CARPET WASTE, AN EXPENSIVE LUXURY WE MUST DO WITHOUT!

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Abstract

In the U.K. the carpet industry accounts for £935 million of income each year. About 7% or £65 million of would-be extra earning is annually lost in the form of waste produced during manufacturing processes and fittings.

In a recent confidential study made under the Environmental Technology Best Practice Programme landfill was identified as the main destination for most carpet waste with incineration a close second. Cost of disposal to landfill is currently estimated at about £750,000 a year. However, with increasing public concern for the environment, this figure is already rising due to introduction of large tax duties on the use of landfill. Manufacturers are consequently under pressure to reduce waste and find alternative means of utilising their waste.

This paper, in the first instance, investigates the sources of waste along the entire carpet manufacturing route and assesses their quantitative measurement. It then critically reviews the current methods of dealing with processed and post consumer wastes, exploring the various methodologies applied. In conclusion the paper recommends short and long term solutions with respect to current legislative and environmental issues and calls for novel and prime quality products utilising carpet wastes as valuable raw materials rather than cheap secondary implants.

1. Introduction

The global carpet industry is largely dominated by the United States and Belgian manufacturers who account for approximately 50% of world's total production. In 1994 Europe alone produced nearly 1 billion square metres of carpet, the United Kingdom ranked 5th internationally being responsible for 15% or 150 million square metres. This amounts to nearly £1 billion worth of business for the UK manufacturers. However, annually 7% or £70 million of possible additional earnings is lost in the form of waste.

The term "waste" is a collective expression usually meaning surplus or substandard left overs from fittings and replacement carpets. In fact, waste occurs at all levels of production and increases exponentially along the entire manufacturing route with post-consumer waste accounting for most of this. The carpet waste is eventually incinerated or preferably, as is the case in the UK, dumped into landfill sites at a further annual cost of £750,000.

In manufacturing, the potential value of waste or loss factor increases the further it is created along the production route. The earlier this problem is diagnosed and a solution offered, the greater will be the potential savings. However, this may not be, as yet, an easy task given the current manufacturing machineries and established marketing structures. But with an average estimate of 2.5% rise in carpet manufacture per year and increasing costs of landfill dumping, this tradition may soon have to change. Already, in Germany costs of landfill have tripled since 1992 to almost 400DM per tonne and further restrictions introduced in 1996 prevent dumping of any waste with calorific value greater than 11MJ/kg, which includes most carpets [1].

In the United Kingdom, landfill taxes were only introduced for the first time in 1996 at a comparatively modest charge of £7 per tonne, but this figure is expected to rise by the turn of the century.

2. Carpet manufacturing routes

There are at least four methods of making carpets. They include woven carpets, which had up to the late 1950s dominated the carpet market. Axminster and Wilton are two well known types of woven carpet manufacturing where colour and design freedom in Axminsters is often compromised for greater strength and durability of the Wilton types. Relatively low speeds of production (averaging to around 70 rows per minute) in both methods of manufacture and their subsequent high costs have been the reasons for their gradual downfall since the introduction of comparatively cheap tufted carpets. Tufted carpets were first introduced into Europe in the 1950s and by late 1970s had dominated the market. The reasons for their swift adoption and subsequent rapid growth are primarily their speed of production (averaging to around 2000 rows/min) and hence their availability in large volumes at relatively low cost. Tufted carpets today account for over 85% of all the carpets produced in Europe and around 76% of all carpets manufactured within the UK. Woven carpet speeds of up to 200 rows per minute have recently been reported [2] but, by and large, they remain uncompetitive. Needle-punching is the third method by which carpets are made, but they only account for 9% of the carpet market. This method of carpet production knots substandard and/or coarse fibres together with the aid of barbed needles, which penetrate the fibrous assembly. Subsequent heat or resin treatment to reinforce the carpet could also follow. Although reasonably durable and cheap to produce, they are in no way comparable to tufted carpets. The remaining carpet market, amounting to around 3%, is covered by a range of production techniques too insignificant in size to be considered in this paper.

In light of their popularity and growth within Europe and in particular the UK, tufted carpet manufacturing route will be used as the main focus of this paper to highlight waste generation and their subsequent accumulation. Cross references to carpet weaving will also be made when comparative routes are considered.

2.1 Types of fibres used and their conversion to carpet yarns

Both natural and man-made fibres are used in manufacturing carpet yarns. Wool or fleece sheered from the back of sheep is expensive to produce and is limited by the available number of animals. However, hard-wearing, warm-feeling and comfort are associated with wool fibres which account for nearly 31% of the carpet market. Silk and other natural fibres are also used in the carpet industry but their relative consumption is much too small for consideration here.
Man-made fibres, today, dominate the carpet industry with nylon and polypropylene accounting for approximately 65% of the total market. Nylon fibres have traditionally been preferred for their resilience, good compressive recovery and low moisture uptake. However, polypropylene with properties not too different to nylon and with additional advantage of availability in large quantities and hence low costs, has become the second most important man-made fibre in carpet manufacturing. Acrylic fibres are also used in carpet yarns but their relative consumption is low amounting to around 3%. They are often used in blends with other natural and man-made fibres. The remaining 1% is covered by considerably less popular man-made fibres [3].

2.2 carpet manufacturing methods

Once fleece has undergone opening, cleaning and the carding processes it can then be spun into pure woollen yarns or blended with other fibres. Similarly, after extrusion, drawing and crimping, man-made fibres are cut to suitable staple lengths and baled. Within the yarn spinning mill, bails are opened and fibres carded and possibly blended before entering the spinning zone. Spinning has traditionally been carried out by either ring or open end methods. The ring spinning converts roving or finely combed, lightly twisted assemblies of fibres into yarns by drawing and inserting further twist. The open-end method directly converts sliver or loose rope-like continuous fibrous masses into yarns by entering a rotating drum from one end and exiting as yarns from the other.

Spun yarns are wound on appropriately sized packages before going on creels to feed into tufting machines or wound on beams, as warp yarns, to be used for weaving. Tufting is simple in principle and involves a base scrim or primary backing into which loops are inserted by vertical movements of needles. The bases of these loops are then secured by resin and secondary backing, which may include polyvinyl chloride, polyvinyl acetate copolymer (latex) or polyurethanes foams as well as fillers. Patterns and colours are introduced by controlling the movements of the needle bars and using coloured yarns. Alternatively pile printing with intricate designs and wide choice of colours could follow. Tufted carpet may subsequently be cut into predetermined shapes as tiles.

In contrast, woven carpet production is much more complicated requiring yarn preparation, beaming, weft insertion and independent control of warp threads especially when jacquard weaving is used.

3. Waste associated to processes

Figure 1, shows the full processing route involved in carpet manufacturing and the amount of wastes generated at each stage along the entire path.

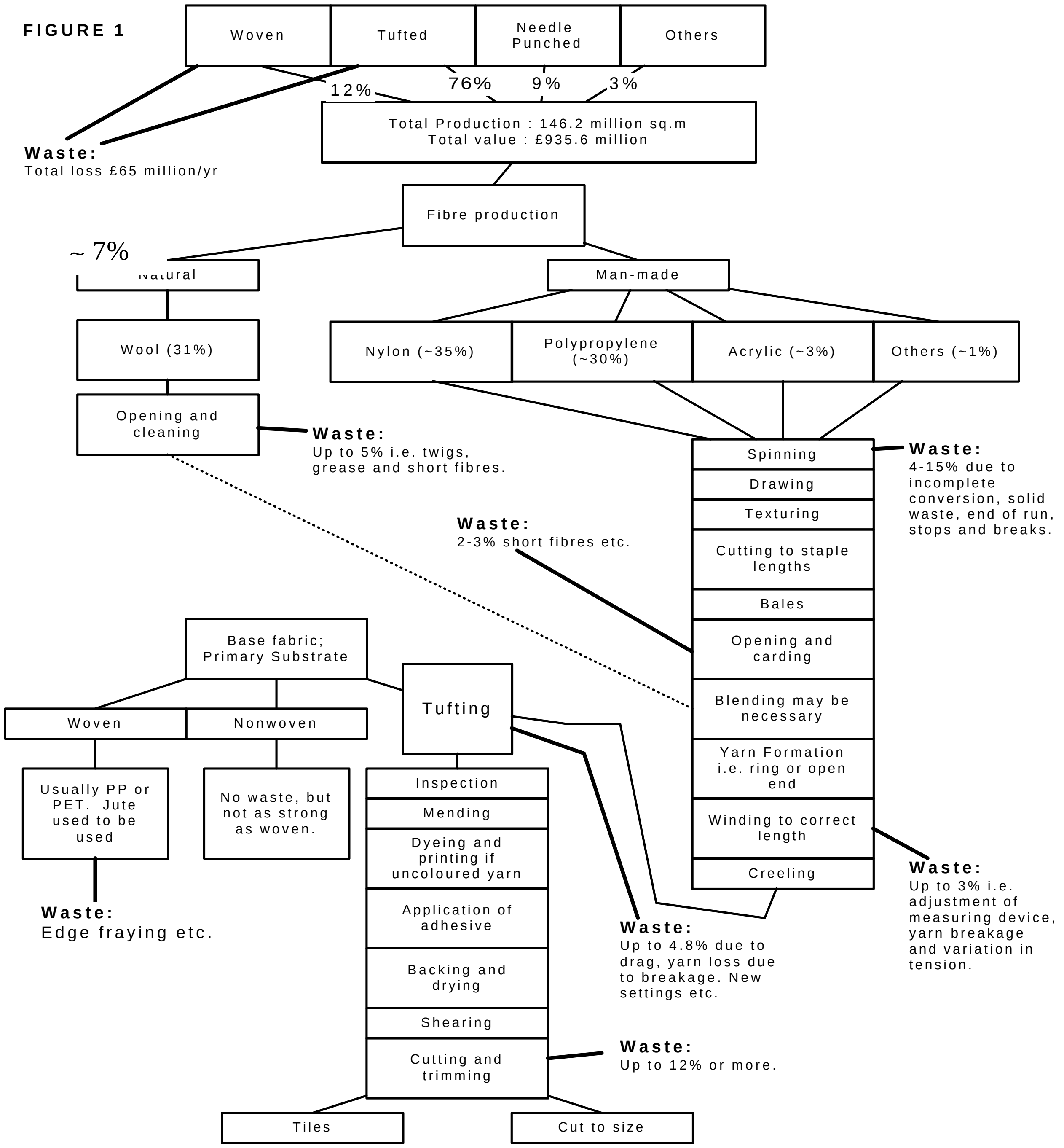

Figure 1: Processing Routes Involved in Carpet Manufacturing and the Associated Waste Generated

Freshly sheared wool fleece contains a large quantity of grease, dirt and twigs as well as unprocessable short fibres which must be removed. After scouring the total unavoidable waste associated with this early stage is often quoted [4] at around 5%. Some of this waste can be recovered and used as fillers or be included in low grade products.

Man-made fibre production, by virtue of its creation method, may be assumed to produce no waste at all. In fact polymerisation of the parent monomer and subsequent extrusion into fibres could give rise to as much as 15% waste [5]. The high level of waste is partly due to incomplete conversion of some raw materials to the final polymer and wastes resulting from one or combination of the following factors;

a) the operator
b) equipment breakdown
c) power failure

Since man-made fibre production is a continuous process, incorrect machine settings by the operator could lead to inferior quality fibres which would have to be discarded as waste. Partial or full breakdown of the spinning equipment due to wear and tear or such faults as clogging at extruder heads results in stoppages and more fibre wastage before smooth running conditions can be resumed. Power failures may ruin a whole series of the production sequence and create excessive cleaning work as well as fibre wastage. Further waste could result from end of runs, filament breakages and change-overs from one specified condition to another.

After spinning and drawing of filaments, they are then usually crimped and cut into staple lengths before undergoing subsequent opening and carding stages. These mechanical actions cause some fibres to stretch beyond their load bearing ability and eventually break, making them unsuitable for further processes. The waste associated to these kind of actions is estimated at around 2-3%, but they are usually in reasonable enough quality to be used in furniture and pillow fillings.

During tufting, yarn is usually drawn simultaneously from a series of packages stationed on creel frames. Despite their supposedly identical weight and linear density, variations in actual length of packages occur and could be as high as 3%. A further element of variation in yarn length is introduced by the physical layout of the packages on the creel i.e. those furthest away from the tufting machine run out sooner; the subsequent imbalance in length often leads to more waste when fresh packages are knotted in.

In the actual tufting process, the piles are created on a fine woven or nonwoven flat scrim which may also include a secondary backing as well as resin. The processed carpet is eventually cut and trimmed along both edges. The waste, by this stage has considerably increased both in terms of size (i.e. 12%) and value. Whether coloured yarn or pile printing methods are used, such faults as stripes and streaks and similar defects caused by faulty needles or knives are picked up during inspection and subsequently discarded as yet more waste.

By and large, the biggest quantity of waste in newly processed carpet occurs during fitting with an average waste of up to 20% or more. Cutting carpets into tiles largely avoids this otherwise valuable waste, but their applications are limited by the market they address.

In weaving, waste associated to beaming, breaks, weft insertion and subsequent inspections and fittings results in even greater losses, both in terms of quantity and value.

3.1 Current methods of tackling carpet waste

Carpet is claimed [1] to account for approximately 2% of all waste dumped into landfill. In the first instance, this may not appear to be a cause for concern but given the steady rise in consumption and high volume to weight ratio, the trend, if not controlled could grow out of all proportions.

Currently 93% of this waste is associated with used carpet and many fibre manufacturers are already considering various methods of salvaging these wastes. The techniques used will be briefly discussed later in this paper. The remaining 7% are clean and potentially more valuable waste resulting from the processing and installation operations already highlighted.
If landfill dumping and incineration are to be avoided, the alternatives must include one or more of the following routes:

- incineration to recover energy
- re-use in alternative forms
- mechanical and chemical recycling

3.2 Incineration to recover energy

The locked in potential or LIP in carpets can be as high as those attained from normal fuel. Table 1 shows comparative calorific values for a range of fibres and those of more common sources of heat. Polypropylene and polyethylene in particular, produce high amounts of energy matching those of diesel oil and naphtha.

Table 1: Comparative calorific values [6]

Calorific values, MJ/kg			
Fibres		**Other sources of fuel**	
Polypropylene	46	diesel oil	46
Polyethylene	46	naphtha	42-46
Polystyrene	41	carbon	21-33
Polyurethane	24-31	wood	16-21
Polyester	19-30	paper	16-19
Polyvinal chloride	20		

However, burning carpets to generate energy also produces its own waste commonly referred to as ash, which is also hard to dispose of. The ash consists of inorganic metals and halogens that are often included in the binder material to increase bulk. Efforts to replace these with organic substances has already led to some composite backing structures where polypropylene is used as the main binder with reinforcing threads to secure the carpet assembly [7].

Pyrolysis or burning in absence of oxygen is another process by which carpet waste is carbonized at high temperatures to generate synthetic coal. The manufactured coal has quite a high calorific value and can be burned with or instead of regular coal, leaving relatively small quantities of ash [8]. The carbonization process is rather energy intensive and, therefore as yet, not economical.

3.1.2. Re-use in alternative forms:

Short and unprocessable fibres resulting from different stages of manufacture already find use in soft furniture fillings, mattresses and pillows. This is likely to continue as a feeder to an already established manufacturing practises. Other utilisation schemes include shredding, granulation and mixing of the waste with binders to produce sheets or panels suitable for thermal and sound insulation materials in the building industry. Outdoor and more demanding applications of these panels would require further stabilisation treatments and thus increase their costs.

Finely fragmented carpet waste is often used as passive fillers to increase bulk in concrete and similar building and plastic materials. Currently, attempts are being made to utilise selected range of carpet wastes in a more positive way where overall load-bearing abilities of such matrices are enhanced [9].

Other novel ideas include use of cutting edges and trimmed materials to produce needle felt structures to replace foams or secondary backings in tufted carpets.

3.3. Mechanical and chemical recycling

Carpets are multi-component structures, normally designed to provide optimum performance characteristics as well as versatility in colour and design. The notion of waste and the need for dismantling fully made-up carpets has never been a strong enough issue to influence raw material selection and manufacturing processes. However, recent public pressures, reinforced by legislation have compelled manufactures to clean up their technology and recycle their waste.

DuPont, BASF, Hochest and Allied Signal among other manufacturers, have taken the lead in this crusade and between them, they have tried a number of recycling processes. Despite different approaches, all manufacturers agree that their biggest challenge is the collection of post-consumer carpets followed by separation and cleaning [9-11].

One approach has been the extension of the shredding and granulation, followed by density separation where nylon and polypropylene, in particular, are effectively sorted. The separated nylon could be used as low grade engineering resin or, alternatively, depolymerised to its parent monomer and subsequently repolymerised to feed into the manufacturing cycle. Success rates of up to 99% purity are reported with these techniques. The entire operation, however, is rather lengthy and, as yet, more expensive than the virgin polymer route. Other alternatives include dissolution of one or two components in solvents which, arguably, generate their own waste and cost more. A more recent approach to separation has been the use of near infrared (NIR) detection system employed by Allied Signal. This method is extremely fast and reportedly very accurate but also very expensive.

Since only a third of a typical carpet consists of fibres it is most important that, whichever separation and thus recycling techniques are used, the final cost of production should not override the virgin route. Practicality and survival of any one recycling system is ultimately dependant on its commercial viability.

4. Legislation with respect to waste

With German initiative, a group of European carpet manufacturers in 1990 founded the Association for Environmentally Friendly Carpets or GUT. With current membership of 86 carpet manufacturers [12], representing approximately 70% of the total European market, GUT has become a formidable organisation. In 1995 some GUT members, together with a number of carpet and chemical manufactures initiated a three year European funded project, known as RECAM. The general aims of this project were to reclaim recyclable materials from carpet wastes and to reuse them in an economically viable manner. To achieve these objectives a closed loop system using all known recovery processes are used. With a budget of 5.5 million ECU and the backing of at least four major European countries, ambitious solutions are predicted for the year 2000 and beyond.

The UK as yet, is not affiliated to these activities and the Department of Trade and Industry, takes the view that as there are no current proposals on end-of-life carpet recycling on the European scene, there is nothing for British exporters to be concerned about [13]. However, in a recent conference [14] held in Aachen, Andreas Bohnhoff from the recycling department of the German national carpet test house or TFI hinted on end-of-life recycling assurances already being demanded by some regional governments in Germany. If this attitude should prevail it will only be a matter of time before some sort of European ruling becomes imminent. The danger for the UK carpet manufactures could then be the inability to export into Europe without firm commitment to recycling.

5. Futuristic approach to waste management

The most effective way of preventing waste is to avoid or minimise its creation in the first place. This in itself, however, calls for new and novel technologies as well as processing techniques that will have to come with time. The long term strategy for eradication of waste however, cannot be left to the manufacturers alone but it needs to grow out of partnership between the manufacturers, consumers and the governments working together towards a common goal. These partnerships may take the following form:

Manufacturers need to concentrate efforts on:

a) creating homogeneous as opposed to heterogeneous carpet structures which would simplify manufacturing processes and reduce subsequent separation difficulties and hence recycling costs. Hoechst Celanese have already tried, with some success, making 100% polyester carpets known as Trevira One. They have also been able to extend their programme to carpet packaging materials and labels made from recycled polyester bottles;

b) adopting computer aided systems similar to those widely used in the clothing sector to drastically reduce fitting wastes. Incentive driven tactics by the manufacturers could be used to encourage their regular use by the retailers; and

c) new and novel approaches to carpet making which, for instance, would allow installation of heavy and life-long underlays with relatively cheap and light top layers that would fit on and peel off by some velcro-like action mechanism.

The consumer's role could include:

a) adaptation to single fibre carpets and acceptance of perhaps less variety in choice at possibly higher costs;

b) acceptance of carpet tiles rather than full length carpets, whenever possible;

c) use of reconditioned carpets where new designs and colours are applied on old carpets; and

d) responding favourably to voluntary or cash-back incentives for recycling purposes.

Government's cooperation can be reinforced by:

a) legislating and implementing strict roles and regulations with regards to waste and its environmental impacts;

b) subsidising and supporting companies who take initiatives in recycling programmes.

c) increasing tax levies on landfill and nonrecoverable incineration practises; and

d) educating and informing public to the potential dangers of mounting waste and identifying their role in helping the situation.

6. Conclusions

In the next century, waste of all types will be one of the biggest challenges facing man. Synthetic carpets will only account for a small but significant portion of this waste. If today's standards of living are to be maintained and even improved, delay tactics and half-hearted measures to tackle waste will only postpone rather than solve the problem. What needs to be done, is collective long-term planning, supported by serious investment commitments that would turn waste into a valuable commodity essential for sustainable development and ultimately preservation of balance in nature.

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