "Code for Indoor Environmental Pollution Control of Civil Building Engineering (GB 50325-2001, 2001), the indoor air formaldehyde health standard (maximum allowable concentration) is 0.08 mg m^{-3} in habitable room of civil building Class I, we take this as evaluation standard.

RESULTS

Residential rooms are divided into living room, master bedroom, guest bedroom and study room according to different function, we selected 400 samples in these rooms, in addition, selected 100 samples in the decorated wardrobe as reference. The monitored results show that in 400 samples of formaldehyde concentration, 303 samples exceeded, exceeded rate is 75.75%, in the detected 100 suites, indoor formaldehyde of 26 suites reach the standard, 74 suites are not up to the standard, including 24 suites of high or more pollution, monitoring formaldehyde concentration was in the range of 0.02~1.04 mg m^{-3}.

Test results of formaldehyde concentration for different types room since decoration: The descending order of formaldehyde concentration exceeded rate of various types rooms was master bedroom, study room, guest bedroom and living room, the highest average of formaldehyde concentration was in wardrobe, it was significantly higher than that of other rooms, concentration mean difference has statistical significance ($p<0.05$), Table 1.

Different periods comparison of indoor formaldehyde concentration in decorated habitable room: According to the time after decoration, tests were divided into two groups, i.e., 1~6 month group, 7~12 month group, their formaldehyde concentration exceeded rates, respectively 84.93 and 56.25%. Monitoring results show that two time periods formaldehyde concentration mean difference has statistical significance ($x^2 = 38.97$, $p<0.01$), indoor air formaldehyde concentration after decoration gradually reduces with the extension of time, consistent with the relevant reports (Chen, 2007; Yang and Lu, 2003; Wu and Huang, 2006), Table 2.

Effect of different ventilation situation on indoor formaldehyde concentration: In the decorated habitable room, formaldehyde concentration of occasionally ventilation group and often ventilated group were significantly different, the difference of two groups concentration average has obvious statistical significance ($p<0.05$), Table 3.

Table 1: Formaldehyde concentration test results of different type of rooms

Location	No. of samples (A)	Tested concentration range (mg m^{-3})	Concentration average (mg m^{-3})	Average concentration exceeding multiples	No. of exceeding samples (A)	Exceeding rate (%)
Master bedroom	100	0.02~1.04	0.35±0.29*	3.38	81	81
Living room	100	0.02~0.95	0.26±0.24*	2.25	65	65
Guest bedroom	100	0.02~1.01	0.33±0.27*	3.13	75	75
Study room	100	0.03~0.89	0.34±0.29*	3.25	82	82
Wardrobe inside	100	0.08~3.28	1.86±1.72	22.25	100	100

*Formaldehyde concentration average has significant difference compared with the wardrobe group ($p<0.05$)

Table 2: Formaldehyde concentration test results of different periods in decorated habitable room

Time (month)	No. of samples (A)	Tested concentration range (mg m^{-3})	Concentration average (mg m^{-3})	Reference value (mg m^{-3})	No. of exceeding samples (A)	Exceeding rate (%)
1~6	272	0.06~1.04	0.36±0.32	0.08	231	84.93
7~12	128	0.02~0.64	0.23±0.17	0.08	72	56.25
Summation	400	0.02~1.04	0.32±0.27	0.08	303	75.75

Table 3: Indoor formaldehyde concentration test results of different ventilation situations

	Often ventilated group		Occasionally ventilation group	
Location	No. of samples (A)	Concentration average (mg m^{-3})	No. of samples (A)	Concentration average (mg m^{-3})
Master bedroom	42	0.11±0.08	58	0.53±0.27
Living room	60	0.07±0.05	40	0.55±0.23
Guest bedroom	40	0.12±0.05	60	0.47±0.23
Study room	40	0.09±0.05	60	0.51±0.26

DISCUSSION AND ANALYSIS

Seen from the test results in Table 1, indoor air formaldehyde pollution of the newly decorated habitable room is serious, especially that of the master bedroom in which formaldehyde concentration average is 0.35 mg m^{-3} and exceeded 3.38 times. The cause are mainly that the bedroom room area is small, the closed, the bedrooms had less ventilation time and frequency and placed a large number of furniture such as wardrobes, most ground were laid wood floor, etc. Formaldehyde concentration of study room and guest bedroom were slightly lower, because these rooms used materials contained formaldehyde to make bookcase, wardrobe, etc.,and had poor ventilation. Formaldehyde concentration average of the living room was 0.26 mg m^{-3},and exceeded standard 2.25 times, the explanation is that this type room is larger, often open and has better ventilation, ceramic tile for laying ground is preferred, so formaldehyde concentrations were significantly lower.

It is particularly noteworthy that average of detected formaldehyde concentration in the wardrobe was the highest, 1.86 mg m^{-3}, exceeded standard 22.25 times, far higher than other rooms, exceeded rate reaches 100% and this is also confirmed that furniture is an important source of indoor air formaldehyde pollution. Reason is that the wardrobe space is small and rarely ventilation, a lot of family used man-made plank and adhesive to make wardrobe, some of them used inferior materials and paint, so this resulted in a large amount of harmful substances releasing.

Based on the detected formaldehyde of different periods (after decorating, 1~6 and 7~12 months), it was found that the indoor formaldehyde concentration is inversely proportional to time after decorating, i.e., the longer the decorated time is, the lower indoor formaldehyde concentration is.In our case formaldehyde concentration exceeded rate presented obvious decline, were 84.93 and 56.25%, respectively, the reason is that with the extension of time, the formaldehyde of furniture and floor were constantly volatilized and with different degrees of window ventilation migrating formaldehyde to the outside, so that the indoor formaldehyde concentration gradually decreased.

Besides, based on the formaldehyde monitoring and survey of ventilation conditions, it was found that different ventilation situation affected indoor formaldehyde concentration, the regular ventilation indoor formaldehyde concentration can drop 3~6 times, compared to the occasional ventilation. This is because formaldehyde is highly volatile under normal temperature, formaldehyde releasing from furnitures is a slow and continuous process, short time indoor ventilation can temporarily make the formaldehyde concentration reduce, if stop ventilation or ventilation is bad, formaldehyde will be in indoor accumulation and rises with the continuous release of formaldehyde from pollution sources (Shen *et al*., 2007; Liu and Peng, 2007).The mean and exceeded rate of formaldehyde concentration from the living room were lower than that of the master bedroom, guest bedroom and study room,and this are related to the following factors: the sitting room is generally larger than bedroom and residents pay more attention to the window ventilated for family activities. It is confirmed from another side that the ventilation has a great influence on formaldehyde concentration; this is consistent with the results of domestic similar studies (Liu *et al*., 2006).

CONCLUSION

In the detected 100 suites of Wuhan city, indoor formaldehyde of 26 suites reach the standard, 74 suites are not up to the standard, including 24 suites of high or more pollution, monitoring formaldehyde concentration was in the range of 0.02~1.04 mg m^{-3}. Analyzed the cause of excessive formaldehyde, the conclusion is that indoor air formaldehyde pollution level has a certain relationship with these factors: Complex degree of decoration, decoration materials, furniture brand and its production process,wall treatment way, vacancy ventilation time and so on, any of these factors are likely to cause high formaldehyde content, only each factor is controlled within reasonable limits, formaldehyde may be standard. Therefore, concise design concept should be advocated in house decoration (Lu and Yang, 2010). In the premise of meet appropriate aesthetic feeling, should try to simplify decoration and use less decoration materials (Wang *et al*., 2006), must avoid excessive decoration.

Especially should pay attention to choose green environmental protection material to decorate, choose better quality, brand good, green environmental protection furniture. Decorating time should be chosen in well ventilated, temperature higher season, such as during May to October, in order to accelerate the volatilization and release of formaldehyde from dalle. Check-in time should be considered in November to next April,conditions allow and then keep good ventilation for more than half a year after the decoration.

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