Honours Project (BIEGN3005) Literature Review

# The potential use of recycled wool-rich carpet waste as a soil amendment

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**Abstract**

Currently there are no established or proven recycling options for an estimated 100,000 tonnes of wool-rich carpet shred waste produced annually in the UK. The aim of this essay is to review existing knowledge and to identify areas of future research required to identify practicable recycling options. A study of the literature on the possible uses for wool waste identified three main avenues of research that have received significant attention. There is knowledge using the waste as compost and its potential uses for soil improvement in horticulture. The latter appears to be the most practicable option for the waste, although a third application of using wool-rich carpet waste in soil re-enforcement has also been studied. There are clear gaps in knowledge to be resolved before the waste can be used as a soil amendment, and it is concluded that further research is required on contamination of the product, and on its effects on soil quality.

## Introduction

Wool is a significant carpet fibre around the world; it predominates in New Zealand, and represents some 37% of the market in Western Europe. Most carpet is made to last, but once soiled, worn or out of style, it is often thrown away, and approximately 0.5M t annum $^{-1}$ of waste arising from disposal of carpets currently goes to landfill (www.carpetrecyclinguk.com). There are established recycling options for a small proportion of this, with 10,000 t currently recycled for all-weather equestrian surfaces. However, no practicable options exist for recycling 100,000 t of wool-rich carpet shred; its disposal to landfill is expensive and increasing environmental pressure makes incineration unsustainable (McNeil *et al*, 2007). Along with growing public concern for the environment and tighter restrictions and costs of landfill in recent years, many carpet producers have had to look for more efficient manufacturing methods and/or alternative uses for their inevitable waste. Recycling technologies are becoming increasingly important, and more-or-less closed cycle processes without significantly producing waste are being developed for many products and materials, but rarely for fibre products (Bartl *et al*, 2005) There is a clear need to identify an alternative use for this protein-rich product and its by-products (Zheljazkov, 2005). The use of these recycled fibres from both industrial and post-consumer waste would offer additional advantages of waste reduction and resources conservation (Watson 2005; Miraftab & Lickford, 2008).

This literature review aims to investigate research that has been carried out, and to evaluate the existing state of knowledge of recycling of wool wastes. Wool waste comes in many forms beside that from carpet disposal, including that from textile industries, wool scour sludge, and excess wool that cannot be processed. These types of wool waste are included in the present evaluation of relevant literature, before the focus returns to the applications and potential benefits of recycled carpet wool-waste as a soil amendment, and to identify areas where there is insufficient knowledge to implement its usage.

## Composting and use as a soil amendment

There is large demand for compost and partial peat-substitutes; for example, 400,000 m $^{3}$ of growing media are used in hardy ornamental nursery stock in the horticultural industry in the UK and peat accounts for 80% of this (GrantScape, 2006). Materials such as wool waste frequently require composting prior to use as soil amendments, largely to provide appropriate substrate qualities for plant growth, including lowering of carbon/nitrogen ratios and the provision of available plant nutrients (BSI, 2005). Composting also removes parasites and pathogens and, to some extent, degrades potential contaminants (Cogger, 2005). There appears to be no published research on composting of wool waste, but there are a limited number of studies investigating the incorporation of shredded carpet waste directly into soil. In most cases, there has been a comparison of the use of wool waste with much

more extensive research on the use of organic fertilizers such as animal manures and sewage sludge (Zheljazkov, 2005).

In early work, Plat *et al* (1984) suggested the utilization of wool waste in composted form, as feed stocks and nitrogen sources for plants, and Tiwari *et al* (1989) reported a marked response in chickpea and wheat growth using differently amended soils with wool waste composts. However, it was known that composting in this way results in an immediate immobilization of nutrients, especially nitrogen. To that end, research into composted wool waste for plant nutrition appears to have received little further attention for 16 years, until Zheljazkov (2005) noted that 'there is no comprehensive study in the literature on the possible use of un-composted wool waste'. After this, investigations of the uses for wool waste then began to see a revival. A further paper by Zheljazkov *et al*, (2009) considered the use of un-composted wool waste as a nutrient source for both container grown plants, crops and field crops, reporting research that suggested wool waste may be an excellent soil amendment, providing increases in plant yields and essential oil content. Mubarak *et al* (2009) found that a decrease in water movement in sandy soils amended with organic residues including carpet wastes offered a better chance for crops to absorb water and nutrients instead of them being leached. Whilst this paper confirmed increases in plant yields of up to 28% dry matter weight it also interestingly notes that wool 'seems to have greater imbibitions for water since soil moisture content at harvest was greater than in soils without wool amendment' a point researched further in studies in to wools ability to stabilise soil.

**Soil reinforcement**

There is significant evidence that some structural characteristics of soil, as well as water-holding capacity may improved through the incorporation of carpet waste. In a series of research papers, Wang *et al* (1994) and Wang (1997, 2006) investigated the use of fibres, particularly those from carpet-industry waste, as reinforcement of both concrete and soil for the construction industry. Carpet waste fibre reinforcement of concrete showed improved shatter resistance, toughness, shrinkage and ductility. In soil, they recorded an increase in tri-axial compressive strength that may have relevance to unstable and sandy soils. Although the concentration of these papers was in concrete re-enforcement and synthetic end of life carpets, they outline a potential market for all recycled carpet fibres noting 'for soil applications, virtually all types of carpet are suitable, and therefore sorting is not necessary' (Wang, 2006). In other work by Ghiassian *et al* (2004), looking predominantly at soil re-enforcement within the construction industry, reported that randomly distributed synthetic strips had a significant influence on the shear characteristics and constitutive behaviour of fine sand. Murray *et al* (2000) found that for every 1% increase in carpet fibre content a 1% increase in optimum moisture content occurs. More recent work (Miraftab and Lickfold, 2008), further reported that nylon carpet pile waste can be successfully mixed with substandard soil up to a maximum of 10% to enhance cohesion and strength of the soil as well as its internal friction.

**Soil improvement for crop growth**

Wool industry fibrous solid wastes have been shown to a have content of some important plant nutrients content and good water-holding capacity, which can potentially benefit their uses in agriculture. Wool carpet waste contains nutrient elements that can provide fertilising benefit over and above that of non-biodegradable mulch or simple organic mulch. The wool in carpet contains significant amounts of nitrogen and sulphur, and the latex backing is predominantly calcium carbonate filler. Overall, the range of major elements reported for carpet waste in the literature are 5.5 - 17% nitrogen, 1.2 – 3.5% sulphur and 10.8% calcium (McNeil *et al*, 2006; Mesman *et al*, 2007). Recent analyses of UK wool rich carpet waste have shown that wool-rich carpet waste has a content of N and S comparable to farm yard manures, but low contents of phosphate, potash and Mg (Table 1).

In related earlier work, Wainwright *et al* (1984) investigated the use of keratin as a fertilizer, concentrating research on another commercially-available form, poultry meal. Keratin is a major component of both hair and wool, and the work has clear relevance to carpet waste. The work showed a substantial increase in ammonium ($NH_4^+$) when poultry meal was used; they pointed out that this was a positive effect as, not only could plants

utilize $NH_4^+$ as a nitrogen source, but also it would be fixed and not readily leached (as would be the case with $NO_3^-$ forms of nitrogen. However, they also suggested that a disadvantage of keratin, and a limitation on its use as a fertilizer, is that it may enrich the soil with keratinophilic fungi which may be pathogenic to humans and animals if fertilized crops are bound for the food chain.

***Table 1.*** *Plant nutrient content of UK wool rich carpet waste compared with standard figures for farm yard manures (FYM). Data supplied by Carpet Recycling UK [NRM, 2009].*

| Nutrient | Wool Rich Carpet Waste | Cattle FYM | Pig FYM | Broiler Litter |
|---|---|---|---|---|
| Total N (%) | 9.84 | 6.0 | 7.0 | 30 |
| Ammonium N (mg $kg^{-1}$) | 748 | 600-1,500 | 700-1,800 | 8,100 |
| Total P (%) | 0.027 | 3.5 | 7.0 | 25.0 |
| Total K (%) | 0.052 | 8.0 | 5.0 | 18.0 |
| Total Mg (%) | 0.093 | 0.7 | 0.7 | 4.2 |
| Total S (%) | 1.38 | 1.8 | 1.8 | 8.3 |

AgResearch, the Crown Research Institute of New Zealand (www.agresearch.co.nz) has been undertaking research investigating the use of post consumer wool-rich carpet as an aid to plant establishment. This is based on the wool carpet being largely biodegradable and containing plant nutrients as well as possessing the physical properties to provide weed suppression, moisture retention, moderation of soil temperature and soil stabilisation thus opening the opportunity for environmentally friendly disposal options as alternatives to land filling and incineration (Mesman *et al*, 2006). In three documents prepared for the Wool Organisation of New Zealand (Mesman *et al*, 2006, 2007; Barker *et al* 2009) reported significant benefits and positive effects from the fertilization of soils with carpet fibre prior to planting. The effects of the carpet were said to be similar to those of conventional fertilizer, increasing plant growth and health thought they point out that carpet backing and pile decay at quite different rates. McNeil *et al* (2006) showed elevated levels of nitrogen, sulphur and magnesium as well as increased dry matter yield in grass grown, by between 24 and 82%. They conclude by stating that wool carpets have the potential for closed-loop recycling, involving returning the used carpet to the soil as a fertiliser.

**Conclusion**

This literature review has shown there is limited but significant evidence to show that carpet waste is likely to provide benefits as a soil amendment, in terms of improving physical characteristics and soil fertility. Nitrogen contents are relatively high, and S could be added to soil without lowering pH, due to the additional presence of chalk in the waste. Analyses of wool rich carpet waste had a pH of 6.35. Discussions with Kate Chappell, Development Manager of Carpet Recycling UK, have indicated that much of the lack of investigation in the use of wool-rich carpet waste as a fertilizer in the UK is due to restrictions on its use as a soil amendment enforced by the Environment Agency. This is because of a lack of evidence of its safety and the risk of contamination. Wainwright *et al* (1984) and Zheljozkov *et al* (2009) considered that more research is needed to reveal if wool-waste containing organic contaminants of biohazards present possible health hazards to humans when used as a nutrient source and growth media constituent for edible crops.

Clearly the use of wool-rich carpet as a fertilizer is a new concept, worthy of further research. Further studies demand both a more broad-scale approach with regards to establishing the most effective application rates and, for example, the dynamics of nitrogen release in order to synchronise the complex interaction of nitrogen availability and plant demand. Other manufacturing improvements may make recycling of carpet waste to the soil easier in the future. Development of a biodegradable polymer primary backing is feasible, which may make the carpet structure ideal for recycling to soil. There is a current lack of literature of knowledge of the contaminants and potential pathogens contained within wool-rich carpet waste and this requires further study. Lastly, more work on the effects of this amendment on the biology, functionality and quality of soil is required (Zheljazkov, 2005; Zheljazkov et al, 2009).

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