

NEW APPROACH TO ENVIRONMENTAL TOBACCO SMOKE EXPOSURE AND ITS RELATION TO REEMISSION PROCESSES

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Abstract

Indoor air quality is one of the factors that determine human well-being and health. Being aware of this fact, it is essential to identify the origin, kind, mechanism, and effects of harmful substances contained in the air. The issue concerning the contents and primary emission of these substances from building materials and interior furnishings is well known. Adverse effects of environmental tobacco smoke (ETS), including exposure of passive smokers, are also very well documented. To the contrary, reports on secondary and indirect emissions, especially those focused on mechanisms by which pollution is “transferred” by materials used in interior furnishings are very rare. Textiles are used in a great variety of ways as functional and decorative materials. These materials in general, and textile floor coverings in particular, are extensively utilized in fitting apartments, public buildings, and transport means. Studies on this aspect of the role played by textile materials in ETS exposure have been only fragmentary documented.

Key words:

Environmental tobacco smoke, Indoor air quality, Textile floor covering

INTRODUCTION

Civilization has shaped our life styles in a way that forces us to spend most of our time in varied premises. This results in exacerbation of certain health complaints, and thus the term “sick building syndrome” (SBS) has recently emerged [1–3]. This observation encourages numerous researchers to study effects of conditions occurring in premises and dwellings on the health of their users. A feeling of comfort in building facilities depends on biological (bacteria, endotoxins, fungi), physical (temperature, humidity, ionization), and chemical factors, including emission of toxic air contaminants, especially volatile organic compounds (VOC). Building materials, wood-derived boards, lacquers, elements of interior fittings are only some of many other sources of emission [4–6].

Studies have revealed that VOC concentrations in the indoor air are higher than those recorded in the outdoor air [1,7,8].

In view of the above, the quality of air breathed in premises is the subject of great concern throughout the world, especially in American and Scandinavian research centers. The term “indoor air quality” (IAQ), adopted some years ago, embraces varied aspects of this issue, e.g., concentrations of harmful substances in the air and materials used in premises, their sources and emission levels, monitoring and research methodology as well as effects of those substances on human health. Numerous epidemiological studies focus on these problems.

ENVIRONMENTAL TOBACCO SMOKE EXPOSURE

Environmental tobacco smoke (ETS) exposure is one of the major problems of indoor air quality. It has been evidenced that ETS is one of the most common and most hazardous agents responsible for air pollution. [9–14].

This work was supported by an internal grant from The Institute of Textile Materials Engineering, Łódź, Poland (2034/ND/S).

Received: April 4, 2006. Accepted: May 8, 2006.

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Recognizing the fact that in the United States alone, 48 million adults smoke about 500 billion cigarettes per year, it is estimated that 31 million non-smokers (16 million juveniles) are exposed to ETS in private residences, which corresponds to 11% of the US population [11]. It is absolutely clear that this is a critical source of pollution, especially if we consider that the amount of ETS-contained compounds of different physicochemical nature and degree of harmfulness is estimated at 2000–4700. This group of compounds is predominated by carbon monoxide, nicotine, tar, sulfur dioxide, ammonia, nitric oxides, formaldehydes, nitrosoamines, cresol, ethylbenzene, phenol, xylene, benzene, benzo- α -pyrene, toluene, vinyl chloride, styrene, hydrogen cyanide, arsenic, radionuclides and respirable suspended particles (RSP) [1,2,13]. Animal studies show high toxicity of these substances [7]. It has been found that 43 compounds typical of ETS are carcinogenic, and some of them mutagenic. For example, formaldehyde contained in cigarettes (57–115 ppm/one cigarette) contributes to the production of up to 1.7 mg of formaldehyde in the air after only one cigarette smoked. About 138 billion cigarettes smoked in Germany alone are responsible for 200 tons of this substance emitted to the environment. Other studies reveal that 105 mg of carbon monoxide, 2.7 mg of nicotine, 40–70 mg of tar, and about 0.1 mg of carcinogenic compounds are emitted during smoking process [2]. It has been shown that among all non-smokers living in California, the proportion of ETS exposure in the total inhalation exposure is: 5% for *o*-xylene; 3% for *m,p*-xylene; 5% for benzene; and 8% for styrene [11].

Recently, the documented adverse effect of tobacco smoke components on so called passive smokers has been very strongly emphasized. The terms “passive tobacco smoke” (PTS) or “secondhand smoke” (SHS) are now in common use [14–18]. Bearing all this in mind, studies of all possible aspects of PTS as well as actions aimed at reducing related effects have been markedly intensified during the recent years [19].

In the United States, smoking is forbidden in all public buildings, and it is obligatory not only to section off certain areas of premises for smokers, but also to monitor whether they meet very strictly defined requirements on ventilation systems. Each system must ensure that the

“produced” smoke is effectively removed from smoking rooms or corners [16].

This results from unambiguous opinions that passive smoking, also called involuntary tobacco smoke, presents a serious public health issue as it contributes to the following health effects: carcinogenic (lung and nasal sinus cancer), cardiovascular (heart disease mortality, acute and chronic coronary heart disease morbidity), respiratory (in children: acute lower respiratory tract infections, asthma induction and exacerbation, chronic respiratory symptoms, middle ear infections; in adults: eye and nasal irritation), and developmental (fetal growth: low birth weight or small for gestational age, sudden infant death syndrome) [20–25].

There are also effects with suggestive evidence of a casual association with ETS exposure, including cervical cancer, exacerbation of cystic fibrosis, decreased pulmonary function, spontaneous abortion, adverse impact on cognition and behavior [25].

Based on the total body of scientific evidence, the US Environmental Protection Agency (EPA) categorizes ETS in Group A that includes compounds carcinogenic to humans. According to the EPA report, 3000 deaths from lung cancer are recorded annually among non-smokers in the United States. It also estimates that 200 000 to 1 000 000 asthmatic children have their condition worsened by ETS exposure [24].

Newborns and babies under 18 months of age whose parents smoke are particularly susceptible to respiratory (150 000–300 000 cases per year, including 7500–15 000 hospitalizations) and cardiovascular infections. In addition, their psychophysical development is substantially impaired [7]. Children at this age need to be particularly protected against any kind of ETS exposure, direct and secondary, as they have no chance to make a choice, especially in the case of secondary exposure. Therefore, it is crucial to identify different forms of ETS exposure.

THE ROLE OF TEXTILE MATERIALS IN ETS EXPOSURE

The effect of textile materials used in premises is one of the aspects of this vital issue. Owing to long-term studies of harmful processes and textile products it is now fea-

sible to identify exposure sources and set their hierarchy. There are numerous well documented findings on harmful agents emitted from this group of products, especially from textile floor coverings (TFC). However, the available data mostly apply to primary emission related to production technologies, particularly those employed in the finishing process. It is worth noting that the development of TFC production technology now in use, characterized by low or even no emission of VOC, is a tangible outcome of those studies [4,26–28]. Nevertheless one should remember that the problem of emission is not only limited to its primary form.

There is a large proportion of TFC in internal fittings not only because of their overall dimensions, but mainly because of their specific surface. A specific surface of a carpet, defined by Bouhamra and Elkilani [29] with BET isotherms, is threefold larger than that of a curtain and twice as large as furniture fabric (1.4167; 0.4796; and 0.7572 m²/g, respectively).

Owing to the specific morphological and structural constitution of fibers, used in the TFC production, they may indirectly influence the composition of indoor air. This in turn is due to a specific feature of textile material, susceptibility to sorption, which varies and is determined by physicochemical factors [30–33].

A clear-cut determination of mechanisms and effects of sorption processes and reemission on the IAQ in natural conditions is more difficult. It is due to extensive diversity of building materials and fittings, type of premises, ventilation systems and behavior of users. Studies of these aspects combined with the assessment of health effects are also extremely expensive. Therefore, a topical trend of model studies have been recently launched [12,34]. Studies of sorption are usually based on simple schemes: one- or two-component sorbent, and a single sorption compound, as shown in Table 1 [29,31,33–37]. To date, investigations in this field have been performed in different conditions and parameters of various processes have been estimated, therefore, the obtained results are not comparable. Some authors [35] suggest that the capacity of a given material to adsorb indoor air pollutants is best described by the equilibrium constant, whereas others determine the kinet-

ics of sorption [31], or monitor the concentration of tested compounds in the indoor air [38]. For example, in the case of formaldehyde, categorized by the International Agency for Research on Cancer (IARC) into group 2A, a strait majority of studies focused on its concentration and emission into the atmosphere as well as on the ways of reducing the related risk. As to formaldehyde sorption from the atmospheric air, it has been suggested that products made of natural fibers absorb formaldehyde and thus “improve the indoor air quality”. It has been also hypothesized that formaldehyde is permanently bound to woolen fiber [38]. But this hypothesis was supported neither by the studies of the sorption mechanism and efforts to find out whether it is of physical or chemical nature, nor by the studies of consecutive desorption.

Studies of formaldehyde and styrene sorption by seven different textile raw materials (Table 1) showed relatively extensive susceptibility of both compounds to sorption and consecutive reemission. It has been found that generally natural fibers are more susceptible to formaldehyde accumulation than synthetic fibers, which are more susceptible to styrene sorption. Both compounds are then reemitted from tested textile materials into clean air with different rates. In the case of formaldehyde adsorbing capacity of textile materials is determined by their hydrophilicity, so that sorption/desorption processes of this compound are significantly affected by the air relative humidity (RH) [33].

Despite differences in methods/measured parameters/adsorbates, the obtained results explicitly demonstrate the susceptibility of textile materials to sorption of single VOC, determined by the type of fibrogenic polymer, temperature and relative air humidity as well as by their influence on the indoor air quality.

Wolkoff [39] also draws a distinction between primary emission and secondary emission. Primary emission is equated with VOC of low molecular mass not related to material. Secondary emission concerns VOC bound chemically or physically and released as a result of oxidation, chemical and physical degradation or mechanical effects, and also substances adsorbed from other sources. Morrison and Nazaroff [40] investigated a phenomenon of secondary emission of aldehydes from carpets treated with

ozone. Having compared the obtained results with those of primary emission, they found that secondary emission may have a damaging effect on IAQ. Studies aimed at explaining how far sorption or reemission influences the quality of air are now topical.

Owing to the fact that ETS is the major and most harmful source of air pollution, exposure of passive smokers to ETS has been recently the subject of thorough investigations. The studies are mainly concerned with direct “inhalation” of smoke originated from main and side streams as well as from butts.

Studies of reemission were carried out by Singer et al. [13] who revealed secondary emission of some ETS components one week and one month after one-day indoor smoking. Other researchers showed that a short-term adsorption on surfaces of the premise, furnished and inlaid with flooring, apparently limits the concentration of and exposure to ETS

compounds during smoking, but the reemission increases them during successive weeks after termination of smoking [41]. These observations are justified in terms of surface physicochemistry and phenomena observed at the phase borderlines. When the ETS air concentration decreases in the non smoking period, a tendency towards leveling of concentrations – reaching the state of equilibrium is observed, and adsorbed substances are desorbed to medium of the lower concentration. Concentration levels and desorption kinetics are obviously determined by the kind of a given substance, sorbent, temperature and relative humidity. Van Loy et al. [34] investigated nicotine sorption on metal surface, paneling and undefined carpet. This study revealed that the constant pace of the carpet adsorption proved to be highest (fourfold higher than that of paneling), whereas the constant pace of the carpet desorption proved to be lowest (over one order of magnitude comparative to paneling).

Table 1. Studies of sorption for textile materials

Material (sorbent)	Compound (adsorbate)	Test Method/Conditions	Comments/Determined parameters	References
Fibers: nylon/acrylic, cotton, wool, nylon carpet	Chloroform, 1-trichloroethane, carbon tetrachloride, trichloroethylene, p-dichlorobenzene, 1,1, tetrachloroethylene, benzene, toluene, m-xylene, 1,2-dichloroethane,	GSC 10, 20, 25, 30, 40°C Batch reactor (0.001m ³)	Partition coefficient Kinetic studies For single compound (but not every adsorbate with every sorbent)	[31]
Fibers and fabrics: wool, cotton, viscose, nylon, polyester, acrylic, polypropylene Carpets: wool/polyamide, polypropylene, polyamide	Formaldehyde, styrene	Chambers (0.01 m ³ , 0.02 m ³ , 0.2 m ³) 22, 30°C 25, 38, 50% RH	Sorption isotherms, equilibrium concentration, change of sorbent surface energy, sorption/desorption kinetics For single adsorbate	[33]
Unidentified carpet	Nicotine (from ETS)	Chamber (20 m ³) 23, 25, 26°C 41, 47, 55% RH	Adsorption/desorption rate Constants for nicotine as a marker of ETS	[34]
Cotton and nylon fabrics	Nicotine, ethenylpyridyne	Chamber (1 m ³) 23°C 32–76% RH	Sorption and desorption kinetic parameters For single adsorbate	[36]
Wool and nylon carpets	α – pinene, toluene	Chamber (0.05 m ³) 23°C 50% RH	Desorption kinetic parameters For single/both adsorbates and single/both carpets	[35]
Acrylic carpet	1,1,1-Trichloroethane, 1,2-dichlorobenzene, toluene	TGA 25, 30, 35, 45°C Chamber (0.0335 m ³) 25, 45°C	Adsorption/desorption kinetics, adsorption isotherms Adsorption and desorption rates For single adsorbate	[37]

GSC – gas solid chromatography;
ETS – environmental tobacco smoke;

TGA – thermogravimetric analyzer;
RH – relative humidity.

The results of previous studies of the performance of woolen fibers in the ETS environment, revealed explicitly their high susceptibility to sorption and emission [42]. The same susceptibility to sorption of ETS was found for wool/polyamide (80/20) carpets. As calculated from the desorption isotherm, the initial smoke content was 7% by weight, which is a substantial value taking account of relatively high carpet mass per unit area [43].

Wool, protein fibers of animal origin, has a very complex structure from both physical and chemical points of view. Protein fibers are composed of polymolecular and polymeric compounds generated from optically active α -amino acids. Woolen fibers are almost entirely composed of protein-keratin mixture of 21 amino acids of different structures, chemical nature and percent fractions. High reactivity of wool creates favorable conditions for chemisorption, whereas an expanded typical surface and the presence of numerous pores favors physical sorption. Both these mechanisms have been found when investigating the wool-formaldehyde sorption scheme. As a result not only extensive susceptibility to sorption, but also incomplete process of desorption were revealed [33,44]. A similar observation was made in the wool-ETS sorption scheme [43].

In view of the aforesaid facts, ETS components may be inhaled with air polluted due to reemission and adsorbed on fiber particles they may also enter the lungs.

FUTURE STEP?

Each substance of both organic and inorganic origin enters the lungs in a defined quantity, and thus may induce pathological changes. Among numerous factors responsible for the damage to respiratory epithelium in occupational and environmental exposures, the role of dusts, especially dusts of synthetic and natural fibers used in the production of some textile goods or insulation materials, is particularly emphasized [45,46].

However, there is still lack of comprehensive information about the mechanism involved, and the indirect exposure, resulting from reemission and entering of ETS components into the body by means of solid fiber particles inhaled with the air has not yet been elucidated.

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