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STUDIES ON THE MANAGEMENT OF TEXTILE FLOOR COVERING WASTE

Keywords

Textile floor coverings, TFC, waste, recycling.

Abstract

Textile floor covering waste (TFC) is a complex material, and, to a great extent, non-degradable: therefore, it should not be disposed in landfill sites. The paper discusses some developments connected with the management of this type of waste implemented in the USA, the EU countries and also describes the current situation in Poland. Mechanical recycling of various types of TFC, including the segregation and disintegration of waste has been investigated and the screen analysis of the recycled products has been carried out.

Introduction

Considering the composition and the origin of textile floor covering (TFC) waste, it can be, at the same time, treated as textile, municipal and construction waste: since, according to an obligatory catalogue, they can be classified and denoted with various codes [3]. They include production waste and used TFC. Due to its composition, size and amount, the latter one poses an important problem to the environment. In addition to various types of synthetic and natural fibers, TFC contain large amounts of mineral components, synthetic rubbers, bituminous compounds and others. In the manufacturing technology of TFC-s include special chemical agents, such as halogen derivatives are used in order to improve their performance properties, e.g. to reduce the flammability. TFC waste can also contain heavy metal compounds derived from dyes and catalysts used in the synthesis of polymers. A direct recycling of used TFC is impossible, as its textile material is durably combined with the binding agents. Owing to material composition of TFC, only an insignificant portion of TFC waste can be degraded in landfill sites, but this process is difficult and long lasting. On the other hand, the fibers contained in TFC can be reused as secondary raw materials [1, 15, 17].

1. Characteristics of TFC waste

With respect to the manufacturing techniques, textile floor covering can be divided into the following groups:

- *Woven TFC*, with the use-surface made of homogeneous or blended yarns of wool and polyamide (PA6 or PA 6.6), polypropylene (PP) or polyester (PES, mainly in the USA) and backing made of jute, cotton, PES and PP. The binding agents applied onto the backing present rather a low content in this TFC group. They mostly include butadiene-styrene resins or poly(vinyl acetate) without any or with few fillers.
- *Tufted* TFC with the use-surface consisting of similar fibers as above, on a primary backing made of PP woven fabric or non-woven PES, PES/PA or PP. The backside is coated with butadiene-styrene resin containing a considerable amount of chalk and laminated with a secondary backing. The most secondary backings are PP or jute woven fabric and non-wovens with various compositions. This sort of TFC very often have an additional back layer of bitumen, poly(vinyl chloride), butadiene-styrene or polyurethane foam.
- *Needled TFC* (non-woven type) include mono- or multi-layer non-wovens of PP, PA or blended and waste fibers, sized with butadiene-styrene resin, also with additional back layers of bitumen, foam, PVC.
- *Other TFC*, made by means of different techniques than the above mentioned (e.g. by knitting, flocking and sizing).

A great share in the market of individual consumers belongs to TFC made of PP fibers or blends with a high PP content, which are difficult to decompose. In case of TFC designed for public utility buildings, most of them are made of modified PA fibers, with a thick bituminous or PVC backing. Such waste fails to decay and can be a source of harmful chemical substances. In facilities of a high standard often TFC with woolen piles containing some PA fibers are used.

2. The scale of the problem

In Germany and Belgium, countries leading in the production and export of TFC, 670.8 million m^2 of these products were manufactured in 2000, including 56.5% of tufted, 27.9% of needled, 14.8% of woven and 0.8% of other types of TFC [18, 19]. In the Western Europe 1.5 – 1.7 million tons of used TFC are disposed annually [5, 26]. In Germany, the amount of used TFC is estimated to 450 thousand tons, which means about 5.8 kg of TFC waste per capita a year. Together with production waste of 32 thousand tons, about 5.8 kg of TFC waste fall to an individual per year [23]. The TFC life is estimated to 8–12 years in residential buildings and to 6 years in public utility buildings.

The annual production of TFC in the USA destined for internal market amounts to 1.25 billion m^2 of TFC. The replacement of TFC is estimated to constitute about 55% of sold goods, hence it is assumed that 2 million tons of TFC waste is produced yearly [7]. According to the Carpet and Rug Institute, the TFC waste consists of 59.3% PA, 33.7% PP, 6.5% PES and 0.4% wool [22].

In Poland the annual consumption of TFC per capita is about 1 kg. It may be estimated that currently about 80 thousand tons/year of waste is produced.

3. Worldwide solutions

The problem of TFC waste in Western Europe and the USA has been dealt with for several years [4, 12, 13, 20, 24]. A 3-year RECAM (Recycling Carpet Materials) project was initiated in December 1995 with the financial support from the European Union amounting to 5.5 million ECU [3, 21]. The following companies and institutions participated in its implementation: caprolactam manufacturers DSM (Holland), EniChem (Italy), European carpet industry represented by GuT (Gemeinschaft umweltfreundlicher Teppichboden e.V.), institutes such as TFI (Deutsches Teppich-Forschungsinstitut e.V), TNO (Netherlands Organisation for Applied Scientific Research), INCA (Interuniversity Consortium - Chemistry for the Environment) and industrial partners Laroche, Recotex, Durmont, Recycling Concept Textil GmbH, and Südrohrbau GmbH & Co.

The project included the development of a system for collecting, identification, sorting and recycling methods. In order to implement the results of the RECAM project, the CARE society (Carpet Recycling Europe) was appointed with a task to recycle 80% of TFC waste [2, 21]. It is expected to reduce the costs of waste management by 30%, to save mineral fuels corresponding to 8 million GJ, to recover and reuse the quality raw materials, such as caprolactam, and finally to improve multi-parameter effects on the environment by 50%. The rational functioning of the accomplished solutions is based on a controlled system of waste collection. The European carpet industry, through GuT and KABE (Konzentrierte Aktion Bodenbeläge Entsorgung), has carried out a pilot system of TFC waste collection in the area of Frankfurt, having collected about 10 thousand tons of waste over a year [21].

The research department of DSM has developed a device for sorting waste according to the types of fibers, thanks to which it is possible to select mono-streams of waste for further processing. In case of PA waste the depolymerization of PA is performed in order to recover caprolactam. The Rhodia company processes 30 thousand tons of PA waste in Europe [24]. In Great Britain, the Waste and Resources Action Program (WRAP) is under realization, aiming at the reduction of waste storage, waste utilization and the creation of outlets for processed and recovered materials [27].

In the USA the problem of TFC waste has been dealt with by the Carpet Recycling Initiative organization on the basis of a governmental long-term program (2002-2012), aimed at increasing the role of material recycling, the reuse and energy recovery (Fig. 1) [6]. This project will be accomplished by the Carpet America Recovery Effort (CARE) organization. The Institution Recycling Network (IRN) that comprises institutions dealing with recycling, in association with DuPont, implements a program in which TFC waste are delivered to DuPont Flooring Systems Recycling where their processing takes place. DuPont has established an experimental plant for the recovery of caprolactam, hexamethylenediamine and adipic acid nitrile. In 2001 over 8 thousand tons of waste was processed, reaching the recovery rate of 99%. Evergreen Nylon Recycling, a company established by DSM Chemicals North America and Allied Signal Chemical Intermediates, converts 90 thousand tons of waste into raw materials including 45 thousand tons of caprolactam yearly [6].

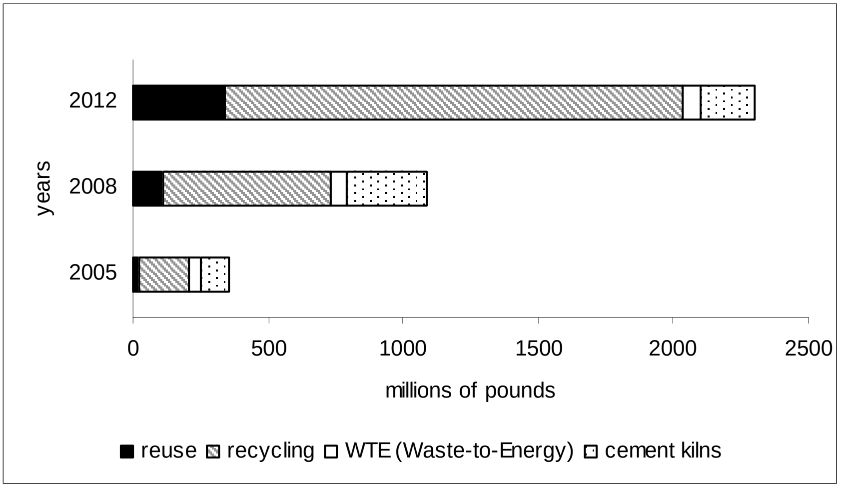


Fig. 1. Expected changes in the structure of TFC waste management in the USA [6]

Both in Europe and the USA, many companies carry out small-scale recycling of used TFC, utilizing the resultant products for various applications [1, 11, 15, 17, 26].

4. Legal status and possible solutions to the problem in Poland

In Poland the essential legal regulations concerning the waste management are included in the following acts:

- Acts of 27th April 2001 on the Law of Environmental Protection (Journal of law No. 62, item 627) and on waste (Journal of law No. 62, item 628).
- Act of 11th May 2001 on the manufacturers' responsibilities with respect to the management of some waste and product duty and deposit duty (Journal of law No. 63, item 639).
- Act of 29th July 2005 on the amendments of waste act and some other acts, as well as in appropriate directives, including the Directive of the Minister of Environment of 27th September 2001 on waste catalogue (Journal of law No. 112, item 1206).

The domestic industry connected with the manufacture of TFC is unable to solve the problem of waste management, the more so as imports dominate the market. The management of waste includes their collection, transportation, recovery and neutralization, as well as the supervision of the activities. To get closer to the world solutions, we need not only appropriate legal and administrative regulations in Poland, but also the development of waste collection system and methods of TFC waste management, which is associated with indispensable financial means.

Considering the structure of waste management, currently there is a real prospect of material recycling in Poland, consisting in the segregation of used TFC, their disintegration, defibering and partial separation of mineral and resinous components to obtain recycled product suitable for reuse. It is also possible to reclaim energy. The most expensive is the recovery of raw materials and so far only big chemical concerns can afford it.

5. The examination of material recycling

The possibility of TFC waste disintegration to obtain secondary raw materials suitable for reuse was tested. Considering different structures and compositions of TFC, the waste was segregated into groups of different manufacturing techniques, textile compositions and finishing processes of the back layer. Samples of the following types of TFC were disintegrated: tufted PA and PP floor coverings, needled TFC from blended fibers and woven TFC with wool-PA pile, TFC with backing consisting of cross-linked butadiene-styrene resins and various contents of mineral fillers, mostly chalk. A high-speed T2

SW cutting mill, designed for disintegrating plastics by TRYMET Metal Works (Fig. 2) was applied using screens with mesh diameters of 4, 6, 8, 10 and 12 mm.

Fig. 2. T2 SW mill (TRYMET, Poland): a – overall view, b – disintegrating system, c – screens

The disintegrated waste contains fiber bunches with or without residues of size particles, separated size particles, single fibers, sections of PP yarns and strips, all of them in different contents and dimensions resulting from the sieve used and type of TFC. Fig. 3 shows the recyclates obtained from three basic types of TFC with latex backings, disintegrated with the use of 4 and 10 mm sieve mesh. The resultant recyclates were segregated and the unwanted components were separated. The sieve analysis of the material was carried out using sieves with mesh sizes of 0.1, 0.25, 0.5, 1, 1.5, and 2 mm (0 – residue) and the qualitative and quantitative compositions of particular fractions were assessed.

The results of sieve analysis show that the waste of tufted TFC with PP pile undergo better disintegration. The fraction passing through 0.1 mm mesh sieve is high in all recyclates. The recyclates from tufted TFC with PA piles obtained with screens of higher mesh diameters contain a clearly lower content of small particles. These differences become insignificant in the case of the recyclate obtained with 4 mm mesh screen as illustrated in Fig. 4 showing the percentage contents of recyclate sieve fractions obtained with 4 and 10 mm mesh screens.

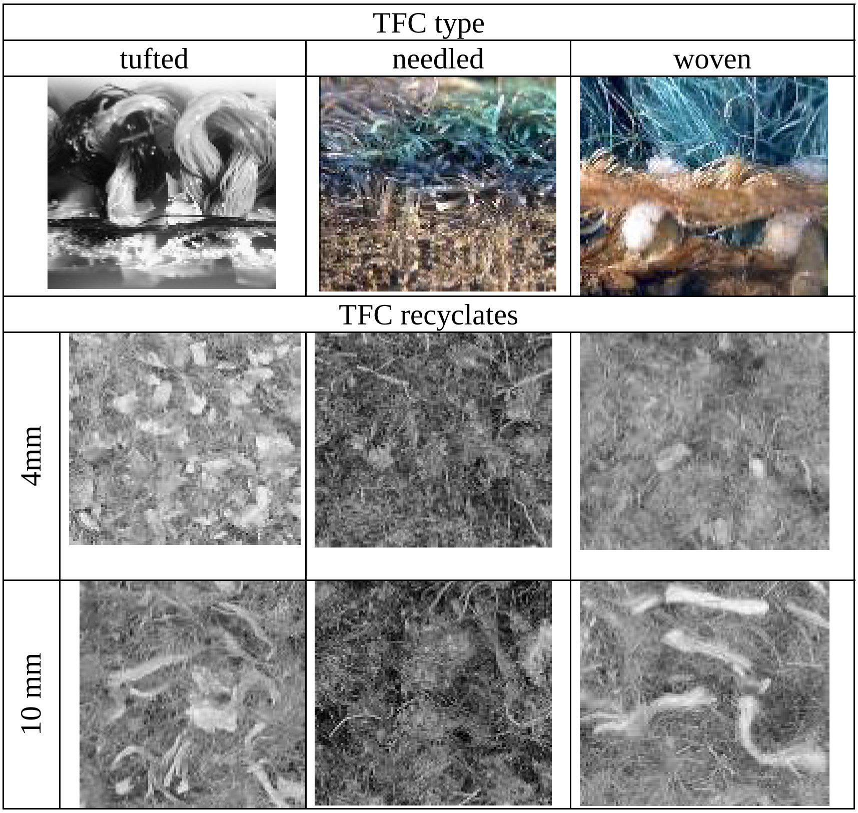
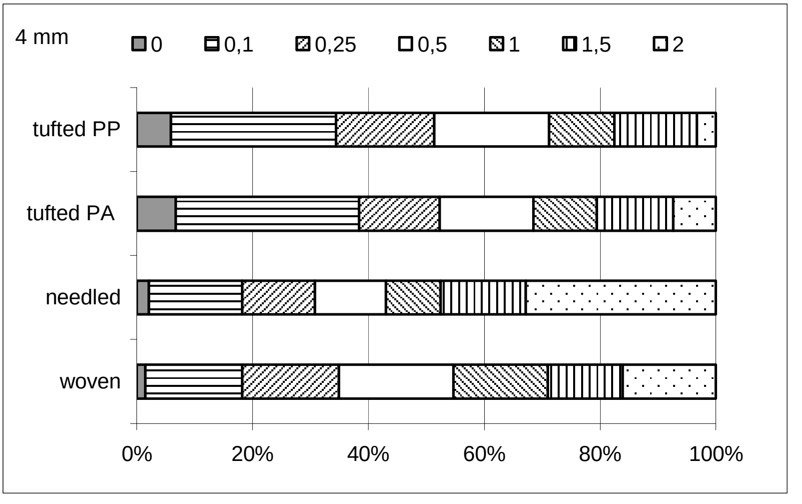


Fig. 3. Three types of TFC waste disintegrated with the use of 4 and 10 mm mesh screens

The particles of sized backing were relatively easily separated in considerable amounts from the tufted TFC with PP piles, as compared to those of TFC with PA piles. This is due to the differences in the surface properties of PP and PA. The surface energy of PP is 30.1 mN/m, while that of PA amounts to 46.5 mN/m [25]. The backing is strongly combined with PA fibers; therefore, the particles of sized backing are separated to a lesser extent during the disintegration. In new tufted TFC, latex-sized backing amounts to up to 75% of their weight (about 1000 g/m^2). In the recyclates of woven TFC with wool-polyamide piles there are almost no particles of sized backing, which results from the method of their finishing. Butadiene-styrene resins or poly(vinyl acetate) without fillers constitute mostly 10 to 15% of woven TFC weight. Insignificant amounts of the sized backing are combined first with the fibers of the bottom layer (jute, PES/Cotton, PP), while the pile fibers (Wool/PA) remain almost without resinous impurities. In the case of needled and woven TFC, the residue after the sieving consisting first of all of crushed sized backing is scanty.



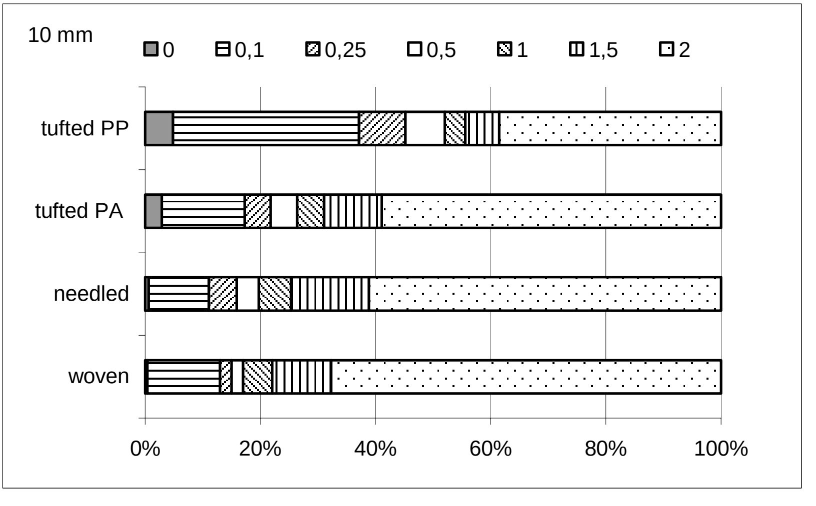


Fig. 4. Percentage contents of sieve fractions of recyclates disintegrated with the use of 4 and 10 mm mesh screens

If the use of recyclates requires the removal of the sized backing fraction, it will be necessary to employ an additional process, e.g. a procedure based on hydrodynamic methods [26]. In case of PP floor coverings, the particles of sized backing can be separated by means of the flotation method, utilizing the difference in PP density (about 0.9 g/m^3) and that of latex with filler (over 1 g/cm^3). However, there are many opportunities to use TFC recyclates that require no additional separation of the fibrous portion from the finishing residues.

Conclusions

The implementation of solutions, similar to those developed within the European and American projects, in Poland would require the support of administrative bodies and capital outlay. At present there is no system for collecting and dealing with TFC waste. Trials have been undertaken to solve the problem of TFC waste management associated with the development of its recycling [8, 9, 10, 16]. From the performed studies on material recycling it results that from the waste of TFC with latex backings one can obtain recyclates with various degrees of disintegration suitable for the reuse.

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Badania nad zagospodarowaniem odpadów włókienniczych pokryć podłogowych

Słowa kluczowe

Włókiennicze pokrycia podłogowe, WPP, odpady, recykling.

Streszczenie

Odpady włókienniczych pokryć podłogowych (WPP) są materiałami złożonymi i w zdecydowanej większości trudno degradowalnymi, nie powinny więc trafiać na składowiska. W artykule przedstawiono rozwiązania związane z ich zagospodarowaniem, stosowane w Stanach Zjednoczonych, krajach Unii Europejskiej oraz aktualną sytuację w kraju. Przeprowadzono badania mechanicznego recyklingu różnych rodzajów WPP, obejmujące segregację i rozdrobnienie opadów oraz analizę sitową uzyskanych recyklatów.