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Contamination of Wool Fibre Exposed to Environmental Tobacco Smoke

Abstract

The development of our civilisation has led to such a lifestyle that most inhabitants of urban agglomerations spend 90% of their lifetime in rooms. The issue of Indoor Air Quality (IAQ) is extremely important, and currently comprises very different aspects. One of them is the problem of Environmental Tobacco Smoke (ETS). The number of harmful compounds present in ETS is estimated at 2000-4700. Nowadays, it is clearly stressed that tobacco smoke has an adverse effect on so-called passive smokers. Terms such as PTS (Passive Tobacco Smoke) and Secondhand Smoke are commonly used in the literature of this subject, followed by unambiguous opinions that passive smoking causes lung cancer. Passive smoking does not only assume the form of direct inhalation of the tobacco smoke. Wolkoff and the authors he cites divide smoke emission into primary and secondary emission. From the tests carried out so far at the Institute of Textile Material Engineering, it follows that textiles absorb volatile substances and then they release them. This study demonstrates the impact of fluorocarbon treatment of wool fibres on the sorption and desorption of ETS. The change in the wool fibre weight due to the sorption and desorption of tobacco smoke emitted from a cigarette and the kinetic curves of sorption and desorption of tobacco smoke calculated on the basis of weight changes have been shown. The experimental data obtained have been compared with the theoretical models described mostly by adsorption equations.

Key words: environmental tobacco smoke, passive tobacco smoke, wool fibres, sorption.

the emission connected with the manufacturing process used, and particularly the textile finishing process. A practical effect of this knowledge comes from the fact that textile fabrics are marked with appropriate informational labels, which indicate that there is no risk of harmful substance emission, e.g. with labels from the GuT® and Öko-Tex® associations [1-3]. However, the emission problem does not resolve itself into its primary form only.

In residential and public utility rooms, as well as in means of transport, there are textiles which can adsorb harmful compounds from the air. These most frequently include carbon oxide, nicotine, carcinogenic tars, sulphur dioxide, ammonia, nitrogen oxides, formaldehyde, nitrosoamines, benzene, benzo- α -pyrene, vinyl chloride, styrene, hydrogen cyanide, arsenic, radioactive nuclides and so-called RSP (Respirable Suspended Particles) [5-8]. The interest in this issue dates from the late 1990s when literature reports on secondary emissions appeared. The subject of interest was formaldehyde, which was classified by the IARC (International Agency for Research on Cancer) in group 2A as probably carcinogenic [9]. The decided majority of studies, however, concerned the formaldehyde content in fabrics and its emission into the atmosphere as well as the methods of reducing it.

The tests performed at the Institute of Textile Materials Engineering confirmed

the secondary emission of formaldehyde from carpets [10,11]. Wolkoff and the authors he cites divide the emission into primary and secondary types [12]. The first concerns volatile organic compounds (VOC) with low molecular weights, which are not combined with the fabric material, while the second is shown by VOC chemically or physically combined with the material, which are released due to processes such as oxidation, chemical or physical degradation, mechanical action or sorption phenomena. Van Loy, Nazaroff and Daisey [13] have performed interesting studies of nicotine adsorption on a metal surface, panelled wall and unspecified carpet. From these studies it follows that the adsorption rate constant for the carpet is decidedly the highest (four times as high as that for the panelled wall), while the desorption rate constant is the lowest (by an order of magnitude, compared to that of the panelled wall) [4]. Thus, it is clear that volatile compounds can be periodically accumulated in textile fabrics and then emitted into the atmosphere. A pre-ecological approach to textiles - which is

Theoretical

Long-standing studies on the harmfulness of textile fabric manufacture and quality in respect of users' health have resulted in the identification of hazard sources and their order by hierarchy [1-4]. One of the major problems is the emission of harmful compounds, especially from the fabrics of interior furnishing. At first these studies involved

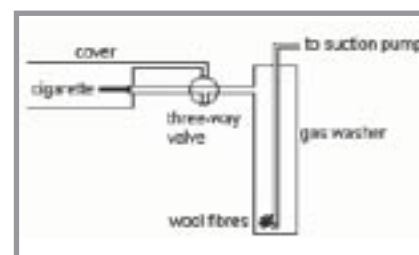


Figure 1. Cigarette smoking system.



Figure 2. Microbalance MK2-G5.

aimed not only at reducing the hazards to the environment caused by textile manufacturing processes, but also at providing users with a harmless product with minimised content and emission of harmful compounds - demands that the product be free of any secondary source of pollution.

Experimental

Materials

New Zealand wool fibres with a thickness of 36-37 μm and a length of 147 mm were used for the experiments. Wool samples were cleaned by triple shaking for 1 h each in distilled water at a temperature of 40°C followed by drying at 23°C. Some wool samples were finished with a fluorocarbon resin, Texguard AS of Deurotex GmbH (TAS). The wool was padded with a 100 g/l TAS solution and dried followed by heating at 130°C for 10 min. to cross-link the resin. The resin content in wool was 0.6%.

Apparatus

The cigarette smoking system (Figure 1) consists of a covered mouthpiece, a three-way valve, a washer with a sample

holder, and a pump. Air is sucked in at a rate of 2.6 l/h. The smoking cycle duration is 5 min. Air is sucked in for 2-3 s through the burning cigarette, and then it is sucked in from the space limited by the mouthpiece cover for about 30 s. Once the cigarette is burnt out, the wool sample remains motionless in the washer for 25 min. The airflow and the system volume are selected so that the washer is entirely filled with smoke at the end of burning.

A stand consisting of a high vacuum line and an MK2-G5 microbalance by C.I. Electronics Ltd. (Figure 2) makes it possible to directly measure and record the changes in the weight of sample versus time and pressure within a range from 10^{-4} mbar to 1000 mbar. The maximum load of the balance is 5 g, and the dynamic range of weighing is 1g with a sensitivity of 0.1 μg .

Results

All the tests of smoke adsorption and desorption were carried out at a temperature of 23°C. A 1g wool sample was degassed on the microbalance pan under a final pressure of 10^{-4} mbar to a constant weight. Then the weighing system was filled with nitrogen, and when the equilibrium under a pressure of 1000 mbar was reached, the sample was transferred into the washer (Figure 1). After the smoke adsorption, the fibre sample was rapidly placed on the balance pan. In the determination of sorption isotherms, the pressure was decreased stepwise from 1000 mbar to 10^{-4} mbar. The concentrations of tobacco smoke components were calculated from the sample weight after smoke adsorption and the final weight

after degasification. The course of isotherms is shown in Figure 5.

Discussion

Desorption kinetics

Wool has a very developed surface and readily sorbs moisture and various impurities from air. Additionally, volatile components can be emitted from the TAS-finished wool. In order to eliminate any possible differences resulting from the different volatile components' contents, all the wool samples were degassed and saturated with nitrogen before testing. The volatile compound loss from the TAS-finished wool is 0.208 mg/mg, while that from the untreated wool sample is 0.034 mg/mg; however, the weight increase due to nitrogen adsorption is 0.002 mg/mg. These results indicate a high content of volatile components, originating probably from the resin and water adsorbed from air. An example of the smoke desorption from untreated wool is shown in Figure 3. Figure 4 shows the kinetic curves of the desorption of tobacco smoke components from untreated and resin-finished wool samples. From the TAS-finished wool, 0.091 mg/mg of smoke is desorbed, while from the untreated wool sample 0.120 mg/mg.

It is difficult to maintain precisely reproducible conditions of 'cigarette smoking'. Even with the same adsorption time and the 'smoking' procedure, the concentration of smoke in the washer and its composition can vary. This is also due to differences in particular cigarettes. Although only one type of cigarette was used in the tests, the structures of the burned portions were different (tobacco structure, granulation, packing etc.). These factors affected

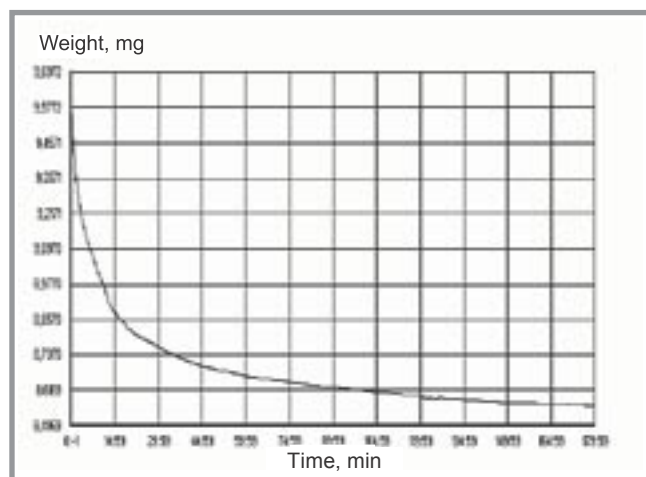


Figure 3. Smoke desorption from untreated wool.

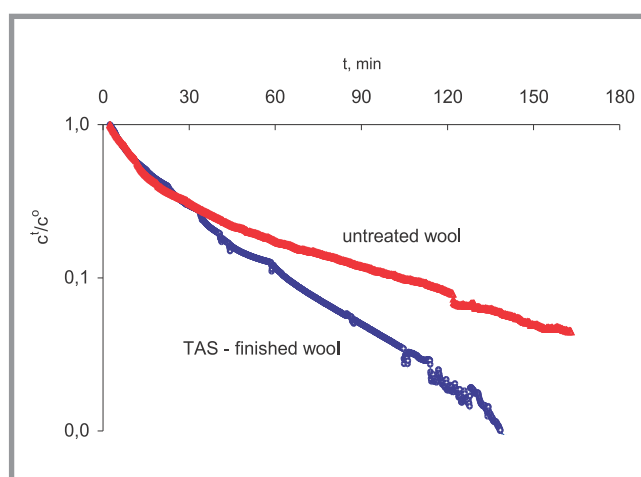


Figure 4. Comparison of the kinetic curves of smoke desorption from TAS-finished and untreated wool.

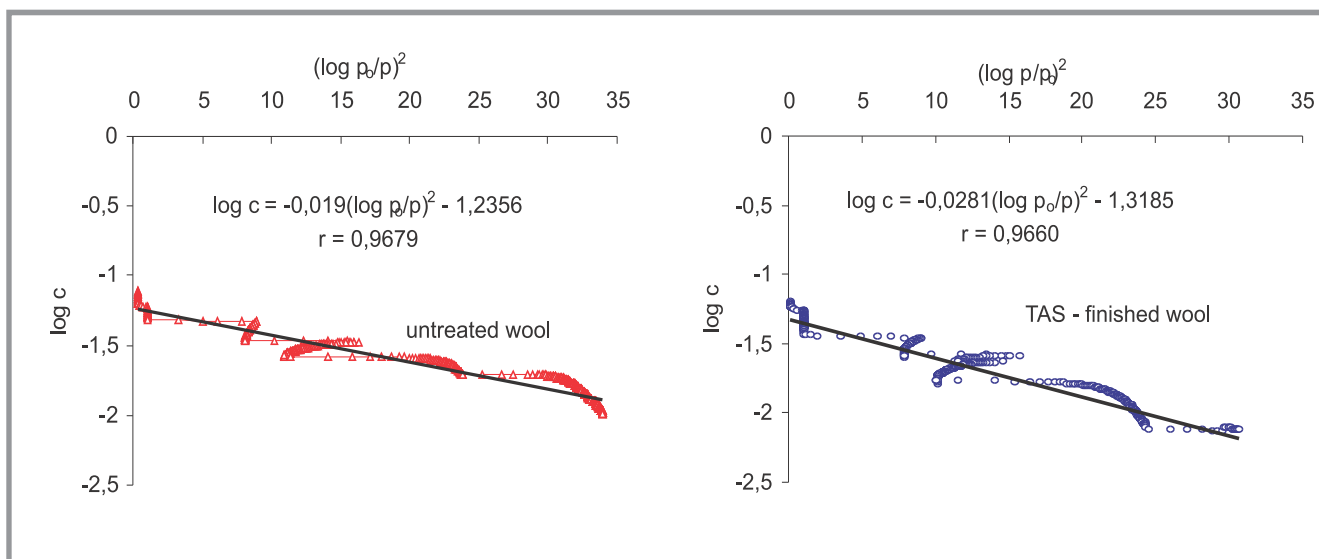


Figure 5. DR's isotherms of smoke desorption from untreated and TAS-finished wool.

the smoking mode and rate, resulting in different quantities of adsorbed smoke components. Therefore, to compare the desorption kinetics, relative changes in the concentration of smoke components in fibre (c/c^0) related to the initial concentration were assumed ($c^0=0.1192$ mg/mg and $c^0_{TAS}=0.1977$ mg/mg respectively). From the diagrams in Figure 4, it follows that the desorption proceeds faster and completely, while in the untreated wool the concentration is maintained at a level of 0.004 mg/mg, despite the higher initial smoke concentration in the TAS-finished wool.

The desorption kinetic curves with a good correlation coefficient are described by the equation

$$c=c_0 e^{-kt}$$

The desorption rate constant k for untreated wool is 0.0163 min^{-1} , and that of the TAS-finished wool is 0.0331 min^{-1} .

Determination of desorption isotherms and verification of their consistence with Dubinin-Radushkievich's theory

The equilibrium vapour adsorption of many volatile organic compounds can be described with good approximation by Dubinin-Radushkievich's theory (DR) [14]. To analyse the adsorption isotherms of tobacco smoke by wool, DR's equation

$$\log a = D (\log p_0/p)^2 - \log a_0$$

was used. Due to the specificity of the sorbate - that is, a mixture of many different compounds, instead of the molar concentration a_0 expressing the number of moles needed to fill the micro-pores of 1 g adsorbent with the liquid adsorbate

- the weight concentration c_0 was used. From the isotherms shown in Figure 5, the values of c_0 were found to be 0.048 mg/mg for the TAS-finished wool and 0.058 mg/mg for untreated wool. This indicates that wool pore volume is decreased due to the treatment with TAS.

Conclusions

- The examinations of adsorption and desorption have shown that wool fibre is characterised by a high capability to adsorb tobacco smoke components.
- Finishing the wool with the Texguard AS resin resulted in a considerable reduction of the adsorption.
- The tobacco smoke desorption from wool is consistent to a large extent with Dubinin-Radushkievich's theory ($r=0.9679$, $r_{TAS}=0.9660$). The concentrations determined on the basis of DR's theory, which characterise the filling of micro-pores of 1 g adsorbent with the liquid adsorbate, are higher for the untreated wool than those for TAS-finished wool (0.058 mg/mg and 0.048 mg/mg, respectively).
- The analysis of the desorption kinetics has shown that desorption from the TAS-finished wool proceeds considerably faster than that from untreated wool. The desorption rate constants are $k=0.0163 \text{ min}^{-1}$ and $k_{TAS}=0.0331 \text{ min}^{-1}$ respectively. The desorption from the TAS-finished wool is complete, while in untreated wool the concentration is still at a level of 0.004 mg/mg.

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