Chapter 7

Non-Woven Textiles in the Indoor Environment

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Additional information is available at the end of the chapter

http://dx.doi.org/10.5772/61324

Abstract

The chapter presents the basic metrics of the indoor environment that are used to assess the quality of living and working, together with the risk factors and pollutants indoors. From this point of view the non-woven textiles are presented and discussed. Different groups of non-woven materials are considered: floor coverings, wallcoverings, upholstery and furniture textiles, filters of the HVAC systems, etc. Their particular application on the indoor environment is presented and their effect on the metrics of the Indoor Environmental Quality (IEQ) is analyzed.

Keywords: Non-woven, indoor environment, textiles, indoor environmental quality

1. Introduction

Nowadays, people in urban areas spend more than 90% of their life in enclosures – homes, offices, public buildings, and means of transport [1, 2]. Therefore, the Indoor Environmental Quality (IEQ) is of a particular importance for people's comfort, health, and productivity.

Textiles are part of every indoor environment and influence its basic metrics. Textiles and clothing are an excellent tool to maximize comfort and personification of the working and living environment. Textiles affect the comfort of people in the indoor environment as [3]:

- *A direct insulation layer* between the human body and the indoor environment: clothing, bedding, textiles for furniture
- *An indirect insulation layer* between the human body and the indoor environment: floor coverings, wall coverings, curtains, etc.

Unlike clothing that can be changed, and linen, which is easy to replace, the other textile items in the indoor environment are relatively constant and their correct selection is essential for IEQ.

Non-woven textiles are an important part of textiles in the indoor environment. Different groups of non-woven materials can be found in buildings and means of transport: floor coverings, wallcoverings, upholstery and furniture textiles, filters, etc. Depending on their application, they can be classified as:

- *Hidden non-woven textiles* as part of clothing, bedding, furniture, and heating, ventilation, and air-conditioning (HVAC) systems;
- *Visible non-woven textiles* as part of floor coverings, wallcoverings, and furniture systems.

The purpose of the chapter is to discuss the application of non-wovens indoors from the point of view of the basic metrics of the indoor environment used to assess the quality of living and working. Different types of applications are considered: non-woven textiles, used as floor coverings, bedding, furniture, wallcoverings, walls, and curtains, as well as non-woven textiles, applied in cars. The influence of the non-woven materials on Indoor Air Quality (IAQ), Indoor Thermal Quality (ITQ), Indoor Lighting Quality (ILQ), Indoor Sound Quality (ISQ), Indoor Odor Quality (IOQ), and Indoor Vibration Quality (IVQ) is presented. The risk factors, related with the use of non-wovens indoors and their possible role as sources of pollutants are also detailed.

2. Indoor environment

2.1. Basic metrics of the indoor environment

Indoor Environmental Quality (IEQ) is a complex term in the field of indoor climate engineering, which reflects the combined impact of the different characteristics of the indoor environment on the basic senses of the human body. Figure 1 summarizes the basic metrics of the IEQ: Indoor Air Quality (IAQ), Indoor Thermal Quality (ITQ), Indoor Lighting Quality (ILQ), Indoor Sound Quality (ISQ), Indoor Odor Quality (IOQ), and Indoor Vibration Quality (IVQ). Textile and particularly non-woven textiles may contribute to all these characteristics of the indoor environment.

The review article [4] discusses the difficulty to assess which of the basic metrics and particular characteristics of the indoor environment plays the most important role for the quality of life and work of the inhabitants. The authors attribute that fact to concomitant problems of investigations cited in their work: problems with the studies' settings, the percentage of respondents, or the analysis of the data obtained.

A later study [5], however, has already reported such results. According to their analysis, the *five* main characteristics of the IEQ, which are important for the occupants (taken as absolute values of the regression coefficients for positive/negative effects) are:

- Amount of space
- Visual privacy

http://dx.doi.org/10.5772/61324

Figure 1. Basic metrics of the Indoor Environmental Quality (IEQ)

- Noise level
- Colors and textures
- Comfort of furnishing

The first two characteristics are related with the ergonomics of the working and living environment, but at the same time they influence basic metrics of the IEQ like Indoor Air Quality (IAQ). Noise level contributes to Indoor Sound Quality (ISQ). The last two characteristics are also related with the ergonomics, but at the same time they are relevant to Indoor Thermal Quality (ITQ), Indoor Lighting Quality (ILQ), and Indoor Sound Quality (ISQ).

Non-woven textiles in the indoor environment can contribute to the amount of space and visual privacy being used as freestanding constructions that divide the indoor space into smaller areas. Non-wovens, as all textile materials, decrease the noise in the built environment and car compartments. All visible non-woven textiles (floor coverings, wallcoverings, upholstery textiles, etc.) influence people's comfort through their colors and textures. At the same time, both visible and hidden non-woven textiles in furniture systems, car seats and compartments influence the comfort of people, which is related to furnishing convenience.

2.2. Human comfort in the indoor environment

Comfort is a relative and subjective category, but when it is associated with the interaction between the human body and textiles it can be considered as physical, physiological, and psychological comfort. Figure 2 summarizes the main factors related to textiles and clothing, which define human comfort in the indoor environment.

The *physical comfort* is largely a subjective factor: although influenced by receptors that are common to the human body, individuals have varying degrees of sensitivity. The physical

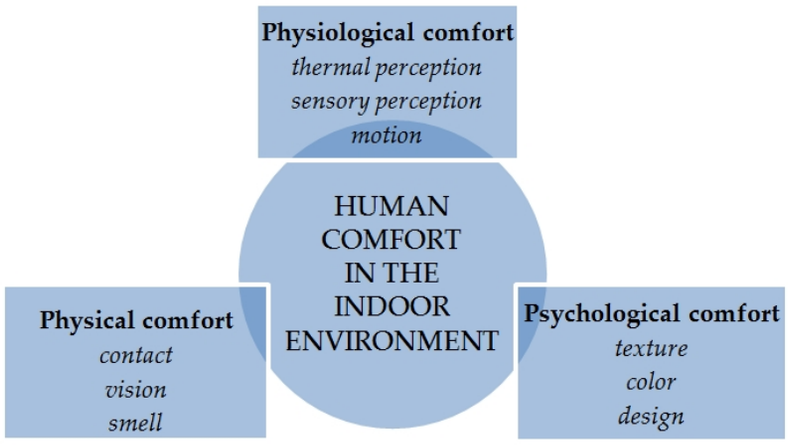

Figure 2. Factors that determine human comfort in the indoor environment, related to textiles and clothing

comfort is preconditioned by the contact between the human skin and the textiles, the presence of odors and the stimuli for the eyes. Ensuring physical comfort is a task of both the engineering aspect and the design aspect of the textiles production.

The *physiological comfort*, though again dependent on individual reactions and perceptions, is preconditioned to a high degree by the textiles design and engineering: from the selection of materials and structures, through their production and finishing, to their incorporation in the indoor environment as single items (floor covering, curtains) or parts of complex structures (bedding, furniture). It is predetermined mainly by the sensors for warmth/cold in the body, which are susceptible to thermal environment, presence of room airflow (draft), temperature asymmetry, etc.

The *psychological comfort* – not less subjective – depends largely on the textile design, fashion trends, and other factors, mainly related to art.

2.3. Risk factors in the indoor environment

The concept of Sick Building Syndrome (SBS) was developed in the 1970s. Nowadays, it is associated with the negative attributes of the Indoor Environmental Quality (IEQ). The SBS concept summarizes the dissatisfaction of the occupants from IEQ and series of clinical complaints, related to the stay of people in buildings. However, traditional clinical studies have not completely identified the causes of those complaints. Female subjects and elderly people are more sensitive to IEQ, but the mechanisms by which such sensitivity occurs, remain unspecified enough [6]. SBS is still a subject of clinical, chemical, and engineering studies; for the past decades, significant knowledge about the factors that determine SBS has been accumulated.

The main risk factors, related to indoor air quality (IAQ), which can provoke dissatisfaction among the inhabitants have been summarized in [7]. The results from that research are visually presented in Figure 3.

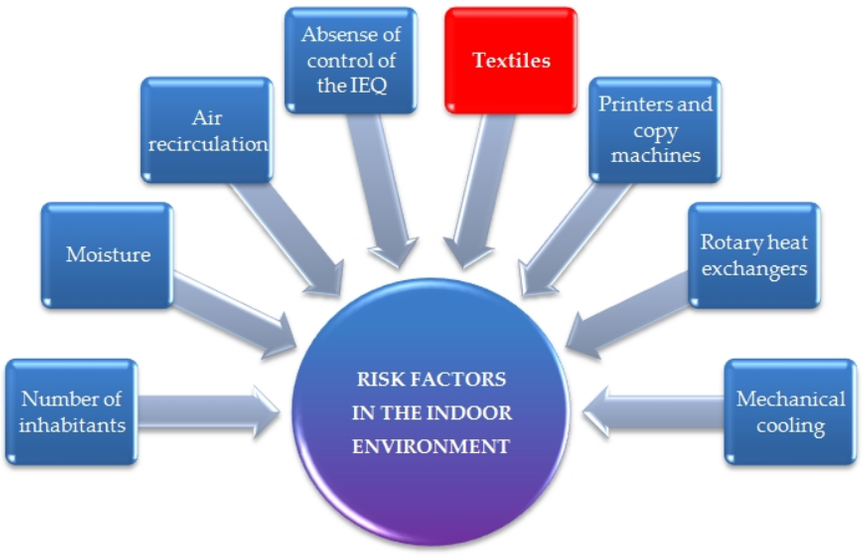

Figure 3. Risk factors for IAQ: summary of data from [7]

Textiles are among the risk factors for the quality of the indoor environment. Their influence on the IEQ is related with the ability of the textile surfaces to accumulate dust and odors, to emit dust and odors, to play the role of insulation layer thus affecting the thermal environment, to have influence upon the acoustics and lighting, etc. The type of the textiles macrostructure: woven, non-woven, or knitted, is also very important, as it determines the application of the particular textile in the indoor environment and its possible contribution to the IEQ.

2.4. Pollutants in the indoor environment

The up-to-date knowledge on the airborne pollutants in the indoor environment differentiates between the following pollutants of the indoor environment:

- Volatile Organic Compounds (VOCs)
- Microbial Volatile Organic Compounds (MVOCs)
- Particulate matter
- Inorganic compounds – CO_2, CO, O_3
- Semi-Volatile Organic Compounds (SVOCs)

Volatile Organic Compounds (VOCs) (formaldehyde, pesticides, ingredients of paints, dyes, etc.) are the most widely discussed pollutants that impair indoor air quality [7-9]. The highest levels of VOCs emissions indoors are measured immediately after building finishing or installation of furniture, flooring, etc. Due to their absorption ability textiles should not be installed in the indoor environment during the intensive release of VOCs from other items.The period of VOCs emissions can last from days to months, depending mainly on ventilation (natural or HVAC system), temperature, and humidity [10].

Semi-Volatile Organic Compounds (SVOCs) are associated with the presence of phthalates, pesticides, and flame retardants, which can be frequently found on textile surfaces in the indoor environment [11]. Microbial volatile organic compounds (MVOCs) are formed in the metabolism of fungi and bacteria [12]; therefore, they can be found in the indoor environment due to presence of moisture and mold growth.

A recent work [13] has summarized the state of the art in the field of the Very Volatile Organic Compounds (VVOCs) – an important subgroup of indoor pollutants that involves a wide spectrum of chemical substances. However, there is still no clear definition of VVOCs and techniques for their assessment.

3. Non-woven textiles in the indoor environment

Needle-punched non-woven textiles can be found as backing of carpets and wall coverings, and also as low-quality blankets, hidden layers in furniture systems, and wadding/padding. Spunlaced/hydroentangled non-woven materials are used in furnishing and bedding, as coverings and sheets. Spunbonded non-wovens are applied as a backing layer for wallcoverings, carpets, curtains, and furniture. They are also used as upholstery layers, filters, and tablecloths. Tablecloths are also made of wet-laid and spunlaced non-wovens. Chemically bonded non-woven textiles are applied as wadding and padding. The same is the application of the thermally bonded non-wovens, which are also applied in carpets underlying and furniture systems, including as upholstery textiles. The tufting technology is used for production of carpets for both built environment and car interiors.

Table 1 summarizes the main applications of different types of non-wovens in the indoor environment.

Several specific requirements have to be taken into account when designing non-wovens for application in the indoor environment. These requirements are related with both the product in question and its particular function: strength, dimensional stability, volume density, wear resistance, air-permeability, etc. There are other design considerations, however, related to the basic metrics of IEQ, which should be taken into account.

Non-wovens influence all basic metrics of IEQ. They may be used for sound control in residential and public buildings, or for glare reduction. As many textiles in public places, non-wovens are required to be flame-resistant. This additional treatment may be in a conflict with the demands for indoor air quality. The maintenance of the textiles surfaces is related to their ability to accumulate dust; therefore, the cleaning of the visible non-woven textiles in the indoor environment has to be easy. The last is also related with the products, as the cleaning agents themselves could frequently be sources of airborne pollutants.

Non-wovens have very good insulation abilities, used as floor coverings, wallcoverings, upholstery textiles (hidden layers or outer, visible layer), bedding, and they influence the indoor thermal quality. At the same time they can be a source of unpleasant odors, decreasing the indoor odor quality, especially in the case of floor coverings, including carpet backing. The

http://dx.doi.org/10.5772/61324

Nonwovens Indoors application	Needle punched	Spunlaced / Hydro-entangled	Spunbonded	Chemically bonded	Thermally bonded	Wet-laided	Tufted
Backing for wallcoverings		+	+				
Bedding coverings		+	+				
Bedsheets		+					
Blankets	+						
Carpet underlay/ backing	+		+		+		
Curtain backing			+				
Filters	+		+				
Floor covering	+						+
Furniture backing			+		+		
Tablecloths		+	+			+	
Upholstery	+	+	+		+		
Wadding and padding	+			+	+		

Table 1. Application of non-wovens in the indoor environment of buildings

sources of unpleasant odors could be either the non-woven item itself or the adhesive materials used for fixing the carpet to the floor.

4. Influence of the non-woven textiles on the indoor environmental quality

4.1. Non-woven textiles as floor coverings

Non-woven textiles, used as floor coverings in the indoor environment, increase the aesthetic comfort of the inhabitants. At the same time they influence thermal, acoustic, visual and odor environment, as well as indoor air quality.

Textile floor coverings have several advantages over other types of flooring (tiles, cement, wood, linoleum, bamboo, etc.) [9]. They increase the quality of the thermal environment; their insulation varies between 0.1 m^2K/W and 0.3 m^2K/W [14]. The insulation abilities are even better if a combination between hard flooring and textile floor covering is used.

Non-woven carpets influence the quality of the acoustic environment as they reduce noise levels indoors. They absorb the sound of steps and dropped objects and the absorption is higher when a pile carpet (tufted carpet) is used. At the same time, the quality of desired sound (music, speech) remains constant.

From economical point of view, the use of textile floor covering indoors can decrease or even eliminate the costs for sound and thermal insulating materials, especially in residential buildings.

Textile floor coverings do not reflect light; therefore, they can be used for glare reduction in the indoor environment, especially when hard flooring is also applied. The contact between sunlight and the textile fibers (mainly wool) leads to photobleaching effect, which requires additional treatment. However, all treatments of carpets, including those for stain blocking, fire resistance, moths blocking, etc., may affect negatively the indoor air quality (IAQ).

Several authors report and analyze the connection between IAQ and wall-to-wall non-woven carpets. Tufted carpets release Volatile Organic Compounds (VOCs) weeks after their installment in the indoor environment, due to the adhesives used for their fixation [15]. The cleaning of the near-wall zones is also very important, as they are a big source of airborne pollutants due to difficulty of access [16].

The surface pile of tufted carpets is indicated as a very important source of airborne pollutants in the indoor environment [15, 17-19]. The pile accumulates dust and particles, thus converting the tufted carpet into a "reservoir" for pollutants [9]. In addition, wool fibers can absorb formaldehyde, oxides of nitrogen and other toxic pollutants from the air [14]. Regular vacuum cleaning and wet extraction with cleaning products is a way of reducing the VOCs absorbed in the floor covering, but the cleaning products themselves are also a source of VOCs [9].

Tufted and needle-punched floor coverings can also be a source of VOCs and SVOCs in the indoor environment because of the backing. Tufted carpets need more complex finishing than woven carpets to obtain dimensional stability [20]. Synthetic latex is applied for backing of both needled and tufted floor coverings, which can be associated with airborne pollutants and unpleasant odors.

At the same time, Whitefoot [14] has reported the absence of scientific evidence that the removal of carpet alone has a proven effect on the health of the inhabitants. The author has discussed the advantage of pile carpets, including non-woven carpets, the surface of which can trap airborne pollutants and allergens, thus decreasing health problems related to allergy and asthma.

The study by Kidesø et al. [21] has concluded that heavy-weight needle-punched and tufted carpets from polypropylene and polyamide are particularly appropriate for residential buildings. The authors especially have underlined the requirement for smooth surface or surface with very low pile. The use of floor coverings with synthetic fibers, however, increases the risk of Microbial Volatile Organic Compounds (MVOCs) in the air. The higher humidity of the indoor air may provoke the development of mold and mildew; as a result, the carpet becomes a source of microbial airborne pollutants. Regular cleaning and use of antimicrobial

http://dx.doi.org/10.5772/61324

additives is a solution against MVOCs, especially in indoor environments with high traffic and high humidity [22]. At the same time, antimicrobial treatment (applied on the carpet fibers, the carpet backing, etc.) must exclude volatile organic chemicals (VOCs and SVOCs), toxins, allergens, carcinogens, and other substances that are dangerous for humans and animals [23].

4.2. Non-woven textiles as bedding

Bed linen and blankets are mainly related to two types of hazards in the internal environment: Microbial Volatile Organic Compounds (MVOCs) and particulate matter. In specific cases, Semi-Volatile Organic Compounds (SVOCs) can be also detected, usually for relatively short periods of time.

The main task of bedding in the indoor environment is to provide thermophysiological comfort for the person at rest [24]. Since at rest the human body produces minimal heat energy, higher requirements are demanded for the thermal insulation capacity of textiles for bedding [25]. Like the fabrics for clothing, textiles for bedding and blankets should absorb and transport water vapor emitted by the human body during rest and sleep. The role of bedding is critical for bedridden patients, adults with a high degree of immobility, and infants, because they spend a substantial part of their time in bed [26,27]. To avoid discomfort and getting bedsores, bedding items as material, structure, and finishing, should ensure the thermophysiological comfort by transferring air, heat, and moisture and not be a cause of allergic reactions.

Bed linen and blankets are serious battery of particulate matter. That, in a combination with high humidity and improper ventilation, leads to the development of MVOCs and microorganisms that cause allergic diseases. Non-wovens are excellent barrier against microorganisms (dust mites) because of their low porosity: with an average size of mites around 10 μm, the average pore size in fabrics for bedding has to be 6 μm or less. Non-woven mattress covers create impenetrable layer against microorganisms. Another solution is the use of textiles with zero permeability, but they do not provide breathability and reduce the comfort in general; they are also unsuitable for people with sensitivity to synthetic materials.

Non-woven textiles participate as visible or hidden elements in textile mattress pads, where a non-woven web is usually quilted between two woven or non-woven layers. Spunbonded polyester is used as face cloth because of its high wear resistance and resistance to washing.

An essential characteristic of the non-woven textiles for bedding is their ability to be subject to antimicrobial treatment [28]. Thus, the amount of MVOCs and unpleasant odors in the indoor environment is reduced by inhibiting the growth of mold, mildew, etc. The antimicrobial treatment, which can involve both antibacterial and antifungal treatments, is performed as part of the finishing of the non-wovens textiles (i.e., coating and spraying) or by adding additives directly to the fiber spinning dope.

Non-woven webs and fiber fills are frequently used in the production of pillows, quilts, and duvets. The use of hollow fibers increases the insulation abilities of fiber fills. Polypropylene spunbonds of around 50 g/m² replace the tightly woven fabrics, used as a nonremovable pillow cover [29]. Non-woven textiles are also applied as outer covering of economical quilts and duvets. Cheaper needle-punched blankets are produced from regenerated fibers for disposable

and emergency use, though high-quality needle-punched blankets are also produced from natural and synthetic fibers [30].

4.3. Non-woven textiles in furniture

The comfort, related with upholstery textiles, is generally associated with their touch [31,32]. In fact, the touch of the textiles is one of the factors for physical and neurophysiological comfort of the individual. However, the comfort of furniture, covered with fabrics, is determined by the thermophysiological comfort of the person. The thermophysiological comfort, in turn, depends on the behavior of the textile barrier between the body and the piece of furniture [33].

Non-woven textiles are applied in 80–90% of foambacked furniture systems and mattresses [34]. They are the outermost layer of the system (being the upholstery layer) or are used to provide support for the upholstery fabric. Currently, there is a trend of replacing the traditional woven covers of mattresses, made of cotton yarns, with filament non-wovens made of polyester and polypropylene.

Different types of non-woven coverings are in use [34]:

- Bonded polyester non-wovens as the outermost layer of furniture systems, which are not subjected to high loads
- Thermobonded non-wovens as the outermost layer of foambacked upholsters
- Laminated or quilted non-wovens as the outermost layer of foambacked upholstery with high dimensional stability

Inside furniture systems, non-wovens are used for support, insulation, and comfort. Needle-punched waddings and paddings, made from natural and chemical fiber that are recycled from textile production waste, or virgin fiber from acrylic, polypropylene, and polyethylene terephthalate are among the most commonly used [35]. The non-wovens replace the polyurethane foams in furniture systems and mattresses. These are products, based on stitch-bonding technologies, which provide thermal insulation and reduce noise and vibration during operation of furniture and mattresses. Composite non-woven textiles, produced by a web from bi-component fibers, are also in use. They have the same quality as foam of the same thickness [34], but demonstrate higher air permeability, which is important for ensuring both the thermophysiological comfort and the retention of MVOCs.

There is no risk for the Indoor Air Quality (IAQ) in terms of gas emissions from the upholstery textiles [36]. The upholstery surface, however, creates the same problems of accumulation of dust and particulate matter as the floor coverings. Therefore, furniture systems can be a source of VOCs, MVOCs, etc. due to accumulation of dust and allergenic particles from other sources of harmful substances in the indoor environment.

A solution of that problem is the use of synthetic leather as outermost layer of furniture pieces. Non-wovens are successful substitute for genuine leather. Different materials and technologies are applied for the production of synthetic leather. At the same time, synthetic leathers are an excellent substitute for both woven and knitted upholstery fabrics, which positively influences

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the IAQ of the indoor environment. Synthetic leather does not accumulate dust as woven and knitted textiles; it is not permeable toward the inner layers of the furniture system and can be cleaned more easily compared to traditional textiles.

4.4. Non-woven textiles as wallcoverings

Non-woven textiles are used more as commercial wallcoverings, applied in the interiors of public buildings (hotels, offices, hospitals). They must meet a series of requirements for flammability, abrasion resistance, washability and stain resistance, tear strength, etc.

The application of non-woven textiles for wallcoverings in the indoor is developing in two main directions: backing for wallcoverings and wallcoverings.

Non-wovens are used in fabric-backed vinyl wallcoverings, where a non-woven substrate is laminated to form a decorative surface of solid vinyl. Light or medium weight wallcoverings are produced with a non-woven backing. Traditional wallcovering substrates are produced with a non-woven backing: needle-punched or stitch-bonded layers [34].

Non-woven wallcoverings influence the IAQ as they can accumulate dust and are used in big areas in the indoor environment. Certainly, their effect on accumulation of dust and particles, released from other sources in the indoor environment is much lower than in the case of carpets and upholstery. Flocked wallcoverings, which have velvet appearance or 3D effects, require special attention. Being overlaid with very fine fibers of cotton, silk, or man-made fibers, the flocked wallcoverings must be subjected to frequent cleaning.

Non-wovens are applied for the production of textile wallcoverings with a variety of designs and textures. Products from synthetic/polyolefin fibers are additionally treated for higher abrasion and stain resistance. Polyolefin and polyester fibers are also applied for the production of acoustic wallcoverings. They have different levels of sound absorption, thus influencing the Indoor Sound Quality (ISQ).

4.5. Non-woven textiles as filters

Non-woven textiles are used as filters in Heating, Ventilation, and Air-Conditioning (HVAC) systems in buildings. HVAC systems provide clean air for the inhabitants in public and residential built environment, including buildings where natural ventilation is not possible (i.e., due to closed glass facades). They also provide clean air for sensitive work places, which require zero dust and microbial emissions: operating rooms in hospitals, pharmaceutical production lines, production of electronic components and devices, research laboratories, etc.

Six types of non-woven filters used in residential buildings have been identified [37]. Five of them contain non-woven media: fiberglass filters, pleated filters with non-woven mats, reusable filters, electret filters, and deep pleated filters. All require regular change or cleaning: from one month in periods of normal use (for fiberglass filters) to once a year (for deep pleated filters).

Non-wovens are also used in air purifiers: portable units in the indoor environment, aimed to remove particles and odors and provide clean air for the occupants. Pleated and electret filters

are used, like Technostat ® needle-punch felt media [38]. Glass microfiber HEPA filters, filter media of blends between synthetic and glass fibers, as well as composites with non-woven media are also in use. Non-woven felts from a mixture of natural and synthetic fibers are applied for a backing support [38].

In their role of filter media non-woven materials can influence the Indoor Air Quality (IAQ) and indoor odor quality (IOQ). HVAC systems and air purifiers increase the quality of the indoor environment when working properly and maintained correctly. Noncompliance with the requirements for cleaning or replacement of the particular filter media can lead to change of the indoor environmental quality for the worse. The main reasons are either the incapacity of the filters to retain dust and particles, or the growth of airborne microbial contaminants, which are spread from the filter media to the air of the enclosure, leading to increment of VOCs, MVOCs, and other pollutants of the indoor environment.

4.6. Non-woven textiles in cars

The use of non-woven textiles in the sector of transportation is growing and the car industry is leading this trend. A number of applications of non-wovens in car construction are described in details in [39,40]: lining of doors boot and hoodcase, seat construction (including upholstery cover), filters, engine housing, etc. The requirements for the types of the non-wovens used and their characteristics depend on the particular application and related stresses and loads, as well as the long-term effect from their application for example, specific requirements for the non-woven items in car construction are their light resistance and temperature resistance [40].

Non-woven textiles in cars and other means of transport may influence all six basic metrics of the Indoor Environmental Quality, including the Indoor Vibration Quality (IVQ), which is rarely discussed in the case of built environment. The way the non-woven items in cars affect the IEQ is similar to the application of non-woven textiles in buildings, where they are used as upholstery coverings, floor coverings, backing, etc.

The level of emissions from all items in the interior of the car, including the non-wovens, is important for both the IEQ and the fogging, which may occur. All non-wovens have to be environmental friendly with low emissivity, including in cases of extreme indoor temperatures. Therefore, the car industry takes special care to use materials that have low emission potential, either as release of volatile chemicals (VOCs, SVOCs, VVOCs) or as reaction products. The last is closely related with the temperature and partial pressure drop.

The Indoor Odor Quality (IOQ) in cars is influenced by the non-wovens applied and is preconditioned in many cases by the emission of substances that influence the IAQ [41,42]. The emissions frequently occur at high temperatures only, but due to condensation on flat surfaces (mainly the windscreen and side windows) they form unacceptable fogging.

Non-woven materials in the car are used for thermal and acoustic insulation, thus improving the Indoor Thermal Quality and Indoor Sound Quality not only in the car compartment, but also in the boot and the engine housing. The main insulated parts are the dashboard, the roof, and the floor, the side walls and the rare wall, the parcel shelf, the doors, the tailgate, the ABC pillars, the boot sides, the air-conditioning conduit, etc. [39]. Non-woven textiles made of

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recycled natural fibers are still competing with polyurethane foams for being used as insulation materials in cars. Chemically bonded fiber webs with volume densities from 50 to 150 kg/m^3 are used for acoustic insulation [39]. At the same time, high-density webs are applied for production of car components like the roof or the parcel shelf, which can emit strong-smelling amines immediately after the installment. According to the study in [42], these emissions decrease rapidly after days, eliminating their negative effect on the IOQ.

Thermally bonded non-wovens with volume densities from 40 to 130 kg/m^3 from polypropylene fibers have been developed in order to replace the chemically bonded cotton webs and to avoid the undesired emission inside the cars [39]. These non-woven insulations demonstrate less fogging capacity and lower emissions.

Thermally bonded non-wovens with special shape of the fiber cross section (triangular, star-shaped, etc.) are also used to improve the Indoor Sound Quality.

Non-woven textiles of different type are widely used as covers in car compartments: needle-punched, spunbonded with reinforcement, thermally bonded, or meltblown non-wovens. Tufted fabrics are applied as floor coverings and light non-woven webs are also used as backing of the tufted floor coverings. Needle-punched fabrics are also in use, but for cheaper car models. In any case, cut pile of the tufted floor coverings are preferable than the loop pile, which accumulates more dust and particulate matter.

The analysis of the market and the research in the field, including the patents, show that much more effort, know-how, and economical support are put in the development of non-woven fabrics for car interiors than for the interior of buildings. Therefore, new materials and blends, methods for bonding, lamination, and new composite materials can be found much more in the car production industry than in the construction of buildings. The driving force of one of the biggest industries in the world – the automotive industry – is of particular importance for the advances in the field of non-woven textiles.

4.7. Other applications of non-woven textiles in the indoor environment

Non-woven walls: Non-woven textiles are used for building of flexible freestanding constructions for partition of open indoor spaces. Special polyethylene Tyvek© is applied for the production of the non-woven walls, which includes 10–15% recyclable content [43]. Non-woven flexible walls influence the ILQ and ISQ, as they can sculpt the light of the indoor environment and dampen the sound.

Non-woven curtains: Similar to floor coverings, non-woven textiles are used in the indoor environment either as the outer fabric or as the reinforcing lining of blinds and curtains. When visible, and in contact with the indoor air, non-woven textiles can affect the metrics of the indoor environmental quality in a similar way as the wallcoverings. Non-woven curtains reduce sound from the outdoor environment and affect the Indoor Light Quality (ILQ). Synthetic materials dominate over natural fibers as they are easy to maintain and have good resistance to UV rays. Like non-woven upholstery textiles, curtains and screens accumulate odors and particulate matter and need regular cleaning.

5. Conclusions

Textiles are an important factor for Indoor Environmental Quality (IEQ). The increasing application of non-woven textiles in the built environment and means of transport requires more research to be performed for the estimation of the particular influence of non-woven textiles of different types on the metrics of the indoor environment. Every step for improvement of IEQ will increase the human comfort, will improve human health, and will support higher productivity and school work performance.

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