THE EFFECT OF FABRIC WEIGHT AND COMPOSITION ON RATE OF DEGRADATION OF BURIED TEXTILES

M HAMILTON AND S CAUSER

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The Effect of Fabric Weight and Composition on Rate of Degradation of Buried Textiles

M. A. Hamilton-Chisholm

S.M. Causer

The New Zealand Merino Company Ltd

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Executive Summary

There is a growing global trend toward eco-friendly apparel and textile products. In today's 'throw-away' society, the ability of a product to be composted, and to meet the 'cradle-to-cradle' philosophy provides retailers an important point of difference and is perceived as an advantage in the market. Bio-degradation, rather than anaerobic landfilling, where many products committed to landfill do not biodegrade, is also been driven by the increasing awareness and responsible demand of consumers.

This study specifically assesses the biodegradation behaviour of a range of wool, wool-rich and synthetic apparel, hosiery and carpet products. A range of wool knit apparel fabrics, polyester knit fabric, woven wool apparel, and wool, wool-rich and synthetic carpeting and wool/nylon blend and wool/Bio-tec blend socks (melt extrusion additive that renders the nylon polymer more hydrophilic and therefore more susceptible to microbial attack) were buried in soil- filled pots and sampled over a nine month period at one, two, three, six and nine month intervals. The socks were sampled at nine months only.

The results clearly demonstrated the biodegradation behaviour of the wool products. The thin, lightweight woven wool fabric quickly degraded with over 90% mass loss after two months burial. At the nine month sampling period there was virtually no sample left to retrieve with nearly 100% biodegradation of the material having occurred.

The knitted wool fabrics all demonstrated around 36% mass loss after two months burial and ~ 76-99% at nine months. In comparison, the polyester knit fabric did not degrade at all during the course of the nine month burial period.

The carpeting samples demonstrated a clear degradation trend. The 80:20% wool/nylon carpet showed the greatest rate of degradation with approximately ~ 43% mass loss after nine months, compared to ~ 27% for the tufted wool carpet and no mass loss for the nylon carpet. Whilst the wool/nylon carpet had a 20% nylon component, it also had both jute and cotton backing yarns which contributed to the degradation behaviour of the entire carpet. In comparison, the 100% tufted wool pile carpet had a synthetic polypropylene backing.

The hosiery samples were excavated after nine months burial and both demonstrated a similar mass change of approximately 43-47%. However, these samples did not show any significant mass loss difference between the traditional wool/nylon construction and the wool/Bio-tec construction. It may be that the biodegradation behaviour of the alternative Bio-tec additive in the nylon component breaks down quite slowly and the nine month burial period was not long enough to capture this.

Overall, this study has shown that fabric mass and fabric thickness play a significant role in the rate of degradation when buried in soil. The wool materials with the lightest mass and thinnest construction degraded the most rapidly.

Contents

1 Introduction

A social consciousness is growing with both consumers and retailers that is creating a demand for eco-friendly products. Consumers in particular, want to know where their products are sourced from and the subsequent social and environmental impact. This has driven retailers to proactively seek sustainable product options. One facet of this is the cradle-to-cradle philosophy and the ability of textile products to be either recycled, down-cycled or disposed of in an environmentally effective way. The cradle to cradle philosophy is a holistic eeconomic, industrial and social framework that seeks to create systems that are not just efficient but essentially waste free. For wool products, this is an extremely positive story.

In an endeavour to understand and compare the biodegradation behaviour of a range of natural and synthetic textiles, a number of apparel (knitted and woven), hosiery and carpet samples were individually buried in soil and excavated at regular intervals over a nine-month duration. More specifically, the objective of this trial was to determine the effect that fabric mass has on the degradation time and behaviour of a range of different weight, structure and composition materials.

2 Methodology

2.1 Materials

Where possible, commercial samples for use in this trial were sourced from participating brand partners. Wool knit fabrics were sourced from Icebreaker and a comparison 100% polyester fabric was purchased from a local fabric retailer. Woven wool apparel fabric was sourced from Reda, Italy, hosiery was sourced from SmartWool and two tufted carpets were supplied by Cavalier Bremworth. A used 80/20% wool/nylon carpet was provided by Wools of New Zealand.

- 150g/m^2 Icebreaker single jersey wool knit apparel fabric
- 260g/m^2 Icebreaker single jersey wool knit apparel fabric
- 320g/m^2 Icebreaker single jersey wool knit apparel fabric
- 133g/m^2 double jersey polyester knit apparel fabric
- Two REDA woven wool apparel fabrics both @ 150g/m^2
- Wool/nylon socks, ex Smartwool
- Wool/Bio-tec socks, ex Smartwool
- 100% wool tufted carpet, ex Cavalier
- 100% solution dyed nylon loop pile carpet, ex Cavalier
- 80/20% wool/nylon woven carpet with cotton warp and jute weft

2.1.1 Wool Knit Fabric

A range of dyed, 19µm single jersey knit fabrics of different weights (150, 260 and 320g/m^2) were sourced from Icebreaker (Figures 1-3) for the 1005 wool knit trial.

Figure 1. Icebreaker 150g/m2

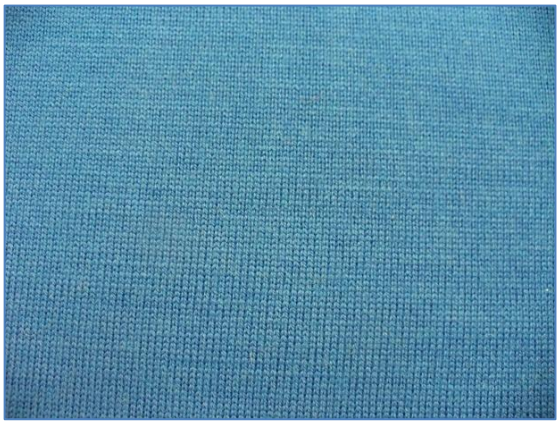


Figure 2. Icebreaker 260g/m^2

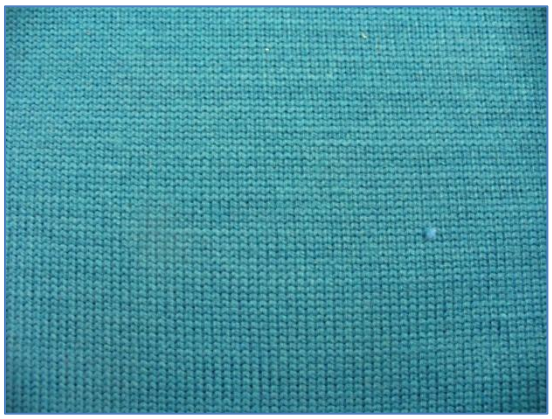


Figure 3. Icebreaker 320g/m^2

2.1.2 Polyester knit fabric

A double jersey polyester knit fabric was sourced from Haralds of Christchurch for comparison with the 100% wool knit fabric. The fabric was~133g/m^2, dyed to a pastel shade (Figure 4).

Figure 4. 100% Polyester

2.1.3 Woven wool fabric

Two 100% woven wool fabrics were sourced from REDA (Article 6900 and Article 669); top dyed and yarn dyed, respectively. Both fabrics weighed ~150g/m^2 (Figures 5 and 6).

Figure 5. REDA Article 6900

Figure 6. REDA Article 669

2.1.4 Hosiery

Sample wool/nylon blend 'tube socks' were sourced from SmartWool that incorporated both their traditional nylon component (Figure 7) and also 'Bio-Tec' biodegradable nylon (Figure 8). The nylon and Bio-tec components equated to around 30% of the sock mass. The Bio-Tec technology incorporates Eco-

Pure, an additive that is melt-compounded into the nylon master batch resin, which is then pelletised before filament extrusion. The incorporation of this additive is claimed to render the normally water-repellent nylon polymer more hydrophilic, which in turn facilitates the growth of hydrocarbon-degrading organisms that enhances the biodegradation process. Bio-tec suggests that degradation can be achieved in 1-5 years (http://www.bio-tec.com/).

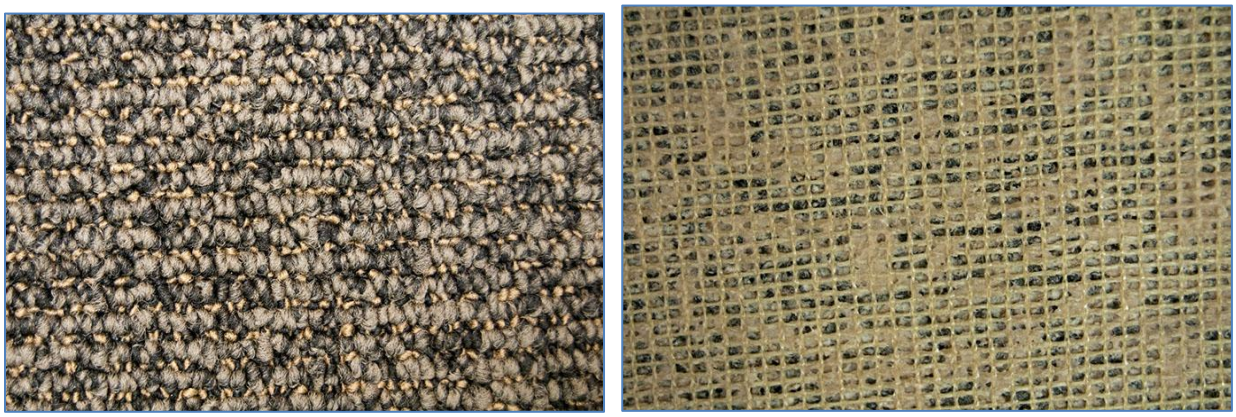
Figure 7. Traditional Nylon component tube sock

Figure 8. Bio-tec component tube sock

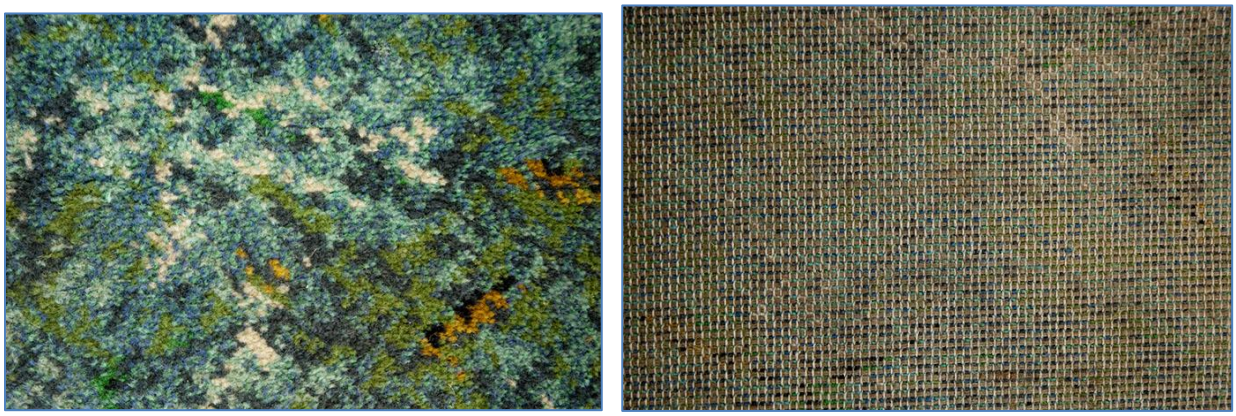
2.1.5 Carpet

Carpet samples were also included in this trial: new 100% tufted wool with polypropylene primary and jute secondary backing and 100% solution-dyed nylon tufted carpeting with polypropylene primary and secondary backing (Figures 9-11). Also included was a used 80/20% wool/nylon woven carpet with cotton warp and jute weft yarns. The carpets were sourced from Cavalier Bremworth and Wools of New Zealand.

Figures 9. 100% tufted wool-face and back



Figures 10. 100% solution-dyed tufted Nylon – face and back



Figures 11. 80/20% wool/Nylon woven – face and back

2.1.6 Control samples

The trial also included six control pots containing soil only. These controls were used at trial end (nine months) for a general soil analysis and were compared to the initial soil sample analysed prior to the trial commencing and soil from pots containing both wool (mid-weight 260g/m^2 and polyester knit fabric).

To ensure that the moisture content of all the trial pots was maintained at a consistent level, six moisture control pots were also included in the trial and used to maintain the field capacity. The field capacity was first calculated, and then the average weight of the moisture control pots was utilised as an indicator in which to adjust the moisture content of all the trial pots to 80% throughout the duration of the trial period; particularly during the drier summer period.

2.1.7 Soil

The soil used for all the experiments encompassed within this body of work was a sandy loam, sourced from the Rolleston area. This was purchased in bulk from Southern Horticultural Products ltd, Christchurch. The soil was pre-screened and had not undergone any fumigation or spray treatment.

An initial 'general' soil analysis was carried out by Hills Laboratories, Christchurch (Table 1).

Table 1 General Soil Analysis

Sample Name: Dunsandel Biodegradation Trial **Lab Number:** 833622.1
Sample Type: SOIL General, Outdoor (S10)

Analysis		Level Found	Medium Range	Low / Medium / High
pH	pH Units	5.6	5.8 - 6.3	
Olsen Phosphorus	mg/L	21	20 - 30	
Potassium	me/100g	0.57	0.50 - 0.80	
Calcium	me/100g	4.4	6.0 - 12.0	
Magnesium	me/100g	0.69	1.00 - 3.00	
Sodium	me/100g	0.14	0.20 - 0.50	
CEC	me/100g	12	12 - 25	
Total Base Saturation	%	50	50 - 85	
Volume Weight	g/mL	1.10	0.60 - 1.00	
Base Saturation %		K 4.9	Ca 38	Mg 5.9 Na 1.2
MAF Units		K 13	Ca 6	Mg 17 Na 7

2.1.8 Planter Bags

Polyethylene planter bags measuring 360h x 180 x 180mm when empty and containing approximately 10 litres of soil when full were utilised in this trial.

2.2 Trial preparation

2.2.1 Sample preparation

Six replicates of each of the two control groups and material groups were allowed for. Fabrics were sub-sampled to 10 x 15cm, which fitted with room to spare around the fabric edges when laid flat in a horizontal configuration in the planter pots. Enough fabric was prepared to allow for six replicates to be sampled at one, two, three, six and nine month intervals with the exception of the hosiery trial which was sampled at nine months only. Each sample was individually identified using a plastic marker.

2.2.2 Dry Mass

To measure the total mass of the various materials, each sample was dried at 50°C in a Contherm air circulating oven until constant dry mass had been achieved and weighed. This weight was used as the control weight reference for comparison after each excavation and retrieval to determine the total dry mass change over the nine month sampling duration.

2.2.3 Trial Site

The trial and control pots were placed in a purpose built shade house (Figures 12) situated in the Dunsandel/Horarata area, approximately 40km south west of Christchurch. The shade house was 1.8m wide x 24m long with the primary axis running east/west. The shade house was covered in along the sides and the top with shade cloth.

The pots for all the pot burial trials (306 in total) were randomised within each of the four test groups i.e. wool and polyester knit fabrics and woven wool fabrics, carpeting and biodegradable materials, hosiery and fungal and microbial soil analysis samples (Figure 13). The twelve controls and moisture control pots were then further randomised within the four test groups. Each pot was individually numbered and labelled to clearly identify the positioning of the pots.

Figures 12. Pot Trial shade house and pot layout

The ground was first pre-sprayed with a residual herbicide to kill any immediate weeds and prevent subsequent weed growth. The ground was then covered with aggregate chip to an approximate depth of 50mm and the pots then placed on top of the chip. These measures were taken to inhibit weed growth and to assist with pot drainage. The pots were placed in rows of six ~ 400mm away from the shade house walls to minimise any potential effect of drying. Each of the four different trial groups was separated by a walkway ~ 600mm to allow easy access for moisture measurements and watering.

Table 2. Pot Trial sampling regime

Sample	Total number samples	Number of replicates	Sampling Period
Control (soil only)	6	1	9 months soil analysis
Moisture control	6	1	~ weekly
1 x Polyester knit fabric	30	6	1, 2, 3, 6 and 9 months
3 x wool knit fabrics	90	6	1, 2, 3, 6 and 9 months
2 x Woven REDA fabrics	60	6	1, 2, 3, 6 and 9 months
2 x Hosiery samples Nylon and Biotec	24	6	9 months
3 x carpeting	90	6	1, 2, 3, 6 and 9 months
Total	306		

2.2.4 Moisture Maintenance

To ensure a level of consistency across the trial, the moisture level within each of the soil containers was kept at around 80% of field capacity. Field capacity can be described as the state of the soil after rapid drainage has effectively ceased and the soil water content has become relatively stable (MLaren and Cameron, 2004). The weight of water held by the soil as a fraction of the original weight of soil is the field capacity (expressed gravimetrically; that is by weight). Field capacity can be expressed as a percentage (weight of water per 100g of soil) or per gram of soil. Field capacity was initially calculated by carrying out the following procedure:

1. Weigh sieve and add dry soil, re-weigh to find weight of soil
2. Allow to drain for 24-48 hours, using a suitable form of drainage in the latter stages to help draw out the water held in the sieve holes by surface tension.
3. Re-weigh sieve and wet soil
4. Calculate weight of water held by the soil, and then in turn 80% of this, to find the level which is needed to be watered to.

The mass of a representative selection of six moisture control pots was determined periodically and the appropriate amount of water added to each pot to bring it up to a field capacity of 80%.

To ensure consistent moisture content in all the trial pots, six moisture control pots were included in the trial. These pots were filled with soil, as per the fabric trial pots, and weighed. The moisture control

pots were then saturated with water and allowed to drain until the water content had stabilised and the field capacity calculated. 80% of this capacity, plus the weight of the soil worked out to be 9.463kg. To ensure this moisture content was maintained, the six moisture control pots were periodically weighed and moisture adjusted to this weight for all the trial pots. This was done more frequently in the drier summer period.

2.2.5 Sample Preparation

During preparation, each bag was half filled with around 10 cm soil, the sample placed on top, then a further 10cm of soil put on top of the sample. For the hosiery samples (nylon and Bio-tec); the socks were longer than the width of the planter bag, so each sock was buried in the pot folded over, but with soil between the fold of the sock.

Preliminary work carried out by The New Zealand Merino Company (Farrell and Causer, 2010) looking at the degradation behaviour of a range of wool textiles has followed much of the methodology used in this study. One example of this was for the burial of the socks, as the preliminary work demonstrated that the rate of degradation was considerably compromised if the fabric was in a folded state, so it was considered important that the entire surface area of the sock was in direct contact with the soil.

2.2.6 Weather Monitoring

Throughout the duration of the trial, both temperature and humidity were monitored using a CEM Temperature Humidity Datalogger DT-171. Rainfall was also monitored using a Scientific Sales

Model: Z758 rainfall gauge.

3 Sampling

At each sampling period, the individual pots were cut open and the soil carefully removed until the sample was exposed. The sample was then carefully lifted out; often still sandwiched between soil. The soil covered sample was then placed on a sieve with an approximate mesh size of 2-3mm and washed with a low pressure water spray until all the soil was removed (Figures 13-16). Any fabric matter that was small enough to wash through the sieve holes was considered irretrievable (or 100% decomposed). The samples were then dried in a Contherm air circulating oven at 50°C (Figure 17) until completely dry and then weighed. This resultant retrieved dry weight was then compared to the initial total dry mass and the total dry mass change calculated.

Figure 13. Sample excavation

Figure 14. Delamination of soil at sample position

Figures 15. Sample exposed for retrieval

Figure 16. Gentle spray washing of sample over sieve

Figure 17. Excavated samples in drying oven

4 Results

4.1 Excavated samples – Images and mass loss

After excavation, drying and calculation of the total dry mass loss, images of the remaining fabric at each sampling stage were taken to demonstrate the visual rate of degradation. (Figures 18-75)

Icebreaker 150g/m^2

Figure 18. One month burial

Figure 19. Two month burial

Figure 20. Three month burial

Figure 21. Six month burial

Figure 22. Nine month burial

Icebreaker 260g/m^2

Figure 23. One month burial

Figure 24. Two month burial

Figure 25. Three month burial

Figure 26. Six month burial

Figure 27. Nine month burial

Icebreaker 320g/m^2

Figure 28. One month burial

Figure 29. Two month burial

Figure 30. Three month burial

Figure 31. Six month burial

Figure 32. Nine month burial

100% Polyester

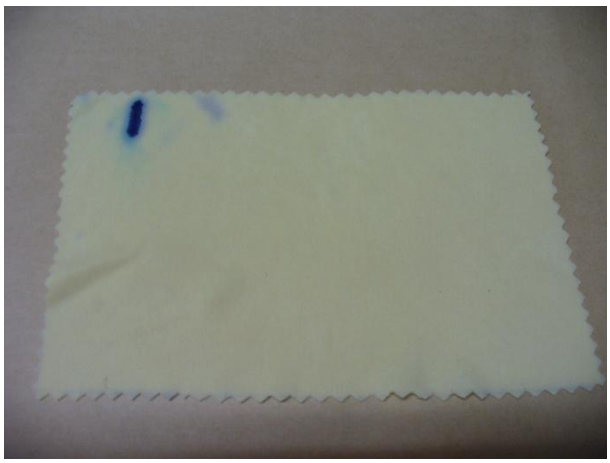


Figure 33. One month burial

Figure 34. Two month burial

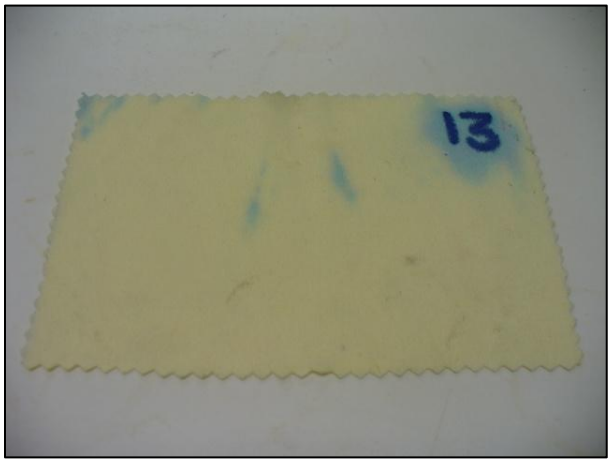


Figure 35. Three month burial

Figure 36. Six month burial

Figure 37. Nine month burial

Woven wool fabric

Figure 38. REDA 6900 – one month burial

Figure 39. REDA 669 – one month burial

Figure 40. REDA 6900 – two month burial

Figure 41. REDA 669 – two month burial

Figure 42. REDA 6900 – three month burial

Figure 43. REDA 669 – three month burial

Figure 44. REDA 6900 – six month burial

Figure 45. REDA 669 – six month burial

Figure 46. Reda 6900 – nine month burial

Figure 47 . Reda 669 – nine month burial

Wool carpet

Figure 48. Face – one month burial

Figure 49. Back – one month burial

Figure 50. Face – two month burial

Figure 51. Back – two month burial

Figure 52. Face – three month burial

Figure 53. Back – three month burial

Figure 54. Face – six month burial

Figure55. Back – six month burial

Figure 56. Face – nine month burial

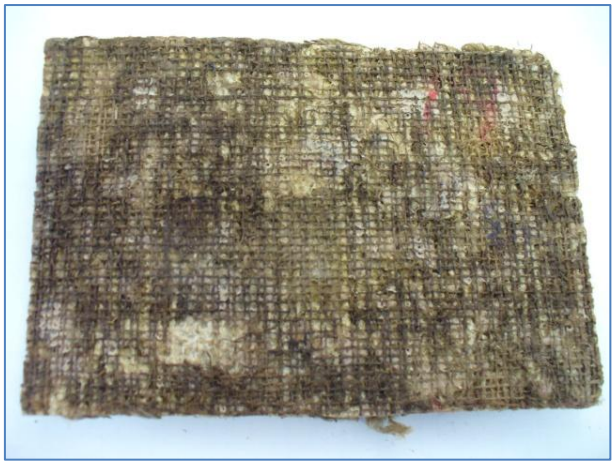


Figure 57. Back – nine month burial

Solution dyed Nylon carpet

Figure 58. Face – one month burial

Figure 59. Back – one month burial

Figure 60. Face – two month burial

Figure 61. Back – two month burial

Figure 62. Face – three month burial

Figure 63. Back – three month burial

Figure 64. Face – six month burial

Figure 65. Back – six month burial

Figure 66. Face – nine month burial

Figure 67. Back – nine month burial

80:20% wool/nylon carpet

Figure 68. Face – one month burial

Figure 69. Back – one month burial

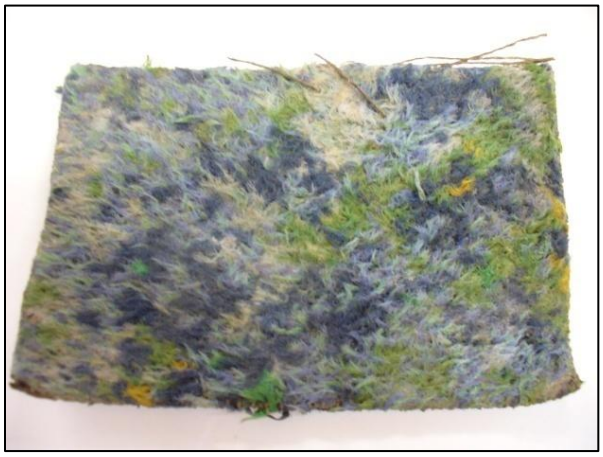


Figure 70. Face – two month burial

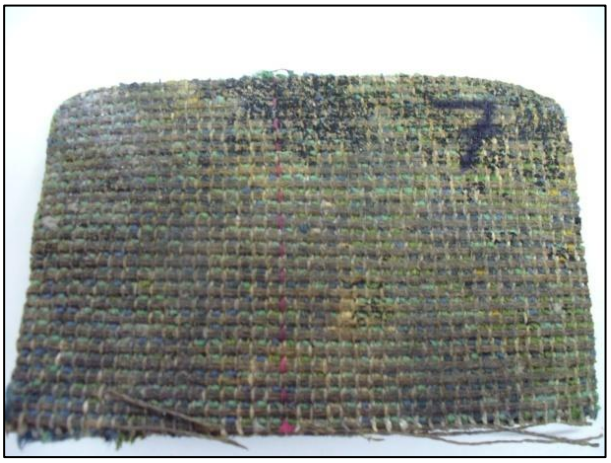


Figure 71. Back – two month burial

Figure 72. Face – three month burial

Figure 73. Back – three month burial

Figure 74. Six month burial

Figure 75. Nine month burial

4.1.1 Knit fabric

For the wool knit fabrics, the rate of degradation appeared to be directly correlated to fabric weight, in that, the 150g/m^2 fabric degraded at a faster rate than the 260 and 320g/m^2 fabrics respectively. This trend is reflected in the mean total mass change after nine months burial for the three fabrics with the exception of a couple of anomalies between the 260 and 320g/m^2 fabrics at month three and month nine sampling periods. During the latter stages of sampling, if an unexpectedly large sample was retrieved from one of the six repetitions, this created the anomaly and is reflected in the large standard deviation of the particular sample group.

In comparison, the polyester knit fabric did not biodegrade at all; remaining completely intact after nine months burial (Figure 69). The mean mass change and standard deviation are reported in tables 3-6. The raw data is tabled in the appendix.

Table 3. Knit fabric - 150g/m^2 wool

Burial period (months)	Mean mass loss (%)	Standard deviation
1	-3.8783	1.5751
2	-35.8495	25.5087
3	-93.2537	7.8208
6	-94.5513	4.6221
9	-97.9139	2.4242

Table 4. Knit fabric - 260g/m^2 wool

Burial period (months)	Mean mass loss (%)	Standard deviation
1	0.4795	0.5109
2	-36.5413	10.9567
3	-82.0858	8.7993
6	-71.3079	26.5846
9	-75.9195	17.7317

Table5 . Knit fabric - 320g/m^2 wool

Burial period (months)	Mean mass loss (%)	Standard deviation
1	-0.7467	1.7063
2	-34.1238	10.0766
3	-74.9103	25.7941
6	-75.1509	26.8382
9	-89.9887	8.1246

Table 6. Polyester fabric - 133g/m^2

Burial period (months)	Mean mass loss (%)	Standard deviation
1	0	0
2	+0.0403	0.1043
3	+0.1187	0.1215
6	+0.0471	0.3214
9	+0.2504	0.0764

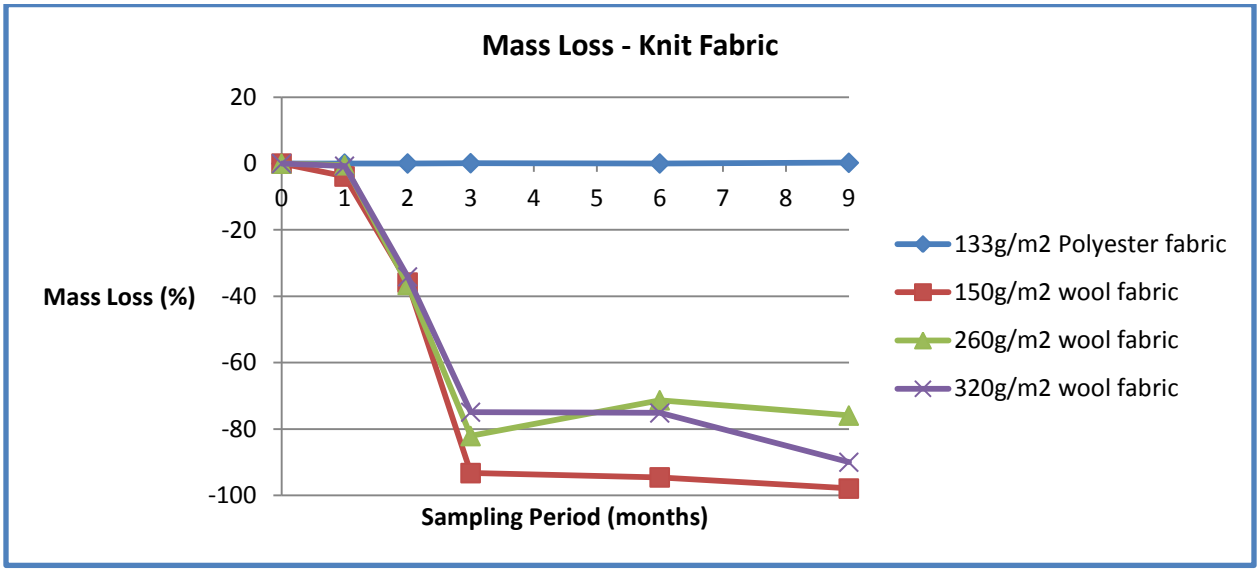


Figure 77. Mass change of knit fabrics

4.1.2 Woven fabric

Over the nine-month sampling duration, biodegradation progressed rapidly. The thin and light weight woven wool fabrics degraded rapidly with nearly 100% degradation achieved after only two months (Tables 7 and 8 and Figures 35 and 36). The complete mass change data is tabled in the appendix.

Table 7. Reda 669 woven fabric - 150g/m^2

Burial period (months)	Mean mass change (%)	Standard deviation
1	-47.6371	14.6245
2	-96.3918	4.8130
3	-98.6743	1.5453
6	-99.8966	0.1654
9	-99.7372	0.5590

Table 8. Reda 6900 woven fabric - 150g/m^2

Burial period (months)	Mean mass change (%)	Standard deviation
1	-28.1539	10.4795
2	-93.2507	7.5436
3	-94.2940	2.2935
6	-98.0144	2.0661
9	-98.7425	1.2172

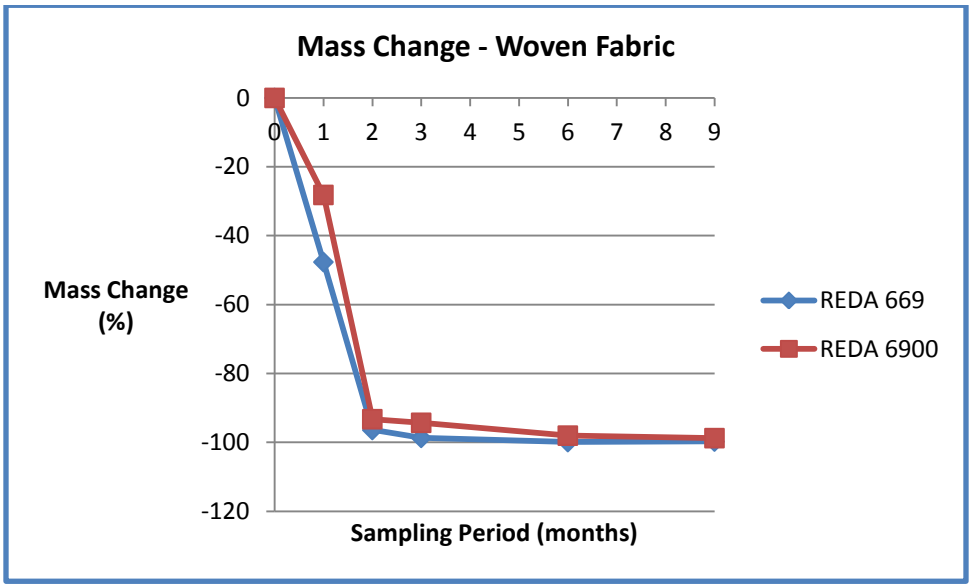


Figure 78. Mass loss of woven fabric

4.1.3 Carpet

The degradation behaviour of the carpets over the nine month trial duration demonstrated a clear trend in that the 80/20% degraded the most rapidly, and then followed by the tufted wool carpet. The nylon carpet did not degrade at all, and in fact gained weight in many cases, due to plant contamination that could not be removed during washing. This trend is demonstrated in the mean mass change results after nine months burial (Tables 9-11 and Figures 79-81). Refer to the appendix for full data results.

Table 9. Tufted wool carpet

Burial period (months)	Mean mass change (%)	Standard deviation
1	-2.4497	1.2195
2	-12.6207	0.9434
3	-19.4015	2.0078
6	-25.4758	4.7110
9	-27.2337	1.6142

Table10 . Tufted nylon carpet

Burial period (months)	Mean mass change (%)	Standard deviation
1	+0.6281	0.0678
2	+0.5348	0.1640
3	+0.3559	0.2475
6	+0.7166	0.5142
9	+0.3085	0.70792

Table 11. 80/20% wool/nylon carpet

Burial period (months)	Mean mass change (%)	Standard deviation
1	-10.5744	4.2368
2	-20.5327	4.1087
3	-32.6673	3.9321
6	-44.5357	6.3005
9	-37.0779	16.9732

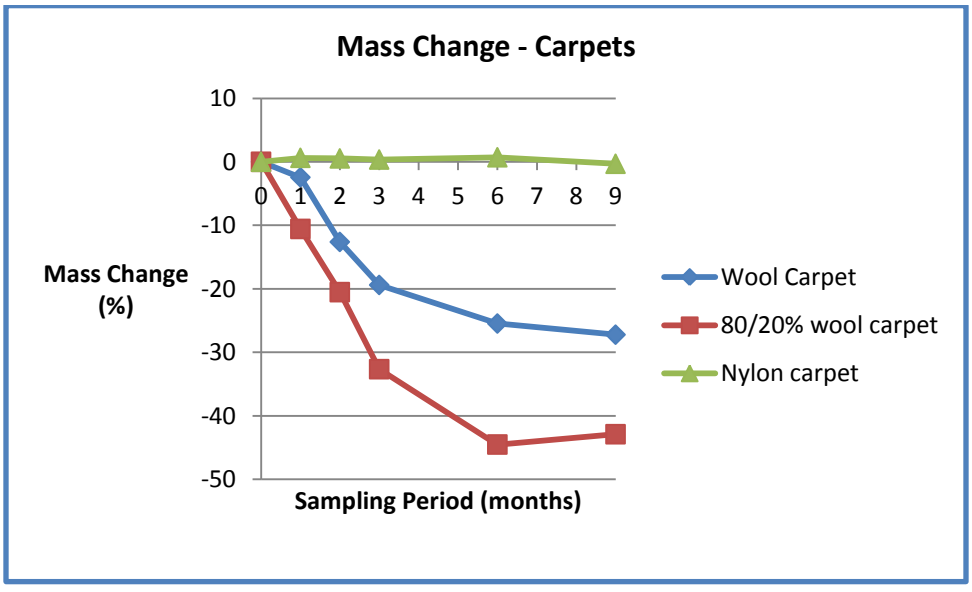


Figure 79. Mass loss of carpets

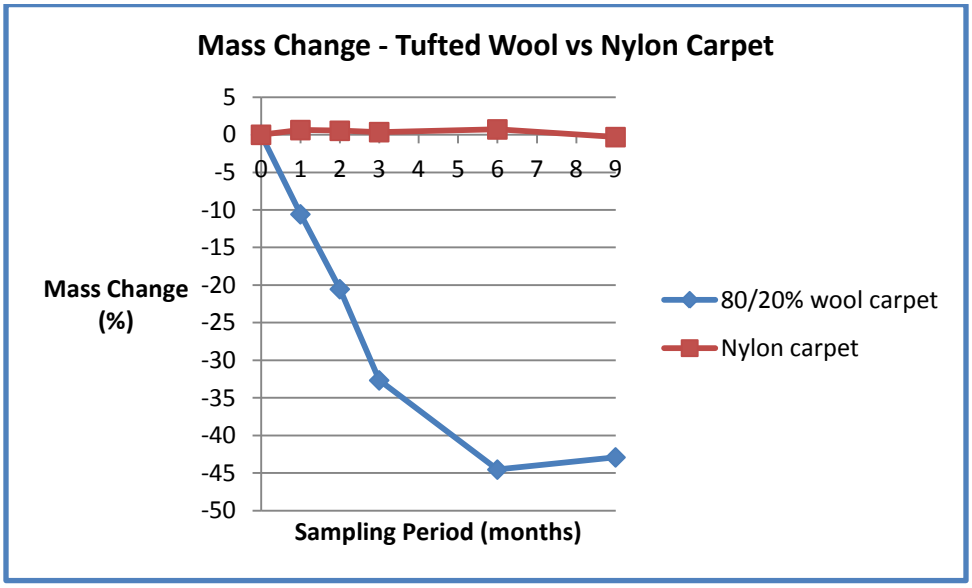


Figure 80. Mass loss comparing tufted wool vs tufted nylon carpet

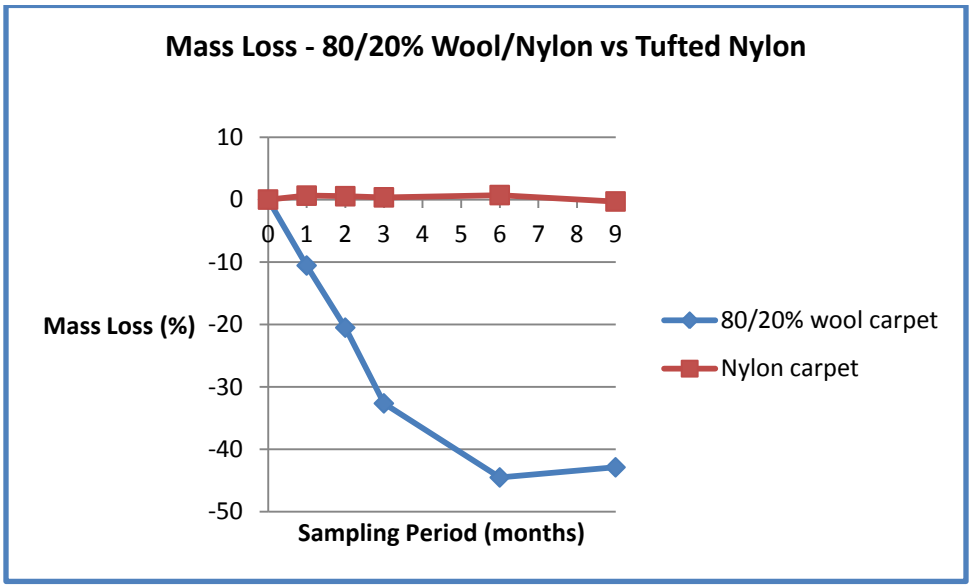


Figure 81. Mass loss comparing wool nylon blend vs 100% nylon carpet

4.1.4 Hosiery

Three replicates of the hosiery samples were recovered after nine months only, demonstrating an average mass loss of ~44% for the traditional wool/nylon socks compared to ~47% for the wool/Bio-tec

socks, however, statistical analysis confirmed that there was not a significant difference (P>0.05) between these two results (Table 12).

Table 12. Hosiery

Burial Period (months)	Sample	Mean	Standard Deviation
9	Wool/nylon socks	-43.76373333	6.920326637
	Wool/Bio-tec socks	-47.204333	5.11891251

Figure 82. Smartwool Wool/Nylon sock

Figure 83. Smartwool Wool/Bio-tec sock

5 Climate measurements

5.1 Temperature, humidity and rainfall

Data logger measurement for both temperature and humidity over the nine-month trial duration resulted in maximum and minimum temperatures of 34.9°C and -3.6°C respectively and maximum and minimum humidity levels of 95.6 and 20.9% respectively. The wide temperature and humidity range can be demonstrated by some of the extreme weather conditions experienced over the course of the trial.

Monthly rainfall measurements over the 9 month trial duration resulted in a mean rainfall of 1065.789mm.

6 Discussion

The cradle to cradle philosophy is a compelling story for choosing natural and sustainable products and the outcome of this study provides a very clear and compelling story for the environmental advantages

of wool products at the end of consumer life in comparison to the synthetic materials trialled. The synthetic materials did not demonstrate any signs of biodegradation at all.

It is known that wool will readily degrade when buried in soil (Line, 2003) with a range of factors such as soil pH, temperature, availability of oxygen, moisture content and the presence of micro-organisms having the most significant impact on rate of biodegradation (Arshad and Mujahid, 2011).

While, all the wool textiles demonstrated varying degrees of bio-degradation, this study showed that fabric mass played a significant role in the rate of degradation. The lightest weight wool knit fabric degraded the fastest, with the mid-weight and heaviest weight wool knit fabric degrading more slowly over the nine-month trial duration. Interestingly, fabric thickness also had a significant impact on the rate of degradation. While the woven wool fabrics were the same weight as the lightest weight wool fabric, the woven fabrics were thinner and degraded significantly faster than the wool knit. This may be due to the larger surface area of the woven fabric compared to the wool knit fabric, thereby having a larger contact area with the soil, and in turn more contact points for biodegradation to occur.

7 Conclusions

The burial trial gave a very clear picture of the degradation behaviour of wool textiles. The lightest weight materials with the thinnest construction (woven) degraded the most quickly in comparison to wool knit fabric of the same weight. This was quite an interesting outcome and could be due to the larger surface area of the woven fabric presented to the soil and/or the difference in yarn strength between the thinner woven wool yarns in comparison to the thicker yarns in the lightest weight wool knit fabric, however, this isn't known.

The degradation behaviour of the three wool knit fabrics was quite clear in that there was a very distinct correlation between fabric weight and rate of degradation; the lightest weight wool fabric degraded the fastest in comparison to the mid and heavy weight fabrics respectively. Not unsurprisingly, the polyester knit fabric did not degrade at all and remained completely intact with no mass change after nine months of burial**.**

The carpet samples also showed a clear trend, in that the 80/20% woven carpet degraded the fastest, followed closely by the tufted wool carpet. This may appear, on first consideration, to be an unexpected result, but the woven carpet had natural jute and cotton weft and warp backing yarns in comparison to the tufted wool carpet that had a polypropylene primary backing. The synthetic nylon carpet did not degrade at all.

After nine months burial, there was no significant difference measured in the mass loss of the traditional wool/nylon compared to the wool/Bio-tec socks, which is most probably due to the limited time this trial afforded to measure the biodegradation behaviour of modified synthetic materials.

It would be beneficial to clarify in more detail, the different fabric considerations that affect the rate of biodegradation of wool textiles when buried in soil as it would appear that considerations apart from fabric mass such as yarn and fabric tenacity and yarn and fabric thickness could also be contributing factors to the biodegradation behaviour.

It is the intention that the results of the pot burial trials will be published in peer reviewed literature, in conjunction with findings from existing New Zealand Merino fabric decomposition trials to support brand partner claims around biodegradability behaviour of their products.

8 Acknowledgements

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9 References

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10 Appendix

10.1 Dry Mass

Knit fabric - 150g/m^2 wool

One month burial

Sample #	Initial total dry mass (g)	Recovered total dry mass (g)	Mass change (%)
1	2.2358	2.2103	-1.1405
2	2.4311	2.4037	-1.1271
3	2.3687	2.3273	-1.7478
4	2.3043	2.2628	-1.8010
5	2.3049	2.2305	-3.2279
6	2.3104	2.1907	-5.1809
Mean	**2.3259**	2.2709	**-2.3709**

Two months burial

Sample #	Initial total dry mass (g)	Recovered total dry mass (g)	Mass change (%)
7	2.3592	0.6645	-71.8337
8	2.3534	1.9786	-15.9259
9	2.3709	0.9062	-61.7782
10	2.4093	2.1572	-10.4636
11	2.4251	1.5796	-34.8645
12	2.2579	1.8011	-20.2312
Mean	**2.3626**	**1.5145**	**-35.8495**

Three months burial

Sample #	Initial total dry mass (g)	Recovered total dry mass (g)	Mass lchange (%)
13	2.2299	0.1374	-93.8383
14	2.3517	0.0601	-97.4444
15	2.2721	0.1562	-93.1253
16	2.3796	0.5228	-78.0299
17	2.2971	0.0408	-98.2238
18	2.2819	0.0260	-98.8606
Mean	**2.3021**	**0.1572**	**-93.2537**

Six months burial

Sample #	Initial total dry mass (g)	Recovered total dry mass (g)	Mass change (%)
19	2.2610	0.1076	-95.2410
20	2.2498	0.2896	-87.1277
21	2.2627	0.1078	-95.2358
22	2.2265	0.0150	-99.3263
23	2.2717	0.0256	-98.8731
24	2.2905	0.1946	-91.5040
Mean	**2.2604**	**0.1234**	**94.5513**

Nine months burial

Sample #	Initial total dry mass (g)	Recovered total dry mass (g)	Mass change (%)
25	2.3410	0.0260	-98.8894
26	2.3125	0.0112	-99.5157
27	2.3110	0.0065	-99.7187
28	2.3281	0.0368	-98.4193
29	2.3930	0.0538	-97.7518
30	2.2242	0.1515	-93.1886
Mean	**2.3183**	**0.0476**	**-97.9139**

Knit fabric - 260g/m^2 wool

One month burial

Sample #	Initial total dry mass (g)	Recovered total dry mass (g)	Mass change (%)
1	4.0521	4.0324	0.4862
2	4.1366	4.1540	+ 0.4206
3	4.1557	4.1814	+0.6184
4	4.1354	4.1592	+0.5755
5	3.9630	4.0024	+0.9942
6	3.8833	3.9126	+0.7545
Mean	**4.0544**	**4.0737**	**+0.4795**

Two months burial

Sample #	Initial total dry mass (g)	Recovered total dry mass (g)	Mass change (%)
7	3.9091	2.9577	24.3381
8	3.9054	2.9814	23.6595
9	3.8895	2.1292	45.2577
10	3.7791	2.5025	33.7805
11	3.8085	2.1694	43.0379
12	3.6981	1.8796	49.1739
Mean	**3.8316**	**2.4367**	**36.5413**

Three months burial

Sample #	Initial total dry mass (g)	Recovered total dry mass (g)	Mass change (%)
13	3.9371	0.5207	86.7745
14	3.7966	0.8729	77.0084
15	3.8375	0.4261	88.8964
16	3.8525	0.9525	75.2758
17	3.7311	0.2469	93.3826
18	3.7349	1.0765	71.1773
Mean	**3.8150**	**0.6826**	**82.0858**

Six months burial

Sample #	Initial total dry mass (g)	Recovered total dry mass (g)	Mass change (%)
19	3.7420	1.3741	63.2790
20	3.7352	2.6608	28.7642
21	3.7431	1.4848	60.3323
22	3.8332	0.0089	99.7807
23	3.7422	0.1043	97.3618
24	3.8142	0.8744	78.3291
Mean	**3.7683**	**1.0846**	**71.3079**

Nine months burial

Sample #	Initial total dry mass (g)	Recovered total dry mass (g)	Mass change (%)
25	3.8432	0.3352	-91.2781
26	3.8286	1.0197	-73.3662
27	3.8221	0.7595	-80.1287
28	4.0332	2.1516	-46.6528
29	4.0224	1.2769	-68.2553
30	3.9696	0.1653	-95.8359
Mean	**3.9199**	**0.9514**	**-75.9195**

Knit fabric – 320g/m^2 wool

One month burial

Sample #	Initial total dry mass (g)	Recovered total dry mass (g)	Mass change (%)
1	4.6323	4.4423	4.1016
2	4.6654	4.6408	0.5273
3	4.7000	4.6898	0.2170
4	4.5508	4.5406	0.2241
5	4.5972	4.6053	+0.8100
6	4.5898	4.5797	0.2201
Mean	**4.6226**	**4.5831**	**0.7467**

Two months burial

Sample #	Initial total dry mass (g)	Recovered total dry mass (g)	Mass change (%)
7	4.7844	3.6831	23.0186
8	4.6552	2.6287	43.5320
9	4.6517	2.6525	42.9778
10	4.6841	3.0888	34.0578
11	4.7977	3.8011	20.7725
12	4.6620	2.7793	40.3840
Mean	**4.7059**	**3.1056**	**34.1238**

Three months burial

Sample #	Initial total dry mass (g)	Recovered total dry mass (g)	Mass change (%)
13	4.7125	0.9219	80.4371
14	4.6044	0.4118	91.0563
15	4.6805	0.1855	96.0367
16	4.7112	1.2945	72.5229
17	4.6638	0.7263	84.4269
18	4.6690	3.5026	24.9818
Mean	**4.6736**	**1.1738**	**74.9103**

Six months burial

Sample #	Initial total dry mass (g)	Recovered total dry mass (g)	Mass change (%)
19	4.6485	3.0407	34.5875
20	4.6961	2.4000	48.8938
21	4.6547	0.0831	98.2147
22	4.7434	0.8609	81.8506
23	4.5897	0.2320	94.9452
24	4.5883	0.3481	92.4133
Mean	**4.6535**	**1.1608**	**75.1509**

Nine months burial

Sample #	Initial total dry mass (g)	Recovered total dry mass (g)	Mass change (%)
25	4.7400	0.0769	-98.3776
26	4.7034	0.7130	-84.8408
27	4.5834	0.2748	-94.0045
28	4.4685	1.0481	-76.5447
29	4.5394	0.4470	-90.1529
30	4.7311	0.1887	-96.0115
Mean	**4.6276**	**0.4581**	**-89.9887**

Knit fabric - 133g/m^2 Polyester

One month burial

Sample #	Initial total dry mass (g)	Recovered total dry mass (g)	Mass change (%)
1	1.9926	1.9929	**~0**
2	1.9772	1.9767	**~0**
3	2.0071	2.0073	**~0**
4	1.9811	1.9807	**~0**
5	1.9871	1.9851	**~0**
6	1.9928	1.9923	**~0**
Mean	**1.9897**	**1.9892**	**~0**

Two month burial

Sample #	Initial total dry mass (g)	Recovered total dry mass (g)	Mass change (%)
7	2.0007	2.0002	0.0250
8	1.9801	1.9789	0.0606
9	1.9327	1.9318	0.0466
10	1.9515	1.9526	+0.0564
11	1.9299	1.9321	+0.1140
12	2.0134	2.0175	+0.2036
Mean	**1.9681**	**1.9689**	**+0.0403**

Three months burial

Sample #	Initial total dry mass (g)	Recovered total dry mass (g)	Mass change (%)
13	1.9838	1.9893	+0.2772
14	1.9389	1.9370	0.0980
15	1.9716	1.9734	+0.0913
16	1.9570	1.9584	+0.0715
17	1.9512	1.9538	+0.1333
18	1.9871	1.9898	+0.1359
Mean	**1.9649**	**1.9670**	**+0.1019**

Six months burial

Sample #	Initial total dry mass (g)	Recovered total dry mass (g)	Mass change (%)
19	1.9742	1.9763	+0.1064
20	1.9279	1.9361	-0.4253
21	2.0062	2.0111	-0.2442
22	1.9297	1.9323	+0.1347
23	1.9743	1.9825	+0.4153
24	2.0299	2.0359	+0.2956
Mean	**1.9737**	**1.9790**	**+0.0471**

Nine months burial

Sample #	Initial total dry mass (g)	Recovered total dry mass (g)	Mass change (%)
25	1.9962	1.9987	+0.1252
26	2.0028	2.0075	+0.2347
27	2.0123	2.0177	+0.2683
28	1.9735	1.9786	+0.2584
29	1.9459	1.9508	+0.2518
30	2.0341	2.0415	+0.3638
Mean	**1.9941**	**1.9991**	**+0.2504**

NB. Positive result indicates a gain in mass

Woven fabric - 150g/m^2 REDA 6900

One month burial

Sample #	Initial total dry mass (g)	Recovered total dry mass (g)	Mass change (%)
1	2.3122	1.7470	24.4443
2	2.2544	1.3208	41.4123
3	2.2431	1.4928	33.4492
4	2.2324	1.6414	26.4738
5	2.3319	2.0854	10.5708
6	2.2875	1.5424	32.5727
Mean	**2.2769**	**1.6383**	**28.1539**

Two months burial

Sample #	Initial total dry mass (g)	Recovered total dry mass (g)	Mass change (%)
7	2.1415	0.4538	78.8046
8	2.1396	0.0199	99.0700
9	2.1500	0.0968	95.4977
10	2.1643	0.0952	95.6013
11	2.1494	0.1751	91.8535
12	2.1395	0.0283	98.6773
Mean	**2.1474**	**0.1449**	**93.2507**

Three months burial

Sample #	Initial total dry mass (g)	Recovered total dry mass (g)	Mass change (%)
13	2.1505	0.1546	92.8110
14	2.2136	0.2119	90.4274
15	2.1537	0.1163	94.6000
16	2.1388	0.0752	96.4840
17	2.1836	0.1002	95.4112
18	2.1764	0.0864	96.0301
Mean	**2.1694**	**0.1241**	**94.2940**

Six months burial

Sample #	Initial total dry mass (g)	Recovered total dry mass (g)	Mass change (%)
19	2.1559	0.0270	98.7476
20	2.1735	0.0336	98.4541
21	2.1564	0.0571	97.3521
22	2.1492	0.0023	99.8930
23	2.1824	0.0121	99.4456
24	2.2063	0.1281	94.1939
Mean	**2.1706**	**0.0434**	**98.0144**

Nine months burial

Sample #	Initial total dry mass (g)	Recovered total dry mass (g)	Mass change (%)
25	2.1698	0.0016	-99.9263
26	2.2008	0.0265	-98.7959
27	2.1690	0.0634	-97.0770
28	2.1533	0.0034	-99.8420
29	2.2159	0.0563	-97.4593
30	2.2456	0.0145	-99.3543
Mean	**2.1924**	**0.0276**	**-98.7425**

Woven Fabric - 150g/m^2 REDA 669

One month burial

Sample #	Initial total dry mass (g)	Recovered total dry mass (g)	Mass change (%)
1	2.2078	0.8580	61.1378
2	2.2531	1.3870	38.4401
3	2.2370	1.2179	45.5565
4	2.2281	0.7738	65.2709
5	2.1967	1.1038	49.7519
6	2.1913	1.6289	25.6651
Mean	**2.2190**	**1.1616**	**47.6371**

Two months burial

Sample #	Initial total dry mass (g)	Recovered total dry mass (g)	Mass change (%)
7	2.1771	0.2747	87.3823
8	2.1624	0.1071	95.0472
9	2.1858	0.0688	96.8524
10	2.2026	0.0072	99.6731
11	2.1840	0.0078	99.6429
12	2.1835	0.0054	99.7527
Mean	**2.1826**	**0.0785**	**96.3918**

Three months burial

Sample #	Initial total dry mass (g)	Recovered total dry mass (g)	Mass change (%)
13	2.2238	0.0011	99.9505
14	2.2260	0.0402	98.1941
15	2.2030	0.0027	99.8774
16	2.2175	0.0846	96.1849
17	2.2108	0.0001	99.9955
18	2.2072	0.0476	97.8434
Mean	**2.2147**	**0.0294**	**98.6743**

Six months burial

Sample #	Initial total dry mass (g)	Recovered total dry mass (g)	Mass change (%)
19	2.2067	0	100
20	2.2205	0.0085	99.6172
21	2.1690	0	100
22	2.1875	0	100
23	2.2271	0.0052	99.7665
24	2.2490	0.0001	99.9956
Mean	**2.2100**	**0.0023**	**99.8966**

Nine months burial

Sample #	Initial total dry mass (g)	Recovered total dry mass (g)	Mass change (%)
25	2.2061	0	100
26	2.2102	0	100
27	2.2235	0.0001	99.9955
28	2.2329	0.0023	99.8970
29	2.2063	0.0309	98.5995
30	2.1814	0.0015	99.9312
Mean	**2.2101**	**0.0058**	**99.7372**

Carpet - 100% tufted wool

One month burial

Sample #	Initial total dry mass (g)	Recovered total dry mass (g)	Mass change (%)
1	41.5695	40.9848	1.4066
2	40.9406	39.4562	3.6257
3	43.2982	41.7674	3.5355
4	41.8061	41.3355	1.1257
5	42.0954	41.4658	1.4957
6	42.7658	41.2651	3.5091
Mean	**42.0793**	**41.0458**	**2.4497**

Two months burial

Sample #	Initial total dry mass (g)	Recovered total dry mass (g)	Mass change (%)
7	42.1408	36.7377	12.8215
8	45.7734	40.5283	11.4588
9	42.7241	37.5311	12.1547
10	41.5714	36.6263	11.8954
11	42.8580	36.9958	13.6782
12	43.5073	37.6462	13.7153
Mean	**43.0958**	**37.6776**	**12.6207**

Three months burial

Sample #	Initial total dry mass (g)	Recovered total dry mass (g)	Mass change (%)
13	42.7582	33.9541	20.5904
14	42.7785	34.4812	19.3960
15	41.9467	33.3148	20.5783
16	43.8106	36.8830	15.8126
17	41.4142	32.5598	21.3801
18	43.0993	35.0607	18.6513
Mean	**42.6346**	**34.3756**	**19.4015**

Six months burial

Sample #	Initial total dry mass (g)	Recovered total dry mass (g)	Mass change (%)
19	45.3664	31.9194	29.6409
20	41.4777	28.1522	32.1269
21	42.4049	31.5046	25.7053
22	42.3636	32.1330	24.1495
23	44.4996	35.1431	21.0260
24	41.5343	33.1418	20.2062
Mean	**42.9411**	**31.9990**	**25.4758**

Nine months burial

Sample #	Initial total dry mass (g)	Recovered total dry mass (g)	Mass change (%)
25	41.2470	30.2797	-26.5893
26	41.8662	30.0359	-28.2574
27	43.6745	32.2081	-26.2542
28	41.6240	31.1623	-25.1338
29	42.1331	29.6140	-29.7132
30	43.0580	31.2368	-27.4541
Mean	**42.2671**	**30.7561**	**-27.2337**

Carpet – 100% solution dyed tufted nylon

One month burial

Sample #	Initial total dry mass (g)	Recovered total dry mass (g)	Mass change (%)
1	35.4564	35.2015	-0.7189
2	36.9544	36.7154	-0.6467
3	35.0691	34.8540	-0.6134
4	35.0540	34.8146	-0.6829
5	35.6675	35.4699	-0.5540
6	35.4729	35.2768	-0.5528
Mean	**35.6124**	**35.3887**	**-0.6281**

Two months burial

Sample #	Initial total dry mass (g)	Recovered total dry mass (g)	Mass change (%)
7	34.8391	34.6292	0.6025
8	34.7099	34.5457	0.4731
9	36.9249	36.6865	0.6456
10	37.8075	37.5616	0.6504
11	35.9593	35.8777	0.2269
12	35.2067	34.9918	0.6104
Mean	**35.9079**	**35.7154**	**0.5348**

Three months burial

Sample #	Initial total dry mass (g)	Recovered total dry mass (g)	Mass change (%)
13	35.8479	35.7644	0.2329
14	35.8212	35.7273	0.2621
15	34.6385	34.3951	0.7027
16	35.6055	35.6048	0.0010
17	36.7766	36.5774	0.5416
18	35.9711	35.8289	0.3953
Mean	**35.7768**	**35.6497**	**0.3561**

Six months burial

Sample #	Initial total dry mass (g)	Recovered total dry mass (g)	Mass change (%)
19	37.8124	37.5822	0.6088
20	38.1190	37.9624	0.4108
21	36.6902	36.6483	0.1142
22	37.2874	37.0962	0.5128
23	37.6470	37.2172	1.1417
24	38.7063	38.5676	1.5113
Mean	**37.7104**	**37.5123**	**0.7166**

Nine months burial

Sample #	Initial total dry mass (g)	Recovered total dry mass (g)	Mass change (%)
25	35.7495	35.6279	-0.3401
26	34.1119	34.0252	-0.2542
27	34.5007	34.4330	-0.1962
28	34.4599	34.5580	+0.2847
29	36.0080	36.4312	+1.1753
30	36.5517	36.9835	+1.1813
Mean	**35.2303**	**35.3431**	**+0.3085**

Carpet - 80/20% woven wool/nylon carpet

One month burial

Sample #	Initial total dry mass (g)	Recovered total dry mass (g)	Mass change (%)
1	27.4230	25.0272	8.7365
2	26.4871	24.6938	6.7705
3	25.9256	23.6738	8.6856
4	26.6073	24.1795	9.1246
5	26.4001	23.3728	11.4670
6	25.9648	21.1192	18.6622
Mean	**26.4680**	**23.6777**	**10.5744**

Two months burial

Sample #	Initial total dry mass (g)	Recovered total dry mass (g)	Mass change (%)
7	26.7416	21.1635	20.8593
8	26.9470	21.6669	19.5944
9	26.2621	20.8565	20.5833
10	26.6668	22.8725	14.2286
11	25.1429	19.9146	20.7943
12	25.1250	18.3070	27.1363
Mean	**26.1476**	**20.7968**	**20.5327**

Three months burial

Sample #	Initial total dry mass (g)	Recovered total dry mass (g)	Mass change (%)
13	26.2608	17.7428	32.4362
14	26.0960	17.0016	34.8498
15	26.4083	18.0546	31.6329
16	26.8714	19.7570	26.4757
17	25.5668	17.3322	32.2082
18	25.6460	15.7977	38.4009
Mean	**26.1416**	**17.6143**	**32.6673**

Six months burial

Sample #	Initial total dry mass (g)	Recovered total dry mass (g)	Mass change (%)
19	25.5985	14.0387	45.1581
20	26.2302	17.1940	34.4496
21	26.9415	15.9287	40.8767
22	26.5040	13.9072	47.5279
23	25.5621	13.7443	46.2317
24	26.1429	12.2949	52.9704
Mean	**26.1632**	**14.5180**	**44.5357**

Nine months burial

Sample #	Initial total dry mass (g)	Recovered total dry mass (g)	Mass change (%)
25	28.0043	**14.6532**	**47.6752**
26	27.4343	**16.8513**	**38.25758**
27	27.4638	**16.9625**	**38.2369**
28	26.9297	**14.3500**	**46.6945**
29	26.3478	**15.6938**	**40.4360**
30	26.0523	**14.1076**	**45.8489**
Mean	**27.0387**	**15.4364**	**42.9112**

Hosiery – Bio-tec socks

Nine months burial

Sample #	Initial total dry mass (g)	Recovered total dry mass (g)	Mass change (%)
1	13.5804	6.9789	-48.6105
2	14.1493	6.8662	-51.4732
3	14.1794	8.2908	-41.5293
Mean	**13.8396**	**7.3786**	**-47.2043**

Hosiery – Nylon socks

Nine months burial

Sample #	Initial total dry mass (g)	Recovered total dry mass (g)	Mass loss (%)
1	13.8031	8.5605	-37.9813
2	13.9329	8.0980	-41.8786
3	13.8443	6.7240	-51.4313
Mean	**13.8609**	**7.7942**	**-43.7637**