MIRO - FINAL REPORT

A Generic Model For The Formulation Of Growing Media From Composts And Quarry Fines

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SUMMARY

The production of a growing media or topsoil from blended quarry fines and compost will potentially provide a value-added and sustainable outlet for two underused/waste-derived materials. The growing media and topsoil markets are both highly competitive and will require the blended materials to match the criteria of existing products. To produce a viable product there are some key considerations that need to be addressed. The largest barrier to be overcome will be the bulk density of the material. This is higher than all other growing media, and is similar to, or greater than that of most synthetic topsoils. As growing media and topsoils are usually sold by volume but transported by weight, the bulk density will have a significant effect on the transport costs of the material. The specific physical and chemical characteristics of the quarry fines and composts will have a significant effect on the viability of the product. Assessing the suitability of specific quarry fines and composts will require comprehensive laboratory analysis and ideally the undertaking of blending and growing trials. Some artificial topsoils are already being produced using blends of quarry fines and composts. This tends to occur in areas where the cost of natural topsoils is high, or where the properties of the quarry fines and compost match the requirement of a particular application. The relative sustainability of the materials can be used as a selling point in comparison to peat-based growing media, or agriculturally derived topsoils.

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1. INTRODUCTION: SCOPE OF STUDY

The blending of quarry fines and composts to produce a growing media and topsoil utilises two low-value and underused/waste-derived materials to produce a potentially valuable new product. This product can be used to replace less sustainable materials such as peat for use in growing media, and agriculturally-derived topsoils, with a quality capable of matching existing growing media and topsoils.

This report addresses the key issues regarding the production of a growing media/topsoil from blended quarry fines and compost. This includes sourcing of the raw materials, the location of the production facility, the production method and costs, the potential markets for the material, and environmental and health and safety issues. An appendix containing a summary of the most relevant legislation and industry standards has also been included.

The primary objective of the project was to identify the production requirements for a growing media. Although some definitions of growing media state that it is a material used to grow plants in pots or other containers, in this report the term growing media has been used in the widest sense and includes the production of artificial topsoil.

2. KEY FINDINGS

This study has generated the following key findings:

- The higher bulk density of the blended quarry fines and composts will have the greatest influence on the viability of the production of a growing media or topsoil, this is due the increased transportation costs relative to competing products.

- The success of a particular growing media and topsoil will depend on specific characteristics of the quarry fines and compost. Their suitability for use will need to be assessed on an individual basis.

- Some synthetic topsoils are already being produced from blended quarry fines and compost. They are being produced where the local price of topsoil is high, or where the specification of a particular contract commands a higher selling price.

- The cost of production and distributing a growing media or topsoil composed of blended quarry fines and compost will usually be greater than, or similar to, competing products. An increase in the production of growing media and topsoil from quarry fines and composts will require either a reduction in the production costs, or the targeting of specific markets in which the relative sustainability of the material can be used to attract a premium price.

3. PRODUCTION OF GROWING MEDIA AND TOPSOILS FROM QUARRY FINES AND COMPOST

3.1. Drivers

The main drivers for this project relate to legislation affecting the aggregates industry and the disposal of waste. The Aggregate Levy (HMSO 2002 and Appendix 2.2) has affected the outlets for quarry fines in the construction and road building areas. Although prior to the introduction of the Levy significant volumes of unused fines were being stockpiled, the introduction of the Levy has now made it even harder to find suitable outlets for this material due to Levy exempt competing materials such as secondary aggregates and recycled C&D waste being used instead. The implementation of the Landfill Directive (EU 1999) requiring increasing amounts of organic waste to be diverted from landfill and recycled, and the introduction of the Landfill Tax (HMSO 1996a) have both contributed to an increase in the amount of organic waste material being composted. The production of a growing media/topsoil from blended quarry fines and compost will provide an outlet and potentially add-value to both of these materials.

3.2. Description of growing media and topsoil

A growing medium is material used to grow plants in containers. It should be physically and biologically stable and with little variability, physically and nutritionally, between batches (ODPM 2003); and it should be able to provide roots with firmness, a good oxygen supply under very wet conditions, water, and nutrition ions buffered by a small adsorption complex (only humus colloids, no clay minerals) (Koolen & Rossignol 1998).

BS 3882 (BSI 1994) describes a naturally occurring topsoil as '…the dynamic product of chemical, physical and biological processes'. Any manufactured topsoil should have similar properties to a natural topsoil. The use of BS3882 enables the classification of natural and synthetic topsoils according to a range of parameters including texture, stone content, nutrient content, and organic content.

WRAP (2003a) describes the ideal characteristics of a successful growing medium. The air-filled porosity (AFP) and the water-holding capacity (WHC) of growing media are dependent on the proportion of particle sizes in the mix. This requirement highlights the need for the quarry fines to be of a suitable grading. The ideal proportion of AFP to WHC will depend upon the type of cultivar, the size of the container, the irrigation system and other circumstances. The growing media should also be free flowing in order to facilitate efficient blending, bagging and eventually, filling of plant containers. Flow properties are a function not only of particle size and shape but also of moisture content.

The Government has set a target of 40% of the former uses of peat to be replaced by alternative materials by 2005 (DoE 1995). This target is well on the way to being realised. However the amount of replacement of peat in growing media is very low; most of the peat replacement has been in the soil conditioner sector. Organisations such as "Peatering Out™" have set targets to replace approximately 45% of peat in growing media (Rainbow Wilson Associates *et al.* 2003), by the progressive substitution with greenwaste compost and woody materials. There is some debate as to whether peat can be successfully eliminated from all horticultural applications. Composted greenwaste, for example, has a higher pH (8.4 compared with 4.5), a higher conductivity and a greater bulk density. Godley *et al.,* (2002) thinks that while these properties will produce a good soil conditioner in order to make a growing medium the pH and conductivity will need to be reduced. Blending such composts with quarry fines will help to moderate the conductivity of the compost and in some cases the pH.

3.3. Previous work on blending quarry fines and compost to produce a growing media/topsoil

There have been a number of studies which have investigated the potential of blended quarry fines and composts for use as a growing media or topsoil. This includes work undertaken by Mineral Solutions (2004a), and by Keeling *et al.* (unpublished). These studies have shown that most types of quarry fines and composts will support satisfactory plant growth but with varying success depending upon the specific physical and chemical properties of the materials used.

Mineral Solutions (2004a) investigated the use of igneous rock quarry fines from southern Scotland and northern England with a range of composts. Tomato growth trials showed that the compost type had the greatest effect on the quality of growth, and the rock fines either improved or had no effect. Quarry fines however, were shown to significantly improve the quality of the growing media produced from the least successful (low nitrogen) compost. The most successful blends were found to be those which had a high nitrogen concentration (sourced from the compost). However this high nitrogen concentration had implications in terms of the potential release of nitrates to the environment (Nitrates Directive Appendix 2.3). Lysimeter trials on grass plots showed that a lot of this nitrogen was being leached from the growing media/topsoil blends. It was likely that this high concentration of mobile nitrogen was related to the maturity of the composts used, with the highest release from the least mature compost which was still in the final stages of the composting process. The release of potentially toxic elements (PTEs) was found to be negligible for all of the blends tested.

The most important effect the quarry fines on the blended growing media/topsoil was with regards the soil texture. The precise grading of the quarry fines will affect the soil texture and hence the physical properties of the material. Fines with a high proportion of silt of clay minerals had a much lower trafficability than sand-grade dominated fines.

Keeling *et al.* (unpublished) investigated the use of quarry fines from sandstones and limestones of the midlands of England with a range of composts. The trails involved the growth of trees and grass on synthetic soil produced from quarry fines (including sands, silt and clay) and composts (green waste, paper sludge waste and tannery waste). Over the 15 month trial period grass growth was good with most blends, but the establishment of trees was more variable, with the development of tree growth mostly influenced by the compost type than the mineral type. Tannery waste compost had the best overall growth, due to its high initial N content. All of the synthetic soils produced in the trial had pH values of between 6.7-8, and electrical conductivity of between 2000 and 3000 mS/cm, which were found to be acceptable for grass and tree growth (despite the conductivity being at the limit of the recommendations for compost as a component for use in topsoil manufacture and above that recommended for use in growing media and general landscaping (The Landscape Institute and WRAP 2003). Both the paper sludge and green waste composts were found to be low in nitrogen. Tree and grass growth was found to be best in soils which contained predominantly sand-grade fines, in which rooting was easily facilitated and drainage was good. The soils with a high clay/silt content feared less well although they still produced a reasonably grass growth. This was due to the structure of the soil produced, which reflects both the inherent soil textural properties of the clay/silt grains in the fines and the implications these had on the mixing and spreading of the material.

In both of the projects the compost was found to exert the greatest effect on the potential for plant growth of the growing media/topsoil. The quarry fines influence the texture of the material and therefore its structure and workability.

3.4. The role of quarry fines and composts in the production of a growing media/topsoil

3.4.1. Quarry fines

The addition of rock fines to a blended growing media/topsoil produced with compost can improve its structural and chemical properties, contribute plant available nutrients, and act as a moderator of soil chemistry. Table 1 describes the range of minerals found in the main rock types used in aggregate production. These nutrients will be released over time and provide a supply throughout the growing season, and without the pollution caused by soluble fertilisers.

Table 1. Particle-size and mineralogy of quarry fines from UK quarries (Mitchell *et al.* 2001)

Rock type	**Particle-size distribution**		**Mineralogy (not all minerals may be present**
	Sand (wt% 2mm-0.075mm)	**Silt/clay (wt%<0.075mm)**	
Limestone			Mainly calcite (or dolomite) with a minor amount of quartz, mica, fluorite, barytes, kaolinite, pyrite & iron oxide
-Plant fines	57.9	17.2	
-Filler fines	11.4	88.4	
Sandstone			Mainly quartz, with s small amount of feldspar & calcite and a minor amount of mica, chlorite, rutile, dolomite & iron oxide
-Plant fines	55.9	19.3	
-Filler fines	18.4	80.2	
Igneous			Mainly quartz & feldspar, small amount of pyroxene & amphibole, and a minor amount of rutile, olivine, mica, chlorite & serpentinite
-Plant fines	53.5	14.0	
-Filler fines	7.2	92.5	
Sand & Gravel			Mainly quartz and a minor amount of feldspar, calcite, mica, rutile & kaolinite
-plant fines	49.7	48.4	

Data derived from analysis of quarry fines from 11 limestone quarries, 4 sandstone quarries, 7 igneous rock quarries and 9 sand & gravel processing plants

The type of rock and the grading of the fines will affect the success of the blended growing media/topsoil. The fines from a crushed quartzite rock (consisting mostly of quartz - SiO_2) will provide a very limited amount of plant nutrients and their benefit to the growing media/topsoil will be solely from the improved structure to the growing media, and as a means of diluting the high conductivity of many composts (Section 3.5). Some rocks (e.g. dolerites) contain minerals which are more susceptible to weathering and also contain a higher concentration of major and trace elements. These can help to compensate for any nutritional deficiencies in the compost. The size distribution of fines will influence the texture of the growing media/topsoil that is produced. The texture will affect the ease of blending of the material during production, and the trafficability of the material when in use. The size distribution of fines and therefore the texture can vary markedly even for rocks with the same composition (Table 2). Texture is one of the key parameters that is used to classify the quality of topsoil in the British Standard for topsoil, BS 3882:1994 (BSI 1994 and Appendix 2.1)

Table 2. Relative proportions of sand, silt, and clay fractions for igneous fines from different quarried sources (Modified from Mineral Solutions Limited (2004b))

	Dolerite	**Dolerite**	**Basalt**	**Felsite**
Sand (% w/w) 2.00-0.063mm	70	8	81	88
Silt (% w/w) 0.063-0.002mm	15	82	7	4
Clay (% w/w) <0.002mm	15	10	12	8
Textural Class (BS3882:1994)	Sandy loam	Silt loam	Sandy loam	Loamy sand
Soil grade - BS3882:1994	Premium	Premium	Premium	General purpose

3.4.2. Composts

Compost as a source of organic matter improves the available soil water reserves, drainage, and resistance to erosion, largely through its effect on the structure of the soil by increasing the formation of soil aggregates (BSI 1994, and The Landscaping Institute & WRAP 2003). When organic matter is added to soil its ratio of carbon to nitrogen C:N is important, generally speaking for topsoil and similar applications the C:N ratio in the compost should be up to a maximum of 20:1 (WRAP 2003c). The proportion of carbon to nitrogen in compost can vary due to changes in the feedstock and with seasons.

Compost can also reduce the need for inorganic fertilisers, be beneficial to soil micro-organisms, increases the CEC and trafficability, and improves the visual performance of a growing media or soil conditioner (WRAP 2003b). Compost contains slow release sources of nitrogen, phosphate and sulphur (Table 3). It contains good amounts of readily available potash plus smaller but useful amounts of magnesium, calcium and essential trace elements including iron, copper, manganese, zinc, boron, & molybdenum (Rainbow Wilson Associates *et al.* 2003).

Table 3. Typical total nutrient content of compost kg tonne^{-1} moist compost (WRAP 2003b)

Nitrogen as N	**Phosphate as P_2O_5**	**Potash as K_2O**	**Magnesium as Mg**	**Sulphur as S**
8.1	3.3	6.6	2	1

Compost also has a small acid neutralising value and is about 10% as effective as limestone, tonne for tonne of dry matter. Compost can therefore stabilise soil pH and reduce the acidifying effects of inorganic fertilisers (WRAP 2003b). Some micro-organisms in compost can help to mobilise nutrients (WRAP 2003a), this function would be important in helping to release nutrients from within the quarry fines of the blended growing media/topsoil.

3.5. Limitations of using quarry fines and composts

There are concerns regarding the high salinity of composts which can have an osmotic effect on root activity; a toxicity effect; and a soil structural stability effect, depending on the proportion of sodium in the form of soluble ions. In most cases the quarry fines will have a low salinity/conductivity as they are largely composed of insoluble minerals.

In Germany the use of green compost in growing media at rates of greater than 35% has caused problems due to high nutrient levels (ODPM 2003). The effect of blended the compost with quarry fines will result in the overall reduction of the salinity of the topsoil/growing media but salinity of the growing medium/topsoil should still be routinely assessed to ensure it fulfils the required specifications. Increasing the standing period (maturation) after the completion of the composting process can also reduce the salinity as the compost becomes more stable. However immature may still be suitable for the production of topsoils that are going to be planted with trees and shrubs and not a growing media suitable for the growing seedlings and cuttings.

Although the addition of quarry fines will solve the potential problem of high conductivity it will have the counter effect with regards the bulk density. For the vast majority of quarry fines the bulk density will be greater than green compost, therefore the bulk density of the blended quarry fines and compost will be even greater. It is the effect the density has on the cost of transportation that appears to pose the largest barrier to the use of blended quarry fines and compost. The implications of the density of transportation are discussed in Section 7.3. The higher density of blended quarry fines and compost will also affect its suitability for use in certain markets. The WRAP Fact Sheet 09 'Use of composted material in growing media for professional growers (WRAP 2003a) sets the maximum bulk density of compost suitable for use in a professional growing medium as 600 kg/m^3 (fresh weight basis). It also states that although this is a higher density than peat, when blended with other materials such as peat or wood waste the overall density will be reduced, and that when thoroughly watered the difference is reduced. Using the recommended mixing ratio of compost for use in topsoil in (WRAP 2003c) gives a density of 1541kg/m^3 for some of the blends of quarry fines/greenwaste used in a study by Mineral Solutions Limited (2004a).

4. RAW MATERIALS

4.1. Quarry fines – composition, volumes and locations

The current trend is for an increase in the accumulation of stockpiles of fines within quarries from the production of primary aggregates. This has occurred due in part to changes in the specification with both an preference for smaller aggregate grading that requires greater crushing, and a demand for higher PSV (Polished Stone Value) material, which in many cases has resulted in an increased extraction of sandstones, which produce the largest volume of fines (Table 4) The introduction of the Aggregates Levy (HMSO 2002 & Appendix 2.2) on primary extraction has also affected the markets for fines; they attract the levy for all construction and road building applications and are in direct competition with demolition fines and other industrial waste materials which do not qualify for the Aggregates Levy. The change in the type of crusher to impact crushers from cone crushers has also increased the production of fines.

Table 4. Estimated production of quarry fines in Great Britain from different rock types (Mineral Solutions Limited 2004b)

Rock type	Annual production (2002)	Typical % fines	Estimated fines production
Sandstone	12 million tonnes	30%	3.6 million tonnes
Limestone[1]	106 million tonnes	20%	21.2 million tonnes
Igneous	45 million tonnes	20%	9.0 million tonnes
Sand and gravel[2]	75 million tonnes	10%	7.5 million tonnes
Total			**41.3 million tonnes**

[1]including dolomite and chalk; [2]land-won

Fines are an inevitable outcome of processing of rocks during crushing for aggregates. The proportion of fines produced depends upon the type of rock and the nature of the processing. The total amount of primary aggregates produced annually in the UK is approximately 200 million tonnes (Highley *et al.* 2003). Quarry fines consist of a graded mix of coarse sand, medium sands and fine sand sized particles, plus a clay/silt fraction (known as the 'filler' grade) which is material less than 0.075mm (75mm) (Mineral Solutions 2004b).

Mineral Solutions Limited (2004b) discovered that the quality of most fines produced in the UK is poorly known with very little technical information available in published literature and limited access to known data due to commercial sensitivity. However a BGS report (Mitchell *et al.* 2001) assessed fines from 30 aggregate operations in the UK and determined their mineralogy, chemistry, and particle size distribution (Table 1). As can be seen the proportion of sand grade particles is greatest from the crushing plant fines, with the filler fines predominantly in the silt/clay grade. The output from sand and gravel operations, where no or little crushing takes place, is split evenly between the sand and silt/clay fractions. The size distributions of fines will have a significant effect on the texture of the blended growing media/topsoil. Under BS 3882:1994 (BSI 1994) the textural classification is used as part of the assessment of the grade of the topsoil. The proportion of 'filler' grade (<75mm) (clay and silt sized) material will have a major impact on the textural class of the material.

Quarry fines tend to be slightly alkaline and may contain naturally high levels of certain heavy metals. Keeling *et al.* (unpublished), also discovered that the pH of samples of quarry fines from the same quarry varied considerably with time. This was believed to reflect the variability in the sedimentary geological units being quarried, and the duration of exposure of quarry fines to leaching by rainwater from the stockpiles. Mitchell *et al.* (2001) discovered that the properties of the quarry fines of a particular rock type could not be predicted between quarries due to the natural variability of the rock worked and the different crushing technologies employed. Generally igneous rock derived fines, from a single source/quarry will give a more consistent product than fines derived from sedimentary quarries.

4.2. Composts – production, volumes and locations

There are a number of types of compost (Table 5), and within these categories there can be variations in the composition of the compost due to the precise characteristics of the feed. Presently most compost that is used in the growing media, topsoil, and soil improver market is greenwaste compost. This is perceived to have the least risk of pathogens and potentially toxic elements and is deemed by the industry to be the most acceptable material to the public, and the most straightforward to process and achieve BSI PAS 100 (BSI 2002 and Appendix 2.1) accreditation. This does not mean that it is necessarily the best compost to use in a blended growing media/topsoil particularly as it can often have a lower nitrogen concentration than some other composts (Keeling *et al.* unpublished). As more organic waste is diverted from landfill the range of compost types will increase.

In 2001 there were 132 centralised (non-farm based) composting sites which were run by 83 operators. The centralised sites were responsible for processing over 90% of the separately collected organics in the UK. Small-to-medium sized facilities remain the focus of the industry, with the average centralised site processing 8000 tonnes per annum (Davies 2003). 82% of the centralised sites producing compost held a waste management license, this compares to only 17% at on-farm sites. The remainder of the latter are on-farm sites which process material under a Waste Management License Exemption (HMSO 1994a & EA 2001b) (Appendix 2.3) and so are unable to sell, or use their compost off-site. The source of material composted in the UK is currently dominated by municipal waste and the majority of this is composed of garden waste, taken to civic amenity sites.

Table 5. Types of compost and general characteristics (Adapted from Mineral Solutions Limited 2004a and Gilbert *et al.* 2001)

Compost Types	Feedstock	Nitrogen content
Food Industry (FI)	Food industry wastes (from restaurants, etc.)	Medium to high
Green Waste processed indoors (GW)	"Organic garden waste such as grass clippings, tree prunings, leaves, etc. which can be used as composting feedstocks. Synonymous with 'garden wastes', 'yard trimmings', 'botanical wastes' or 'garden trimmings'. They can arise from domestic gardens, public areas, private parks or gardens, or landscaping activities."	Low to medium depending on the composting process used, such as maturation of the composted material outdoors (low in key nutrients N, P, K), or indoors (higher in key nutrients N, P, K)
Anaerobic Digested (AD)	Any feedstock, including animal by-products (carcasses, blood, etc.) "A natural, biological process in which bacteria break down organic matter in a controlled oxygen-free (anaerobic) environment. The major end products of AD are biogas and digestate. "Occurring in the absence of oxygen. Some micro-organisms (anaerobes) only function and break down substances in environments without oxygen. In the process, they release by-products such as methane (a potent greenhouse gas) and volatile fatty acids (frequently odorous), which can be problematic in aerobic composting.	Depends on feedstock used, but the digestion process reduces greatly the initial high nitrogen and E-coli contents.
Municipal Wastes (MW) And Municipal Solid Waste (MSW)	"Household waste plus any other wastes collected by a Waste Collection Authority, or its agents, which may include municipal parks and gardens waste, beach cleansing waste, commercial or industrial waste and waste from the clearance of fly-tipped materials" MSW generally refers to household wastes.	Depends on feedstock used.
Kerbside Collection (KC)	"Organic wastes, or other recyclables, which are regularly collected from commercial and industrial premises and households"	Low to medium

The use of compost in growing media and other horticultural applications is currently dominated by greenwaste compost. An assessment of the potential production of greenwaste compost for use in growing media was made by Waller and Temple-Heald (2003). This study revealed that there were 55 green compost production sites in the UK which each had inputs of more than 10,000 tonnes of green waste per annum. These sites have licences for the production of about 1 million tonnes and currently produce about 740,000 tonnes between them. However of this, only 165,000 tonnes (300,000m^3, assuming a bulk density of 550kg m^{-3}) were of a suitable grade (0-12mm) for use in growing media, and only 68,000m^3 (~37,400 tonnes) per annum was actually sold to growing media manufacturers (with 72% of this material supplied by three producers (SITA, Moody and Onyx). The remainder of the 165,000 tonnes of the graded (0-12mm) greenwaste compost was sold into the soil improver market (including 100,000m^3 a^{-1} by a consortium of four waste management companies (Godley *et al.* 2002)).

Waller and Temple-Heald (2003) assessed that the potential volume of green compost suitable for inclusion in growing media is likely to rise to about 275,000m^3 per annum in the next two to three years, with the potential for extra capacity of at least another 150,000m^3 by 2005. This could represent an average 29% of retail growing media formulations. This study identified that despite legislative pressure to reduce the use of peat in growing media, it will ultimately be economic and logistical factors (particularly transportation costs) that will determine the mix of substrates used in the production of UK growing media.

The viability of using composted materials in growing media will also be influenced by the availability and the price of imported peat. The current trend is for the price of peat to increase as the continuing decline in availability of UK and German peat will lead to increasing dependence upon peat from Ireland, the Baltic States and Scandinavia. Peat available from theses sources is not infinite and membership of the European Union of most of these countries in 2004 will bring further restrictions on the rate of peat extraction.

Waller and Temple-Heald (2003) looked at the size of greenwaste composters and the market structure and concluded that the volume of green compost required by growing media producers is likely to favour large suppliers who can produce a large volume of consistent, quality assured product at a reasonable cost. It was thought to be less likely that a proliferation of small green compost producers would be able to meet the needs of the growing media manufacturing industry. This study focussed on the bagged retail market for growing media production. The opportunity for small operators producing a bulk topsoil for use by landscapers and amenity contractors has not been assessed. In the context of producing topsoil for specific contracts the use of a compost from a small local producer could significantly reduce the cost of production by eliminating some transport costs.

4.3. Sourcing of quarry fines and composts

4.3.1. Quarry fines

While it is possible to make general descriptions of the characteristics of fines, variability can be significant even within a single quarry, reflecting changes in geology and processing. The method of crushing and screening will have an impact on the size distribution of the material, and therefore the texture of the growing media/topsoil, and potentially the rate of nutrient release from the quarry fines. Samples of material from a specific quarry would need to be analysed to assess its suitability for its use in a growing media/topsoil. Particle-size distributions for soil classification can be found in BS 3882 (BSI 1994). Analysis of quarry fines will also need to be undertaken for the bulk mineralogy, trace element concentrations and other chemical and physical parameters. It would also be necessary to monitor the fines periodically during production to check that they conform to the desired characteristics. In some cases it may be necessary to process the fines further to the match the required properties. It is possible to obtain the details of quarries in the UK by area and by rock type using the United Kingdom the ‘Directory of Mines and Quarries 2002 (Cameron 2002). This contains over 2000 entries for active and inactive mines and quarries. The data is arranged by mineral commodity, region and Mineral Planning Authority area, and includes the name of an individual quarry or mine, its grid reference and location, and the geology and specific products. Addresses and telephone numbers to all of the quarries are provided by company in an index.

4.3.2. Compost

Compost can be produced from a range of materials (Table 6), and by a number of processes. The BSI PAS 100 (BSI 1994) standard for compost production is the only industry standard which provides a robust quality standard for compost. This standard does not include every parameter that would be useful to the producing of a blended growing medium/topsoil such as the major nutrient concentrations and grading. Therefore all compost to be used to produce a growing media/topsoil, including PAS 100 accredited compost will need to be analysed for all the parameters appropriate to the end-use of the material. To produce a consistent quality of blended growing media/topsoil it is important that the composition of the compost is constant throughout the year. Some types of compost have a large potential for variability due to different source material and seasonal changes of supply. The potential for variability in compost composition will need to be assessed and monitored/amended as part of the production process.

Sources of compost can be found via The Composting Association website (The Composting Association 2004) (www.compost.org.uk). This site contains a searchable database, by region listing producers of compost and their contact details (www.compost.org.uk/dsp_producers.cfm). An up to date list of BSI PAS 100 accredited compost producers is available on The Composting Association website and also on the WRAP website (WRAP 2004) (www.wrap.org.uk/organics_home.asp).

Table 6. Quantities and types of feedstocks composted in the UK. (Davies 2003)

Waste type	Source	Quantity (tonnes)	% of category	% of total
Municipal	**Garden from Civic Amenity/bring sites**	1,037,756	86.2	62.4
	Garden only from kerbside collections	115,196	9.6	6.9
	Garden and kitchen from kerbside collection	46,816	3.9	2.8
	Other	3,767	0.3	0.2
	Total household	**1,203,535**	**100.0**	**72.3**
Municipal non-household	**LA parks and garden**	38,460	28.5	2.3
	Other municipal landscape	12,499	9.3	0.8
	Food from processors (municipal)	60,566	44.9	3.6
	Food from retailers (municipal)	8,096	6.0	0.5
	Other municipal	15,340	11.4	0.9
	Total non-household	**134,961**	**100.0**	**8.1**
Commercial and industrial	**Commercial landscape**	89,798	27.6	5.4
	Forestry	122,512	37.7	7.4
	Sewage sludge	27,615	8.5	1.7
	Food processing	32,475	10.0	2.0
	Food retailers	545	0.2	0.0
	Paper pulp	4,748	1.5	0.3
	Paper and card	1,357	0.4	0.1
	Other organic by-prod	6,716	2.1	0.4
	Agriculture	39,590	12.2	2.4
	Total commercial and industrial	**325,356**	**100.0**	**19.6**
TOTAL COMPOSTED		**1,663,852**		**100.0**

Table 6 shows the break down of the composting data according to the source and type. This gives an idea of the volumes and types of compost material available that could be used for blending with quarry fines to produce a growing media/topsoil. Currently the high quality PAS 100 accredited compost has been sourced mainly as greenwaste from household or Local Authority parks and gardens, but other sources of compost may offer a better range of nutrients. Table 7 shows the range of potential sources of commercial wastes organic wastes suitable for composting and the estimated volumes. The selection of the compost type will need to be determined by the requirements of the proposed application and suitable local supply.

Table 7. Estimated quantities of potential compost feedstocks and amount composted at present. (Godley *et al.*, 2002)

Feedstock	Quantity of feedstock available kt	Quantity composted (1999) kt
Food wastes	2260	Not known
Agricultural wastes **-farm slurries and manures**	90,700	32
Forestry waste	500	Not known
Municipal waste **-greenwaste**	17,580*	580-618
Industrial organic waste **-paper mill waste** **-wood processing**	14,114 (710) (710)	136
Construction and demolition	Not known	Not known
Sewage sludge	1058	Some
Total	**125,000**	**900+**

** Estimated as 60% of total municipal waste arising is biodegradable organic waste*

Growing media production would require the finest grade of material (up to 12mm max). Discussions with some of the greenwaste compost producers as part of this project has suggested that they may be some reluctance to grade to the finer fractions if this will compromise the quality of their soil conditioner by removing the fines fraction. Soil conditioners fetch a similar price to growing media so the cost of the finer fraction may increase in order to compensate for the loss of value to the soil conditioner. One option to get around the issue of the grading of this material is to shred the material once it has been composted. However this additional processing will add costs to the production of the material. Gilbert *et al.* (2001) has shown that there may be slight differences in the chemical composition between the different grades of compost (Table 8).

Davies (2003) assessed the volume and gradings of compost used in horticultural applications. The split of size fractions of composts produced in the UK are 0-40mm (42%), 0-25mm (22%), 0-10mm (35%), and 5mm or less (1%). For growing media most of the compost was in the 0-10mm fraction (62%) and for topsoil half of the compost was in the 0-10mm fraction (53%), with the remaining split between the 0-25mm (24%) and 0-40mm (17%) fractions. The use of compost in all of these applications increased between 1999 and 2001, with the greatest growth being for use in topsoil manufacture (2%-9%) (Davies 2003). The latter was mostly used in the on-site blending of existing or screened brownfield soils.

Table 8. Difference in composition of composts (median values) of different compost grades produced in the UK and tested by The Composting Association in 1998 (Gilbert *et al.*, 2001).

Property	Fine compost (£10mm)	Coarse compost (10-25mm)
Total nitrogen (%)	1.0	1.4
Total phosphorous (%)	0.2	0.2
Total potassium (%)	0.5	0.5
PH	8.4	8.5
Electrical conductivity (mS/cm)	715	592
C:N	12.6	12.1
NO3 N (mg/kg dry matter)	44.0	37.5
NH4N (mg/kg dry matter)	12.0	2.0
Mg (mg/kg dry matter)	902	78
Organic matter (%)	26	28

5. CURRENT PRODUCTION OF GROWING MEDIA AND TOPSOIL

5.1. Growing media

The volume of growing media produced in the UK in 2001 was estimated at 3.6 million m^3 per annum, of which 2.3 million m^3 is supplied to the retail market, and 1.3 million m^3 is used by professional growers (ODPM 2003). 1.5 million m^3 of growing media used in the UK is manufactured in Great Britain, with a further 0.4 million m^3 being mixed by individual growers. Of the remainder 1.3 million m^3 is manufactured in Northern Ireland, 0.8 million m^3 is imported as a ready made growing media from the Republic of Ireland, and exports from the Baltic States makes up most of the rest (Waller and Temple-Heald 2003). In the UK most of the growing media production was in Northern Ireland, northwest, and northeast England (Table 9), with no significant growing media production in Scotland or Wales. In England there are no GM manufacturing sites in the southeast region despite this containing the largest market for retail growing media. This distribution reflects the dominance of peat as an ingredient in growing media, with 90% of the material used in growing media manufacture in the 2001 being peat (ODPM 2003). The growing media manufacturing plants are all located adjacent to the sources of peat.

Table 9. Estimate of growing media manufacture by region (Waller and Temple-Heald, 2003)

Region	Retail 000's m^3 per annum	Professional 000's m^3 per annum	Total 000's m^3 per annum
Northeast England	540	275	725
Northwest England	380	220	600
Southwest England	125	60	185
Northern Ireland	1070	250	1320
Direct imports	754	70	824
Own mix (estimate)		400	400
Total	**2779**	**1275**	**4054**

In 2001 the proportion of non-peat substrates used in growing media production in the UK was bark (4%) and greenwaste compost (2.5%). There has been a 66% growth in the use of peat alternative materials (including loam) since 1999 (ODPM 2003). Most of this growth is in the amateur gardening, landscaping and Local Authority sectors, where quality requirements are less stringent than for professional growers (ODPM 2003). The lower uptake by professional growers has been confirmed by responses to telephone questionnaires with professional horticulturists as part of this study. They are very reluctant to use any peat-free or reduced peat materials if they compromise the quality if their product. To encourage a greater use of compost in the production of growing media WRAP have developed a compost specification for use in growing media manufacture (Table 10).

Table 10. Compost characteristics recommended as a good compost for use in growing media manufacture (WRAP, 2003a)

Parameters	Reported as (units of measure)	Recommended range
Bulk density (fresh weight basis)	grams per litre	600 maximum
PH	pH units (1:5 water extract)	8.5 maximum
Electrical conductivity	ms/cm or mS/m (1:5 water extract)	1000 ms/cm max or 100 ms/m max
Screen aperture size	mm	10 maximum
Moisture content	% m/m of fresh weight	35% minimum 55% maximum
Organic matter content	% dry weight basis	>25 minimum

The theoretical potential volumes of compost used in the horticultural sector for growing media and soil conditioners was judged by Godley *et al* (2002) to be limited to about 1 mt a^{-1}, compared to the likely production of compost of about 5mt a^{-1} by 2010 (Godley *et al.* 2002).

Most growing media in the UK is sold in packs of 75 litres or less (2.6 million m^3), and with about 0.3 million m^3 sold in semi-bulk format in big bales or bulk bags of up to $6m^3$. The remainder is sold loose or is 'own-mixed' by nurseries (Waller and Temple-Heald 2003). With the very high seasonal demand for the material (70% of all bagged growing media is sold in the spring), it is not possible to make the material on demand (Waller and Temple-Heald, 2003). Therefore growing media needs to be produced during the year and the material must be capable of being stored for at least 18 months.

Growing media products have to meet a comparatively tight specification in terms of biological, chemical and physical properties (Godley *et al* 2002). This largely reflects having to match the characteristics of peat-based products which are familiar to users, and have a proven track record. Traditionally sphagnum peat has been used to produce a 'compost' for a wide range of horticultural applications. The benefits of using sphagnum peat are it is virtually sterile, it has a good water holding capacity, good aeration and a lower bulk density than soil. It is also relatively simple to add any required nutrients or lime to produce a tailored end-product (Godley *et al.* 2002). Early peat-free or reduced peat alternatives did not perform very well and this has led to a perception that peat-free alternatives will never be able to match the performance of peat. However there are now a range of successful peat-free growing media being used in professional horticulture and sold to the public through retail outlets in the UK. These make use of substrates such as compost, bark, wood brush, coir, wood fibre, sterilised soil, loam, and even biodegradable foam (Petersfield Growing Mediums 2004).

Sterilised loam is used in many peat-free growing media where it is used to improve the water and nutrient holding characteristics (ODPM 2003). This material is often sourced from waste soil from brownfield site developments and other building or road projects. Loam accounted for 17% of the peat alternatives used in growing media in 2001, being the third largest alternative used for all purposes (ODPM 2003). The loam is used at 5-20% by volume of the growing media. It is the clay content of loam/soil that gives the beneficial chemical buffering effect and pure clay minerals are sometimes added to professional growing media to give this effect without increasing the bulk density of the product (ODPM 2003). This approach takes the benefits of adding minerals to a growing medium without significantly increasing the density and transport costs. Higher concentrations of clay-grade particles would have an adverse effect on the properties of the growing media/topsoil.

5.2. Topsoil

Landscapers have highlighted the problem that it has become increasingly more difficult to locate high quality topsoils to use on their projects, and that soils have become more expensive to purchase (The Landscaping Institute and WRAP 2003). It is also becoming less acceptable to harvest soil from agricultural lands only to sell it off as topsoil. It is possible that in a few years the extraction of topsoil from agricultural land may become perceived as an unsustainable source of material in a similar way that peat extraction is perceived now. The Landscape Institute and WRAP have produced a guide ‘Compost specifications for the landscape industry’ (The Landscaping Institute and WRAP 2003), which covers in detail the appropriate selection and production methods for compost for a range of landscaping applications; these include specifications for the use of compost in topsoil (Table 11) and general landscaping (Table 12).

Table 11. Compost characteristics recommended as a good compost for use in topsoil manufacture. (Modified from WRAP 2003c and The Landscaping Institute and WRAP 2003.)

Parameters	Reported as (units of measure)	Recommended range
pH	pH units (1:5 water extract)	6.5-8.7
Electrical conductivity	ms/cm or mS/m (1:5 water extract)	3000 ms/cm max or 300 ms/m max
Moisture content	% m/m of fresh weight	35-55
Organic matter content	%, dry weight basis	>25
Screen aperture size	mm	25 Maximum
Particle sizing	% m/m of air dried sample passing the selected mesh aperture size	95% pass through 25mm screen 90% pass through 10mm screen
C:N Ratio		20:1 Maximum

Table 12. Compost characteristics recommended as a good compost for use in general landscaping (planting beds, tree, shrub and herbaceous planting, turf establishment). (The Landscaping Institute and WRAP 2003.)

Parameters	Reported as (units of measure)	Recommended range
pH	pH units (1:5 water extract)	7.0-8.7
Electrical conductivity	ms/cm or mS/m (1:5 water extract)	2000 ms/cm max Or 200 ms/m max
Moisture content	% m/m of fresh weight	35-55
Organic matter content	%, dry weight basis	>25
Particle sizing	% m/m of air dried sample passing the selected mesh aperture size	99% pass through 25mm screen 90% pass through 10mm screen
C:N Ratio		20:1 Maximum

Most topsoil is currently either removed from agricultural land and greenfield developments or is produced from screening of soil from brownfield sites. There are also companies that are using such materials as sterilised soil (often synonymous with ‘loam’), subsoils, parent materials, overburden, and demolition rubble to blend with compost to produce topsoils. Other materials which can be used depending on a specific local source are silt dredgings, chalk fill, foundry sands, weathered PFA and china clay wastes (Mayer Environmental 2004). A lot of this topsoil production is undertaken on-site of new developments, by simply blending either the existing topsoil or demolition fines with compost. Davies (2003) noticed an increase in the use of compost in topsoil production that appeared to be a result of an increase in aggregate recycling, with crusher fines from on-site demolition being blended with compost to produce a topsoil. This approach minimises the transport costs and provided the material is not contaminated (Section 6.2) should prove to be as effective as most blended quarry fines and composts.

Gregory & Vickers (2003) showed that the addition of crushed brick and composted greenwaste to a clay textured soil in a landfill restoration project, prior to planting, resulted in some improvement in the drainage of the soil and the size of stable soil aggregates. It is the supply of nutrients in an available form which is likely to make recycled aggregate fines less suitable as a source of nutrients in a growing media. Bricks. which consist of fired clay minerals, and concretes, which are made of hydrated minerals will be more stable than quarry fines and will be less likely to release trace elements. This material is likely to have high alkalinities (pHs in the range of 7-10) and will be deficient in potassium and phosphorous (Gilbert 1989).

The authors undertook telephone questionnaires with landscapers. One of the landscaping companies indicated that they are already producing topsoils from blended quarry fines and compost to produce bespoke topsoils to match the specific requirements of their contracts. Understandably they did not wish to provide details of their manufacturing processes and operating costs for this study. The authors have knowledge of at least one other company that is also blending quarry fines and compost to produce a topsoil. This evidence clearly shows that there is a market for this type of material.

The current industry best practice for using compost in landscaping (The Landscaping Institute and WRAP 2003) recommends in paragraph 345; ‘Use imported soils only when required to meet the required soil grade or the textural requirements of the ‘finished’ manufactured product’. It is understood that this refers primarily to the importation of natural topsoil in relation to both the cost, but also has implications for the sustainability of the development. Part of paragraph 300 states however that ‘it may also be required to add another soil material to meet the textural requirements (percent sand, silt, clay) of the manufactured topsoil’. This would be a potential outlet for quarry fines but not in the form of a blended growing media.

Although no artificially produced topsoil can technically be classified as a premium grade soil (BSI 1994), its characteristics may match those soils of this category. The classification between the premium, general purpose and economy grades of topsoil is based on a range of criteria including the texture, nutrient content (Table 13) and pH (Table 14). It is likely that most of the blended quarry fines and compost will be in the equivalent ranges of premium and general purpose grade topsoil. The texture will largely be based upon the grading of the quarry fines and the nutrient content will mostly come from the compost. The pH of some blends of quarry fines and composts used in trails undertaken by Mineral Solutions (2004a) were in the range of 7.5-8.0. This is within the range of general purpose topsoils, but some of the blends would exceed the criteria for classification as a 'premium' grade topsoil. Economy topsoil does not have to provide any nutrients. Under BS 3882 (BSI 1994) any soils with greater than 20% organic matter can be described as peaty. It is likely that most of the blended quarry fines and compost growing medium will be below this threshold.

Table 13. Classification of topsoil analysis results by extractable P, K and Mg (BSI 1994).

Index	Concentration of extractable elements in milligrams per litre of soil		
	P	K	Mg
0	0-9	0-60	0-25
1	10-15	61-120	26-50
2	16-25	121-240	51-100
3	26-45	241-400	101-175
4	46-70	401-600	176-250
5	71-100	601-900	251-350
6	101-140	901-1500	351-600
7	141-200	1501-2400	601-1000
8	201-280	2401-3600	1001-1500
9	over 280	over 3600	over 1500

Table 14. Topsoil characteristics (Adapted from BSI 1994).

	Premium grade	General purpose grade	Economy grade		Method of test
			Low clay	High clay	
Source	Origin to nearest 100m				
Textural classification	See BS 3882	See BS 3882	See BS 3882		BS 1377:Part :1990
Maximum stone content % (m/m) Stone Size					
>2mm	30	60	65		BS 1377:Part2:1990
<20mm	10	30	60		
>50mm	0	10	40		
pH value	5.5-7.8	5.0-8.2	5.0-8.2		BS 1377:Part3:1990
Nutrient content					
P index min.	2	2	n/a		
K index min.	2	2	n/a		
Mg index min.	1	1	n/a		
N% (m/m) min.	0.2	0.2	n/a		
Loss on ignition % (m/m)	See BS 3882	See BS 3882	See BS 3882		
Exchangeable sodium percentage (ESP) %	<10	<15	<15		

6. ENVIRONMENTAL CONSIDERATIONS

6.1. Sustainability

The use of two waste-sourced or low value materials to produce a new product, as is the case of blended compost and quarry fines should be considered relatively sustainable. Energy has already been used to extract and process the quarry fines so utilising this material will be maximising the use of this energy. The composting of organic material will have prevented its disposal to landfill and subsequent production of methane, which would produce a more significant contribution of greenhouse gases. However the transportation of the blended quarry fines and compost will consume a significant amount of energy. If this is compared with the transportation of other growing media, including peat-free materials, it is debatable as to how sustainable the blended quarry fines and composts should be considered.

With regards the production of topsoils the addition of compost to poor quality soils, subsoils or other inert material (e.g. demolition fines) already on-site which could be used as an effective replacement for imported topsoils would be the most sustainable option. WRAP (2003c), recommends that this approach should be used where possible to reduce the use of imported (natural) topsoil and to reduce the transport costs of the development. Although there might be concerns regarding the possible contamination of secondary aggregates with trace elements and organic these can easily be assessed by the same methods as the blended quarry fines and compost (Section 6.2). However where it is necessary for both a new organic and a mineral component to form a soil, a blended quarry fine and compost mixture should be considered as the next sustainable option, as they are both waste/underused materials and are effectively substituting for the unsustainable use of extracted natural topsoil.

There will be contributions of greenhouse gases associated with the machinery common to all growing media and topsoil production, transportation and packaging.

6.2. Chemical and biological release to the environment

Chemical contamination of the growing media/topsoil may be a hazard to three potential targets; the plants being grown, the surrounding environment, and people using the material. Routine analysis of the trace element and organic compound concentrations in the composts and quarry fines prior to blending and of the blended product should be used to determine the potential risks to these targets. Previous work on blends of quarry fines with various compost types showed that even when the composts contain high total concentrations of trace elements the plant available fraction tended to be low Mineral Solutions (2004a). However the release of major elements (especially nitrogen and sodium) in the same study was high. This was attributed to the immaturity of the compost being used.

There are no specific standards for contamination in growing media or topsoil. Compost can be certified to BSI PAS 100 (BSI 2002), which sets limits of particular contaminants, including potentially toxic elements (Table 15), physical contaminants (Table 16) and pathogens(Table 17). Compost produced to BSI PAS 100 (BSI 2002), should also be free of tars and phenols, and will only have a slight risk of herbicides being present from the composting of treated greenwaste. BSI PAS 100 also includes the recommended sampling frequency for composts (Table 18).

Table 15. Potentially toxic elements (BSI PAS 100:2002, BSI 2002).

Element	Upper limit mg kg^{-1} dry matter	Method of analysis
Cadmium	£1.5	BS EN 13650 (aqua regia extractable)
Chromium	£100	BS EN 13650 (aqua regia extractable)
Copper	£200	BS EN 13650 (aqua regia extractable)
Lead	£200	BS EN 13650 (aqua regia extractable)
Mercury	£1	ISO/DIS 16772 (aqua regia extractable)
Nickel	£50	BS EN 13650 (aqua regia extractable)
Zinc	£400	BS EN 13650 (aqua regia extractable)

Table 16. Physical contaminants (BSI PAS 100:2002, BSI 2002)

Contaminant	Upper limit % mass/mass of total air-dried sample
Total glass, metal and plastic >2mm	£0.5 (of which £0.25 is plastic)
Stones and other consolidated mineral contaminants >2mm	£7

Table 17. Biological contaminants (BS PAS 100:2002, BSI 2002)

Contaminant	Units of measure	Limits
Salmonella sp.	MPN/35g	Absent
Escherichia coli	CFU g^{-1}	£1000 CFU g^{-1}
Weed seeds	Visible propagules/litre	£5 maximum
Phytotoxicity	Score % of control	80% minimum

Table 18. Minimum frequency for compost sampling and analysis (BSI PAS100:2002, BSI 2002)

Parameter	Minimum number of representative samples per quantity of compost produced	
	Process validation phase	**Post-process validation phase**
Pathogens (human, indicator species)	1 per 500 m^3 or 1 per 6 months, whichever occurs sooner	1 per 2000 m^3 or 1 per 6 months, whichever occurs sooner
PTEs	1 per 1000 m^3 or 1 per 6 months, whichever occurs sooner	1 per 5000 m^3 or 1 per 6 months, whichever occurs sooner
Physical contaminants	1 per 1000 m^3 or 1 per 6 months, whichever occurs sooner	1 per 5000 m^3 or 1 per 6 months, whichever occurs sooner
Phytotoxins (plant germination and growth bio-assay)	1 per 5000 m^3 or 1 per 6 months, whichever occurs sooner	1 per 5000m^3 or 1 per 6 months, whichever occurs sooner
Weed propagules	1 per 5000 m^3 or 1 per 6 months, whichever occurs sooner	1 per 5000 m^3 or 1 per 6 months, whichever occurs sooner

If the blended material is used as a topsoil in residential, public amenity or industrial settings the trace element concentrations and some organic contaminants could be assessed with reference to the CLEA model for contaminated land assessment and the derived soil guideline values (Table 19) (DEFRA & EA 2002a-e). For material used in other situations where there are no set guidelines it has been suggested to use either the PAS 100 limits for compost, the Sludge to Land Directive (EEC 1986) values (Table 20), or, if the material is going to be used in an environmentally sensitive area then the Soil Association of Eco-Label guidelines could be used (Table 21). All encompassing guidelines for soils are expected to be a part of the proposed EC strategy on soil protection (EC 2002) (Appendix 2.3).

Table 19. CLEA soil guideline values (DEFRA & EA 2002e)

	As	Cd			Cr	Pb	Hg	Ni	Se
		pH6	pH7	PH 8					
Residential with plant uptake	20	1	2	8	130	450	8	50	35
Residential without plant uptake	20	30			200	450	15	75	260
Allotments	20	1	2	8	130	450	8	50	35
Commercial/industrial	500	1400			5000	750	480	5000	8000

Table 20. Sewage sludge EU directive PTE limits (present and proposed). (Modified from Godley *et al.* (2002))

Metal	Directive 86/278/EEC mg/kg	Proposed sludge mg/kg	
		Now	2015
Zn	2500-4000	2500	1500
Cu	1000-1750	1000	600
Ni	300-400	300	100
Cd	20-40	10	2
Pb	750-1200	750	200
Hg	16-25	10	2
Cr	-	1000	600

Table 21. Eco-label (1998), TCA and SA standards for soil improvers and green waste compost. (Modified from Godley *et al.* (2002) and EA (2001))

Parameter	Units	Eco-label	TCA std	Soil Association (manures)	Soil Association (soils)
Cd	mg/kg dm	1	1.5	10	2
Cr	mg/kg dm	100	100	1000	150
Cu	mg/kg dm	100	200	400	50
Pb	mg/kg dm	100	150	250	100
Hg	mg/kg dm	1	1	2	1
Ni	mg/kg dm	50	50	100	50
Zn	mg/kg dm	300	400	1000	150
Mo*		2			
Se*		1.5			
As*		10			
F*		200			
Salmonella	Absent in g	25	25		
E.coli	MPN/g	1000	1000		
N content	% m/dm	2	n/a		

All compost can be a potential source of diseases and harmful organisms with the risks related to the type of material used to produce the compost and the type of composting method used. Compost produced to best practice guidelines such as BSI PAS 100 (BSI 2002), which includes assessment of the concentrations of pathogens would pose very little risk. Godley *et al.* (2002) has proposed a grading scheme for compost use based on the potential risk arising at the intending use site. The source of the material and the type of composting processes, and the level of monitoring of would be used to assess the risk of the material containing harmful biological contamination. Compost could then be used in applications according to this risk. The high exposure risk outlets would be horticulture, the moderate exposure risk outlets would be agriculture, forestry and land restoration, and the low exposure risk outlets would be landfill operations.

Godley *et al.* (2002) made an assessment of the key hazards that may affect composting and whether these may be mitigated during the composting process. Only the potentially toxic elements (PTEs) and unwanted bulk contaminants ('contras') and sharps will pass through the composting process with no possibility of remediation and could therefore potentially be included in a blended growing media/topsoil. The potential in the compost for high levels of PTEs can be eliminated by careful selection of the feedstock, and for contras and sharps by screening of the finished compost.

Table 22. Hazards and their attenuation during composting (Godley *et al.* 2002)

Hazard	Attenuation during composting	Other controls
Animal/human pathogens	Composting process conditions (time/temperature)	Selection of feedstocks Containment
Plant pathogens	Composting process conditions (time/temperature)	Selection of feedstocks
PTEs	Not attenuated during composting	Selection and blending of feedstocks
Toxic organic chemicals	Composting process conditions (biodegraded)	Selection of feedstocks (recalcitrants)
Contras and sharps	Not attenuated during composting process	Selection of feedstocks Screening of feedstocks (pre-treatment) Screening products (post-treatment)
Pernicious weeds	Composting process conditions (time/temperature)	Selection of feedstocks
Phytotoxicity	Composting process conditions optimisation	Selection and blending of feedstocks

6.3. Energy

The energy requirements for the processing of blended quarry fines and compost will be the same as for existing growing media or topsoil manufacturing operations. The processing of the quarry fines at the quarry site is already undertaken in order to extract the aggregates and so no additional energy will be required. The transport costs for the material however will be higher than for most existing growing media/topsoil. This has both environmental and economic implications.

6.4. Visual impacts

Bulk contaminants in growing media or artificial topsoil can cause a high negative impact. Ensuring that the concentrations of material like plastics, large stones, glass, and metal fragments are kept to a minimum will be critical to the success of the product. The quarry fines are likely to be free from all such material, although care may need to be taken to ensure that larger aggregate sizes from other quarry stockpiles are not included during the collection of fines. The compost is more likely to be the source of most of these types of contaminants. Most weeds should be destroyed during appropriate composting operations, and compost certified to BSI PAS 100 (BSI 2002) is tested to ensure compliance to the limit of 5 weed propagules per litre. Similarly the upper limit in PAS 100 for glass, metal and plastic fragments is £0.5% mass of air dried sample (of which £0.25 is plastic), with stones and other consolidated mineral contaminants accounting for less than £7% of the compost.

Certain compost sources will be more susceptible for the inclusion of foreign bodies, so selection of the compost should take into account the likely level of physical contamination and the implications of the inclusion of such material on the end-use application of the growing media/topsoil. In certain landscaping applications the tolerable levels of weeds and foreign bodies will be higher than for use in growing media and other retail products.

6.5. Odours

Odours from growing media or topsoil produced from blended quarry fines and composts should not contain any strong odours. Although there may be odours produced from the production of compost, compost itself is usually considered to be odour free when properly stabilised and mature (Godley *et al.* 2002).

7. PRODUCTION OF GROWING MEDIA/TOPSOIL FROM BLENDED QUARRY FINES AND COMPOST

7.1. Location of production facilities

The relatively high density of the blended material (Table 23) and the associated high transport costs compared to other growing media, topsoils and soil conditioners are likely to be a restricting factor on the use of the quarry fines in growing media, except for situations where the location of suitable quarry fines and composts are optimal with regard to markets. This is likely to preclude in most cases the construction of dedicated sophisticated production sites to produce the material on a national basis, as is currently undertaken for most peat-based growing media. Instead it is more likely to be viable if the material is produced in smaller volumes for a local market or a specific contract.

Table 23. Density of various growing media (kg/m^3)

Material	Irish peat[1]	Green compost[1]	Bark fines[1]	Coir[1]	Topsoil	Dolerite (50%) +greenwaste compost (50%) blend[2] by mass	Dolerite (70%) +greenwaste compost (30%) blend[2] by mass
Density	220	550	375	300	1150	1235	1541

[1] Data from Waller and Temple-Heald (2003), [2] data collected as part of another Mineral Solutions Limited project

Waller and Temple-Heald (2003) investigated the suitable location of growing media manufacturing sites. These have traditionally been located close to the substrate source (usually peat) and serve a national market. However as the price of peat is likely to rise these may no longer be the optimum locations. The higher density of greenwaste compost and the associated increase in transport costs compared to peat was identified as being a limiting factor for the use of compost in growing media. This situation could only be rectified if the production sites moved closer to both the sources of compost and the largest markets. It is likely therefore that growing media production may become more regionalism, with growing media manufacturers operating more than one site or engaging a series of contractors around the country.

The regional/local type of production would be the most suitable option for the production of growing media/topsoil from blended quarry fines and compost as the material is denser than greenwaste compost and the higher transport costs will contribute an even greater amount to the total costs of the material. To make the product viable the location of the quarries in particular would have to be very close to population/compost production centres. The only exception to this would be if a particular source of quarry fines was identified with very beneficial properties that would add significant extra value to the blended product.

Waller and Temple-Heald (2003) assessed the cost at source, the costs of transport from the production site to the growing media manufacturer, and the transport cost to the customer to produce a regional end-to-end substrate cost model for potential growing media substrates in the UK. The other financial inputs to growing media production such as the incorporation of fertilisers and packaging were considered to be essentially the same for any type of growing media material. This very simple model can also be applied to growing media/topsoil production from blended quarry fines and composts (Figure 1). The main differences between the production of a compost or peat-based growing medium with that of blended quarry fines and compost is that for the latter there will be two costs at source and potentially two transport costs of the primary material to the manufacturing facility. Although with regards the cost at source, the effect of having two source materials may be a disadvantage or an advantage depending on the prices of the materials. The cost of quarry fines tends to vary more than the costs of compost, and as they will usually make up the greater proportion of a blended growing media/topsoil the price of quarry fines will therefore be significant. The two transport 'cost in' values, from the sources of both the quarry fines and compost to the growing media/topsoil manufacturing site could be a significant burden to the cost of production. This extra cost can be reduced if the manufacturing site is located at the source of either the quarry fines of the compost. This will eliminate one of the 'transport in' costs. Most hard rock quarries are located outside of major population areas while composting sites, particularly those for greenwaste compost tend to be located within areas of high population density, and close to large potential markets for both growing media and topsoils. This means that for transport reasons the production site would be best located at or adjacent to a composting site. However in terms of the availability of suitable processing equipment, space and obtaining any required planning permission, a quarry may be the preferred location.

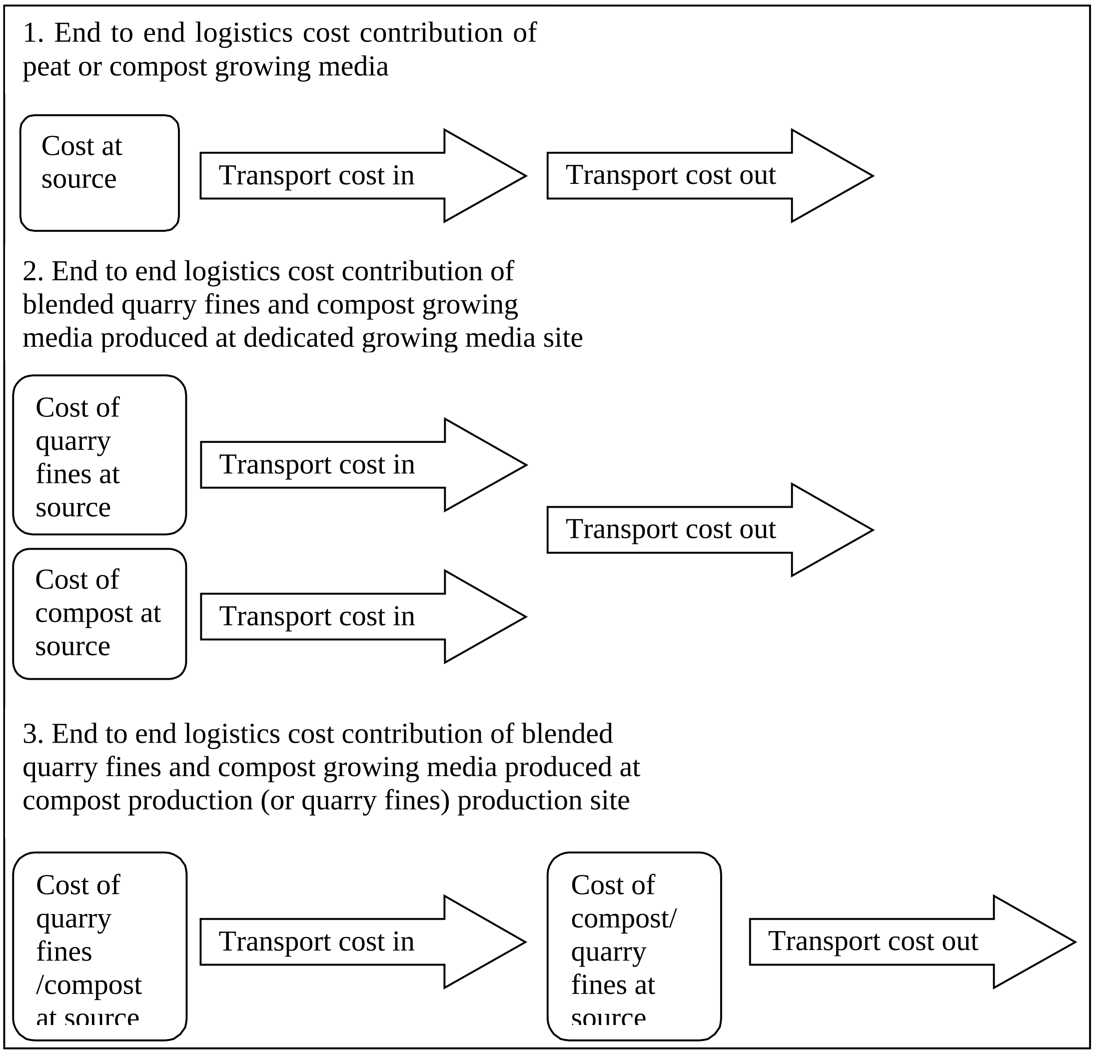

Figure 1. End to end logistics costs. (Modified from Waller and Temple-Heald 2003)

7.2. Suitable processing methods

There are a number of potential methods for producing the blended growing media/topsoil. These range for specialist blending and screening machinery, similar to that used in the sports turf and golf landscaping industry, to tractor-based agricultural machinery.

When blending the quarry fines and composts, calculations of the organic matter concentration should be based on percentage dry weight. This is because the compost will always contain a variable proportion of water. The blended ratios of quarry fines to compost should be based upon the desired characteristics of the growing medium/topsoil. Detailed guidance on the specification of growing media using compost can be found in WRAP Fact Sheet 09 ‘Use of composted material in growing media for professional growers’ (WRAP 2003b), while guidance on topsoil specification can be found in 'Composting Specifications for the Landscape Industry' (The Landscape Institute and WRAP 2003) and BS 3882 (BSI 1994).

7.2.1. Simple/modest production method

Suitable machines identified by Szmidt *et al.* (2003) for blending compost and topsoil are front-end loaders, rotating drum-type mixers, augers, or soil shredders. Using a front end loader the best technique identified by Szmidt was to layer the ingredients in the loader, then roll the pile by lifting and dumping the mix forward with the loader bucket; while WRAP (2003c) recommended placing the lighter material (compost) in a bed on the surface and then to add the heavier material on top before mixing. Blending and screening of this material after mixing as outlined in the modest production option, will produce a more consistent material.

7.2.2 Sophisticated production method

The use of a sophisticated mixing machine will enable both a larger volume of production, and a more precise blending of the ingredients and therefore a much more refined product. Similar plant used in the sports turf industry have hoppers and conveyors that can be controlled to release specific quantities of material at a defined rate. When used in conjunction with a high quality packaging system large volumes of growing media could be produced suitable for distribution to the large retail chains.

7.3. Product density implications

The effect of density of a substrate on the overall end-to-end logistics of a growing medium was identified as being very significant by Waller and Temple-Heald (2003). Although most growing media are sold by volume, most transportation costs are based on weight. The increased in transport costs of a dense material are very significant and will have a large impact on the viability and distribution distance of blended quarry fines and compost. Which ever mode of manufacture is taken for the blended growing media/topsoil, the density of the material will be greater than most typical growing media and topsoils. Table 29 (Section 8.3) shows the typical densities and calculated transport costs by volume (m^3) for a range of growing media, topsoil and soil conditioner products. It is clear that even at a 50:50 (w/w) mix of quarry fines:greenwaste compost, the density (1235 kg m^{-3}) is greater than all of the other products.

Table 24 shows the selling price in the northwest of England (similar for the other regions) that a producer of green compost could receive from a growing media producer in order for the growing media to compete on price with peat-based growing media, as a function of density and distance (Waller and Temple-Heald (2003). With the typical price for green compost ex-works at £4-6 tonne, the break-even distances for green compost at a density of 600 kg m^{-3} are less than 25 miles in each region.

Table 24. Break even source cost estimates for GM substrates: North West Region (Waller & Temple-Heald 2003)

Density (kg m^{-3})	Distance (miles)				
	0	**25**	**50**	**100**	**150**
400	7.98	6.13	5.83	5.21	4.6
450	7.18	5.1	4.76	4.06	3.37
500	6.38	4.07	3.69	2.92	2.15
550	5.58	3.04	2.62	1.77	0.93
600	4.78	2.01	1.55	0.63	-0.3

Demand for a relatively dense material will only be accepted if the benefits of its use outweigh the disadvantages. As a bagged retail product it would be heavy and inconvenient for the employees to stack the product and for the customer to carry home. The effect of the density on the topsoil market would largely be the cost of the material, and concerns regarding the workability of the material. The latter is would also be affected by the precise composition and textural class of the material

7.4. Storage of blended material

Most retail growing media currently being produced have a storage capacity off at least 18 months (Waller and Temple-Heald 2003). The long-term storage of compost is a potential limiting factor to its use in growing media/topsoil. Once the composting process is complete, and the material has matured, if it is not stored properly it can decompose quickly. This may result in a volume reduction, particle size breakdown and under some conditions (anaerobic) the release of ammonium-N, and a change in the pH. These problems can be mitigated by the correct storage of the material.

BS 3882 (BSI 1994) describes in detail the best methods for the use, storage and handling of topsoil. This will also be applicable to the storage of growing media/topsoil after manufacture. The recommendations include ensuring the topsoils receive a reasonable rate of oxygen diffusion into the soil atmosphere, with oxygen being unlikely to penetrate more than 1m from the surface of a pile of topsoil. It is recommended to minimise the storage of topsoil, and where it is necessary to store it to do so in low and narrow piles. It is recommended that topsoil should not be stored for more than 6 months without being reprocessed, and it is also advisable to not handle the soil when plastic as deformation rapidly occurs.

7.5. Analysis

A number of UKAS accredited laboratories have standards analysis suites for horticultural materials, including compost and soil conditioner, topsoil, landscaping topsoil and soil fertility. The costs of these range from £90-£190 per sample depending upon the chosen analytes. Some laboratories and consultancies offer to design of synthetic topsoil required specifications.

The nature of the mineral component in a synthetic blended topsoil derived from quarry fines will be different from the minerals present in natural topsoils. These minerals are only likely to have undergone a limited amount of weathering. These minerals will break down with time and release what ever nutrients they may contain slowly to the soil. This has some implications for the analysis of the material as using a 'total' concentration method it is likely that for quarry fines for some rocks, particularly basalts, dolerites and some sandstones, the trace element concentrations will be relatively high, albeit that a lot of this material will not be in an readily available form. It is recommended therefore that the trace element and major nutrients are also analysed for their water extractable and plant available concentrations. The latter using such tests as CAT-extractable (aqueous solution of $CaCl_2$ and DTPA (Diethylene Triamine Pentaacetic Acid)) (WRAP 2003c).

8. POTENTIAL COSTINGS FOR THE PRODUCTION OPERATION

An assessment was made of the anticipated costs of production for blended quarry fines and composts. The worked examples are not based on actual case studies, but have been produced as guide values based upon the knowledge of the authors and project partners, and from commercial quotes. The main aim of these cost-scenarios is to provide an illustration of the costs of the potential costs of the different production options. There are of course a great many variables which will need to be addressed for a specific operation, these include:

- the types of quarry fines and composts used (source cost, blending characteristics);
- the intended use for the material – e.g. growing medium requiring high specification of blending, lower quality topsoil;
- the utilisation of existing, hiring as required, or buying new plant and machinery;
- the production volumes;
- the packaging options;
- the selling price – reflecting competing products in the area.

8.1. Raw material costs

The costs of the quarry fines and compost raw materials will vary both regionally and with the type of material. For the purposes of these examples the cost estimates for the price of quarry fines (typically ranging between £2-£12 per tonne) have been assessed at two prices (£4 & £8 tonne), and for compost, the price of £5 per tonne has been used as a typical price for PAS 100 accredited greenwaste compost. The blend proportions of the two raw materials will obviously affect the price per tonne of the material. Table 25 shows the estimated prices of the blends produced using blending ratios of 30%, 50% and 70% quarry fines by weight. The price per tonne of the raw materials may vary between £4.30 and £7.10 depending on the mixing ratios and the price of the raw materials.

Table 25. Estimated raw material costs for blended quarry fines

	Quarry fines	**Compost**		**Quarry fines**	**Compost**		**Quarry fines**	**Compost**
Blend (% w/w)	30	70		50	50		70	30
Price/tonne	£4	£5		£4	£5		£4	£5
Price/tonne blend		£4.70			£4.50			£4.30
	Quarry fines	**Compost**		**Quarry fines**	**Compost**		**Quarry fines**	**Compost**
Blend (% w/w)	30	70		50	50		70	30
Price/tonne	8	5		8	5		8	5
Price/tonne blend		£5.90			£6.50			£7.10
	Mean	**£5.30**		**Mean**	**£5.50**		**Mean**	**£5.70**

8.2. Production costs

The production cost examples are based upon three scenarios of production, these have been classified as minimum, modest and sophisticated. The main assumptions that have been used, are that the production of growing media/topsoil is the only activity being undertaken at the site; the material will be produced in batches through the year to take account of the shelf life of the material and the supply of compost, the number of people required will be constant even with different volumes of material being processed (using the assumption that the production at lower volumes was not running at full capacity), the payback period for the development and production costs is 5 years.

As can be seen from Tables 26-28 the costs of production vary considerable depending upon the type of operation and the volume of material. At smaller volumes (5-20k tonnes a^{-1}) a minimum or modest production operation would be able to produce the blended material at a much lower cost than the sophisticated operation. At larger volumes (50k tonnes a^{-1}), the sophisticated production plant can produce the material at a similar price to the modest operation, and it would also have the advantage of producing a higher quality material. The use of a pre-existing sophisticated type operation could dramatically reduce the production costs even for a relatively small volume of material.

Table 26. Costing estimates for a minimum processing operation

Item	Details	Unit cost (£)	No.	Total
Labour	1 person at 3 days/month & £80-£120/day	£100.00	36	£3,600.00
Plant hire	Digger/loading shovel	£50.00	36	£1,800.00
Blending machine	Use digger/loading shovel	£0.00	0	£0.00
Hard standing and storage	Small area or rent space £3-5,000	£4,000.00	Fixed	£4,000.00
			1 year	£9,400.00
			5 year	£31,000.00
Cost per tonne over 5 years to cover the installation and operating costs			Tonnes yr^{-1}	Cost per tonne
			5,000	£1.24
			20,000	Probably not feasible
			50,000	Not feasible

Table 27. Costing estimates for a modest processing operation

Item	Details	Unit cost (£)	No.	Total
Labour	2 people at 3 days/month	£100.00	72	£7,200.00
Plant hire	Digger/loading shovel	£50.00	72	£3,600.00
Blending machine	Tractor-based blending machine, £17-25k	£21,000.00	Fixed	£21,000.00
Hard standing and storage	Small area and storage	£7,500.00	Fixed	£7,500.00
		Total	1 year	£39,300.00
			5 year	£82,500.00
Cost per tonne over 5 years to cover the installation and operating costs			Tonnes yr^{-1}	Cost per tonne
			5,000	£3.30
			20,000	£0.83
			50,000	Probably not feasible

Table 28. Costing estimates for a sophisticated processing operation

Item	Details	Unit cost (£)	No.	Total
Labour	2 people at 3 days/month	£100.00	72	£7,200.00
Plant hire	1 loading shovel/digger @ £7-13K	£10,000.00	Fixed	£10,000.00
Blending machine	Complete machinery (hoppers, conveyors, blending and screens) @ £100-150k	£125,000.00	Fixed	£125,000.00
Hard standing and storage	High specification storage and hard standing £30-50k	£40,000.00	Fixed	£40,000.00
		Total	1 year	£182,200.00
			5 year	£211,000.00
Cost per tonne over 5 years to cover the installation and operating costs			Tonnes yr^{-1}	Cost per tonne
			5,000	£8.44
			20,000	£2.11
			50,000	£0.84

8.3. Transport costs

The potential transport costs for the blended quarry fine and other growing media and topsoil materials are shown in Table 29. The transport of bulk materials is charge by the tonne, whereas growing media and topsoils are usually sold and specified by volume. The costs of transportation therefore favour the least dense materials. The transport costs (per tonne) were calculated using a typical rate of £0.10 per mile and with a minimum charge of £1.50. The density of the various types of growing media and topsoils have been used to calculate the cost of transport by volume (m^3). The density of the blended growing media have been calculated from the raw material densities of materials collected as part of a project of Mineral Solutions (2004a), to investigate the use of basaltic quarry fines and composts as a growing media. The costs of transport per m^3 are greatest for the blended quarry fines and compost, with the 50:50 blend being similar to that of a typical topsoil. The densest blend quarry fines and compost would have approximately 10 times the transport costs as that of peat. Clearly the density of a particular blend of quarry fines and compost will reflect that of the specific constituent materials but it is always likely to be similar or greater than that of natural/screened topsoil.

Table 29. Transport costs by volume of material (m^3)

Distance	Transport	Material type and density & transport £/m^3					
		70% quarry fines 30% (w/w) compost blend*	**50% quarry fines 50% (w/w) compost blend***	**Topsoil°**	**Peat•**	**Greenwaste compost•**	**Bark•**
		kg m^{-3}	**kg m^{-3}**	**kg m^{-3}**	**kg m^{-3}**	**kg m^{-3}**	**kg m^{-3}**
		1541	1235	1150	180	550	375
Miles	**£/tonne**	**£/m^3**	**£/m^3**	**£/m^3**	**£/m^3**	**£/m^3**	**£/m^3**
5	£2.00	£3.08	£2.47	£2.30	£0.36	£1.10	£0.75
10	£2.50	£3.85	£3.09	£2.88	£0.45	£1.38	£0.94
15	£3.00	£4.62	£3.71	£3.45	£0.54	£1.65	£1.13
20	£3.50	£5.39	£4.32	£4.03	£0.63	£1.93	£1.31
25	£4.00	£6.17	£4.94	£4.60	£0.72	£2.20	£1.50
30	£4.50	£6.94	£5.56	£5.18	£0.81	£2.48	£1.69
35	£5.00	£7.71	£6.18	£5.75	£0.90	£2.75	£1.88
40	£5.50	£8.48	£6.79	£6.33	£0.99	£3.03	£2.06
45	£6.00	£9.25	£7.41	£6.90	£1.08	£3.30	£2.25
50	£6.50	£10.02	£8.03	£7.48	£1.17	£3.58	£2.44
75	£9.00	£13.87	£11.12	£10.35	£1.62	£4.95	£3.38
100	£11.50	£17.72	£14.21	£13.23	£2.07	£6.33	£4.31
125	£14.00	£21.58	£17.30	£16.10	£2.52	£7.70	£5.25
150	£16.50	£25.43	£20.38	£18.98	£2.97	£9.08	£6.19
175	£19.00	£29.28	£23.47	£21.85	£3.42	£10.45	£7.13
200	£21.50	£33.14	£26.56	£24.73	£3.87	£11.83	£8.06
250	£26.50	£40.84	£32.74	£30.48	£4.77	£14.58	£9.94
300	£31.50	£48.55	£38.92	£36.23	£5.67	£17.33	£11.81
400	£41.50	£63.96	£51.27	£47.73	£7.47	£22.83	£15.56
Factor of densest blended material		1.00	1.26	1.35	10.46	2.93	4.44

** data processed from related Mineral Solutions Limited project (2004a), °Approximate average topsoil density in England (Ashmore et al. 2001), •Waller and Temple-Heald (2003).*

8.4. Packaging costs

The options for packaging range from loose bulk transport in a lorry, to individual small volume printed packed bags that are then palletised and wrapped for distribution. The method chosen will reflect the use of the material and its marketability. A complete bespoke packaging machine, suitable to produce 20-80L polythene bags could cost in the region of £150,000, with a hopper and bagging machine for 1m^3 bags costing in the region of £50,000. Polythene bags that would be suitable to pack growing media and topsoil for distribution to garden centres and other retail outlets cost in the range of £130-£200 per thousand. For professional topsoil applications large 1m^3 bags or loose bulk supply would be the most appropriate method of distribution.

9. MARKETING

9.1. Markets for growing media and topsoils

Godley *et al.* (2002) assessed pricing of retail growing media. For a 60L bag size the typical retail cost was £3.50 (inc. VAT), with a 30% profit margin for the retailer. 60L of peat-based compost has an approximate mass of 30kg, so the price per tonne is about £105. However the same study found that the cost of extracting, drying and transporting peat to the bagging facility was only £5-8/m^3 (£10-16/t). The price that a compost producer might be expected to get for the use of compost in horticultural applications was found to be £5-10/t (Table 30).

Table 30. Assessment of compost outlet sizes and price of compost product (Godley *et al.* 2002)

Outlet sector	Use	Potential market kt/a	Sale price £/t	Notes
Horticulture	**Total**	**up to 1000**		Peat replacement potential. High quality compost required.
	Growing media	500+	5-10	Bagged product retails at about 100/t
	Soil improver	200+	5-10	
	Mulch	?	5-10	
Agriculture	**Total**	**10 000+ (all)**	**0-3**	Competition with farm wastes (manures)
	Salad fruit & veg.			Pathogen attenuation and low contras content required
	Food crops			Pathogen attenuation and low contras content required
	Non-food crops			Low contras required
	Grassland			Low contras required
Forestry	**Total**	?		
	Nursery/planting	300+	2-4	Peat replacement for nursery trees
	Forestry	?	0-3	Market could be developed for soil improver
	Bioenergy crops	900	0-5	Potential market for soil improvers Based on predicted 150 000 ha of energy crop
Land restoration	**Total**	**Large**	**varies**	
	General restoration	1000+	0-1	100 000 m3 used in single example (Stockley Park)
	Landfill restoration	5000+	0	Topsoil for landfill completion
Waste management	**Total**			
	Daily landfill cover	5000+	0	Revenue from gate fee
	Landfill	10 000 (all)	0	Revenue from gate fee
	Incineration	10 000 (all)	?	Potential use for energy recovery
Other	**Total**			
	Topsoil	approx. 20	4-8	High grade required
	Livestock bedding	?	10-15	New market development
	Biofilter	0.5	60	Low volume market
	Organic fertilizer	approx. 20	4-8	
	Sports turf/amenity	approx. 50	up to 30	High quality compost required (low contras)
TOTAL (maximum potential market)	**40 000**	**0-30**		

Of the types of compost based products produced in the UK (Table 31), the blended quarry fines and compost could only be realistically used in the growing medium and topsoil categories. These account for only 7% and 9% respectively of the total amount of compost-based products. In all of the other products the compost is added alone to the existing soil material, usually in-situ, to improve the condition of the soil or to prevent the growth of weeds.

Table 31. Quantity of composted products produced in the UK. (Davies 2003)

Product	Quantity (tonnes)	Percentage of total (%)
Mulch	117,270	12
Soil conditioner	561,630	56
Components of growing medium	66,856	7
Turf dressing	6,253	1
Topsoil/subsoil	94,592	9
Other	99,319	10
Stabilised biowaste	52,802	5
Total	**998,721**	**100**

Figure 2 shows the distribution of composted products by market (Davies 2003). Of the seven market types the two largest, agriculture (287 kt), and landfill engineering (320 kt) are not anticipated to become a suitable market for blended quarry fines and compost. In the case of agricultural land which tends to be mostly deficient in organic matter only, and not bulk mineral. Landfill engineering does not demand a high quality material and organic waste sent to landfill can be composted for use onsite, in site remediation at a small amount of the cost of the production of a growing media/topsoil. The blended quarry fines/compost could conceivably be used in all of the other markets.

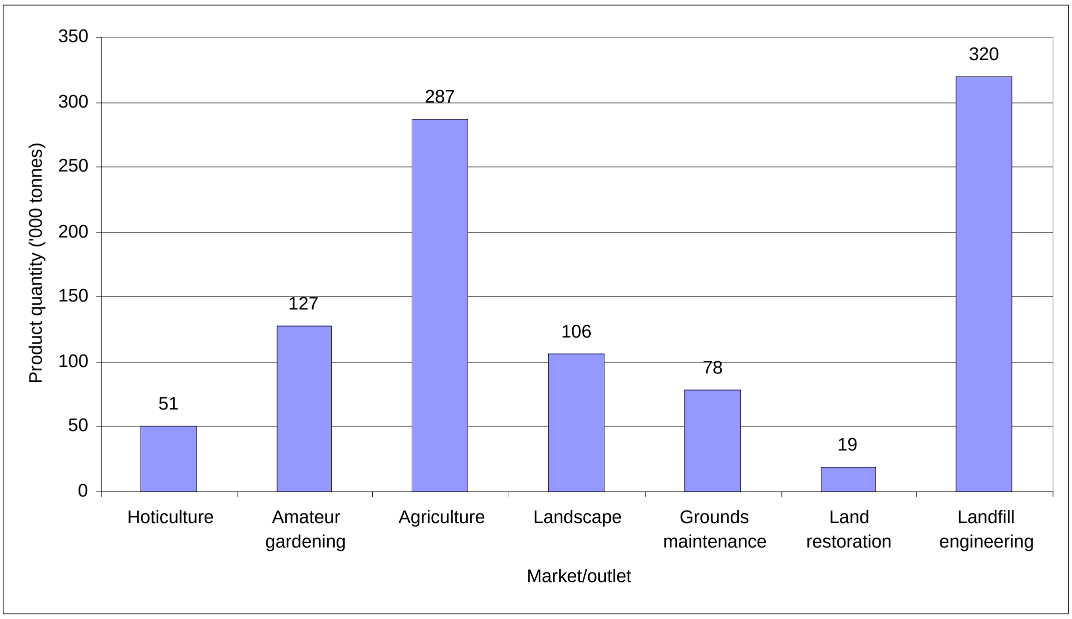

Figure 2. Distribution of composted products by market sector (Davies 2003)

Due to the high density and potential difficulty of working with the blended material, it is probable that the professional horticulture and amateur gardening markets may offer a more limited potential than the landscaping, grounds maintenance and land restoration markets. The responses to telephone questionnaires with professional horticulturists raised concerns regarding the quality and handling characteristics of the blended quarry fines and composts. They commented on previous research which suggested that such blends had proved to be not very successful. One of the companies had already experimented successfully with peat-free and reduced peat growing media, and saw no need to use other peat-free alternatives which do not offer the same handling properties and growing qualities.

It is likely that amateur gardeners will hold similar opinions to professional growers for use in the germination and potting of plants, unless an improvement in yield and quality are clearly demonstrable. Most amateur gardeners will want to improve particular characteristics of their soil. This is usually achieved by adding either organic matter as a source of nutrients and structure (e.g. compost), or minerals to improve the texture and drainage (e.g. sand). Aside from using the blended material as a growing media in pots another potential amateur market would be for people who need a completely new topsoil in such situations as having a shallow depth to bedrock, for the planting of trees with deep roots, garden landscaping, or the re-vegetating of previously developed land (e.g. sites of patios, garage sand areas of hard standing).

Figure 30 shows the proportion of compost-based products sold within the key markets (Davies 2003). Combining the proportion of compost used in the growing medium and topsoil applications with the total market sectors (Figure 29) the current annual mass of use of composted-based material used in the growing media and topsoil/subsoil applications is; horticulture (6kt yr^{-1}), amateur gardening (13kt yr^{-1}), agricultural markets (0kt yr^{-1}), landscape (5kt yr^{-1}), and grounds maintenance (18kt yr^{-1}). This is relatively small compared with the total production of compost, and the total amount of growing media and topsoil used in the UK. The use of compost in a soil conditioners and mulches dominates the market.

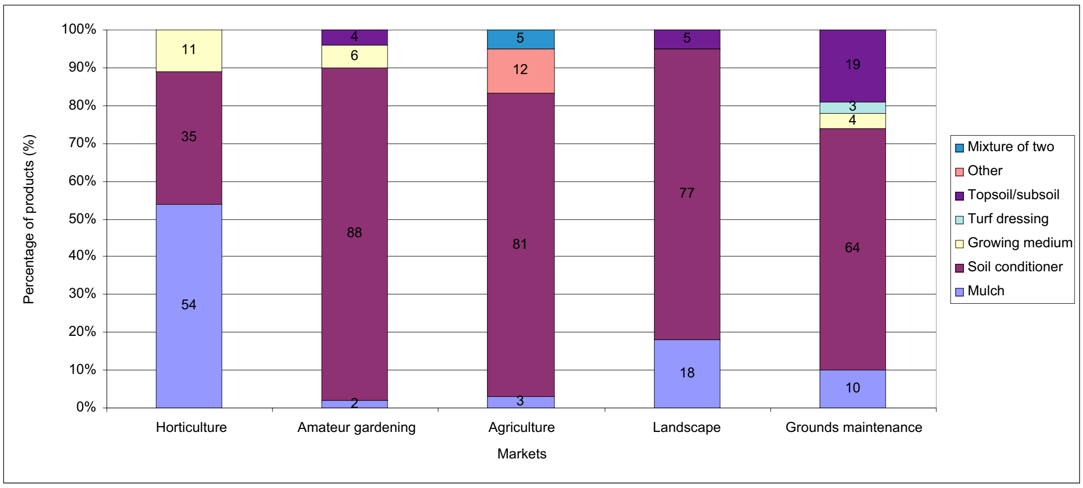

Figure 3. Types of products sold in the different market segments (Davies 2003)

The assessment of the potential compost outlet sizes and price of compost product (Table 30) in Godley *et al.* (2002) gives an indication of the potential market size and the typical gate price per tonne. Growing media applications are estimated to be greater than 500,000 t yr^{-1}, with a sale price of £5-10 t^{-1}. A bagged retail product is estimated to sell at £100 t^{-1}, with most of the mark-up attributed to packaging and retail profit margins. In comparison the potential market size for compost in topsoil is estimated to be approximately 20,000 t yr^{-1}, with a similar sale price of £4-8 t^{-1}. Using these market sizes and assuming a blending ratio of 2:1 quarry fines:compost, this would produce a volume of 1,500,000 t yr^{-1} growing media and 60,000 t yr^{-1} topsoil. It has been estimated by the authors from consultations within the industry that the production of topsoil from blended quarry fines and compost is probably already in the region of 20-40,000t yr^{-1}. It was not possible to get the exact specifications of this material, or its selling price. However it is believed to be produced in areas where they is a high price for topsoil, and is often made to exact specifications for specific contracts. Although the estimated size of the market for compost in topsoil is small it is feasible that the blended quarry fines and composts could expand into the general topsoil market by promoting the material as being more sustainable than extracting the material from agricultural land and possibly of a potentially better quality, and certainly a more uniform material than screened soils from brownfield site redevelopments.

The topsoil industry is very much price driven and operators with screens using soils and rubble from brownfield sites set the base price, which is often found to be less than the cost of manufacturing high quality general-purpose grade topsoil (Godley *et al.* 2002). The cost of low quality topsoil can be as low as £2 tonne in some parts of the UK. Typical ranges of good quality topsoil vary between approximately £5 tonne in northwest England to £15 tonne in the southeast of England. The viability of any growing media/topsoil production facility will reflect the local price of competing products.

Blended quarry fines and composts can also be used in the production of sports field soil mixtures, where the price of the material may be much higher, with up to £30/t being obtained for some materials. However this is very small outlet and most of this material already uses high specification quarry sands as the dominant ingredient.

The BS 3882 (BSI 1994) standard for topsoils classifies the material into three grades (premium, general purpose and economy). Premium grade topsoil must be from a natural source with a defined location (within 100m). Synthetic topsoils (such as blended quarry fines and compost) can only be classified to a maximum grade of 'general purpose'. This may well restrict the selling price of the material, although it would be possible to use the results of analysis of material to BS 3882 to show that the blended material is as good as the properties of a natural premium grade topsoil. The competition for the lower grades of topsoil with developers of brownfield sites who can cheaply screen and process soil from sites may prove to be a significant barrier to overcome.

One of the key advantages of the blended quarry fines and compost is that it will tend to have most of the necessary nutrients for plant growth and will not (in most cases) require the addition of lime or fertilisers. It will also have a very low proportion of weeds, which is very important for producing pleasing planting schemes. A strong selling point for the material is that it can be described as a relatively sustainable option for sourcing of topsoil as both of the ingredients are either an unwanted material or a processed waste product, which can be produced without the unsustainable extraction of agricultural topsoil.

The volume of the land restoration market is large (although mostly dominated by the use of organic amendments (including compost) for use as soil conditioner). The value in terms of improved growth and appearance can also be high but the price received for this material does not usually reflect this (Godley *et al.* 2002). This is largely because the restoration is generally at a net cost to the company, at the end of a contract and is invariably done at the least cost. This makes the viability of a blended quarry fine/compost in the land restoration market relatively unlikely as the competition from lower cost alternatives like soil conditioners and screened topsoil will be very strong.

9.2. Accreditation

Where appropriate the material should be accredited with the appropriate standards and follow trade codes of practice. However the cost of these may be quite considerable with an initial registration fee, followed by a proportion of the sales of the product or company turnover, or else require membership of the organisation. It will need to be determined if the accreditation will be likely to add more sales of the material than the cost of the accreditation.

The Henry Doubleday Research Association (HDRA) and the Soil Association (SA) may permit, subject to approval, rock minerals as a bulk additive to growing media for their organically certified going media and soil conditioners. Rock fines are not specifically listed as a major ingredient but it would be given consideration. It would need to be shown that using the material will help to minimise waste and will have to fulfil stringent criteria regarding the sustainability of the product (particularly with regards the extraction methods of the quarry fines, the transport distances and possible contamination). Each individual blend and source of material would need to be assessed.

The Eco-label scheme (Appendix 2.1) has expanded to include growing media. This is designed for products that can show that they have a reduced impact on the environment throughout their lifecycle.

The Growing Media Association (GMA) (formerly the Peat Producers Association) has developed a code of practice for the ‘determination of a quantity’ for peat and peat-based growing media, soil improvers and mulches, and it expands upon the relevant European Standard method BS EN 12580:2000 ‘Soil improvers and growing media – determination of a quantity’. The code of practice is a mandatory condition of membership of the organisation. The GMA has also produced an environmental code of practice for peat extraction, which aims to limit the extraction of peat from the most ecologically and scientifically valuable sites.

9.3. Labelling

Many horticultural products on sale contain selling points relating to either the sustainability of the ingredients, and production, or the beneficial effects it will have to the environment compared to other products. These should be used as appropriate to help maximise the sales of the material, but only, when these claims are factually correct and are stated unambiguously. To help this type of responsible approach the DTI and DETR developed a ‘Green Claims Code’ (DTI & DETR 2000) in association with various trade and standards organisation to promote best practice in environmental claims. This code requires all information to be truthful, able to be substantiated, relevant, clear and explicit. It takes account of the ISO 14021 on environmental claims. The ‘Green Claims Code’ applies to text, symbols and graphics on the packaging and any related literature or advertising material. ISO 14021 also includes definitions of the terms ‘compostable’, ‘recycled content’, ‘reduced resource use’ and ‘waste reduction’ – each of which could be used for blended quarry fines and composts. Growing media should conform to PD CR 13456:1999 (BS11999) ‘Soil improvers and growing media - labelling, specifications and product schedules.

9.4. Advertising

The potential cost of advertising is considerable; ranging from small classified adverts in general interest magazines and newspapers to full page colour adverts in trade and public magazines. If the material is being produced as part of a range of other horticultural products then the blended quarry fines and compost would simply become part of this range. For the individual production of the material the best method of advertising would be to get a wholesale trader to take the product as part of their portfolio. If the material is proves to be effective and competitive within the market place then word of mouth promotion would become important. It could also be possible to try to contributing to press articles or industry magazine features that would highlight the benefits and the sustainability of the product.

10. HEALTH AND SAFETY

10.1. Raw materials

10.1.1. Quarry fines

In addition to the general health implications of inhaling dust, a number of rock types including some sandstones, granites and gravel deposits may contain a respirable silica dust. This causes the lung disease silicosis. Analysis of the quarry material will be essential to determine the quantity of free respirable silica in a sample. Generation of dusts should be kept to a minimum and all appropriate personal protective equipment should be worn.

10.1.2. Compost

Micro-organisms can be released into the air from processing compost piles. Spores such as *Aspergillus fumigatus* can grow in compost and affect the lungs. These organic particles may still be present in the compost when it is about to be blended. Quarry fines and compost will generate a proportion of dust. A study of municipal waste handling stations and recycling plants (Gladding 2004), which included composting operations, demonstrated that workers are more susceptible to 24hr flu and diarrhoea than most workers. The long term health effects of such work have not yet been determined. When processing such materials it is essential that all of the relevant health and safety requirements including personal protective equipment, and any on-site health and safety risk assessments are complied with.

10.2. Blended growing media and topsoils

The health and safety implications of dust from the blending of quarry fines and compost will also be present when the material is applied. The moisture content of the material will have an impact on the dust level produced. The compost will contain organisms and so has the potential to produce or contain spores and bioaerosols present in the compost raw materials. The risk of these will reflect the type and quality of the compost and the subsequent processing.

10.3 Manufacturing and distribution

Manufacturing operations should follow all relevant health and safety requirements and promote within the work force an open policy regarding the reporting of incidents and the promotion of ideas to improve safety. Hazard and risk assessment documents should be prepared for all aspects of the processing operation. These should be updated when ever the circumstances change (e.g. personnel, equipment, processing set-up). All members of staff should have the training appropriate to their responsibilities and this should be an ongoing processes, with regular refreshment courses.

The main areas that will need to be addressed are:

Transport

- reversing vehicles
- mobile plant
- overhead services
- site traffic management
- drivers are certified and fit to operate the class of vehicle.

Personal protective equipment

- high visibility clothing
- safety footwear
- head protection
- hearing protection
- eye protection
- hand protection.

Lifting and material handling, and processing machines

- appropriate certification of devices and equipment
- assessment of ground surface conditions
- load is within the dynamic and/or static capacities of the lifting equipment
- all machinery is designed and correctly set-up for fail safe operation
- defective machinery is taken out of operation immediately.

Energy and machinery isolation

- lock-out procedure incorporating locks and personal tags at isolation points
- all guarding and safety systems are re-established upon completion of maintenance work

11. LEGISLATION, STANDARDS AND SPECIFICATIONS

Although the source of the compost is a waste, compost (if composted under a Waste Management License) is considered to be a product. There is some uncertainty concerning the classification of quarry fines. EU case law has declared that quarry fines could be considered to be a waste, but the aggregate industry considers quarry fines to be a low-value, underused material. With regards the production of a new product from blended quarry fines and compost it is likely that they will be considered to be raw materials, and so would not come under Waste Management Licensing Regulations (Appendix 2.2)), however this would need to be determined for each operation. Quarry fines used to produce a growing media/topsoil would currently be exempt from the Aggregates Levy (HMSO 2002). If the quarry fines are taken off the quarry site for blending then the aggregate tax will need to be paid at the gate but this can be reclaimed. Appendix 2 outlines the main areas of legislation and industry standards that would be applicable to the production of growing media/topsoil from quarry fines and composts. They are listed by the categories product (Appendix 2.1), raw materials (Appendix 2.2), environment (Appendix 2.3) and manufacturing (Appendix 2.4). They are by no means exhaustive but cover the main themes of this report.

12. VIABILITY OF PRODUCING GROWING MEDIA/TOPSOIL FROM BLENDED QUARRY FINES AND COMPOST

Previous research on blended quarry fines and compost has shown that they can be used to produce a medium suitable for plant growth. The success of the blends was mostly influenced by the type of compost, with the quarry fines contributing to a lesser extent. The quarry fines had the most effect on the texture of the material. This previous work has highlighted some limitations for their use which include the relatively high bulk densities, and for some blends, poor trafficability.

The blended quarry fines and compost will be competing in established markets, in which many of the competing products can be produced at a lower cost. This, coupled with the relatively high density of the blended quarry fines and compost, and the associated increase in transportation costs and difficulty of processing and application, are all potentially significant factors that will affect its viability. The implications of the transportation costs will be most significant in the growing media market where the competing products have a much lower bulk density.

It is known that landscaping companies are already producing modest volumes of blended quarry fines and compost for use as synthetic topsoil, so there is a clear commercial outlet for this material. What is not apparent is how extensive the potential market and applications for the blended quarry fines and compost may be. The current production is driven by requirements of the landscaping industry for a material with particular characteristics that can be matched by quarry fines and compost from a particular source, and is usually in areas with a high topsoil price. Some of this material is produced in response to requirements for the use of a sustainable or recycled material in landscaping contracts. For such applications the cost of the material may not as a significant a factor.

At the outset of the project it was envisaged that it would be possible to produce a guide which would specify the use of particular rock types and compost types for use in particular applications of growing media and topsoil. However as the precise physical and chemical compositions of both the quarry fines and composts may vary even for material from the same quarry, or compost source, this has not proved to be possible. Instead a summary guide of the potential applications for generic rock and compost types has been produced, based mainly on their chemical properties (Table 32). To determine the suitability of particular source of quarry fines and composts for use as a growing media or topsoil it will be necessary to undertake a detailed characterisation of both the quarry fines and compost and the blends.

Table 32. Summary of combinations of rock fines with composts from different sources with evaluation of possible applications, based on rock and compost compositions

Compost type	Basalt/dolerite	Granite/felsite	Limestone	Sandstone
	50% silica, Fe/Mg rich weathers easily	70% silica, K/Na rich, weathers slowly	100% $CaCO_3$, diluted by clays and quartz	80-90% silica, resistant to weathering
Municipal Solid Waste Can contain glass, animal by-products; high metal content	Land restoration only	Land restoration only	Land restoration only	Land restoration only
Green wastes Low N; seasonal variation	Horticulture, agriculture, land restoration	Horticulture, agriculture, land restoration	Land restoration	Land restoration
Anaerobic digestor High N; possible animal by-products	Agriculture, horticulture, land restoration	Agriculture, horticulture, land restoration	Land restoration	Land restoration
Kerbside collection Medium N; possible animal by-products	Land restoration	Land restoration	Land restoration	Land restoration
Seasonal composts (mycelium waste; food waste) May have high N	Agriculture, horticulture, land restoration	Agriculture, horticulture, land restoration	Land restoration	Land restoration

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APPENDIX 1 GLOSSARY OF KEY TERMS

These definitions were either derived for this project or were adapted from EA (2001a), Waller & Temple-Heald (2003), BSI PAS 100 (2002), BSI (1994), and Davies (2003).

Actinomycetes: a specific group of bacteria that is capable of forming very small spores. (EA 2001a)

***Aspergillus fumigatus*:** species of fungus with spores that can cause allergic reactions in some people. (EA 2001a)

Bark: lignified outer protective tissue from the trunks of one or more types of tree specifies that is removed from sawmills and may thereafter be aged or composted and screened to provide material that may serve as a growing media constituent, soil improver or mulch. (Waller & Temple-Heald 2003)

Blended material: mixture of a composted material and one or more other material(s). Other mineral additives can include sand, soil, peat, non-composted biodegradable residues, other substrates e.g. coir and bark, nutrient sources, or other compost from a different production system. (BSI 2002).

Bulk Density (BD): the density of the material as received or reconstituted for use in accordance with the manufacturers instructions and determined by the method specified in BS EN 12580:2000. (Waller & Temple-Heald 2003)

Cellulose: long chain of sugar molecules that makes up the main part of the cell walls in plants. (EA 2001a)

Compost: solid particulate material that is the result of composting, that has been sanitised and stabilised and that confers beneficial effect when added to soil and/or used in conjunction with plants. (BSI 2002).

Composting: process of controlled biological decomposition of biodegradable materials under managed conditions that are predominantly aerobic and that allow the development of thermopile temperatures as a result of biologically produced heat. It results in a final product that has been sanitised and stabilised, is high in humic substances and can be beneficially applied to land. ((BSI 2002) and (EA 2001a)).

Curing: final stage of composting in which stabilisation continues but the rate of decomposition has slowed to the point that turning or forced aeration is no longer necessary. Some microbial activity and chemical changes, such as the oxidation of ammonium ions to nitrate, will continue. Beneficial soil micro-organisms that were inhibited or destroyed during the active composting process also will begin to re-colonise the composted materials. (EA 2001a)

Cubic Metre (m^3): volumetric measure equivalent to 100 litres and the unit in which growing media or their bulky components are traded and the market size expressed. (Waller & Temple-Heald 2003)

Exempt composting site: a composting site that is registered with (but not licensed by) the regulator and does not require a site licence under The Waste Management Regulations 1994. In order to comply with the exemption criteria these sites must use the compost on-site and the total quantity on-site at any time must not exceed 1,000 m^3. (Davies 2003)

Fines (quarry): new EU standards for aggregates (EN?) defines 'fines' as material which passes a 0.063mm sieve, with the definition for 'fine aggregate' being <4mm for general use and in concrete applications and <2mm for use in asphalt plants. Theses values differ from what has traditionally be classified as 'fines' by the UK aggregate industry. Some operators classify material <6mm as fines. Regardless of the specific size fraction quarries used the term to describe the lowest grade fractions of their processing operations.

Garden Waste: biodegradable waste from gardens, such as grass cuttings, leaves, branches etc.

Grade: means of differentiating composts on the basis of particle size range, which may be described as "fine", "medium", "coarse", or otherwise named. (BSI 2002).

Greenwaste: post-consumer waste material of botanical origin that derives from gardens, parks and other horticultural activities; includes tree and shrub prunings, grass and other whole plant material and may include kitchen or vegetable processing waste. (Waller & Temple-Heald 2003)

Green compost: compost derived from the composting of green waste. (Waller & Temple-Heald 2003)

Growing medium: material, other than soils in situ, in which plants are grown (PD CR 13456:1999) (BSI 2002). In this study this has been used to describe bagged material for container growing by amateur and professional horticulturists and for potting out of plants by amateur gardeners. The term is also often restricted to a material which is used to grow plants in containers or bags.

Growing media manufacturer: commercial enterprise engaged in the formulation and blending of constituent parts of a growing medium into a ready-mixed finished product for sale in the professional or retail markets. (Waller & Temple-Heald 2003)

Growing Media Association (GMA): trace association of growing media manufacturers and others involved in the manufacture and/or import of growing media or soil improvers and/or their constituents and the marketing of these products within the UK. (Waller & Temple-Heald 2003)

HACCP: Hazard Analysis and Critical Control Points System that identifies, evaluates, and controls hazards which are significant for production of safe compost. (BSI 2002).

HDRA (Henry Doubleday Research Organisation): Research organisation for organic and sustainable horticulture. Has developed organic standards for soil conditioners and growing media.

Horticulture: the term describes an industry of professional growers that use intensive systems to grow flowers, nursery stock or fruit and vegetables. (Davies 2003)

Land restoration: the process of improving the quality of land, or augmenting inadequate soil e.g. brownfield sites or mining areas. (Davies 2003)

Landscaping: the development or construction of soft landscapes (mainly private sector), including those associated with highways. (Davies 2003)

Licensed site: a composting site that is licensed under The Waste Management Licensing Regulations 1994. It must be operated within the terms and conditions that are stated by the regulator in the site licence. (Davies 2003)

Mature, maturity: degree of biodegradation at which compost is not phytotoxic or exerts negligible phytotoxicity in any plant growing situation when used as directed. (BSI 2002).

Mulch: a material applied to the surface of a soil or other growing medium to minimise cultivation and enhance plant growth by retaining moisture, suppressing weeds and enhancing biological activity. (Waller & Temple-Heald 2003)

Own mix: a bespoke growing medium produced by a grower, nurseryman or other professional horticulturist from individual substrates for use on-site and not for re-sale. (Waller and Temple-Heald 2003).

Pathogen: any organism capable of producing disease through infection. (EA 2001a)

Peat: partially decomposed plant residues derived from bogs, mires or fens consisting principally of mosses such as Sphagnum species, sedges or reeds, etc.; the standard substrate for growing media production in the UK and north-west Europe. (Waller & Temple-Heald 2003)

Phytotoxin: substance that is toxic to plants, causing delayed seed germination, inhibiting plant growth or having other adverse effects on plants. (BSI 2002).

Potentially Toxic Element (PTE): chemical element that has the potential to cause toxicity to humans, flora and fauna. (BSI 2002).

Risk: combination of the probability of occurrence of harm and the severity of that harm. (ISO/IEC Guide 51:1999) (BSI 2002).

Sanitisation: process of biological activities that together with conditions in the composting mass give rise to compost that is sanitary. (BSI 2002).

Screening: process stage usually involving the sorting of compost particles according to their size, by various means, in order to achieve one or more separate grades. (BSI 2002).

Soil Association (SA): The largest certifier of organic products and systems in the UK licensed from UKROFS.

Soil improver (SI)/soil conditioner: material added to soil in situ primarily to maintain or improve its physical properties, and which may improve its chemical and/or biological properties or activity. (BSI 2002).

Stable: degree of biodegradation at which the rate of biological activity under the conditions favourable for aerobic biodegradation has slowed and microbial respiration will not resurge under altered conditions, such as manipulation of moisture and oxygen levels or temperature. (BSI 2002).

The Composting Association: organisation that is the UK's membership organisation that researches and promotes best practice in composting and the uses of composts. The Association acts as a central resource for composting, researching, collecting and disseminating information and has members from all sectors of the UK waste management industry, including compost producers, Local Authorities, consultants, trade suppliers, compost users, academics, individuals and students. (Davies 2003)

Topsoil: natural topsoil or material with a mineral base which will perform the functions of natural topsoil and in which plants will grow healthily. (BSI 1994)

Traceability: ability to trace the history of the product including the identification of the inputs used and production operations undertaken. (BSI 2002).

Windrow: elongated pile of composting material. (EA 2001a)

WRAP: WRAP (the Waste and Resources Action Programme) is a national Government programme established to promote sustainable waste management by tackling the barriers to waste minimisation and increased recycling.

APPENDIX 2 LEGISLATION, STANDARDS AND GUIDELINES

Appendix 2.1 Product related legislation, standards and guidelines

BS 3882:1994 Specification for topsoil (BSI 1994):

Topsoil is defined as 'natural topsoil or material with a mineral base which will perform the functions of topsoil and in which plants will grow healthily'. This standard describes three different grades of topsoil; a. premium, b. general purpose and c. economy grade. The standard gives parameters for the physical (textural, grading), chemical (major nutrients, LOI) and biological requirements (weeds, organic pathogens) for the three classes of soil, together with the recommended methods of analysis. Of particular reference to this project is the fact that the premium grade of topsoil can only be used to describe a natural topsoil, for which there is a record of the origin of the material given to the nearest 100m. This precludes artificial topsoils such as blended quarry fines and green composts from this category even they fulfil all of the remaining criteria. The guidance also provides some direction on the handling, storage and spreading of topsoil.

BS EN 12580:2000, Soil improvers and growing media - determination of a quantity (BSI 2000)

This standard provides the details of how to take a representative sample of a growing media for analysis.

BSI PAS 100 Composted Materials/The Composting Association Standard for composts (BSI 2002)

The BSI Publicly Available Specification for composted materials states the minimum criteria for high quality composts. It provides a guideline for the concentration of PTE and pathogens, together with other contaminants and quality assurance procedures using HACCP (Hazard Analysis and Critical Control Points System) procedure. In the UK BSI PAS 100 is the main industry standard. The Composting Association which helped to develop the standards provides an independent Certification Scheme to assess compliance with BSI PAS 100. BSI PAS 100 only covers biodegradable materials that have been source-separated from non-biodegradable and composted at centralised, community, on-farm and other similar types of facilities. Compliance allows the compost producer to use the scheme's quality mark. The costs of qualification and annual renewal are based on annual input tonnages of material. It the absence of other suitable standards the concentration thresholds for PTEs and pathogens from PAS 100 have been used for compost-based growing media and soil conditioners.

EA National Regulations (NatRegs): Landscaping (EA 2003)

The EA has produced a number of summary guidelines for industries including landscaping, based on the appropriate legislation for a range of activities. These are aimed primarily at small to medium-sized enterprises that do not have a capability for in depth assessments of all of the regulations related to their industry. They and are updated to reflect changes to the legislation.

EU Eco-label for soil improvers and growing media

The Eco-labelling Board has established a voluntary European Union wide standard for soil improvers. The scheme was set up to promote the design, production, marketing and use of consumer products that have reduced environmental impact during their entire lifecycle. The product must have a minimal weed seed content, must not contain sewage sludge, have minimal risk of environmental damage of risks from heavy metals and nutrients. In the UK it is administered by the EU Eco-labelling Board, based at DEFRA.

Henry Doubleday Research Association (HDRA) Standard for Landscape and amenity horticulture, and the Soil Association (SA) Standards for organic food and farming

As there are no statutory requirements for organic certification of material for use in the landscaping and community horticulture markets the HDRA and SA have devised standards based on what would be likely to be expected of such a standard if the European organic food production standards were extended to these markets. The requirements are quite challenging, with the impact of the extraction, processing and distribution of the material compared to the ideals of environmental sustainability.

The Growing Media Association (GMA) standards

Formerly the Peat Producers Association (PPA), the GMA has developed standards principally aimed at the packaging and labelling of the growing media, but for peat-based products in has a category to confirm that the material has been produced according to the Environmental Code of Practice

Appendix 2.2 Raw material related legislation, standards and guidelines

The Aggregates Levy (HMSO 2002).

This was implemented to try to increase the demand for secondary aggregates (C&D, road planings, etc.) by increasing the price of primary aggregates from hard rock, sand & gravel, and near shore (<12 miles) aggregates. The levy is currently set at £1.60 per tonne. Part of the money collected from the Levy has been used to generate a sustainability fund for the aggregate industry, to promote the efficient use of primary quarry materials and to minimise its adverse effect to the environment. The large volumes of fines which are presently being stockpiled already have environmental costs associated with them. One of the effects of the Aggregates Levy has been the reduction in the size of the markets for the 'fine' fraction resulting from the crushing of aggregates. This material is being stockpiled in increasing quantities at quarries. Currently the use of fines for growing media/topsoil production is exempted from the aggregate levy. This exemption is subject to annual review and it is not improbable that this exemption may be lifted at some point in the future.

Animal By-Products Regulations (HMSO, 2003)

These replaced the Animal By-Products Order (1999) and the Animal By-Products (Amendment) Order 2001. The previous legislation permitted the composting and digestion of catering wastes and certain low risk animal by-products, but specified that stringent sanitisation and biosecurity measures were set in place. The new (2003) legislation has made it practically impossible to use composted animal wastes on land were it could come into contact with any wildlife (e.g. birds). Exemption for the composting of such waste is under review. Future composting of food waste is likely to require large, technology-dependent in-vessel facilities that will need to be established to compost food wastes. This will therefore be at a greater costs than green wastes, which may continue to be composted at either centralised or smaller-scale on-farm sites (Davies 2003).

Biowaste (EC 2001)

A proposal document relating to a Biowaste Directive was published (EC 2001) which covers treatment of biological wastes by composting and anaerobic digestion amongst other processes. The document proposes that there should be standards set for two grades of compost/digestate, and also one for stabilised Biowaste (Godley *et al.* 2002). The report also recommends the separate collection of the wastes into the following groups:

- Food wastes – from households, restaurants, canteens, schools and public buildings
- Biowastes - from markets, shops, small businesses and other commercial and industrial sources
- Greens and wood waste – from private and public parks and gardens

The draft Biowaste Directive is not expected to be published until after the Strategy for Soil Protection has been agreed (See environment section). It can be regarded as a natural corollary to the Landfill Directive with its targets for reduction of biodegradable waste sent to landfill (EA 2001a).

European Aggregate Standards (Quarry Products Association 2003):

The culmination of the Construction Products Directive (1988) has been the development of European Standards aggregates by CEN. They currently run alongside the existing British Standards but from June 2004 the British Standards will be withdrawn and replaced in most cases by BSI ENs. Standards have been drawn up for most applications of aggregates and national guidance documents (PDs) and test methods have also been produced. Fine aggregates for asphalt are now defined as less than 2mm and for all other uses less than 4mm. The term fines is now to be used in reference to the fraction which passes a 0.063mm sieve. Filler material is the fines material which may be added to influence the properties of a mixture. The change in aggregate definitions is not likely to have an impact on the production of fines, although the changes may result in a different grading of fine aggregate and fines being produced.

Sludge to land Directive 86/278/EEC)

This directive includes the application of composts derived from sewage sludge. There are proposals to reduce the limits of metals and that limits on specific organic pollutants and human pathogens might be introduced. Like the Biowaste (Composting) Directive, these revisions are on-hold pending the completion of the thematic strategy on soil protection (Godley *et al.* 2002).

The Landfill Directive 99/31/EC (EU 1999)

The Landfill Directive aims to reduce the amount of biodegradable municipal waste disposed to landfill to reduce the amount of methane released to the atmosphere, and thereby contributing to global warming. The target in Article 5 of the directive is to reduce the amount of biodegradable municipal waste disposed to landfill to 35% of the total amount produced in 1995 (Godley *et al.* 2002). This will require the processing of between 6-15 million tonnes of material annually, depending on the definition of biodegradable municipal waste and the growth of rate of waste generation (EA 2001a). This will result in an increase of the amount of compost from different sources being produced.

The Landfill Tax Regulations (HMSO 1996a)

The Landfill Tax was implemented in 1996 and consists of a graded scale of payment depending on the nature of the waste. This has led to a decrease in the amount of topsoil, subsoil and C&D materials going to landfill and an increase in the amount of recycling of these materials either as fill or graded to produce topsoils. Some commercially available topsoils are composed of this material mixed with composts and other sources of organic material.

The safe compost matrix (Godley *et al.* 2002)

The safe compost matrix has been proposed as a means of ensuring the type of composting operation is suited to purpose. It has been developed along the lines of a risk assessment which takes into account the hazards inherent in the compost and the risks these pose in a particular type of landuse. The compost is therefore produced suited to purpose and the possibility of over specification (at increased cost) of compost processing for use in a low risk end-use will be avoided. This will help to maximise the recycling of organic waste without increasing the risk of harm to humans (mostly) and also the environment. In practical terms higher risk organic waste could be composted and used in such applications as the restoration of old industrial land than would be permitted for certain agricultural or retail use. It will also give greater confidence of the use of higher specification composts (that may not conform to PAS 100) in some outlets within the horticultural sector where confidence in a product in product safety and performance is pre-eminent.

Waste Management Licensing Regulations, SI No. 1994/1056 (HMSO 1994a) & described in HMSO (1996b) and EA (2001b):

The key relevance to the production of synthetic growing media relates to the source of the composted organic waste. Only organic waste which is registered under the Waste Management Licensing Regulations (WMLRs) can be sold as a product at the end of the composting process. Any organic waste which has been composted under exemption from the WMLRs can only be disposed of on-site or at another site belonging to the registered owner and could not therefore be incorporating into a growing media/topsoil product. None of the material may be sold on to an external vendor. Licensed operators have to fulfil a range of criteria to ensure the safety of the process and they are subjected to monitoring. Any composting operation which processes more than $1000m^3a^{-1}$ has to be licensed under the WMLRs.

Appendix 2.3 Environment related legislation, standards and guidelines

European Commission 'Towards a thematic strategy for soil protection' (EC 2002)

The European Commission is developing a strategy for soil protection which is intended to co-ordinate soil policy and will involve revision of the Sludge Directive (86/278/EEC) and the introduction of a Biowaste Directive. This may lead to consistent PTE limits, and human and animal pathogens limits for all organic material applied to the land in the EU (Godley *et al.* 2002). Currently the guidance on PTEs in composts and growing media is based on specific individual standards (e.g. PAS 100 for compost in soil improvers and growing media) or the use of standards from other applications (e.g. Sludge (Use in Agriculture) Regulations 1989 (HMSO 1989). Loss of organic matter from soils in Europe is a growing problem, although with regards to the potential outlet for a growing medium consisting of blended quarry fines and compost this is not likely to produce an obvious market opportunity in agricultural land as the compost can be added alone as a soil conditioner.

Nitrates Directive 91/676/EEC (EU 1991) & Nitrate Vulnerable Zones (NVZs)

The Nitrates Directive (EU 1991) aims to reduce water pollution caused or induced by nitrates from agricultural sources. There are restrictions on the concentration of nitrogen that can be applied to agricultural land. Areas which are most susceptible to risk of nitrate contamination have been designated as Nitrate Vulnerable Zones. The area of land designated as NVZ is set to increase. The current limits for arable land are 220kg N/ha a^{-1} and for grassland 170kg N/ha a^{-1}. Although mature compost contains a considerable amount of N, there is a facility in the Nitrate Directive to seek derogation for materials with very slow N release as these would pose less risk of causing excess mineral N in the soil and potential nitrate loss. Mature compost could be classified as a slow release source of nitrogen although there is currently no precedent for this (Godley *et al.* 2002). There could be a substantial market for good quality compost and in some cases blended quarry fines and compost for use in these areas.

Appendix 2.4 Manufacturing related legislation, standards and guidelines

General Product Safety Regulations 1994 SI No. 2328:1994 (HMSO 1994b)

The key points of this legislation are Section 7 which contains a general safety requirement that ‘no producer shall place a product on the market unless the product is a safe product’. This is supported by requirements in section 8;

i) consumers are informed of relevant information to enable them to assess the risks inherent in a product throughout the normal or reasonably foreseeable period of its use, where such risks are not immediately obvious without adequate warnings, and to take precautions against those risks: and

ii) measures are adopted commensurate with the characteristics of the product which he supplies, to enable him to be informed of the risks which these products might present and to take appropriate action, including, if necessary, withdrawing the product in question from the distribution chain to avoid those risks.

The measures suggested include batch marking, sampling, investigating complaints and informing distributors of such monitoring and the results. The PAS 100 Specification for composted materials addresses a number of these issues.

Integrated Pollution Prevention and Control Directive 96/61/EC

The Integrated Pollution Prevention and Control (IPPC) Directive 96/61/EC is designed to ensure that industrial processes are operated efficiently and with all reasonable measures have been undertaken to prevent pollution. They are regulated by the Environment Agency and Local Authorities. Most quarrying and composting operations will already be governed by this Directive. The key points are that:

All preventative measures against pollution are taken based on best available techniques, defines as those that prevent of minimise pollution, can be implemented effectively and are economically and technically viable while meeting the overall aims of the Directive.

- Waste production is avoided as far as possible
- Recovery and safe disposal of waste is practised
- Energy is used efficiently
- Prevent accidents and limits their environmental consequences
- Return sites to a satisfactory state after operations cease

The Packaging (Essential Requirements) Regulations 2003 SI No.1941:2003 (HMSO 2003b)

Schedule 1 (Annex II of the Directive)

1. Requirements specific to the manufacturing and composition of packaging

- packaging shall be so manufactured that the packaging volume and weight be limited to the minimum adequate amount to maintain the necessary level of safety, hygiene, and acceptance for the packed product and for the consumer:
- packaging shall be designed, produced and commercialised in such a way as to permit its reuse or recovery, including recycling, and to minimise its impact on the environment when packaging waste or residues from packaging management operations are disposed of;

- and packaging shall be so manufactured that the presence of noxious and other hazardous substances and materials as constituents of the packaging material or residues from management operations or packaging waste are incinerated or landfilled.

The Supply of Machinery (Safety) Regulations 1992 (HMSO 1992)

Machinery for use in the production of a blended growing media should have compliance with the Supply of Machinery (Safety) Regulations. The regulations cover wide ranging health and safety requirements regarding construction, moving parts and stability etc. of machinery. Specific components must submit to examination by an independent body, and a technical file must be produced. Machinery that fulfils the regulations allows a CE mark to be affixed, and production of an EC Declaration of Conformity of Incorporation.

General safe operation of plant and equipment are covered by the following legislation:

The Health and Safety at Work (HSW) Act 1974; The Provision of use of Work Equipment Regulations 1998; The Lifting Operations and Lifting Equipment Regulations 1998. The HSW Act includes the general requirement ‘An employer has a duty to ensure, so far as is reasonably practicable, the health, safety and welfare of all his employees’