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TiO$_2$/Ag Modified Carpet Fibres for the Reduction of Nicotine Exposure[1)]

Abstract
The study was carried out to analyse the susceptibility of textile polymers, polyamide and polypropylene, used in the manufacture of floor coverings, to the sorption of nicotine from environmental tobacco smoke (ETS) polluted air and nicotine itself. Polypropylene fibres were modified by means of titanium dioxide doped with nanosilver particles (TiO$_2$/Ag). The decomposition kinetics of nicotine adsorbed by polypropylene fibres and the catalytic effect of TiO$_2$/Ag on the decomposition of nicotine were investigated. Having analysed the concentrations of nicotine adsorbed from ETS by polyamide fibres and polypropylene fibres, it was found that the latter demonstrate a much stronger sorption of nicotine. It was also observed that the nanomodifier TiO$_2$/Ag substantially accelerates the photocatalytic decomposition of nicotine adsorbed by polypropylene fibres.

Key words: *polyamide, polypropylene, nicotine, sorption, ETS, TiO$_2$/Ag nanomodifier.*

Introduction

Over many years the sorption of air pollutants by textile materials used in interiors has been a well known and documented issue [1 - 7]. The mechanism of sorption and sequential desorption depends on the character of relations between the absorbent and the substance absorbed. Moreover, it is very difficult to define, especially when the sorption of mixtures is considered [8]. According to the definition of the Environmental Protection Agency (EPA), environmental tobacco smoke (ETS) is a complex mixture of thousands of gases and fine particles emitted by the burning of tobacco products and from smoke exhaled by the smoker. Other minor contributors are from the smoke that escapes while the smoker inhales and some vapor-phase related compounds that diffuse from the tobacco product [9]. ETS is one of the most common and harmful pollutants of indoor air quality (IAQ) [10 - 14]. It is estimated that ETS contains almost 5000 compounds of different physico-chemical nature and varied severity of hazard [15, 16].

Non-smokers sharing premises with smokers or using premises penetrated by tobacco smoke, generally termed "involuntary" or "passive" smokers, form a specific group at risk [17]. Passive tobacco smoke (PTS) or second hand smoke (SHS) has been classified by US EPA as a carcinogen of Group A, and the International Agency for Research on Cancer (IARC) has categorised tobacco smoke in Group 1 ─ the agent is carcinogenic to humans [18]. It is estimated that in the USA, 31 million non-smokers, including 16 million minors, are exposed to ETS [19]. In the European Union the number of EST-exposed people is estimated at 7.5 million [20]. This applies to occupational and environmental exposure as well as to exposure in the living environment. In the former, those exposed are mostly adult people whose exposure may be reduced through legal regulations, whereas in the latter, not only adults but also children and young people are exposed to this hazard.

Environmental tobacco smoke, volatile substances adsorbed from ETS and then re-emitted from interior-equipped materials, as well as the presence of solid particles along with physically and chemically adsorbed substances are directly responsible for inhalation exposure among the users of interiors where tobacco is smoked [10].

Textile materials used in interior equipment are characterised not only by a large surface area (especially textile floor coverings – TFC) but also by very high susceptibility to sorption [1, 4]. Therefore, they play an essential role in shaping indoor air quality and greatly contribute to the exposure of involuntary smokers; they re-emit volatile ETS components, and thus ETS-contaminated textile particles are inhaled by non-smokers.

In view of the complex composition of ETS, it is essential to identify tobacco-specific markers, which should be independent of the tobacco blend and available in the air in quantities sufficient from the analytical point of view [4, 21 - 24]. However, numerous tobacco smoke-contained chemical compounds (e.g., nicotine, 3-vinylpiridine, carbon dioxide, N-nitrosamines, benzo(a)pyrene, polydispersive solid particles) may be regarded as ETS-exposure marker, nicotine and polydispersive solid particles, which are now thought to be the most reliable marker in the qualitative and quantitative assessment of ETS [25, 26]. Nicotine, a semi-volatile component of ETS and a major tobacco alkaloid (pyridine alkaloid), is considered to be the basic marker of tobacco smoke exposure. It is present in both gaseous and partial fractions of ETS [27, 28]. In humans, CYP P-450 family enzymes are involved in the nicotine metabolism, whereas cytochromes CYP 2A6, CYP 2B6 and CYP 2D6 mediate its oxidation in hepatocytes, of which CYP 2A6 shows the most extensive activity [29]. Urinary excretion of nicotine and its metabolites is very fast: 80 - 90% of nicotine is excreted in urine in the form of its metabolites, and the half-life of this compound is about 2 h. Nicotine is highly addictive, and each source of inhalation exposure to this compound is detrimental, especially for young children who are particularly vulnerable to addictions. The US Surgeon General's report states that nicotine is more addictive than alcohol and as addictive as crack [30].

The aim of this study is to assess the nicotine sorption of textile polymers, polyamide and polypropylene, commonly used in textile floor coverings (TFC), and the possibility of accelerating the elimination of nicotine adsorbed by a textile material modified by titanium dioxide doped with silver nanoparticles as the catalyst agent.

Titania photocatalysis technology based on TiO$_2$ is currently at the stage of commercialisation in many branches of industry [31, 32]. Over recent years, similar studies have also been carried out on textile technologies [33, 34]. Progress made in the development of nanotechnology has rendered it possible to intensify

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TiO$_2$ effectiveness (photocatalytic reaction rate) by modifying its surface with noble metal deposition [35, 36]. Falaras et al. applying silver particles obtained for silver-modified TiO$_2$ indicated a threefold increase in the rate of orange methyl decomposition as compared to that of non-modified TiO$_2$ [36]. Alberici et al. found the UV-VIS-influenced photocatalytic reaction of TiO$_2$ more effective in a gaseous fraction than in a liquid one [37]. Therefore, it was assumed that titanium oxide doped with silver nanoparticles should effectively accelerate the decomposition of nicotine adsorbed by textile materials.

■ Materials and methods

Materials

Experiments were performed on two types of polymers: polypropylene (PP S901, Orlen) and polyamide (PA6, Invista), most commonly used in the manufacture of floor coverings. Fibres and textile materials of different structure were subjected to thorough investigation. Fibres and polypropylene nonwoven modified with titanium dioxide doped with silver nanoparticles (TiO$_2$/Ag, VÚCHV) were also analysed.

Materials used in the ETS sorption testing

- polyamide fibres (fPA), 46.1 μm in diameter;
- polypropylene fibres (fPP), 55.2 μm in diameter;
- polyamide foil (flPP), gram per square meter (gsm), 186 g/m^2;
- polypropylene foil (flPA), gsm, 124 g/m^2;
- polypropylene spunbonded nonwoven (nPP), gsm, 30, 40, 50, 60, 80, and 100 g/m^2 (made of fibres 17.5 - 19.8 μm in diameter).

The fibres were tested in bunches with a mass of 0.05 g, whereas the nonwoven and foil were as squares with a dimension of 15 × 15 mm.

Marlboro class A cigarettes (length, 100 mm) containing 11 mg/cigarettes of tar and 0.8 mg/cigarette of nicotine, as declared by the manufacturer, were used to produce smoke in the chamber.

Materials used in the nicotine sorption testing

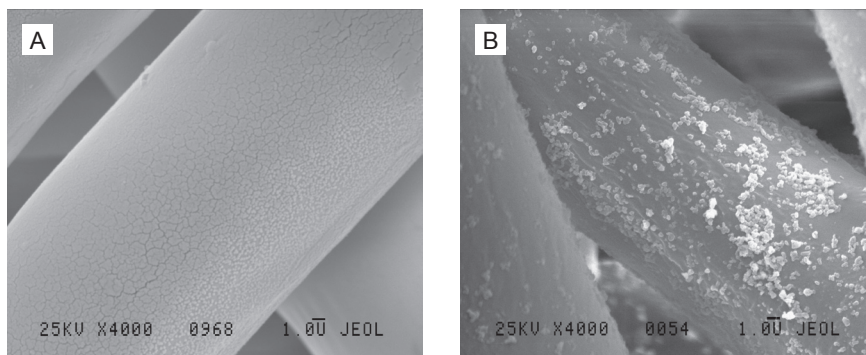- polypropylene fibres (fPP), 55.2 μm in diameter (***Figure 1.A***);

Figure 1. *Surface of PP fibres in nonwovens: A – nonmodified (nPP), B – TiO$_2$/Ag-modified (nPP/T).*

- polypropylene fibres modified by TiO$_2$/Ag (fPP/T) (***Figure 1.B***);
- nanomodifier – titanium dioxide doped with 1.5% silver nanoparticles (TiO$_2$/Ag) (T);
- polypropylene spunbonded nonwoven (nPP), gsm, 100 g/m^2 (made of fibres 17.5 – 19.8 μm in diameter);
- polypropylene spunbonded nonwoven, gsm, 100 g/m^2 (made of fibres 17.5 - 19.8 μm in diameter) modified by TiO$_2$/Ag (nPP/T).

Nicotine (Fluka 72290) 1-Methyl-2-(3-pyridyl)pyrrolidine C$_{10}$H$_{14}$N$_2$ (basic parameters: boiling temperature 243 - 248 °C and density 1.010 g/cm^3) were used. In each experiment, pure nicotine (5 μl) was put in the chamber.

Methods

Sorption test stand
The ETS/nicotine sorption test system consists of a sorptive system and two proportioning units (***Figure 2***).

The sorptive system takes the form of a glass cylinder chamber (diameter, 31 cm; volume, 45 dm^3). A connector pipe with valve 1 and a tube to the vacuum pump, as well as a mercuric vacuummeter with a valve and a tube with valve 2 to supply the volatile substances studied to the chamber are installed in the chamber cover. The tube with valve 2 is connected to the proportioning system.

The ETS proportioning system is composed of a 'mouthpiece' for placing a cigarette and casing with by-passing and valve 3 for collecting and carrying off the smoke from the space surrounding the cigarette.

The system of nicotine vapour proportioning is composed of a U-shaped glass tube with one arm ending in a ground-in stopper. Below it a capillary is placed for slow air supply. The bottom of the tube with a drop of nicotine is immersed in an oil bath.
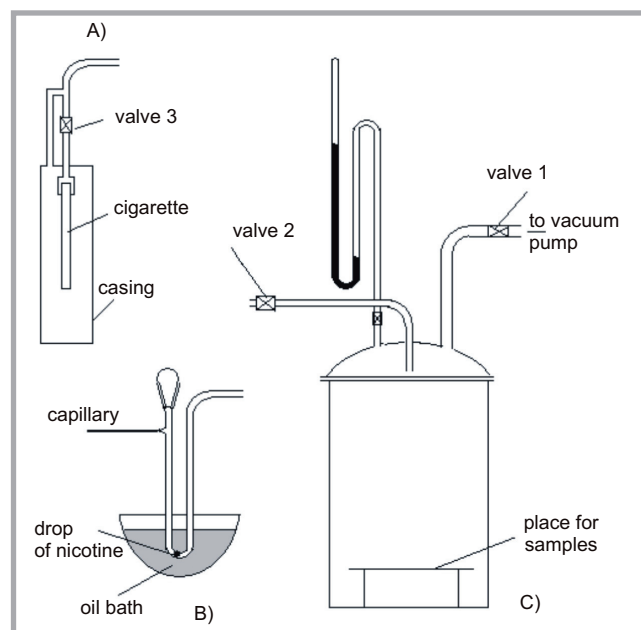

Figure 2. *ETS/nicotine sorption system; A) system of ETS proportioning, B) system of nicotine proportioning, C) sorption system.*

Nicotine concentration in the sorption-subjected samples was determined using a gas chromatograph (Agilent Technologies 6890N) with a mass detector equipped with a capillary column HP-5MS (length, 30 m; diameter, 0.25 mm) and stationary phase film (0.25 μm). The samples were extracted with chromatographically pure carbon disulphide (ANALITYKA). An ultrasonic bath (UNITRA) was used in the treatment of the chromatographic samples.

The mass growth of the samples subjected to ETS sorption was determined on a vacuum microbalance (Microbalance MK2-G5, C.I. Electronics Ltd.). The maximum load of the balance was 5 g, and the dynamic range of weighing was 1 g with a sensitivity of 0.1 μg.

An SEM, JSM 35C JOEL microscope was used for surface examination.

Experiments

ETS and nicotine sorption
The samples were arranged on the sorption test stand. The ETS proportioning system with a cigarette or nicotine proportioning system was connected to the chamber (*Figure 2*). The air was evacuated from the chamber. Valve 2 was closed and valve 1 was opened. When the pressure was about 20 mm Hg, valve 1 and the manometer valve were closed. The cigarette was then lit, and the air with smoke was very slowly supplied by opening valve 2. Due to the cyclic, short-term opening of valve 3, the cigarette smoke was dragged on. The air from the area surrounding the cigarette was constantly collected, with valve 3 closed, as well as during dragging. After the cigarette had been smoked, the chamber pressure was evened out.

In the case of nicotine sorption, a drop of nicotine was instilled in a U-shape tube using a micropipette. Then the bottom of the tube was immersed in the oil bath, which had been warmed up to 250 °C. After opening valve 2, nicotine vapour in a stream of air was slowly supplied through the capillary. Following about 20 min, the pressure in the chamber was levelled with that of atmospheric air.

In all the experiments, a 24-h sorption was applied. Two parallel tests of sorption were performed for all the kinds of samples. Five repetitions were used in the chromatographic determination of

nicotine concentrations in extracts obtained for each sample tested.

Treatment of samples after sorption
After the sorption stage, the textile materials (non-modified and modified by TiO$_2$/Ag) were exposed to different conditions:
1. DR – a smokefree dark room; temperature 22 ± 2 °C and relative humidity (RH) 50 ± 5%;
2. D – daylight (outside), temperature 20 °C, RH 60%.

The effect of storage/daylight exposure conditions on nicotine concentrations in standard (nPP) and modified (nPP/T) nonwoven was investigated. In one group of samples, the nicotine concentration was determined directly after sorption and after a 24-h daylight exposure (A/24hD). The remaining samples were stored in the dark for two months (A/2m), then one group of them was exposed to daylight for 30 min (A/2m/30D) and the other for 60 min (A/2m/60D).

3. X – Xenotest Alpha HE, Xenochrome 320 filters, intensity 60 W/m^2, RH 40%; air temperature 35 °C, sample surface temperature 50 °C.

The nicotine concentration in standard (fPP) and TiO$_2$/Ag-modified (fPP/T) fibres was determined in selected samples after sorption period of 24-h ; other samples were irradiated with a xenon lamp for 394 h, and the remaining samples were stored in the dark for 394 h.

Determination of nicotine concentration
The analytical system used was gas chromatography. The column was set at 50 °C (5 min) to 220 °C at a rate of 20 °C/min. The total run time was 60 min. Experimental samples were analysed in a selected ion monitoring (SIM) mode: m/z 84, 133 and 162 for nicotine. A standard curve (0.3 - 3.0 μg) for nicotine was generated (r = 0.995) for quantification of the experimental samples.

The experimental samples were placed in vessels (volume, 1.8 ml), and after adding 1 ml of CS$_2$, they were treated with ultrasounds for 30 min. The values of nicotine concentrations in samples are the mean of at least three parallel measurements.

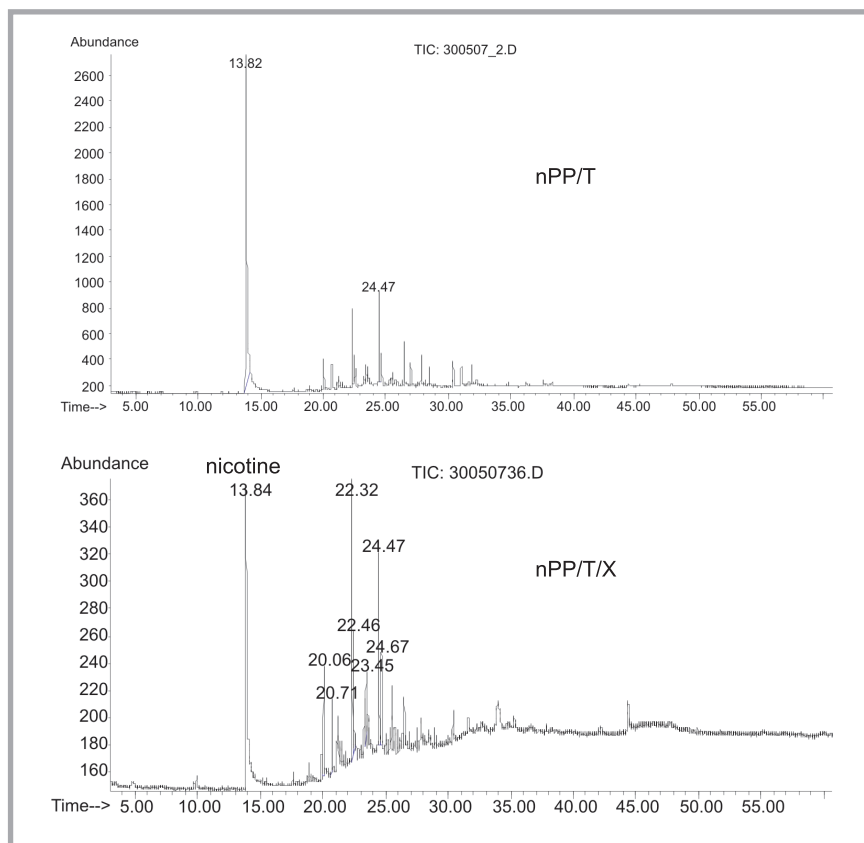*Figure 3* gives some examples of the chromatograms of nicotine extracts from

Figure 3. Chromatograms of nicotine extracts from PP nonwoven modified by TiO$_2$/Ag nonexposed (nPP/T) and exposed in the Xenotest (nPP/T/X).

PP nonwoven modified by TiO$_2$/Ag nonexposed (nPP/T) and exposed in the Xenotest (nPP/T/X).

Determination of desorption coefficient

The fibres were placed in vessels, and 20 µl (20 µg) of the reference CS$_2$ nicotine solution (1 mg/ml) was added to each vessel. The vessels, tightly-closed, were left overnight. The following day 1 ml of carbon disulphide was supplied to each vessel, and then the procedure followed that which was applied to experimental samples tested. Reference solutions of the same nicotine concentration were determined simultaneously. Nicotine desorption coefficient d$_n$ was calculated according to the following formula:

$$d_n = Pd/Po \qquad (1)$$

where Pd is the pick surface area of the component determined in the solution after desorption, and Po is the pick surface area determined in the reference solution.

Results and discussion

ETS sorption

Having analysed the suitability of polyamide and polypropylene in the form of fibres, foils and nonwoven for ETS sorption, it was determined that nicotine concentration in polypropylene fibres amounted to 32.3 ± 4.7 µg/g, which was significantly higher than that determined for polyamide fibres (24.3 ± 6.3 µg/g; p < 0.05). Nicotine concentration in polypropylene foil was found to be 332.6 ± 30.4 µg/g, which was significantly higher than that determined for polyamide foil (228.8 ± 6.6 µg/g; p < 0.001). No statistically significant differences were found in the nicotine concentration in either of the "flat" polypropylene products (foils and fibres) (**Figure 4**). The differences in nicotine concentration between fibres and products made of the same polymer suggest that the extent of sorption of nicotine containing ETS depends on the accessibility of the sorption surface and the so-called "sedimentation" surface. The fibres were studied in bunches, and only some of them were in direct contact with sedimentary ETS. Fibres, which form the structure of nonwoven, were more accessible and arranged, and their surface was better developed, which is also due to the significantly smaller diameter of fibres.

These observations are corroborated by the results of ETS sorption in nPP samples

of the same dimension but of different gsm mass. The mass growth of the sample was determined directly after sorption termination. No rectilinear relationship was observed between the mass growth of the sample and its gram per square meter (r = 0.4019). The mean value of mass growth was 0.27 g/m^2 (sd = 0.095).

After two-months storage of nPP in the dark, nicotine was still present in the samples, however, its concentration decreased rectilinearly (r = 0.9467) with the increasing surface mass of the sample. The results of both determinations are summarised in **Table 1**.

Nicotine sorption

Investigating nicotine sorption for standard (fPP) and modified (fPP/T) fibres, it was observed that after a sorption period of 24-h, the nicotine concentration in the fPP fibre was significantly lower than that in fPP/T fibre (67.2 ± 6.0 µg/g vs. 78.2 ± 3.2; p < 0.05, respectively). The nicotine concentration in the samples of fPP and fPP/T fibres stored in the dark for 394 h was 18.5 ± 1.6 µg/g and 19.3 ± 1.2 µg/g, respectively, which comprises 27.5% and 24.7% of the values determined directly after sorption. After 394 hours of irridation using an xenon lamp, the nicotine concentration was beyond the limit of detection (**Figure 5**).

It was observed that in the samples of modified nonwoven (nPP/T) subjected to nicotine sorption (A) and then exposed to daylight for 24 h, the percentage concentration of nicotine was similar to that found in the sample stored in the dark for 2 months (A/24hD – 12.7% and A/2m – 13.8%). Additional daylight exposure of the samples stored for 2 months (A/2m) caused a further decrease in nicotine concentration to 11.6% after 30 min and to 8.8% after an hour (**Figure 6**). To analyse the effects of the catalyst applied on the decomposition kinetics of nicotine adsorbed by fibres, the nPPT and nPP/T samples were exposed to an Xenotest.

Kinetic curves of nicotine decomposition with a good correlation coefficient can be described by the equation

$$c = c_0\, e^{-kt} \qquad (2)$$

where:
c – nicotine concentration after time t, in µg/g;
c_0 – initial concentration of nicotine in µg/g;
k – decomposition rate constant in h^{-1};
t – time in h.

The analysis of changes in nicotine concentration adsorbed by PP nonwoven shows that despite a higher initial nicotine concentration in the TiO$_2$/Ag-modified nonwoven (2022.0 ± 152.3 µg/g) than in the non-

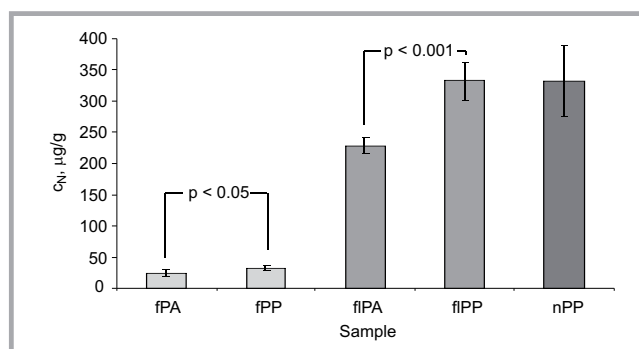**Figure 4.** *Nicotine concentration in fibres (fPA, fPP), foils (flPA, flPP) and nonwoven (nPP) after ETS sorption.*

Table 1. *Results of ETS sorption for polypropylene nonwovens (nPP) with different grams per square meter.*

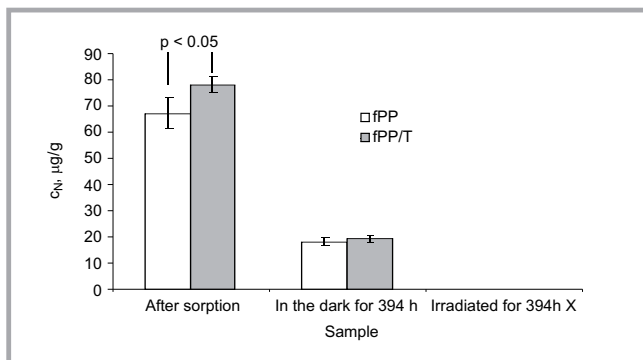| Gram per square meter (gsm), g/m^2	Increase in mass of nPP after ETS sorption, mg	Concentration of nicotine after a 2-month storage in dark room	
		µg/sample	µg/g
30	0.30	1.99	163.4
40	0.23	2.07	127.2
50	0.15	1.75	93.6
60	0.35	1.93	77.7
80	0.20	1.48	39.5
100	0.40	1.44	36.4
Mean value Standard deviation (sd)	0.27 0.095	1.78 0.27	y = -1.8053x + 197.94 r = 0.9467

Figure 5. *Nicotine concentration in nonmodified (fPP) and TiO2/Ag-modified polypropylene fibres (fPP/T), determined directly after sorption, stored in the dark and irradiated in the Xenotest (X).*
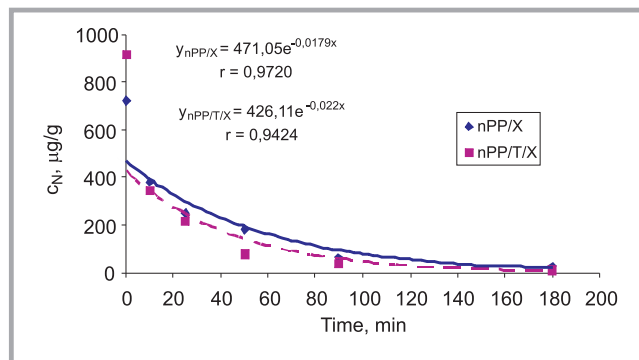

Figure 7. *Time dependent nicotine concentration in nPP and nPP/T nonwovens after sorption and irradiation in the Xenotest (X)*

modified sample (1795.3 ± 98.7 μg/g), the decrease in its concentration was faster. This is evidenced by their decomposition rate constant, k, which are $k_{nPP/T/X} = 0.022$ min^{-1} and $k_{nPP/X} = 0.0179$ min^{-1} (**Figure 7**).

Higher concentrations of nicotine in modified materials are justified by a higher surface area. This is visible in the SEM pictures of fibres of TiO2/Ag-modified and non-modified nonwoven (**Figure 1**).

20.4% of the fibre surface is covered by TiO2/Ag particles of an average of 0.51 μm (spread, 0.01 - 1.5 μm). These particles are strongly bounded up with the polymer surface by adhesive forces. The reversible work of adhesion required to separate TiO2/Ag particles from polypropylene is 50.40 mJ/m^2, whereas in an aqueous environment it is 31.54 mJ/m^2. The high value of work of adhesion ensures joint stability so that water does not remove TiO2/Ag particles from the surface of the PP fibre.

Exposure to artificial light considerably accelerated the decomposition of nico-tine relative to daylight exposure. After a 24-h exposure to daylight, the samples modified by the photodegradation cata-lyst still contained 257.5 μg/g of nicotine. Such a level, calculated theoretically ac-cording to formula (2), could be obtained after a 23-min irradiation with an xenon lamp. The ratio of constant k for modi-fied and non-modified fibres was 1.2. A faster decrease in nicotine concentration in modified fibres was due to the catalytic effect of TiO2/Ag. Analysis of the curves (**Figure 7**) revealed that despite high cor-relation coefficients, the theoretic initial concentration of nicotine, determined ac-cording to formula (2), departed from the experimental data. This suggests that the kinetics of the process in the initial time interval may differ from its later course. The half-time of nicotine decomposition, determined on the basis of the initial time interval value and estimated at 10.8 min for nPP and 7.00 min for nPP/T, showed that the fastest rate of nicotine decompo-sition occurred during the first 10 min. Differences in the nicotine decomposi-tion rates in the initial and later periods of exposure may have been caused by nico-tine diffusion into the polymer. Nicotine and other compounds of tobacco smoke diffuse from the surface of fibres into the polymer. Diffusion into the polymer competes with photodecomposition and desorption into the air. The desorption of volatile compounds, especially those of a hydrophilic nature, should prevail, while semi-volatile organic compounds, espe-cially aromatic polycyclic compounds, may diffuse into the polymer, leading to its swelling. This may also facilitate the diffusion of hydrophilic compounds, e.g., nicotine.

Polypropylene is thought to be a relative-ly efficient nicotine adsorbent. Oldham et al. investigated nicotine sorption from both gaseous and liquid phases. At a tem-perature of 25 °C, they found a 0.05% mass growth after one day's sorption from the gaseous phase, whereas from the liquid phase it ranged from 2.8 to 7.5%, depending on the kind of polymer. After 10-min desorption in a vacuum, the loss of nicotine absorbed ranged from only 0.1 to 1.1% [38].

Polypropylene, being a saturated hydro-carbon, does not absorb light of over 180 nm in wavelength, i.e., lower than 290 nm, beyond which the earth's atmos-phere totally absorbs light of the solar spectrum, and thus it should not undergo photodegradation. However, the photo-oxidative degradation of PP fibres oc-curs in the fibre surface zone, which is accessible to oxygen. It is produced by a number of chromophoric groups gen-erated as a result of thermal oxidation during the fibre forming process and pollution of polymers, which absorb the light of a wavelength not exceeding 290 nm. Their significance is reduced in the following chain configuration: -OOH > = CO > polynuclear aromat-ics >> polymer –O2 complexes.
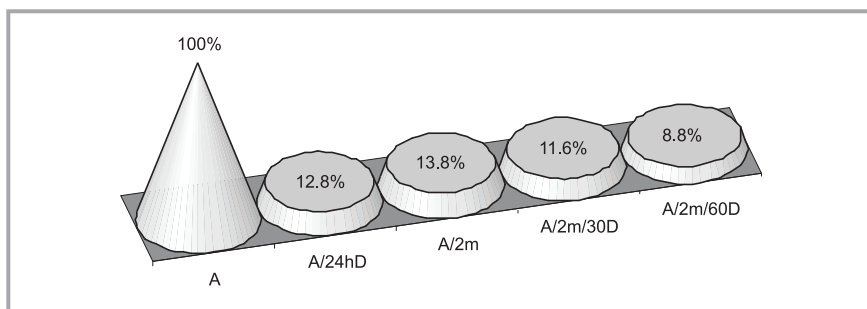

Figure 6. *Percentage concentration of nicotine in TiO2/Ag-modified nonwovens (nPP/T) relative to the nicotine concentration determined in the sample directly after sorption. A – directly after sorption; A/24hD – sample A exposed to daylight for 24 h; A/2m – sample A stored in the dark for 2 months; A/2m/30D – sample A stored in the dark for 2 months and exposed to daylight for 30 min; A/2m/60D – sample A stored in the dark for 2 months and exposed to daylight for 60 min.*

Isotactic PP undergoes degradation under the influence of UV radiation, which leads to the generation of carbonyl and hydroperoxide groups, as well as PPO$^\bullet$ and PPOO$^\bullet$ radicals [39]. Finally, the fibres crumble and produce air polluting particles. This particularly happens with the polypropylene devoid of degradation inhibitors.

The rate of oxygen diffusion in PP, described by diffusion coefficient D, is $D_{O_2} = 4.6 \cdot 10^{-8}$ cm^2/s, which is higher than nicotine diffusion ($D_N = 10^{-11}$ cm^2/s). This value of diffusion coefficient was derived from the time-dependence correlation of nicotine sorption on the PP foil: $C = kDt^{1/2}$ for time t_{tag} for linear extrapolation to value $C = 0$. Values of nicotine sorption after various periods of time and at temperatures ranging from 25 to 50 °C were taken from US Patent 4736755. It cannot be ruled out that radicals and hydroperoxide groups, developed as a result of PP photooxidation, participate in nicotine decomposition influenced by UV radiation.

Measurements of nicotine concentration (µg/g of nonwoven) in nonwoven made of the same fibres but different in the gram per square meter (gsm) showed a decrease with increasing nonwoven gsm. These results indicate that the amount of nicotine adsorbed from tobacco smoke depends mostly on the sedimentation of aerosol particles on the fibre surface and, to much lower degree, on nicotine sorption from the gaseous phase.

Smoke is a composite mixture of the gaseous phase and particles of several thousand chemical substances (volatile, semi-volatile and non-volatile) dispersed in it, characterised by a very diverse chemical structure, vapor pressure, density and viscosity. These substances comprise the low molecular gases CO and CO_2, gases whose boiling point is close to room temperature, such as CHO, the volatile liquid H_2O, semi-volatile organic compounds, including nicotine, and polycyclic tarry compounds. Smoke particles that settle on the surface of various materials, e.g., fibres, which, due to gravitation, contribute much more to their pollution than gaseous molecules absorbed from the air. Nicotine contained in the particle fraction "settles" on an accessible surface, whereas nicotine present in the gaseous phase is adsorbed from a very complex system, in which the interaction of ETS components occurs, and the processes of mounting active centers on the sorption surface compete with each other. Therefore, a simple sorption system cannot be considered in the case of nicotine sorption from ETS, because numerous factors determine both the sorption and desorption processes. This aspect of the issue has become the subject of investigations only since the last decade [40]. Nicotine is a semi-volatile compound with a lower vapour pressure. It can be absorbed by various surfaces in the indoor environment, and then both processes may occur - desorption to the indoor air as well as chemical degradation [41 - 44]. Interior textile materials made of commonly used polypropylene show a susceptibility to nicotine accumulation, and poor lightening of premises creates very favourable conditions for its accumulation. According to the Carpet and Rug Institute, textile floor coverings cover nearly 70% of flooring in the United States. Polypropylene fibres comprise 33.7% and polyamide 59.3% of fibres used in TFC manufacture. The period of TFC residential exploitation is estimated at 8 - 12 years and 6 years in commercial complexes [45]. The time period in which an accumulation of nicotine in carpets can occur is indeed long.

■ Summary

Polypropylene fibres manifest a higher susceptibility to nicotine sorption than polyamide fibres. Nicotine sorption from ETS is determined by the accessibility of "setting" the surface area for gaseous mixtures and solid particles, such as ETS and, possibly, a competitive sorption mechanism. The extent of nicotine sorption may be influenced by ratio of the accessible surface area of the sample to its mass area and so called setting surface area. Nicotine adsorbed by polypropylene remains for a long time, especially in conditions of limited access to light. Particles of polypropylene fibres polluted with nicotine and inhaled by non-smokers can be a potential source of inhalation exposure, especially in the case of polypropylene without degradation inhibitors. Such polypropylene fibres easily undergo the process of disintegration during abrasive wear of textile floor coverings. TiO$_2$/Ag-modified polypropylene accelerates the decomposition of adsorbed nicotine, limiting its accumulation in fibres.

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