Absorption of Formaldehyde by different wool types

Mansour, E.; Curling, S.F.; Ormondroyd, G.A.

Published: 07/10/2015

Publisher's PDF, also known as Version of record

Dyfyniad o'r fersiwn a gyhoeddwyd / Citation for published version (APA):
Mansour, E., Curling, S. F., & Ormondroyd, G. A. (2015). *Absorption of Formaldehyde by different wool types*. 285-288. Paper presented at Green.

ABSORPTION OF FORMALDEHYDE BY DIFFERENT WOOL TYPES

Elie Mansour, Simon F Curling, Graham A Ormondroyd

The BioComposites Centre, Bangor University, Bangor, UK

SUMMARY

This document summarises the quantitative analysis of the absorption of formaldehyde gas by different wool types. Formaldehyde, along with other VOCs, is of increasing concern due to its role as an accumulating indoor air contaminant. Building upon previous data, different wool types were subjected to cycles of exposure to formaldehyde gas whilst the weight gain was measured. The nature, condition and possibly the level of pigmentation of the wool all seem to effect the maximum quantity of formaldehyde absorbed.

INTRODUCTION

Indoor air quality (IAQ) has intrigued scientists since the mid-1800s (von Pettenkofer, 1858) and continued in the 1930s. The main concern was the spread of microbial agents within dwellings and public buildings (Shurtleff, 1933; Wells, 1943). Historical developments such as the London smog of 1952 instigated substantial air pollution investigations, and differences in the health of people working indoors and outdoors were explored (Fairbairn and Reid, 1958). There has been a mild interest in the capacity of construction materials to contribute to a better atmospheric environment (Braun and Wilson, 1970); but the main studies investigating volatile organic compounds (VOCs) in buildings didn't start till relatively recently, whereby 50 studies were conducted between 1978 and 1990 (Brown *et al*., 1994). Unfortunately, indoor air pollution remains a recognised socio-economic problem (EEA, 2013; Franchi *et al*., 2006), potentially costing up to $125 billion (Fisk and Rosenfeld, 1997). Based on further scientific findings, the World Health Organisation (WHO) compiled a set of statements emphasising the right to breathe healthy indoor air and the obligations of responsible authorities (WHO, 2000).

Keeping in mind that 99% of human exposure to VOCs results from direct inhalation (Carrer *et al*., 2000), a large survey (performed in the United States with n=9,386) points out that the public spend 87% of their time in enclosed buildings and 6% of their time in enclosed vehicles (Klepeis *et al*., 2001). According to the European Respiratory Society, pollutants “may have an important biological impact even at low concentrations over long exposure periods”. They localised these pollutants mainly to homes, schools, congregating halls and residences, and vehicles (European Respiratory Society, 2013). Figure 1 summarises the total VOC levels studied in different European countries.

Hazards induced by these pollutants vary, but boil down to exacerbating known respiratory diseases, sensitising to airborne agents, and reducing lung functionality. VOCs are frequently linked to what is termed “sick building syndrome” (SBS), which refers to a bundle of symptoms that include eye irritation, stuffy or runny nose, dry skin, headache, fatigue, and difficulty concentrating. The first noticeable case of SBS was in the 1970s in Sweden, where SBS was observed in preschools; the cause was attributed to casein that was emitted from self-levelling cement. Several similar cases were thereafter reported: 10,000 Canadian buildings in the mid-1990s, and an estimated cost of $1 million at Environmental Protection Agency’s (EPA) U.S. headquarters due to decreased productivity (Wallace, 2001).

In response, the industry introduced a wide range of ‘air cleaning/treating’ products to the market, and the removal of both chemical and biological indoor contaminants remain a subject of interest (Carslaw *et al*., 2013). However, such devices can be energy intensive, contribute to some other form of contamination, and have a short operational life span compared to the building’s life. It is possible that a passive solution can overcome such limitations.

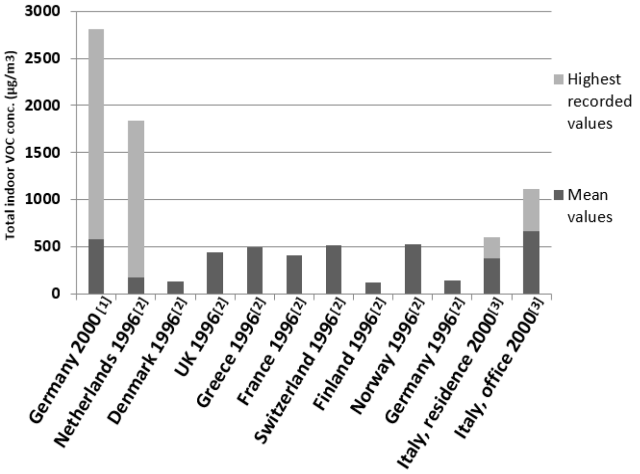

*Figure 1: TVOC measurements ([1]= Hoffmann et al., 2000 ; [2]= Bluyssen et al., 1996; [3]=Carrer et al., 2000). * Personal exposure, high variation*

Formaldehyde, as one of these VOCs, catches the eye for three main reasons: many building products, including all wood-based structures, emit it at significant rates (Meyer and Boehme, 1997); it is a gas in its natural state, so occupants are easily exposed to it; and its health effects include cancer risk (EPA, 1991).

Wool fibre is known to manage the problem when used as furniture, clothing, or insulation (Seo *et al.*, 2009). Compared to previous studies, Curling *et al.* (2012) proposed a quick and simple method to quantify formaldehyde absorption by sheep wool: they exposed wool to formaldehyde gas whilst observing its weight change using Dynamic Vapour Sorption. The 4.9% gain in weight shows that wool absorbs this quantity of formaldehyde from the surrounding air. The sample is then placed in a formaldehyde-free environment allowing it to desorb the formaldehyde it contains. The interesting observation is that the weight of the wool sample does not drop down to its original weight. A quantity of formaldehyde equivalent to 2.9% of the wool’s weight permanently binds to the wool structure. This shows that wool can maintain low atmospheric concentrations, behaving as a formaldehyde buffer.

The aim of this study is to differentiate between the quantities of formaldehyde absorbed by different wool types.

MATERIALS AND METHODS

Sorption analyses were performed using DVS system (Surface Measurement Systems, London, UK).

Wool’s ability to absorb formaldehyde was assessed by the use of dynamic vapour sorption (Curling *et al*., 2012), and is compared with carbon fibre as a control. The method used by Curling *et al* showed good repeatability; therefore, a modified version of the method was used: a flow of formaldehyde gas is emitted by bubbling nitrogen into a solution of formaldehyde and water. By increasing the relative humidity (RH), the amount of gaseous formaldehyde the sample is exposed to increases. A micro-balance is used to detect any uptake of moisture and formaldehyde by the fibre. The sample is subjected to the following cycles to calculate the weight of formaldehyde that the wool is able to chemically bind with (Figure 2):

1. Sample is left to equilibrate at 0% RH; i.e. it is not exposed to moisture or formaldehyde. This sets its baseline weight.

2. Sample is left to equilibrate at 90% RH; i.e. it is exposed to high levels of moisture and formaldehyde where it sorbs both and gains weight.
3. Sample is again equilibrated 0% RH; at this point it loses all the water it sorbed. Any weight gain relative to the sample's state at step 1 is therefore sorbed formaldehyde.
4. Steps 1 to 3 are repeated several times to determine the total sorption capacity.

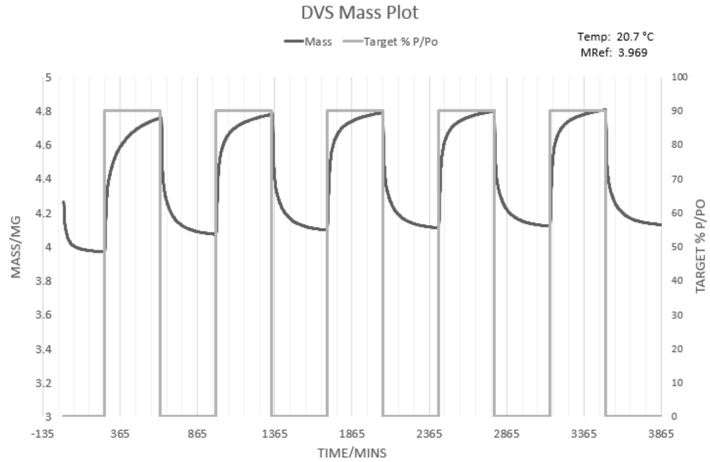

Figure 2: Mass plot of Swaledale wool exposed to formaldehyde gas

RESULTS AND DISCUSSION

Figure 3 shows the amount of formaldehyde per kg of different wool types and carbon fibre as a control. It is evident that both wool type and condition (scoured or unscoured) have an effect on wool's ability to absorb formaldehyde (Fig 3). It was also noticed that there is a general trend that the more darkly pigmented the wool is, the higher its sorption capacity.

Further research will determine if there is a correlation between fibre pigmentation of the same wool source and investigate the trends of absorptions of other VOCs such as limonene, toluene and dodecane.

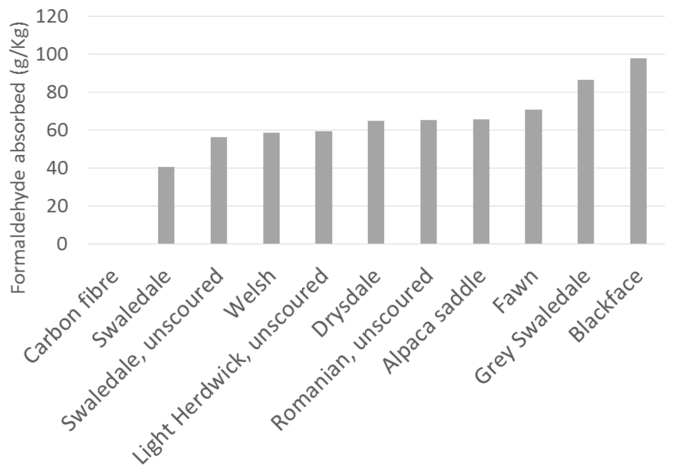

Figure 3: Mass of formaldehyde chemically bound by different wool types

ACKNOWLEDGEMENT

The research leading to these results has received funding from the European Union's Seventh Framework Programme (FP7/2007-2013) for research, technological development and demonstration under grant agreement no 609234.

The authors would also like to thank Black Mountain Insulation Ltd and the Wool Testing Authority (Caernarfon) for their supply of different wool types.

REFERENCES

BLUYSSEN, P.M., DE OLIVEIRA FERNANDES, E., GROES, L., CLAUSEN, G., FANGER, P.O., VALBJØRN, O., BERNHARD, C.A., ROULET, C.A. (1996): European Indoor Air Quality Audit Project in 56 Office Buildings. Indoor Air 6: 221–238

BRAUN, R.C., WILSON, M.J.G. (1970): The removal of atmospheric sulphur by building stones. Atmospheric Environ. 1967 4: 371–378

BROWN, S.K., SIM, M.R., ABRAMSON, M.J., GRAY, C.N. (1994): Concentrations of Volatile Organic Compounds in Indoor Air – A Review. Indoor Air 4: 123–134

CARRER, P., MARONI, M., ALCINI, D., CAVALLO, D., FUSTINONI, S., LOVATO, L., VISIGALLI, F. (2000): Assessment through Environmental and Biological Measurements of Total Daily Exposure to Volatile Organic Compounds of Office Workers in Milan, Italy. Indoor Air 10: 258–268

CARSLAW, N., HATHWAY, A., FLETCHER, L., HAMILTON, J., INGHAM, T., NOAKES, C. (2013): Chemical versus biological contamination indoors: trade-offs versus win–win opportunities for improving indoor air quality. Indoor Air 23: 173–174

CURLING, S.F., LOXTON, C., ORMONDROYD, G.A. (2012): A rapid method for investigating the absorption of formaldehyde from air by wool. J. Mater. Sci: 47: 3248–3251

EEA (2013): Air quality in Europe — 2013 report (No. 9/2013). European Environment Agency

EPA (1991): Formaldehyde (CASRN 50-00-0). URL http://www.epa.gov/iris/subst/0419.htm

EUROPEAN RESPIRATORY SOCIETY (2013): European Lung White book. URL http://www.erswhitebook.org

FAIRBAIRN, A.S., REID, D.D. (1958): Air pollution and other local factors in respiratory disease. Br. J. Prev. Soc. Med. 12: 94–103

FISK, W.J., ROSENFELD, A.H. (1997): Estimates of Improved Productivity and Health from Better Indoor Environments. Indoor Air: 7: 158–172

FRANCHI, M., CARRER, P., KOTZIAS, D., RAMECKERS, E.M. A. L., SEPPÄNEN, O., VAN BRONSWIJK, J.E.M.H., VIEGI, G., GILDER, J.A., VALOVIRTA, E. (2006): Working towards healthy air in dwellings in Europe. Allergy 61: 864–868

HOFFMANN, K., KRAUSE, C., SEIFERT, B., ULLRICH, D. (2000). The German Environmental Survey 1990/92 (GerES II): sources of personal exposure to volatile organic compounds. J. Expo. Anal. Environ. Epidemiol 10: 115–125

KLEPEIS, N.E., NELSON, W.C., OTT, W.R., ROBINSON, J.P., TSANG, A.M., SWITZER, P., BEHAR, J.V., HERN, S.C., ENGELMANN, W.H. (2001): The National Human Activity Pattern Survey (NHAPS): a resource for assessing exposure to environmental pollutants. J. Expo. Anal. Environ. Epidemiol. 11: 231–252.

MEYER, B., BOEHME, C. (1997): Formaldehyde emission from solid wood. For. Prod. J. 47: 45–48.

SEO, J., KATO, S., ATAKA, Y., CHINO, S. (2009): Performance test for evaluating the reduction of VOCs in rooms and evaluating the lifetime of sorptive building materials. Build. Environ. 44:207-215

SHURTLEFF, W (1933): Method and Apparatus for Purifying. 1937483.

VON PETTENKOFER, M. (1858): Besprechung allgemeiner auf die Ventilation bezüglicher Fragen. Cotta.

WALLACE, L.A. (2001): Human Exposure to Volatile Organic Pollutants: Implications for Indoor Air Studies. Annu. Rev. Energy Environ. 26: 269–301

WELLS, W.F. (1943): Air Disinfection in Day Schools. Am. J. Public Health Nations Health 33: 1436–1443

WHO (2000): The right to healthy indoor air (Report on WHO Meeting No. Bilthoven, Netherlands)