GUIDE TO THE PRACTICAL USE OF POST-CONSUMER GLASS IN RURAL AREAS

The Department of Trade and Industry Recycling Programme

Department for Sustainable Communities
Comhairle nan Eilean Siar

September 2003

CONTENTS **PAGE**

EXECUTIVE SUMMARY

As a small island Local Authority, Comhairle nan Eilean Siar faces a considerable challenge to provide sustainable recycling of domestic waste produced in the Western Isles. A prime example of this is the recycling of post-consumer glass. The traditional method of glass recycling in the United Kingdom uses a collection system based on source separation of different colours of glass mainly due to the demands of the re-melt industry. However, with fluctuating prices and unstable demand for the glass it can often be difficult to financially maintain this type of operation even on the UK mainland. For a remote island community with a low population density and the additional costs of ferry transportation to the mainland, followed by a road haulage distance of over 200 miles, this type of operation is clearly not sustainable in either financial of environmental terms.

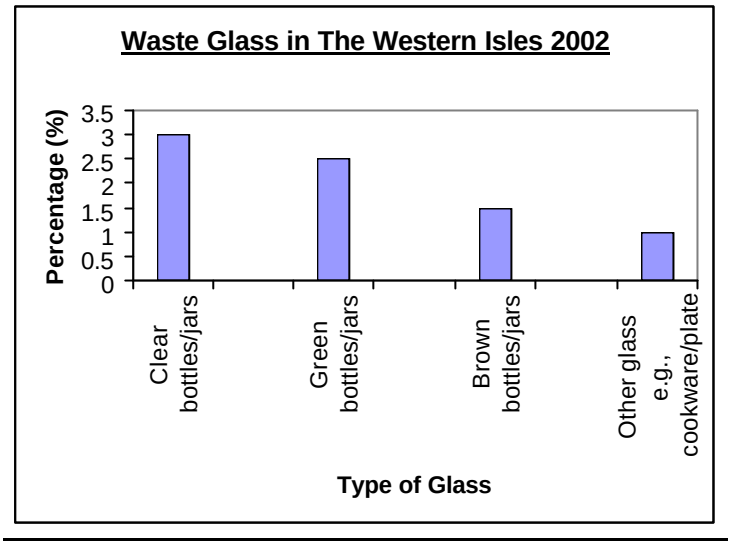
This Department of Trade and Industry approved project was set up in order to develop and evaluate a best practice solution to the recycling of post-consumer glass in rural areas looking specifically at local processing options and the use of processed glass for drainage purposes. This report considers the suitability of the available local process methods and the evidence supporting the use of glass as an appropriate drainage medium.

If waste glass in the Western Isles were to be diverted from landfill and recycled this would have the benefit of reducing landfill tax costs for the Local Authority, extending the life of landfill sites and thus helping to preserve the environment. Post-consumer glass recycling, especially where the local community has an active role, can also be used to increase public awareness of general recycling issues. As part of a community based recycling initiative, the collection of post-consumer glass without the need to separate colours can be developed efficiently in conjunction with the collection of other recyclates.

A recent survey of the composition of household waste in the Western Isles suggests that 8% of the waste produced in the Western Isles is made up of glass. Although this is slightly lower than the United Kingdom average of 9.25% this is still a significant quantity of recyclable material which could be diverted from landfill.

The household waste composition analysis carried out in 2002 divided waste glass in the Western Isles is up into categories as detailed below:

Figure 1: (Source: Analysis of Household Waste Composition in the Western Isles 2002)



Recycled crushed glass (cullet) is a hard, inert material with a high compressive strength that has been used extensively in the U.S.A as a substitute for natural aggregates, only recently have significant quantities been used in the United Kingdom. When considering recycling in a rural and island community such as the Western Isles, sustainable development is considered to be a key concept. Sustainable development as defined by the World Commission on Environment and Development (WECD) is *"development that meets the needs of the present without compromising the ability of future generations to meet their own needs"* (Johnston et al 2000). It is accepted that there is a need to develop peripheral areas and assist the communities living there in order to maintain their culture and heritage.

Traditional recycling projects in such areas are rarely economically feasible due to the distance between the collection of the post-consumer goods and the processing facilities. However it has been found that the recycling of post-consumer glass can be cost effective within peripheral locations provided that the glass does not need to be separated into individual colours (fewer collection points are required) and the processing operation can carried out locally rather than being transported by sea and road to a traditional recycling plant in different coloured batches.

Following unsuccessful trials using a proprietary glass breaker, the GC100 Glasshopper machine manufactured by CP Products as a volume reduction tool for glass, post-consumer glass collected in the Western Isles is crushed using a 360^0 tracked excavator.

This operation breaks us the glass into sub 20mm sized pieces but as there is no screening and polishing process some sharp edges are still present and there is no facility to allow the removal of undersized particles or bottle caps and lids. Consequently the processed glass can only be used for a limited range of applications and the original plan to trial use the processed glass in croft field drains could not be progressed as there could be a risk of the sharp glass being re-excavated by hand at a later date.

Provided the processed glass was only handled by machine and the applications was such that there was little possibility of being re-excavated it was found that the glass worked efficiently for drainage applications. There was little or no soil migrating into the drainage pipe compared to drains that used stone aggregate as a drainage medium. Overall using post-consumer glass in this way was found an excellent alternative to natural quarried virgin aggregate.

The limiting factor to the use of the glass was the quality of the final processed product. Although effective as a drainage medium, the sharp edges and non-consistent particle size restricted the range of use. It is suggested that if it was possible to produce a range of different cullet sizes with all of the sharp edges removed, the processed material could be used for a number of other applications and could even be marketed to generate revenue.

LIST OF FIGURES **Page**

LIST OF TABLES **Page**

LIST OF PLATES **Page**

ACKNOWLEDGEMENTS

With thanks to David Macleod, Uisdean Fraser, Roy Shirkie, Tony Robson, Kenny Maclennan, Hugh McCoach and all the local contractors, community groups and academic institutions mentioned for all their assistance.

1.0 INTRODUCTION

Stone aggregate such as sand and gravel are widely used as drainage mediums, however it has been discovered that by using recycled glass the same results can be achieved while simultaneously reducing environmental degradation.

The use of post-consumer glass as aggregate is no longer regarded as innovative however the use of low-cost processing equipment for small-scale recycling projects in peripheral areas is innovative and there is potential for commercial exploitation. This project aims to find a low-cost practical use for post-consumer glass in rural and island areas, where the distance is too great to allow transportation to a Glass Recycling Facility to be economically or environmentally feasible. Taking glass to a recycling facility can also have a negative impact on the environment e.g., distance a lorry would have to travel, fuel use and emissions. Therefore it is more practicable and environmentally sustainable to identify and develop a local process method and end use for post consumer glass. Recycling glass in this way means that it does not need to be colour separated therefore there is no risk of cross contamination, similarly fewer bottle banks are required, thus fewer collection trips are necessary resulting in additional fuel savings.

Glass waste is generated from a number of sources including, bottles, glass packaging (containers), flat glass (windows) and electrical equipment (TV's, computers). It is estimated there is up to 5.5 million tonnes waste glass generated in the United Kingdom each year and of that less than 1 million tonnes is actually recycled.

Barriers hindering the improvement of recycling include:

- Problems faced by local authorities in introducing more 'collection sites'.
- Public awareness.
- In-sufficient quantity of material being delivered.
- Lack of high volume and high value uses for cullet.

However the Waste Resources and Action Programme (W.R.A.P) have created targets to be met by the end of 2004:

- To recycle 770,000 tonnes of waste glass per year.
- Find new uses for 100, 000 more tonnes per year.

- Use at least 200, 000 tonnes of green and mixed colour glass for use as an aggregate within the construction industry.

There are many reasons to recycle glass:

- To save on landfill tax.
- It is environmentally more sustainable.
- To comply with legislation and regulation.
- Potential to replace virgin aggregate with a recycled material.

The quality of the recycled glass has been obstructing market development, but a concerted effort has gone into research and development in order to discover the many advantages of using recycled glass (Remade 2003).

It is generally accepted that sustainable development should be concentrated at a local level to encourage social and economic development as *"salvation begins with the people"* (Prattis *in* Simpson 1978 p.129). Any approach to local sustainability is likely to raise issues associated with 'quality of life'. This is a central theme in sustainability as it has been suggested that people from all social groups feel that their quality of life can be eroded if there is limited development (CDF 1995).

Rural communities and economies are complex and dynamic entities functioning in an environment of accelerating change (Nothdurft 1990). It is challenging to assist rural areas in seizing change and to utilise it to their advantage by ensuring that the values associated with rural life are protected even although the structure of rural economies is evolving (Nothdurft 1990).

In the United Kingdom there are national policies committed to developing rural areas, it is recognised that a healthy rural economy will not evolve through market forces as the inefficiency of markets is inherent in the very nature of rurality (Nothdurft 1990). In other words the distance from central markets and the scattered population prevents rural communities from achieving and in some cases maintaining a flourishing economy. There has been a history of public funding to combat these inefficiencies and although there have been various budget priorities there is still a commitment to ensuring that those in rural areas are able to access the same services and amenities available to those in urban areas such as recycling (Nothdurft 1990).

Scotland's National Waste Plan has been designed as a blueprint for the future. It is to be the cornerstone of the National Waste Strategy: Scotland and is about the 'real' behavioural change required to minimise the waste we generate and the opportunities that will stem from this.

Separating resource use from economic growth is a challenge to promoting sustainable development especially in regard to waste. In Scotland we dispose of more than 90% of our domestic and municipal waste into landfill sites. By disposing of our waste in this way we are wasting a huge amount of resources while having a damaging effect on the environment through the creation of greenhouse and other gases.

The waste hierarchy identified in the United Kingdom's Strategy on Sustainable Development is embodied in Government planning guidance and sets out 4 options for waste management which are; **reduction, reuse, recycle and disposal**. The geographic location of Western Isles makes it remote in terms of recycling markets while the price instability of recycled materials and prohibitive freight costs have resulted in a need for change. As an island community dependant both sea and road transport links, a different approach to the way materials are recycled is required, one that is different from most councils on the UK mainland.

Community Involvement is of particular importance to any recycling initiative in small communities such as the Western Isles and the Comhairle has recognised the need to work closely with community groups establishing a network of community managed Bring Sites for glass and other recyclates and also developing, where practicable, local applications and local markets for the products from recycled materials.

2.0 AIM

To find a practicable, low-cost process method for post-consumer glass and develop a suitable application for the processed glass which can be used in small island communities.

2.1 OBJECTIVES:

- Assess the suitability of the CP GC100 Glass Crusher as a low cost tool for the purpose of producing a consistent cullet size of the correct shape.
- Consider alternative low cost process tools.
- Assess the suitability of the produced cullet as a drainage medium for Croft Drainage, Verge Drains and Soak away/Bio-filter medium.
- Assess the effect on drainage performance of varying particle size.
- Assess the handling difficulties experienced during the processing operation.
- Assess the handling difficulties experienced while using the material.
- Assess any Health and Safety problems faced when handling and processing glass.
- Receive, collate and assess feedback from practical tests carried out.
- Produce a report to show other rural areas what has been learnt *("Guide to the practical use of post-consumer glass in rural areas").*
- Project results to be documented in the form of a technical guide.
- Produce an assessment in association with *Remade Scotland, Scottish Agricultural College* and *Lews Castle College.*

This information will assist with the development of a marketable product at a local level and by distributing the results similar schemes can be developed in other island communities.

3.0 BACKGROUND

Comhairle nan Eilean Siar (CnES) is a democratically elected local authority whose purpose is to sustain and improve the quality of life for all the people of the Western Isles, respecting the cultural and religious traditions by fulfilling the seven principals of public life; selflessness, integrity, objectivity, accountability, openness, honesty and leadership.

The Western Isles are a chain of islands that stretch c.130 miles from north to south and are situated approximately 30 miles off the northwest coast of the Highlands of Scotland. The major inhabited islands that make up the Western Isles are Lewis and Harris, North Uist, Benbecula, South Uist and Barra. In addition there are the inhabited offshore islands of Great Bernera, Scalpay, Berneray, Eriskay and Vatersay. The total population is estimated to be 27,940 (0.5% of Scotland's population as a whole) a decrease of 6% from 1991–1998 (CnES). The geographical spread of the population is uneven with approximately 19,000 situated in the most northerly island of Lewis whilst none of the other islands has a population greater than 2,000. The total land area of the islands are 289, 000 hectares, it is therefore clear that the Western Isles are sparsely populated (CnES).

The Western Isles are peripheral to both the main population centres of urban and industrial Scotland and to the main focus of expansion in the southeast of England. The Western Isles is regarded as a remote and rural area in Scotland. The word 'rural' can be defined as "an area which is dominated by land uses such as forestry, agriculture or large open spaces of undeveloped land which comprise small, lower order settlements displaying a strong relationship between the buildings and the surrounding expansive landscape which is perceived as rural by most residents and which are thought to generate a way of life that is characterised by a cohesive identity based on a respect for the environment and behavioural qualities of living as part of an extensive landscape" (Johnston et al 2000).

Rural areas can possess a variety of characteristics; those which are defined functionally by geography and land use and those which are nearer to urban centres causing their rurality to be a constructed notion consisting of social and cultural ideologies (Johnston et al 2000). Early studies have noted that rural communities are 'resilient in the face of change' and close relationships can lead to cooperative action for the common good. This is where the idea of community can be merged with the concept of sustainability as they can form long-term strategies to promote development in rural regions (Johnston et al 2000).

Similarly peripherality can be a significant handicap to a variety of economic activities. For example the further away from markets a business is, the higher the transport costs are and the further away from central decision

making in Government. Peripherality acts as an influence regarding an area's 'relative economic need' (Owen et al 1983).

Glass is the most recycled packaging material in the United Kingdom with an estimated 50,000 bottle banks scattered around the country. Despite this only 1/3 of the glass packaging being used is currently recycled, with the rest going to landfill - wasting resources and harming the environment. Most European countries have attained high levels of recycling and maintained them over recent years while in most areas of the United Kingdom the infrastructure is still not in place to allow recycling levels to increase. In Europe there an average of one Bottle Bank for every 1500 people along with kerbside and collection, while the United Kingdom has an average of one Bottle Bank for every 2750 people, with only 10% of households receiving kerbside collection and little or no commercial participation (Glasspac 2002).

Distance and transport are important factors that can influence the potential for development while simultaneously affecting the inhabitants' perception regarding their economic and social well being, especially with regard to recycling being situated so far away from recycling centres.

The current density of Bottle Banks in the Western Isles exceeds the European average with approximately one bank per 1000 people and there is currently a pilot project underway to collect waste glass from commercial premises in the town of Stornoway. However, when the sparsity of population in the Western isles is taken into consideration, it is obvious that to achieve saturation coverage for Bottle Banks in the Western Isles even more sites will be required, possibly one Bank for every 500 people. Stornoway is the only large town in the Western Isles and is probably the only area where a practicable kerbside collection scheme could be sustained therefore it is imperative that access to a Bring Point is made as easy as possible.

It is not worthwhile to transport collected recyclates to the mainland for processing, therefore it is even more important to find alternative uses for post-consumer materials within the Western Isles. There would be little or no money generated from what was sent to be recycled as the transportation costs to the recycling facilities are relatively high while the return on the recycled materials is low.

Of the waste produced in the Western Isles each year, 93% goes into the landfill while only 7% is recycled. However this is set to change in the near future as the local council aim to recycle a higher percentage of materials instead of sending them to the landfill.

Characterising the Highlands and Islands as remote portrays a strong sense of continuing geographic disadvantage and accessibility problems that are viewed as debilitating and pervasive influences.

Remade Scotland states that the success of recycled materials is determined by the **relative cost** of the materials, which is often what causes recycling to fail. However these financial disagreements can be overcome by finding potential markets for the recycled materials.

One such material is post-consumer glass, this can be used for many different applications, and some are listed below:

- Construction of road aggregate
- Industrial abrasive
- Filtration
- Insulation material
- Decoration

Glass can also be used as a drainage medium. The purpose of subsurface drainage is to; improve the soil for vegetative growth; reduce erosion; improve water quality; collect groundwater for alternative uses; remove water from 'heavy use' areas such as around buildings and roads; and regulating water to control health hazards by regulating the flow of ground water and the water table, by intercepting and preventing water from moving into the wet area, by regulating sub-irrigated or waste disposal areas and by serving as an outlet for other sub-surface drains (NYS Dept. of Economic Development 1999).

Research experts from the Ohio State University state that drainage is the number one factor-affecting crop yield. A study carried out by the University showed that improved subsurface drainage can increase crop yield by 50%. Drainage also increases the effectiveness of fertiliser, decreases the risk of flooding, allows for a longer growing season and prevents heavy soil erosion while reducing downtime and labour costs.

Construction aggregates are a secondary glass recycling market and drainage aggregate is a speciality use. Traditional glass recycling projects in peripheral areas have faced problems such as unstable prices and lack of local processing facilities. But the main difficulties in establishing greater levels of recycling are no supporting infrastructure and poor demand for the recycled materials. Remade aims to provide the support and encouragement, which will eventually lead to the increase in the number of markets for recycled goods in Scotland.

Their Strategy is to:

Identify Markets → Material Specification → Process Technology → Cost Benefit Analysis → Implement

4.0 GLASS RECYCLING OPTIONS

Glass is collected through a variety of channels e.g., kerbside collection and bottle banks, then it is either put through a standard furnace where the glass is melted down through a process called *'beneficiation'* (not carried out in the Western Isles) or it is broken up into smaller pieces by machinery such as a glass crusher (this process is carried out in the Western Isles). Clear glass is usually melted down to be made into containers however there is not such a demand for coloured glass especially green glass but mixed colour glass can be used to produce speciality products such as **drainage aggregate**.

Each glass type has different properties influencing how they melt/break up and how recyclable they are. Small impurities (contaminants) can cause defects if left e.g., Organic contaminants – if there's any material remaining it will vaporise; Metal Contaminants – can be magnetically removed or detected electronically; Ceramic Contaminants – are the most problematic as there is no definite means of removal. **The key to recycling glass is to maximise your market and minimise the waste** (Remade 1999).

To improve the level of recycling in the United Kingdom the public should be educated about the benefits of recycling while the number of bottle banks and kerbside collections should increase. Although the United Kingdom currently recycles 35% of glass, by 2006 that figure has to be doubled. To achieve this attention should be paid to 4 factors:

- Bottle banks

  Evidence from Europe shows that more bottle banks results in a higher collection, and maintaining colour separation if desired (Glasspac 2002).

- Colour separation

  50% of glass collected is green, mixed colour glass can only be used to make green containers as clear glass is sensitive to contamination from coloured glass. Therefore, when using a beneficiation process, colour separation enables more glass to be recycled (Glasspac 2002).

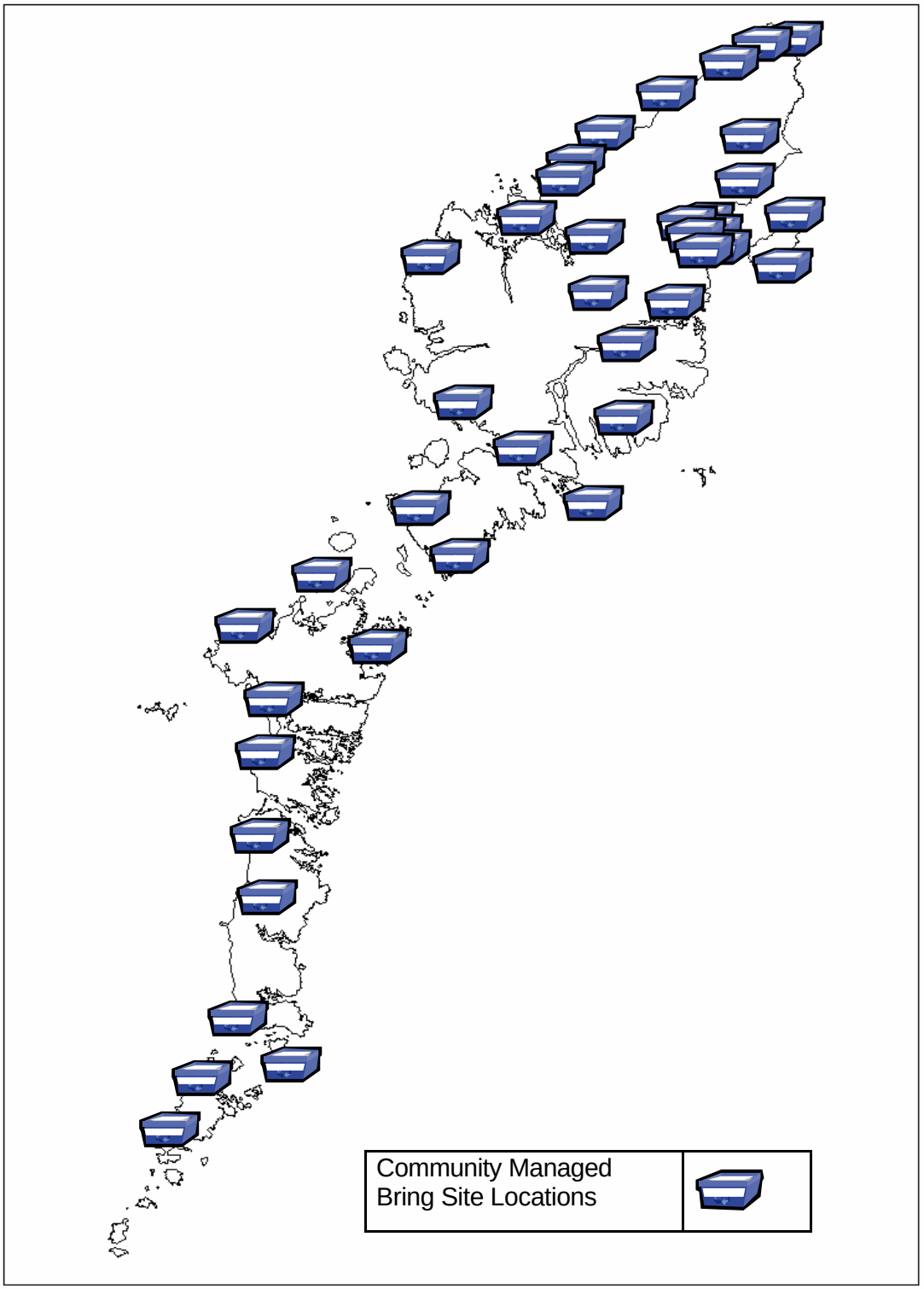
- Kerbside collection

Where there is a sufficient population density, this would increase the amount of glass collected significantly, would be cost effective and easy to use, increase public involvement/awareness, allow coloured glass to be separated easily and there is no concern regarding health and safety. Similarly it is estimated that approximately 500 jobs are generated from every additional 100,000 tonnes of glass collected, therefore if all the glass that goes to landfill in the United Kingdom at present was recycled an extra 7,500 jobs could be created (Glass Pac 2002). However, within the Western Isles, Stornoway is the only location which has a sufficient number of people to carry out viable kerbside collections (trials are to be carried out). It is also hoped that the number of collection bank sites situated throughout the more rural areas throughout the islands would be increased to allow for one bank for every 500 people, as kerbside collection would not be economically sustainable.

- Alternative uses

Having established that there is no benefit in transporting post-consumer glass over 200 miles to a processor equipped to re-melt the glass for the production of "new" glass products an important factor in considering appropriate process methods is the end use of the processed material. This project set out to produce a basic aggregate replacement from post-consumer glass which could be used in drainage applications in the Western Isles without the need to export material to the mainland.

Figure 1. **Location of Collection Points in the Western Isles**



5.0 MARKET USE OF CULLET

The demand for cullet (recycled glass) has increased in recent years. Glass that is not pure in colour but mixed cannot be reused in the container industry as colour purity is essential, instead the cullet must be used elsewhere (www.letsrecycle.com).

Recycled glass finds its way into a variety of uses, including:

- Drain pipe bedding and backfill
- Septic tank drain fields
- French drains
- Retaining wall backfill (Source: www.sustainableworld.org.uk)

The UK government has set a target of 25% of all municipal waste to be recycled by 2005 and 33% by 2015. For the Government to attain the recycling targets it has set, significant increases in the recovery of packaging materials, including glass, must be achieved. The UK consumes approximately 1.4 million tonnes of coloured glass per annum, the majority of which is green (Pascoe et al 2001).

The surplus of green glass in the UK is due to an imbalance between production and imports. The relatively low value of green cullet, combined with increasing transport costs has prompted some local authorities to consider alternative uses of coloured glass cullet that do not require the material to be re-melted. Alternative uses for recycled glass containers include abrasives, construction and decorative aggregates, glasphalt, concrete additives and absorption and filtration aids. A study carried out by the University of Exeter has shown that in most cases these glass products can be produced using standard mineral processing techniques (Pascoe et al 2001).

One of the original objectives of the study was to consider finely ground glass as a potential additive for the treatment of acid mine drainage. The study confirmed that finely ground glass could be used to neutralise the acid content of industrial water. The finer the particle size, the greater the surface area therefore, the more effective the glass became. However despite this finding the effectiveness of glass is far lower (100 times less effective) than conventional neutralising agents such as slaked lime (Pascoe et al 2001).

The Waste Test and Research Centre at the University of Exeter has also reviewed current and potential uses for ground/crushed coloured glass products and the impact these alternative products are likely to have on the UK market. It found a promising alternative for recycled glass, which is detailed in **Table 1**:

Table 1. **Summary of Main Alternative Use of Waste Glass**

(Source: www.ex.ac.uk)

Application	**Products to be replaced**	**Potential advantages of recycled glass product**	**Potential disadvantages of recycled glass product**
Construction aggregate e.g. base course for roads, land drains, backfill	Crushed rock aggregate.	Similar or lower cost. Resistant to load under compression and impact. Good drainage properties.	Engineering specifications can be material specific. Other recycled materials (e.g. construction waste) available.

The application and subsequent potential demand for glass based aggregate replacement will depend on the quality of the processed material. To be suitable for use above ground or applications where the glass could easily be re-excavated by hand the glass would have to be non-sharp. Although the basic crushing process used was expected to minimise the production of shards, without a screening and sanding/polishing process it would be unlikely that the output would be non-sharp.

6.0 METHODOLOGY

In order to carry out this research project many different methods and techniques were used. They varied between both primary and secondary data retrieval. To achieve the aim and objectives the following methods were utilised:

- Interviews (Appendices 1,2) were carried out on the 2nd, 3rd and 9th of September 2003 to complement the questionnaires and to provide a more conversational aspect to the data by getting to appreciate people's personal viewpoints and experiences of the subject matter. By using the interviews to gather information it was crucial to allow the interviewees to talk freely. The interviews were conducted in such a way as to explore the subjective opinions of the interviewee allowing the information, which was gathered from the interviews to be analysed using both a textual and statistical approach.
- A survey was designed and used as a tool to gather relevant field data from the contractors (Appendix 3). These original pieces of research were gathered from carefully considered research objectives and carried out on 4th September 2003. The information was organised and edited to display the most appropriate information concerning the aim and objectives of the research project and is disclosed in the Results Chapter.
- Relevant information was also gathered using Internet sources. A number of useful contacts were obtained through communication by email, which produced crucial and relevant information. Academic journals, reports and other similar desk based evidence was used to support the research paper whilst supplying useful contacts which enabled further exploration of the research paper context.
- Similarly a significant amount of information was gathered through secondary data collection such as environmental reports and regional plans and strategies. Relevant information researched from books; reports and journals produced a vast array of contextual material regarding the broad themes of the research paper. This extensive volume of information has been condensed and exhibited throughout the report mainly in the Background, Introduction and Results sections.
-

7.0 RESULTS

7.1 Assess the suitability of the CP GC100 Glass Crusher as a low cost tool for the purpose of producing a consistent cullet size of the correct shape. (Appendix 2)

Trials were undertaken to test the suitability of the CP GC100 Glass Crusher as a means of producing regular sized cullet from post-consumer glass. Although designed only as a volume reduction tool for glass, with no facility to screen the output material, output particle size could be varied by using different combinations of breaker bars.

The process operation of the GC100 is essentially a vertical hammer mill fitted with either two or four swinging arms or breaker bars. Post consumer glass is loaded into a hopper and carried by a small lift conveyor which discharges vertically by gravity into the processing chamber. The discharge outlet is cone-shaped and it was hoped that, combined with the centrifugal force applied to the glass fragments by the hammer-mill, this would help reduce the sharps content of the processed glass.

In practice however, the high velocity impact of the swinging arm breaker bars resulted in a shattering effect on the bottles, which produced an output material consisting mainly of sharp elongated shards.

The GC100 is designed for use with either two or four breaker bars fitted to the hammer-mill and this can be used as a means of regulating output particle size. Experiments were carried out using each set up but although the output particle size was reduced by using four breaker bars, the quality of the output remained the same with more than 90% of the total glass processed being was too sharp to be used as an aggregate replacement. The glass was processed in batches of approximately one tonne with a measurement taken of a typical particle size. A visual assessment was carried out to estimate the proportion of the output material, which was considered too sharp to be suitable for use as an aggregate replacement.

Results showed that with two breaker bars the average particle size was approximately 35mm x 60mm, but even whole bottles could occasionally pass through the breaker bars without being broken. This presumably was caused by the pivoting action of the breaker bars when two bottles fall into the process area at the same time. With four breaker bars the average particle size was slightly smaller at approximately 25mm x 55mm but there was a higher quantity of very sharp fines.

In each of the trials 90% of the glass processed by the GC100 machine was considered to be too sharp and of an unsuitable shape to be used as an aggregate replacement, while only 10% was considered to be potentially suitable for this use (Shirkie, CnES 2003). The CP GC100 was designed only as a volume reduction tool and the trials have shown that this is the limit of its capabilities.

It was therefore decided that an alternative process method would have to be considered.

From the trials carried out using the GC100 it was apparent that the use of a high-velocity bottle breaking system would probably result in a high level of sharp particles in the output material unless a more sophisticated system was designed to include a grading, screening and polishing stage.

Having considered the plant and machinery available to us on-site, it was determined that it would be possible to use the site's 13 tonne tracked excavator to crush the glass. Using the steel tracks and a wide flat bucket would have a low-velocity grinding action and would potentially reduce the percentage of sharp elongated shards present in the output material. By confining the glass to a small area using concrete walls, the fine particles of crushed glass would acts as an abrasive on the sharp edges of the larger particles. This crushing operation was found to produce

a better product than the CP GC100. Although the larger pieces of glass still had some sharp edges, the percentage of elongated shards present was significantly reduced.

The particle size ranged from approximately 75mm x 60mm (50%) down to a particle size similar to course sand. As with the output from the GC100, there was no screening or polishing process and the product must still be considered as a potentially hazardous material to handle. Because of this, the crushed glass could only be considered for use in subsoil applications where the glass is physically prevented from migrating to the surface and where there is no risk of the material being excavated manually at a later date.

The post-consumer glass is processed in a bay constructed of 'A' blocks which are easy to manoeuvre. These blocks were found by CnES to be an ideal type of block to create a process area and a 'store' for the processed glass. They can be positioned to form various shapes of bay, and trials were carried out to determine the most suitable shape to allow access for unloading banks, processing operations and loading the final product. The bay CnES found to be the 'best fit' for the tracked excavator to lift glass most efficiently, was long and narrow in design and resulted in less spillage when the digger lifted a load. A cost of £5000 was incurred at both landfill sites in the Western Isles, Bennadrove in Lewis and at Rueval in Benbecula to construct these process and storage areas.

7.2 Assess the suitability of the processed glass as a drainage medium for Croft Drainage, Verge Drains and Soak away/Bio-filter medium. (Appendix 3)

7.2.1 EXAMPLES OF PROJECTS USING RECYCLED GLASS IN THE WESTERN ISLES

7.2.2 STORNOWAY AMENITY TRUST

A trench for a drain was dug alongside a new road (April 2003), which had been constructed at the Castle Green in Stornoway, Isle of Lewis. The trench was c.900mm deep, c.400mm wide 200m long and recycled glass was used as a drainage material instead of normal stone aggregate. Approximately 60 tonnes of recycled glass was used as a drainage medium for the project.

The results gathered from this project were:

Good Points

- Practical application for a locally recycled product.
- Cost savings as the glass was free - only had to pay for loading and transportation costs.
- Saves on normal filter material – usually virgin aggregate
- Material allows water to filter through.

Bad Points

- Irregular in shape
- Difficult/dangerous to handle.
- Sharp edges/poorly crushed.
- Messy (when the lorry tipped its load it appeared to spread everywhere).
- If repairs are needed in the future it could prove extremely hazardous as reopening trench would expose sharp pieces of glass.

While tipping the glass out of the lorry the Stornoway Amenity Trust experienced significant problems; they realized that the glass contained sharp pieces of glass, of which a number scattered onto the grass underneath the lorry. To solve this problem a sheet of tarpaulin was laid under the lorry and into the trench so that when the lorry tipped any excess glass would fall onto the tarpaulin. The tarpaulin was then lifted and the excess glass tipped into the trench, this avoided any glass falling onto the grass where it could be hazardous.

This project highlighted the problem of poorly crushed glass. The glass stored in the 'glass bay' at Bennadrove should always be processed correctly at time of collection. However, operator error can result in large chunks of glass being present or the material may not have been fully processed due to lack of notice given for the collection of glass. Other factors which can effect the quality of the processing operation include having too much glass in the bay or not processing the glass soon enough after it arrives at the site.

7.2.3 TONG LAND AND PROPERTY TRUSTEES and the TONG MISSION HOUSE TRUSTEES

Two projects were carried out. New drains were laid in the car park at the community centre and at the car park at the local Church. Approximately 150 tonnes of crushed post-consumer glass were used as a drainage medium for both projects.

Plate 2. 'Normal' soil trench not as deep as in clay soil. Normal soil = 15" deep c.10" glass infill to nearly top of trench then clean boulders put on top to allow water to filter through, if soil put on top could cause filtration to be poor and could lead to the pipe clogging up. Normal 6" drainage pipe used (perforated).

Plate 3. Clay soil trench has to be dug a lot deeper, 18", usually with lateral drains, filled 2/3 with glass then clean stones.

For both soil types drains have to dug at an angle (downwards) have to make sure there are no uneven dips or hollows in the descent as water will eventually gather there and any build-up of soil/glass particles may collect, blocking the pipe and reducing the effectiveness of the drain.

Mr Kenny Maclennan representing the Trustees stated that processed glass was the best drainage material they had ever used. The projects were carried out at one of the wettest times in 2002.

When the drains were laid it was a few weeks before the clean stone was put on-top of the glass and they could see the water filter down through the glass to the pipe below.

The Trustees did suggest that the glass could be dangerous if common sense was not applied due to its irregular shape and sharp edges and because the aggregate replacement being produced at the moment is sharp, it has to be stored safely and sensibly, taking measures to prevent access by people or animals. However, they would definitely consider using it again as they found it to be a better filter medium for drainage purposes than traditional aggregates used in previous projects. Unfortunately they did not consider that it would be suitable for any other applications unless a non-sharp product with a pre-determined size, shape and level of abrasiveness was available.

Mr MacLennan went on to say that the Trustees considered that processed glass could be suitable for other applications if the shape, size and sharpness of the product could be regulated. It is easy to work with, whether using an excavator or manually by shovel. Whereas some stone based aggregate can be difficult to shovel manually, the glass separates easily making it less physically demanding to shovel. It can also be taken easily from the side of the pile and not just the bottom, making it easier to move as less energy is expelled.

The only occasion where the glass proved difficult to use during the Tong projects was where lateral drains were to be joined onto the main drain (lateral drains used in clay soils). If sharp pieces of glass were used where the drains need to be joined this could present a hazard to workmen. Therefore, when required, to allow work to be carried out safely clear space was left around these areas.

It was also recognised that problems could arise if care was not exercised when moving the processed glass on site. If any sharp pieces of glass were dropped this could present a hazard to people, animals and machinery. The Trustees overcame this problem by promptly scraping any fallen material into the trench. The Trustees also found that there was no dust produced when handling the glass based aggregate replacement.

The majority of croft land in the Western Isles that requires drainage can be categorised as Peaty Soil. Glass has been proved to be an ideal drainage material for this type of soil especially if the glass is covered with a layer of clean stone to prevent soil from migrating into the drainage material and clogging up the drain. Where cultivation of root vegetables is to take place over a drain, the trench must be dug deeper with at least 300mm of soil laid on top of the final drainage layer to ensure that when lifting the vegetables no glass is lifted at the same time.

However, Mr Maclennan considered that the processed glass provided to them would not be suitable for use in open drains in croft land, as it would present a potential hazard to people and animals. In addition, although this material

was used by them in sub-soil applications, because croft land is likely to be dug by hand in the future, he considered it to be inappropriate to use glass which was still sharp in croft land even in sub-soil applications.

In general, the Trustees found that the processed glass worked well for their application. The particle size of the material worked well as a drainage medium, performing better than traditional aggregates used previously. Although there were additional Health and Safety consideration, compared to the use of traditional aggregates, these were easily addressed on-site.

7.2.4 CONTRACTORS QUESTIONNAIRE (Appendix 3)

A survey was undertaken in September 2003 asking all the local contractors (10) in the Western Isles questions regarding the suitability of using recycled glass as a construction material specifically as a drainage medium. Over 1/3 completed the survey (37.5%). Of the contractors that had used cullet 100% replied.

Table 2.

RESULTS

Advantage	**Disadvantage**
Reduces amount going to landfill	Might not be readily available
Cheaper then stone fill	Might not be cost effective to use
	Too sharp to work with

The contractors that had used the glass cullet stated that they would definitely consider using it in again as it was an excellent drainage medium. If the size, shape and sharpness of the glass could be regulated they would also consider it for other uses not just for drainage applications.

8.0 DISCUSSION

Glass cullet is primarily silica (as are most sands and gravels) it is therefore a good drainage medium as it is made up of the same properties. Its reuse potential has been hindered by the limited knowledge of its engineering characteristics. In addition, the engineering parameters of glass cullet were believed to vary on a supplier-by-supplier basis depending on the processing equipment used to control the gradation.

Cullet was evaluated by a study carried out by the University of Exeter and was classified as either well-graded sand (SW) by the Unified Soil Classification System (USCS), or as a Number 10 aggregate by the American Association of Highway Transportation Officials (AASHTO). Material of this kind may be used in a variety of strength, filtering, and drainage applications such as: Base Course, Sub base, Embankments, Structural Fill, Nonstructural Fill, Utility Bedding and Backfill, Retaining Wall Backfill, Foundation Drainage, Drainage Blankets, French/Interceptor Drains, Sand Filters (Wastewater), Well Packing Media, Septage Field Media and Leachate Collection Media (www.depstate.pa.us).

The Glass Feedstock Evaluation Project, which was prepared for the Clean Washington Center, a division of the Department of Trade and Economic Development in Seattle, Washington, USA, states that: *"the use or recycled glass as a construction aggregate is feasible due to the documented engineering performance and environmental impact results. Comprehensive testing was conducted on cullet using variables including debris content (5% or 10% debris), max. size, (¾" minus or ¼" minus) and percent cullet (15%, 50% or 100% mixed with gravel). The tests conducted determined specific gravity, gradation, workability, durability, compaction, permeability, filtration capacity, thermal conductivity and shear strength."*

Other uses may exist, but the incorporation of glass in hot mix asphalt and structural concrete (other than flow-able fill) may lead to performance problems. The data presented in the next section is provided to evaluate the suitability of glass cullet for drainage applications.

9.0 SUITABILITY OF CULLET AS A DRAINAGE MATERIAL

The fines (small particles) in glass aggregate do not clump together or retain water like the fines in natural aggregates (stone), instead they 'wick' (?), repel water, rather than attract it. Similarly the fines form fewer 'lenses', in sand-sized fill applications, therefore providing an excellent drainage performance (Remade 1999). The angular shape of cullet removes finer particles resulting in the filter not having to operate for as long to supply clear water.

By using recycled glass as a medium for filtration to improve the cleanliness of the water energy can be saved, operating costs can be reduced and the lifetime of common filters can be extended. Academic research shows that recycled glass 'sand' removes more turbid particles, backwashes with less water (25% less water is used therefore there is less downtime) and sewage charges while helping our environment. Environmentally sound glass is lighter, more grains are compressed into each pound of glass ensuring cleaner water while conserving resources and reducing the cost of operating, all this can occur with approximately 20% filter media (Remade 1999).

9.1 Engineering Data

Specific gravity measure's a materials density. The specific gravity of glass cullet tests show that, at the same weight, there is 10 – 15% more glass aggregate (volume) than natural aggregate. Specific gravity is a widely used specification in order to determine the volume-density relationship. It is also an important baseline factor as density directly relates to engineering properties such as compaction and shear strength (Remade 1999).

A range of physical property tests were performed on the glass cullet samples in its freshly processed (crushed or sieved), i.e. its as-received (AR) condition. Tests were also conducted on the coarse fraction (CF) of each cullet sample, i.e., the material retained on the 2.36-mm (No.8) sieve. This coarser material was selected to be representative of a minimally processed glass cullet, or of a fully processed glass cullet that has lost a significant fraction of its finer material due to vibration-induced material segregation during transportation, or from rainfall-induced "washing" of non-plastic fines from glass cullet stockpiles (Remade 1999).

Additional physical property tests were performed on exhumed samples of compacted glass cullet to assess the effects of compaction-induced particle breakage. Two sets of friction angles were measured using direct shear and CD tri-axial testing equipment. While direct shear tests are relatively easy to perform, the tri-axial test is arguably one of the most accurate tests to evaluate the shear strength of soils and aggregates under *in situ* conditions.

Glass cullet suppliers were able to process glass cullet with consistent, reproducible properties. The engineering characteristics of the glass cullet varied slightly between suppliers, although it appears that these variations are more closely related to grain size distribution than the parent glass characteristics or processing procedures. While some differences in compaction were observed, the real implications of this difference on the perceived strength are negligible, because the measured friction angles (CD tri-axial) of the AR samples were almost identical. It is interesting to note that the loss of fines (CF samples) had a minimal effect on the measured friction angles (2º difference) (www.depstate.pa.us).

The results suggest that as long as glass cullet meets the AASHTO No. 10 (or No.8) classifications, its strength characteristics and overall engineering performance will be comparable to, or exceed those of

natural aggregates of the same gradation, regardless of the actual processing procedure (i.e., quarry crushing equipment versus recycling centre operations). This is an important finding because with gradation as the only control variable, it should be possible for local municipalities to generate reliable sources of glass cullet with these attributes without the sophisticated crushing equipment commonly associated with quarry operations. This not only offsets processing costs, but it also reduces the transportation costs of hauling recyclables (www.depstate.pa.us).

Unfortunately, however, the glass crushed using the tracked excavator in the Western Isles is unsuitable for structural engineering purposes. The consistency of the processed material is variable and is influenced by the level of processing carried out. Similarly it has not been polished or sanded to remove sharp edges or screened to remove over sized or undersized particles.

Although the basic process of using a tracked excavator to crush post-consumer glass can produce a reasonably useable aggregate replacement, applications of this product are limited. To manufacture a higher value product from post consumer glass with a wide range of applications would require a properly designed glass processing system capable of sizing, screening and polishing/sanding the glass, removing any lids or labels and producing a consistent, graded, non-sharp output material. The production of a high-value material such as described, could help generate income which could be used to help support this and other recycling initiatives.

10.0 HEALTH AND SAFETY

The optimum size for glass aggregate is 19mm (¾") as larger pieces could be hazardous. There is field evidence to suggest that cullet, 19mm, and smaller does not harm people (skin cuts and punctures) any more than natural aggregate e.g., crushed rock. However the dust created by processing glass is a concern as the chemical make-up of glass can include trace amounts of contaminants such as heavy metals (often less than 0.5%). The contaminant most evident is silica. Silica can exist as either an amorphous or crystalline structure. Amorphous silica is not considered significantly damaging however it has been shown that exposure to crystalline silica, which is dust of respirable size (below 10 microns) can result in long-term health problems, respiratory complaints and even fibrogenic lung disease otherwise known as SILICOSIS (Remade 1999).

However cullet is not considered to be damaging to health as dust coming of cullet has been determined to be virtually free of crystalline silica as the silica structure is converted to an amorphous state in the glass making process although dust from a glass cullet can contain from 1-3% of respirable crystalline silica it is not of a level that would be classed as having a detrimental impact on health. However to minimise the risk dust suppression techniques should be implemented.

10.1 PROBLEMS ARISING FROM USING RECYCLED GLASS

Recycled glass usually contains moisture either from the original content e.g., food or from being stored outside e.g., dew/rainwater. When cullet is too wet or dry processing and shipment can be extremely difficult therefore it is essential that there are strategies in place to control moisture. High moisture content can cause cullet dust particles to stick to the processing machinery. This in turn can clog up the screening devices, which are used for sizing and removing contaminants. Also as glass cullet is abrasive high moisture content can result in the increased wear and tear of the processing machinery. One way to avoid high moisture content is to ensure that stockpiles of glass are covered and stored inside prior to the processing stage (Remade 2003).

11.0 CASE STUDIES

11.1 Schenectady County, New York State, United States of America

"High permeability makes cullet a good candidate for many drainage applications" (NYS Dept of Economic Development).

Tests carried out proved the hypothesis; glass aggregate performs as well or better than stone as an aggregate for agricultural drainage projects. There were some concerns expressed such as:

- The glass would be sharp and injure grazing animals.
- Dangerous for humans to work where the glass was used.
- Glass might be unsightly, disturbing the natural appearance of the land.

However these fears were soon alleviated when it was realised how well the glass operated as a drainage medium.

Sieve tests were carried out aiming to identify the amount of glass aggregate able to pass through a variety of sieve sizes. This test helped to assess whether the glass would remain in place or whether it would travel downstream of the project site. The results showed that very little glass passed through the sieve (Appendix 4). However there was no formal test designed to show the workability of the glass as all concerned were satisfied with the material. A number of contractors stated that it was easier to work with than stone aggregate.

Similarly visual testing was carried out in the Spring of 1998, which showed that the drainage systems installed previously was functioning well, the target areas were draining and there was no glass to be found downstream. One year after the glass drainage system had been completed two excavations were done one was a cross-section of a drain that used a glass drainage medium and the other cross-section was of a drain that had no glass in it. These excavations were carried out to determine the condition of the drain, whether the soil had migrated and the affects of freeze-thaw conditions. What was discovered was that the drain without glass had soil migrating down into the drain whereas the drain that glass as a drainage medium was running clear, the glass looked dirty indicating that soil was moving down into the glass but had not entered the drain.

The results showed that the glass drain had improved the characteristics of flow into the drain while the soil around the drain that had no glass had extensive moisture retention and the soil around the 'glass drain' held very little moisture.

This report also found that using mixed glass cullet was more cost effective than using crushed stone aggregate as a drainage medium. Farmers were charged $6 per cubic yard for the 19mm (¾") crushed glass while crushed stone of a similar size was costing $8-$10 per cubic yard. It cost Schenectady County $35 per ton to produce while the facility charges were $55 per ton, in 1999, meaning that the $6 per cubic yard did not pay for the cost of processing the glass however the revenues from glass sales added revenue that compensated for the cost of the entire sorting and packaging process.

The Future…….

An indication of the system working, such as the desired drainage of water is being achieved, visual inspections have been undertaken: the target areas have drained well and there has been no glass found downstream of the project sites. No problems have arisen yet regarding the use of glass cullet as a drainage medium.

11.2 Clean Washington Center, Seattle, Washington State, U.S.A

The Clean Washington Center is a non-profit organisation that provides recycling market development services to businesses and Governments by providing advice, equipment and services to help manufacturers use recycled materials. They have carried out numerous studies on recycled glass.

According to the research undertaken for the Glass Feedstock Evaluation Project, prepared for the Clean Washington Center, the use of recycled glass as a construction aggregate is viable due to the documented results regarding engineering performance and the favourable environmental impact results. The tests conducted determined specific gravity, gradation, workability, durability, compaction, permeability, filtration capacity, thermal conductivity and shear strength. The results proved that the use of glass cullet as a substitution for sand and gravel in subsurface drainage applications is feasible.

Another study carried out was the examination of the potential for using finely processed recycled glass sand as a filtration medium in high-rate sand filtration. Previous studies and laboratory evidence generated by Pennsylvania State and San Jose Universities have shown that, when it is processed correctly, recycled glass is an effective filtration medium instead of natural sand in many applications. This project was undertaken at the swimming pool of an athletics club and was designed to determine whether glass 'sand' was able to attain or reduce the clarity of the water achieved by the traditional sand filter and to compare the two mediums on a number of variables including cost-effectiveness. The following conclusions were drawn:

- Using recycled glass improved water quality by 25%.
- Recycled glass increased backwash efficiency.
- Approximately 20% less glass 'sand' (by weight) was required for filtration.

The study supported the findings that glass worked better than 'normal' sand. It appeared to be able to catch more turbid particles, more effectively and efficiently. This may allow pool filters to be operated for fewer hours while still achieving the appropriate water clarity and quality while saving energy and prolonging the life of the filter equipment. Similarly as the backwashing is more efficient (23% reduction in water used) it uses up less pool water, which has been chemically treated, heated and filtered previously, and therefore reducing the amount of staff time required and operating time. These results were attained by using 20% less filter media (in weight), filter media is measured and purchased by weight, in economic terms large savings are made when using glass instead of sand such as; operating costs (CWC October 1998).

However when looking at slow sand filtration it was noted that using recycled glass might not be the best option as it would be difficult to purchase the large quantity (10, 000 cubic feet) of glass required, neither is it suitable to mix the two media, sand and glass together between the filters as the difference in specific gravity between glass and natural aggregate may affect the filter media between back flushing leading to the glass rising to the top over time if the media's stratify (CWC December 1995).

Another project carried out by the Clean Washington Center was one that tested, monitored and evaluated the use of crushed recycled glass for the treatment of residential wastewater. The main focus of this study was to compare the two biological filters using the 'state standard' sand as the treatment medium and the second using crushed recycled glass.

Similarly field tests have indicated that crushed glass be used as a replacement for sand in septic treatment systems as it is more permeable than sand. The higher permeability appears to reduce the potential of filter clogging. Similarly the higher permeability may allow greater hydraulic loading of a septic system while reducing the required size of the filter and thus the installation cost of the filter. Based on test data gathered in October 1996 the Washington State Department of Health amended its filter and sand-lined drain field trench filter media specifications. The Department also noted that the glass filter lasted longer than the sand filter. This may have been due to the higher permeability requiring more water volume to establish biological activity.

11.3 Waste and Resources Action Programme (WRAP), U.K.

WRAP has been established to promote sustainable waste management, with the main focus being on the creation of efficient and stable markets for recycled products and materials. It has received funding of over £40 million for 2001-2004 from the governing bodies of England, Wales, Scotland and Northern Ireland.

It has stated, from observing research carried out in the U.S.A, the prospects for post consumer glass are unclear, although research suggests that relatively fine particles mixed with natural aggregates would be the best way to recycle the glass. But after having discussions with aggregate suppliers W.R.A.P noted that the suppliers displayed a negative attitude to this prospect as they assume that blending will add to the cost of aggregate and their customers may regard the glass as a cheap waste product and think that they are receiving second rate materials.

However glass has been proven to have some useful properties:

- Absorbs little water and can make concrete more durable.
- Its hardness is better than most natural aggregates.
- The unique aesthetic properties may be used for decorative purposes.
- Very finely ground glass has ‘pozzolanic’ (or stabilising) properties that contribute to the strength of some types of concrete.

Tests carried out in the U.S.A state that glass would be suitable for a variety of uses, but the ASTM standards used in the U.S.A are not directly comparable with BS/EN standards present in the United Kingdom. However studies

are underway into the use of glass aggregates in concrete by two W.R.A.P projects taking place at the University of Sheffield and the University of Dundee (W.R.A.P 2003).

12.0 RECOMMENDATIONS

- The installation of a machine that can crush the glass into pre-determined pieces, of a uniform size and shape with non-sharp edges so that it would be more manageable and less hazardous. If this was achieved it would encourage more contractors and community groups to utilise this resource for various projects. Similarly it could be marketed and sold thus generating revenue which could be used for further recycling initiatives.
- Carry out trials of a collection scheme in Stornoway (higher population density than rest of the islands therefore could prove to be cost effective) of kerbside collection of separated recyclable materials e.g., one for glass, one for plastic, one for materials that could be composted and a refuse bin.
- Raise public awareness regarding recycling and implement an 'educating system' e.g., an easy to use brochure explaining how to sort materials and how to dispose of them (collection points or colour co-ordinated bins) which would encourage everyone throughout the islands, regardless of age, to recycle.
- Follow-up inspections to make sure that the cullet is fulfilling its aim as a suitable drainage medium, visual inspections should be sufficient.
- Devise alternative markets/uses for cullet other than drainage. However, to maximise the value of locally produced aggregate from post-consumer glass, equipment should be purchased to ensure that the cullet size, shape etc can be pre-determined depending on what it is to be used for. Even if it is to be used in drainage, it would be better if the cullet had smooth edges and was of an optimum, uniform shape and size.
- All glass processing systems produce an undersized output which could be used as a replacement for shot blast material. Although shot blast is a low-cost material on the mainland United Kingdom, there is no local, on-island source of this material and subsequently the costs are much higher when transportation costs are included.

13.0 CONCLUSION

The main aim of this research and development project when it was initially set was up to develop a low cost method of producing an aggregate replacement from post-consumer glass for drainage applications in rural areas and to use this information to produce a report and a technical guide which would be made available to any other rural areas. It was hoped that the CP GC100 Glasshopper already owned by Comhairle nan Eilean Siar could be used as a process tool to produce a suitable size and shape of processed glass to allow it to be used as an aggregate replacement in drainage applications.

From the trials using the GC100 it was clear that this equipment could not produce glass particles of a suitable shape or size for use as an aggregate replacement. It was therefore decided to consider if alternative process methods and equipment were available on site.

As a crushing action was considered to be more appropriate than the smashing action of the GC100 trials were carried out using a JCB tracked excavator. Using a concrete bay to keep the glass together and crushing the glass with the excavator it was found to be possible to produce a reasonably consistent particle sized product. Although the sharp edges were considerably reduced, the product could not be considered to be non-sharp and would only be suitable for subsoil applications.

The physical characteristics of this product limit its range of potential applications and because of this the proposed field trials in Croft Drainage could not be carried out. All trials were restricted to sub-soil applications where there was very little likelihood of the material being re-excavated by hand in the future.

Similarly, as there was no means of accurately varying particle sizes the trials to determine the effect on drainage performance of varying particle size could not be carried out.

From the trials carried out it was clear that the glass was easy to handle using conventional plant and machinery during the processing operation and no significant handling difficulties were experienced when using the processed glass. Care had to be taken to leave clear space near to pipe joins and access points and when unloading onto soft ground it was essential to provide protection to the tipping area.

There were no significant Health and Safety problems faced when handling and processing glass. Appropriate protective clothing, gloves and boots must be worn, but this would be a requirement in

similar works using conventional materials. Some additional care was necessary to minimise manual handling of the processed glass but this did not create any major operational difficulties.

Demand for the processed recycled glass is limited as it is a low-value product with restricted applications, however the glass has been used in a number of CnES funded Community Environmental Projects such as those funded by the Action by the Community on their Environment (A.C.E) Grant Scheme. Although it is a low-value product, the processed glass saves on extraction of virgin aggregates with subsequent savings on aggregates tax. There is also a saving on landfill tax by diverting what is fairly high-density material from landfill.

Although this system produced a product which could be used to replace some basic forms of virgin aggregate it is clear that to produce a higher grade of product would require investment in more advanced technology.

Significantly, CneS has just replaced the process operation at Bennadrove with a purpose built glass processing plant which can be set to transform post-consumer glass into a variety of shapes and sizes from sand into small, non-abrasive, pebble size cullet. The smaller scale operation at Rueval will however remain in operation using the excavator to crush the glass.

It is unfortunate that this project did not prove to be quite as successful as anticipated, however, it is clear that for small scale operations it is possible to turn post-consumer glass into a useable product using basic equipment which is readily available.

REFERENCES

Analysis of Household Waste Composition in the Western Isles (A.H.W.C.W.I)(March 2002)

Community Development Foundation (CDF) (1995) Towards Local Sustainability: A Review on Local Agenda 21 in the United Kingdom

Glass Pac (2002) Glass Recycling Report – Issue 1

Johnston R.J, Gregory. D, Pratt. G, Watts. M, (eds) (2000) The Dictionary of Human Geography 4th Edition Blackwell Publishers, Oxford.

New York State Department of Economic Development (1999) Glass Recycling Project – Schenectady County Schenectady County, Soil and Water Conservation District.

Nothdurft, W. E (March 1990) Community Led v. Agency Led Rural Development: Lessons from 3 U.K Rural Development Organisations *In* Michael, T. (ed) (1990) Rural Policy Issues The Arkelton Trust.

Owen, D. W and Coombes, M. G (March 1983) An Index of Peripherality For Local Areas in the United Kingdom ESU Research Paper No.6, University of Newcastle.

Pascoe, R.D., Barley, R.W. and Child, P.R., (2001) Autogenous grinding of glass cullet in a stirred mill, Recycling and Reuse of Glass Cullet (ed. Dhir, R.K., limbachiya, M.C. and Dyer, T.D.), pp 15-29, Thomas Telford Ltd, London.

Remade Scotland (2003) Glass Recycling Handbook – Assessment of Available Technologies

Remade Scotland (1999) Towards Sustainable Waste Management for Scotland

Simpson, D. R. F (ed) (1978) Island and Coastal Communities; Economic and Social Opportunities Fraser Allan Institute, Glasgow.

Case Studies

Schenectady County –

May 1999, Glass Recycling Project.

Promotional Video/DVD

Clean Washington Center -

December 1995, Evaluation of Crushed Recycled Glass as a Filtration Medium In Slow Sand Filtration.

March 1997, Crushed Glass as a Filter Medium for the Onsite Treatment of Wastewater.

October 1998, Evaluation of Recycled Crushed Glass Sand Media for High-Rate Sand Filtration.

WRAP

2003, Recycled Glass Market Study & Standards Review

W.R.A.P Factsheet No.8, The Waste and Resources Action Programme 18/03/02

Web Sites

Western Isles Islands Council
www.cne-siar.co.uk

Www.sustainableworld.org.uk	04/09/03
Www.letsrecycle.com	02/09/03
University of Exeter	02/09/03
www.ex.ac.uk	
www.depstate.pa.us	09/09/03
University of Sheffield	02/09/03
www.shef.ac.uk	
Glasgow Caledonian University	12/09/03
www.gcal.ac.uk	
Scottish Environmental Protection Agency	04/09/03
www.sepa.org.uk	
Waste and Resources Action Programme	10/09/03
www.wrap.org.uk	

APPENDIX 1

Interview with Roy Shirkie, Landfill Manager

- Installation and commissioning of plant?

- Introduction of collection points (new ones + how many + where)?

- Public awareness campaign to encourage participation?

- Was a study carried out into the best way to process the glass (flow method) and was it set up?

- What is processed glass like? (Shape/texture/size)

- Is it easy to work with/handle?

- Was the performance of CP GC100 assessed using different crusher bar set-ups?

- What settings were used?

- Which setting was found to be the best?

- How much could be produced, size etc on these settings?

- Why was CP GC100 Glass Crusher rejected as a suitable tool for processing glass?
    - Was it a low cost tool?
    - Did it produce consistent shapes and sizes?
    - What is used in its place?
    - Is it cheaper/better/produce correct shape and size?
    - Is it more economically feasible to use than CP GC100 Glass Crusher?

- How was the glass stored to avoid too much moisture seeping into it?

- Was there enough glass processed to allow field studies to be carried out?

- Was there an ongoing evaluation of the processed material e.g., looking at particle size, the volume of dust and waste (sharps) produced and waste?

- Were both laboratory and field tests undertaken?

E.g., in regards to soil type, precipitation levels, depth etc?

- If glass is broken before the processing stage does it make it more difficult to process/does it alter the way the glass is processed?

- Do many use recycled glass for projects (drainage/decorative/construction etc)?

- Is there a means by which glass could be processed to different specifications e.g., different settings determining the texture, shape and size of the glass?

- Any other comments?

APPENDIX 2

Community Groups

- Were laboratory and field tests carried out using various sizes and a constant (hypotheses?)? E.g., with regard to soil type, precipitation levels etc.

- Were a series of field tests carried out in a range of applications e.g., field drainage?

- Were laboratory trials set up to assess the effect of particle size on the various applications the material is used for?

- What did you think of using glass as a drainage material?

- Would you recommend its use for anything else?

- What difficulties did you have, if any, when using it?

Any other comments?

APPENDIX 3

CONTRACTORS QUESTIONNAIRE

Have you carried out any work on projects that have used recycled glass as a drainage material? If yes, what projects were they and when was the work carried out?

Would you recommend its use as a drainage material?

Where did you get the recycled glass?

What do you believe the advantages and disadvantages of using recycled glass are?

Did you find recycled glass difficult to handle/work with? Why?

Would you rather use recycled glass or traditional drainage materials? Why?

Are there any procedures within your company that are aimed at tackling the issues raised (if any) while using recycled glass? If yes what are they or did you install some after using the material?

Any other comments?

APPENDIX 4

Sieve Sizes

The following is data derived from sieve measurements taken from a Glass Cullet Drainage Project carried out by the Schenectady County, Soil and Water Conservation District. The sieves were obtained from the field office in New York, USA. The tests used approximately 2 pounds of both fine and coarse glass cullet from the recycling centre.

COARSE GLASS #1

PASS	#10	#60	#120	#230
#1		1.57%		<1%
#2		1.51%		<1%
#3		1.47%		<1%
#4		1.45%		<1%
#5		1.43%		<1%

FINE GLASS #2

PASS	#10	#60	#120	#230
#1	59.37%	9.37%	3.12%	1.57%
#2	59.28%	9.35%	3.11%	1.59%
#3	59.27%	9.35%	3.10%	1.60%
#4	59.25%	9.32%	3.10%	1.61%
#5	59.25%	9.11%	3.10%	1.63%

All the data is based on a percentage of material by weight passing through the corresponding sieve. As expected the tests showed that a very small percentage of coarse glass passed through the sieve. The fine glass worked well with tight sieves (smaller mesh sizes) however it did not work as well as the coarse material.