Treating Wastes for Restoring Land Sustainability

Introduction

Treating Wastes for Restoring Land Sustainability (TWIRLS) is a project about improving, restoring or remediating degraded land in Europe, using locally sourced waste materials. These materials can be mixed together for the sustainable production of a growing medium, enabling plants to become established and a whole ecosystem to develop.

The project was funded by the European Commission LIFE-Environment programme between October 2004 and September 2007, and managed in the College of Natural Sciences at Bangor University, Wales. Partner organisations and collaborators in the project were: the quarrying companies Alfred McAlpine Slate (in Wales) and Titan Cement (in Greece), the paper manufacturer UPM Kymmene UK (in Wales), the Soil Science Institute of Athens, the Association of Communities and Municipalities of the Attica Region (ACMAR), the waste-management company Envar (in England), and the Welsh Assembly Government.

This work is important for three reasons. There is now a pressing need to:

- reduce the volume of waste disposed of by landfill. Europe produces approximately 2000 million tonnes of waste per year – a figure that is increasing by around 10 per cent each year. Stricter European legislative targets are reducing the amount of waste that can be sent to landfill, and we have an environmental responsibility to recycle more of our waste.
- protect and improve soil. More than 16 per cent of the EU's total land area is considered to have degraded soil, in terms of erosion, water infiltration or carbon sequestration, or its fertility or microbial biodiversity.
- reduce greenhouse gas emissions. Significant reductions in the EU's emissions are required following the commitments generated by the Kyoto Protocol and the 2007 climate summit in Bali. Improved waste management can make a cost-effective contribution to meeting these targets.

Adding organic matter to soil improves its quality and functionality. The process has long been recognised as beneficial to the soil's fertility, structure, water retention and buffering capacity (the ability to resist rapid changes in pH). Organic matter has large pore spaces, which improve water, gas and nutrient flows, and its particles have a large, highly charged surface area, which can adsorb, or 'attract', nutrients and trace elements, helping to prevent them leaching away and improving their availability to plants. Organic matter is particularly beneficial to microorganisms, as it supplies energy for growth as well as providing a long-term supply of nutrients such as nitrogen, phosphorus and sulphur.

Soil degradation can occur for a number of reasons, including: contamination by pollutants from industry or agriculture; intensive agriculture (especially the production of cereals); disturbance, such as mining or quarrying; and industrial development, which seals the soil with an impermeable surface layer.

Project activities

The TWIRLS project worked with four sites suffering from a range of soil degradation issues.

- The waste rock tips of a slate quarry in Blaenau Ffestiniog, North Wales, which had no soil or vegetation.
- An urban brownfield area in North Wales, the site of the former Shotton Steelworks, which had some areas contaminated with persistent organic pollutants, and other sandy areas supporting little vegetation.
- A former coal mine, Woolley Colliery, where colliery shale made the soil so acidic that it prevented revegetation.

The slate quarry in Blaenau Ffestiniog, which is surrounded by the Snowdonia National Park.

- Kamariza schist quarry in Greece, part of the Parnitha National Park, where the ground had become compacted and waterlogged and had no soil or vegetation.

Compost production

A number of organic waste products were used to manufacture soil-forming material. These included tertiary-treated biosolids (derived from sewage sludge), green waste, recycled paper waste, municipal solid waste (miscellaneous waste, often mainly cardboard), water treatment solids (the 'sludge' removed from tap water), and bracken compost. In addition, fine quarry mineral waste from the waste tips on site was added to some of the compost treatments.

The organic waste products were composted using a mobile, in-vessel system called EcoPOD®, developed and tested by TWIRLS, at the project's two largest sites.

The EcoPOD® system of in-vessel composting used by TWIRLS to produce compost from waste materials

1. Waste products are mixed accurately to achieve optimum properties for composting.

2. Mixed wastes are delivered to a hydraulic ram, which pushes material into low-density polyethylene (LDPE) pods.

3. The pods are approximately 40 m long but can be divided into three sections to contain different feedstock mixtures.

4. Perforated tubing is fed in with the feedstock for forced aeration during composting. Aeration is controlled by fans run from a generator, and via temperature data-loggers inserted into the pods.

Applications of the method

Four different types of compost mixture – tertiary-treated biosolids, green waste and recycled paper waste, plus quarry mineral waste – were used to test and demonstrate several major applications of the method.

At the Blaenau Ffestiniog slate quarry, compost made from tertiary-treated biosolids, green waste and recycled paper waste was used as a top dressing to establish upland acidic heathland on the slate waste tips.

At the slate quarry, some composts worked better than others in the establishment of heathland habitat. Composted organic wastes plus fine slate waste present on site supported the greatest plant biomass, compared with treatments in which slate sand was replaced with recycled paper waste.

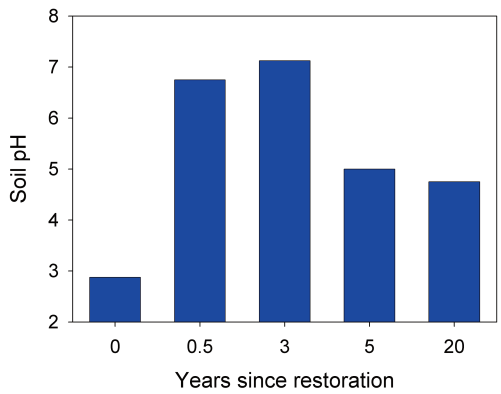
Compost made from these three waste products was also used at the former steelworks site, to remediate contaminated soil and to enhance biodiversity. Soil contaminated with polycyclic aromatic hydrocarbons (PAHs) was composted both

on its own and with tertiary-treated biosolids, green waste or recycled paper waste, in different combinations. Nearly 40 per cent of the hazardous PAHs was removed by the composting process, although there was no evidence that mixing the contaminated soil with organic waste increased this removal.

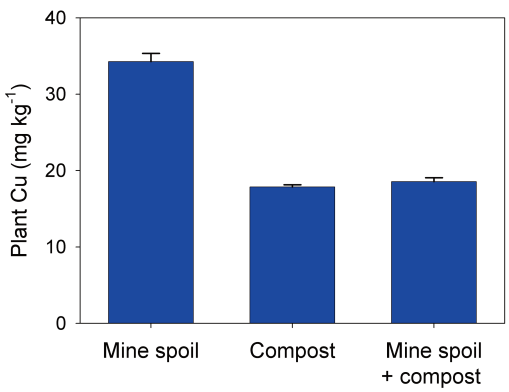
At the Shotton Steelworks site, soil contaminated with polycyclic aromatic hydrocarbons (PAHs) was composted either on its own or with composts made from organic wastes. Nearly 40% of the hazardous PAHs was removed by the composting process.

At the former Woolley Colliery, windrow-composted recycled paper waste was used together with either tertiary-treated biosolids or animal manure to raise the pH of soil acidified by coal spoil, enabling the successful establishment of grazing land.

TWIRLS also collaborated with related research, on a site at Parys Mountain, North Wales, to assess the potential of compost to stabilise or 'lock-up' heavy metals in acid mine spoil. Compost made from tertiary-treated biosolids, green waste and recycled paper waste was used to halt the migration of these potentially toxic elements off site, and to reduce the accumulation of metals in plants. The addition of the compost led to a lower uptake of copper, lead and arsenic by wheat, indicating that the metals were made less available to plants.



At Woolley Colliery, the addition of tertiary-treated biosolids and recycled paper waste increased the soil pH from <3 to nearly 7 in the first year. An increase was sustained in the long term.



Research at Parys mountain found that co-composting mine spoil with organic waste products led to a lower uptake of copper by wheat.

At Kamariza quarry in Greece, tertiary-treated biosolids, green waste and municipal solid waste were composted in-vessel on an enormous scale by ACMAR to provide a growing medium for the establishment of native Aleppo pine trees. Planting in compost increased the average height of the trees, and this effect was further improved by planting in raised rock mounds to increase drainage on the waterlogged site.

At Kamariza quarry in Greece, native pine trees were established in schist quarry waste by pocket-planting into compost produced from municipal waste.

Key findings

Biodiversity of plants and invertebrates was increased at the former steelworks site, where land was spread with different composts and then seeded with a meadow grassland mix.

TWIRLS has successfully demonstrated the use of composted industrial and domestic wastes commonly produced in Europe to restore or remediate land in the following ways.

- Regeneration of brownfield urban areas, by increasing levels of soil organic matter. At Woolley Colliery, composted organic wastes were used to establish grazing land (previous attempted restoration at this site, 20 years ago, was unsuccessful), and at Shotton Steelworks, compost aided the establishment of biodiverse mesotrophic grassland.
- Restoration of post-industrial and degraded sites in rural areas to high conservation-value habitats, as at Blaenau Ffestiniog and Kamariza Quarry. Here composted wastes were used with locally available mineral matter to create materials suitable for soil formation: aiding the establishment of acidic upland heathland (Blaenau Ffestiniog) and native Aleppo pine forest (Kamariza).
- Removal of pollutants from post-industrial land. At Shotton Steelworks, soil contaminated with polycyclic aromatic hydrocarbons (PAHs) – which are persistent, carcinogenic and regarded as one of Europe's priority pollutants – was remediated through composting and the establishment of vegetation.
- Remediation of heavy-metal-contaminated soil. Co-composting with organic wastes led to a reduction in the uptake of heavy metals by plants.
- Raising of soil pH to aid the restoration of 'acid-polluted' land. However, where the target habitat requires a low-pH substrate, as in the case of acid heathland, this effect of adding compost may be counteracted with the addition of sulphur. Preliminary trials are recommended before this is attempted for large-scale habitat restoration.

The project also found that tertiary-treated biosolids are a valuable resource that can be safely included as a compost feedstock material without increasing the final load of human pathogens in the compost.

Benefits of the technology

Environmental benefits

There are clear environmental benefits of using waste materials, as demonstrated by TWIRLS, to restore degraded land. In essence, these are:

- a reduction in the amount of waste buried in landfill sites, and thereby a decrease in the volume of greenhouse gas emissions generated by this method of waste disposal.
- an increase in the fertility and functional capacity of the land, i.e. its ability to provide 'ecosystem services'. These include an improved capacity for food production, the enhancement of water and air quality, nutrient cycling, carbon sequestration, conservation and recreation. The improved quality of land also reduces health risks, both to humans and to other species.

Most organic wastes are originally derived from plant production and should, therefore, be returned to the land to sustain its capacity for the production of food, energy and environmental quality for future generations – i.e. closing the nutrient cycling loop. The use of organic matter to supply essential plant nutrients also reduces the dependence on mineral fertilisers, which are known to cause soil acidification, depletion of soil organic matter, and contamination of groundwater and surface water, and have a large carbon footprint owing to their energy-intensive manufacture and transportation.

There is ever-increasing pressure on the use of land, for development and for the production of food and biofuels. Furthermore, climate change threatens to deplete production yields, due to decreases in summer rainfall. It is therefore crucial that any reduction in the land area devoted to agriculture or forestry is offset

by soil improvements to maintain productive potential, for example through enhanced water-holding capacity, even in a changed climate.

Economic benefits

The potential long-term economic benefits of the TWIRLS technology are significant. It offers a solution to two problems.

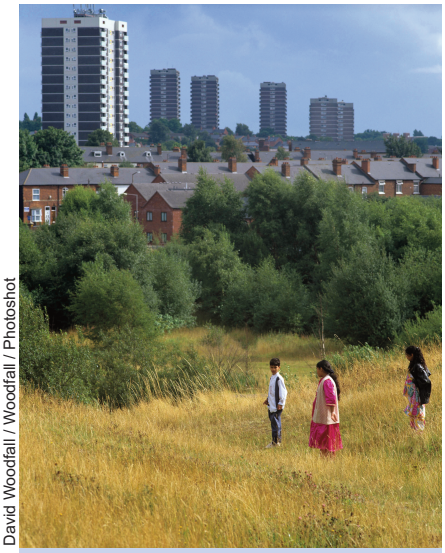
- There is an urgent need for an efficient solution to brownfield regeneration, especially in densely populated countries, if greenfield land is to remain undeveloped – conserved for ecosystem services such as human well-being and food production. The population of the UK, for instance, is predicted to increase from the current 60 million to 65 million over the next ten years.
- Due to ever-tighter legislative targets for reductions in the volume of waste sent to landfill, municipal-scale composting is now common. However, there are currently insufficient added-value uses for the compost produced.

Ecoscene / Chinch Gryniewicz

Europe produces 2000 million tonnes of waste per year. Legislative targets are becoming tighter, reducing the amount that can be sent to landfill.

Policy indicates that brownfield regeneration should become one of the largest markets for municipal-scale compost, providing it is priced correctly. However, before TWIRLS there was a lack of sufficient evidence about how compost can best be used – sustainably and with the greatest net environmental benefit – for this purpose. TWIRLS met this need by demonstrating how industrial organic wastes such as recycled paper waste and tertiary-treated biosolids, which are available in bulk but are environmentally challenging to use (due to negative public perception and potentially high heavy-metal content), can be composted to industry-quality benchmarks and used efficiently for brownfield restoration.

TWIRLS has also pioneered the use of composting in situ at restoration sites, so minimising the costs of waste transport compared with the alternative – transferring wastes to a central composting facility and then out again to restoration sites. Furthermore, the project has demonstrated the use of in situ co-composting (the composting of contaminated material with other wastes) to remediate contaminated soil on brownfield sites. Again, this provides a cost-effective alternative to transporting contaminated material for disposal off site.



David Woodfall / Woodfall / Photoshot

Restoration of degraded land will increase recreational access to areas of natural habitat.

Social benefits

A vast area of brownfield, unused land exists in Europe, with 16 per cent of land regarded as degraded. The potential social benefits of restoration are considerable. These include:

- more jobs in the waste recycling industry
- more profitable and sustainable agriculture (including farms on marginal land)
- increased human well-being through improved access to recreational land and areas of biodiversity, even in urban environments.

TWIRLS sites have been restored for a diversity of end uses, including grazing pasture (both by tenant farmers and as common grazing land), cereal production, beekeeping, conservation and recreation. The sites at Blaenau Ffestiniog and Kamariza Quarry now

merge visibly back into the natural landscapes associated with adjacent national parks, and the results from the former steelworks site demonstrate how bioremediation can be applied to the wider area of the Deeside Industrial Estate.

Transfer and commercialisation of results

The TWIRLS technology is applicable to a broad spectrum of sectors, including agriculture and horticulture, forestry, mining, leisure, conservation, regeneration/development and highways. The project has demonstrated the application of its technology to a range of sites suffering from a variety of land degradation issues. The transferability of the method is shown by its use across:

- a broad climatic range – from hot Mediterranean to wet coastal and cool mountainous regions
- varied substrates – from compacted waste rock to sand and agricultural soil
- a wide range of land types – from semi-natural national park to agricultural land and polluted industrial estate
- a broad socio-economic range – including land owned by industrial companies, government bodies or individual farmers, as well as land with communal grazing rights
- areas of contrasting public exposure – from places with high rural visual amenity and conservation value, to peri-urban greenspaces and sites of future commercial employment or intensive commercial food production.

The technology offers great potential for commercialisation. This would work best under the umbrella of local authorities and regional development agencies, who are responsible for many of the brownfield sites left over from past industries that require remediation or restoration, and are also the main recipients of wastes and government funds for the provision of recycling and composting facilities. The cost-effectiveness of the TWIRLS composting approach compared with other solutions was demonstrated, and this is likely to increase as landfill becomes progressively more expensive.

Conclusion

TWIRLS has been a highly successful project, clearly demonstrating the value of many domestic and industrial waste materials for land restoration. The technology meets the increasing public and policy demand to recycle more waste, reduce pollution and provide more restored brownfield sites for affordable housing. There is high public acceptance of the use of composting processes to meet these demands.

The project has carried its message widely throughout the EU and has disseminated its findings and recommendations at the highest strategic levels. The next phase is for this work to be incorporated into European and national soil protection and waste management strategies, policies and practice.

With ever-growing pressure on land to produce both food and fuels, and ever-increasing degradation of soil – primarily through loss of organic matter – it is time to establish policy to return organic waste to soil in sufficient quantities to halt further degradation. It may well be necessary to include soil in existing and new carbon and nitrogen trading schemes, thereby providing financial incentives to land managers for the restoration of soil organic matter.

TWIRLS: LIFE04 ENV/UK/000820
For more information visit www.bangor.ac.uk/ies/TWIRLS/TWIRLS_home.htm