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Waste Plasterboard Composting

Literature Review

Prepared for the Ministry for the Environment

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Section I: Introduction

1.1 Project brief & background

The purpose of this report is to provide a comprehensive summary of available information on the viability of composting waste plasterboard generated from construction sites. This method for diverting plasterboard from landfill and cleanfill is being investigated because the Ministry for the Environment, in partnership with Winstone Wallboards, has identified composting as the preferred diversion option, but further information on the risks and benefits is required. This literature review collates and summarises information on:

- the benefits and disadvantages of adding waste plasterboard to compost products
- differences between composting technologies
- challenges and solutions to on-site processing
- collection and distribution challenges
- economic and financial issues
- environmental and health impacts
- other applications for reprocessing or reuse of waste plasterboard.

The literature review searched for peer reviewed material as a priority but also includes non peer-reviewed material and profiles of real-world examples of facilities using waste plasterboard as feedstock. Information is sourced from New Zealand and overseas.

The project objectives were to:

- identify benefits and challenges regarding processing waste plasterboard into compost products
- find solutions to some of the potential challenges (eg, the production of hydrogen sulphide when compost becomes anaerobic)
- investigate what other applications may be available for the reprocessing of waste plasterboard
- provide sufficient information to satisfy the requirements of the composting industry.

1.2 Methodology

The research was conducted through three different channels:

1.2.1 International

Enquiries were made with overseas contacts in the private and public sector in Canada, Australia and Europe. Information was gathered on current policy and practices as well as leads to further information sources.

1.2.2 New Zealand

Enquiries were made with representatives of key interest groups such as Compost New Zealand and Bio-Gro, and with community, council and private sector organisations currently composting waste plasterboard.

1.2.3 Desk-top search

The main source of information was a comprehensive desk-top search focused on locating, as a priority, as much peer reviewed and local material as possible. As anticipated in the project brief there was not a great deal of this material to be found. Much of what has been included has come from non peer reviewed or industry/community sources.

Search Methodology

ISIKnowledge databases were searched for the terms ‘plasterboard’ and ‘drywall’. The abstracts, and (if relevant) full texts of each article, were then checked manually. 209 articles were identified but only a small proportion of these were relevant.

The following ISIKnowledge databases were searched:

- Web of Science® (1900-present)
  Access to the world’s leading scholarly literature in the sciences, social sciences, arts, and humanities.
- Current Contents Connect® (1998-present)
  Complete tables of contents and bibliographic information from the world's leading scholarly journals and books; also includes relevant, evaluated websites and documents.
- ISI ProceedingsSM (1990-present)
  Proceedings of international conferences, symposia, seminars, colloquia, workshops, and conventions.
- CAB Abstracts® (1910-present)
  Authoritative research information on agriculture, environment and all related applied science disciplines.

Google Scholar was also searched. Due to the high number of references for plasterboard and drywall, the search was narrowed to the following terms:

- Plasterboard recycling
- Plasterboard composting
- Drywall recycling
- Drywall composting
- Gypsum wallboard recycling
- Gypsum wallboard composting

References within the articles retrieved were followed. Specific search terms were used within Google and Google Scholar as required. For example:

- Phosphogypsum radioactivity Australia plasterboard

Finally, a search was made of websites of plasterboard manufacturing and recycling companies and of waste management and recycling industry bodies in Europe, Scandinavia, North America and Australasia.

Section II: Gypsum plasterboard

2.1 Description & use

Gypsum plasterboard (also known as drywall, wallboard, sheetrock and GIB® plasterboard) is used in the construction industry for finishing interior wall surfaces. It is made primarily of gypsum (hydrous calcium sulphate) with a paper exterior liner, and includes other additives such as glue and binders. The exact composition of plasterboard depends on the purpose for which it is designed and the specific manufacturer's recipe and raw materials. Some types contain fibreglass, waterproofing materials and fire retardants. GIB® plasterboard does not contain fire retardants. It does however contain vermiculite in some fire resistant plasterboards.

Plasterboard is sold in sheets of varying lengths, widths and thicknesses and is typically finished with paint, wallpaper or other coatings once constructed.

2.1.1 Types available in New Zealand

Winstone Wallboards

Winstone Wallboards is the largest distributor of gypsum plasterboard in New Zealand and New Zealand's only manufacturer, with manufacturing plants in Auckland and Christchurch. Gypsum is sourced from Australia as a naturally occurring, mined substance. The paper liner is made from recycled material. (Winstone Wallboards Ltd, n.d.)

Winstone Wallboards produce nine types of plasterboard:

- GIB® Standard plasterboard – a lining material available in 10mm and 13mm thicknesses.
- GIB Aqualine® – an internal lining material designed for use in wet or humid areas such as bathrooms, kitchens, laundries and toilets.
- GIB Braceline® – a wall bracing sheet for light timber framed buildings.
- GIB Fyreline® – a fire resistant board.
- GIB Noiseline® – a plasterboard designed specifically for reducing the level of sound transmission between rooms.
- GIB Toughline® – a plasterboard designed specifically for use in areas requiring improved resistance to dents, chips and breakthrough.
- GIB Wideline® – a plasterboard that is 1350mm wide.
- GIB Ultraline® PLUS – a plasterboard with a Pearlcoat™ coated white surface paper which has a finer, smoother texture, and a mix of plaster and fibreglass reinforcing its core.
- GIB X-Block® – a specialised plasterboard to provide protection from X-ray radiation in medical facilities, dental clinics and veterinary practices without the use of lead.

The Material Data Safety Sheet (which outlines composition of the board) can be found in Appendix 1.

Elephant Plasterboard

Elephant Plasterboard is imported into New Zealand from Thailand. The product range (Elephant Plasterboard, 2007) includes:

- Standard Elephant Plasterboard
- Elephant Superboard – a high performance 10mm board
- Elephant Braceboard – has a higher density gypsum core
- Elephant Fireboard – designed for when higher fire ratings are required
- Elephant Noiseboard – for inter-tenancy applications and higher noise control
- Elephant Impactboard – for high impact areas
- Elephant Aquaboard – recommended for wet areas such as bathrooms, toilets, laundries and kitchens.

No Material Data Safety Sheet or any details on the composition of Elephant Plasterboard was found.

Building Materials (NZ) Ltd (BML)

BML also imports plasterboard into New Zealand from Thailand. Its product range (Building Materials (NZ) Ltd, 2007) is from BPB (British PlasterBoard) and includes:

- Standard plasterboard (blue trim)
- BPB Firestop plasterboard (red trim) – provides superior fire resistance and acoustic control for partitioning, wall lining and ceiling systems. Firestop boards include small quantities of chopped man made mineral glass fibre.
- BPB Aquastop plasterboard (green trim) – for wet area lining of bathroom, kitchens, laundries, and toilets. Moisture resistant boards include a silicone and/or a wax additive for moisture control.

The Material Safety Data Sheet for BPB plasterboard can be found in Appendix 2.

Drywall Direct Wholesale (NZ) Ltd

Drywall Direct (2008) imports plasterboard from BGC in Australia. Their product range includes:

- BGC 10mm Standard board
- BGC Water Resistant (WR) plasterboard

The Material Safety Data Sheet for BGC plasterboard can be found in Appendix 3.

It is worth noting that plasterboard is colour-coded according to type, however it appears that colour-coding is not consistent across the industry.

2.1.2 Different sources of gypsum

There are different sources of gypsum, which have different trace elements and in addition can have other forms of contamination.

Mined gypsum varies in purity. For example a South Australian study noted that mined gypsum from one source contained 92% calcium sulphate, with the remainder being lime, sulphate and other minerals (Moyle & MacGillivray, 2005). Winstone Wallboards import gypsum from Australia to sell as an agricultural soil amendment as well as in the manufacture of plasterboards. Whilst the material safety data sheets for

GIB® plasterboard (Appendix 1) state simply ‘gypsum or calcium sulphate dihydrate’, the agricultural product is described as being 93 to 98% calcium sulphate. Table 1 (Winstone Gypsum, n.d.(a)) shows the mineral analysis of major and minor components of Winstone's horticultural gypsum (quantities in ppm unless otherwise specified).

Mineral	Gypsum
Sulphur	***18%***
Calcium	***23.26%***
Aluminium	300
Antimony	< 4
Arsenic	< 1.0
Cadmium	< 0.2
Chlorine	1315
Cobalt	-
Copper	93.8
Chromium	-
Fluoride	100
Iron	80
Lead	< 10.0
Magnesium	93.8
Manganese	-
Mercury	< 0.05
Molybdenum	-
Phosphate	< 19
Potassium	50
Selenium	< 0.5
Silicon	800
Sodium	820
Tin	< 4
Uranium	-
Vanadium	-
Zinc	5

Table 1 Mineral analysis of horticultural gypsum

Flue gas desulphurisation gypsum arises from the ‘scrubbers’ installed in coal power stations to remove sulphur from the emissions. High purity limestone and forced oxygenation are required to create high quality gypsum, which can be more pure than mined gypsum. This source, along with mined gypsum, is appropriate for plasterboard manufacture and for nearly all reuse applications.

Phosphogypsum arises from the creation of phosphoric acid (for phosphate fertiliser) from the reaction of phosphoric rock and sulphuric acid. Between four and five tonnes of phosphogypsum are created for every tonne of phosphoric acid. As phosphoric rock contains uranium and thorium, which remain in the phosphogypsum, it produces radon gas as they decay. It has been calculated that building with phosphogypsum plasterboards in Australia could double exposure to radiation compared with the background level (O’Brien et al., 1995). There could be potentially greater exposure to installers (especially if dust is inhaled). The range of radioactivity levels is quite significant depending on the site of the mine (eg, Australian phosphoric rock has low levels compared with other countries). Although the installation of phosphogypsum in a home would be unlikely to raise radiation exposure levels to action levels, it would seem to be an unwise material to use.

2.2 Current situation

2.2.1 Current disposal

There is a wide range of estimates on the amount of waste plasterboard going to landfill in New Zealand.

According to the New Zealand Ecolabelling Trust (n.d.) approximately 20% by weight of all waste going to landfill is construction and demolition (C&D) waste and of this approximately 12% is gypsum plasterboard (ie, 2.4% of all landfilled waste is gypsum plasterboard). BRANZ (The Building Research Association of New Zealand) estimate that between 5% and 20% of C&D waste is plasterboard (Jaques, 1999) while REBRI (Resource Efficiency in Building and Related Industries, 2005a) claims that C&D waste makes up 17% of landfills as well as the majority of cleanfills, but does not specify what proportion of this is plasterboard.

The Ministry for the Environment (n.d.) estimates C&D waste may represent up to 50% of all waste generated in New Zealand, including 20% of all waste going to landfill and 80% of all waste going to cleanfill. Plasterboard waste typically makes up 18% by weight of C&D waste. Thus according to Ministry for the Environment estimates, plasterboard makes up 9% by weight of all waste generated in New Zealand, including 3.6% of landfill waste and 14.4% of cleanfill waste.

An Auckland Regional Council report (Street, 1998) found that C&D waste represented 20% of all waste going to landfill and that plasterboard represented 13% of that, which was 2.6% of the total, or 20,889 tonnes per annum in the Auckland Region.

In contrast, Winstone Wallboards (2006) quotes figures from a Landcare Research bulletin in their calculations of waste. They estimate that 25,000-30,000 tonnes of the 3.4 million tonnes of waste landfilled annually is plasterboard. This represents just 0.74 - 0.88% of waste going to landfill each year.

2.2.2 Current diversion

There is little information available on the amount of plasterboard that is currently being recovered from landfill or cleanfill. However, a Landcare Research survey of C&D waste flows in Christchurch City (McNicol, 2000) found that only 7% of C&D waste was diverted. Winstone Wallboards' manufacturing waste is currently diverted into compost. A report is currently being drafted by Winstone Wallboards to detail this activity.

Section III: Composting gypsum plasterboard

3.1 Environmental and health impacts

3.1.1 Environmental impacts

Acidity

There are reports of composters choosing not to use gypsum on the basis of its alleged ability to alter pH (there are several examples in Reindl, 2003). In fact, gypsum *can* lower soil pH in a slow process which takes at least 1-2 years to see a reaction, however this only occurs in sodic (containing high levels of sodium) soils (Vossen, n.d.) with high pH. It is unlikely that compost containing gypsum would be added to such (or any) soils in significant enough quantities to make any noticeable difference to the pH of the soil. It is more likely that gypsum would be added directly to sodic soils as it remediates the soil by allowing the sodium to leach out (in the form of sodium sulphate, leaving calcium behind in the soil), leading to improved structure and drainage. If large quantities of gypsum were added to the soil for agronomic purposes, the potential pH lowering effect would no doubt be considered and appropriate action taken if required.

Although gypsum has a neutral pH, there are reports of plans to use gypsum waste as an amendment for Hawaii's highly acidic soil (reference 4 in Reindl, 2003). This is unlikely to be effective unless the gypsum waste also contains lime as gypsum is not known to raise soil pH. Resource Efficiency in Building and Related Industries (2005a) have also stated that gypsum is alkaline and can correct acid soils, whereas Art Peterson, Professor of Soil Science at UW-Madison has stated that gypsum is a neutral salt which has no impact on soil pH (Reindl, 2003).

Another concern around pH is that gypsum could produce hydrogen sulphide under anaerobic conditions, which could lower pH in a composting process. Hydrogen sulphide production is not an issue with the finished compost, which is relatively stable and no longer undergoing decomposition. The solution with regard to pH is to maintain aerobic conditions.

Sodicity

Excess sodium can lead to sealing of pores in soil, leading to water running off rather than percolating through. This is ameliorated by balancing the sodium ions with calcium from gypsum.

Boron

Boron is an essential plant nutrient which can be detrimental in excess. Boron levels are not likely to be problematic at agricultural application rates as the amount of boron in agricultural gypsum is often higher than plasterboard (Townsend et al., 2001) so rates of boron within compost should not be of concern. Furthermore many New Zealand soils are in fact boron deficient and thus would benefit from the addition of gypsum.

Soil structure

The soil structure is improved by adding gypsum, especially for clay soils. Organic matter is also useful for this, so there is possibly a good synergy between plasterboard and compost in this regard.

3.1.2 Health impacts

In landfill, hydrogen sulphide gas is produced from plasterboard at significant and often dangerous levels. This is due to the sulphate reducing bacteria which thrive in landfills due to the combination of: anaerobic conditions, the presence of organic material (including the paper on plasterboard) and a large source of sulphate ions (especially from the gypsum in plasterboard) (Matrix Management Group, 1990).

A serious health hazard is constituted by concentrations of hydrogen sulphide in excess of 1,000 ppm, whereas in landfills in Western Canada levels exceeding 5,000 ppm have been measured (Matrix Management Group, 1990). Furthermore, metallic sulphides (which are toxic to fish at less than 0.5 ppm) are able to precipitate into the leachate (Matrix Management Group, 1990).

Areas surrounding landfills may have odour nuisance from diluted quantities of hydrogen sulphide gas and indeed even low doses may pose adverse health effects on susceptible populations (Yang et al., 2006).

Composting waste plasterboard would be problematic if it was done using an anaerobic process as it would generate hydrogen sulphide. However as noted by the Clean Washington Center (1997) 'as with all composting operations, aerobic conditions must be maintained (through aeration or mix porosity) in order to limit odors'. This is perhaps an incorrect assumption (that all composting operations are aerobic). Gypsum composting would not be suited to anaerobic composting operations (except perhaps with the addition of 'EM' (Effective Microorganisms), which can be used with composting operations (New Zealand Nature Farming Society, n.d.). See Section 3.6.1, *Wastebusters Canterbury* for an example of a composter using EM.

Fibreglass

Fibreglass *may* be detrimental to health when certain sized particles or types of fibre are inhaled (IARC, 2002) but the fibreglass used in GIB® plasterboard is amorphous. When ground to fine dust it has been claimed that it will behave like any other inert dust and because it does not split along its long axis, it does not behave like asbestos in the lungs (Winstone Wallboards, 2007).

Fibreglass is not biodegradable. However it has been subject to some limited research which indicates no harm to earthworms (and assumes no harm to mammals and soil) provided that fibreglass is crushed into sufficiently small pieces (Kunde and Newenhouse, n.d.; Wolkowski and Crosby, 2001).

Paraffin wax/silicone

Paraffin wax is compostable and is not expected to cause any problems (Davie, 1993). Silicone is used as an alternative by some manufacturers and it is also biodegradable and won't affect the composting process (especially at the low concentrations) (Lehmann et al., 2001).

Asbestos

Older plasterboard manufactured overseas may contain asbestos (Moyle, 2005) but the Smarter Homes website (owned by the Department of Building and Housing) states that old plasterboard does not have any asbestos (Smarter Homes, 2007). However the joint compound used in construction prior to the mid 1970s may have contained asbestos (Resource Efficiency in Building and Related Industries, 2005c). Note: joint compounds made by Winstone Wallboards have never contained asbestos (Mark Jury, Market Manager of Winstone Wallboards, personal communication, 25 July 2008).

Paint (including lead)/wallpaper

Painted plasterboard is not likely to be suitable for composting, although certain products such as limewash and milk paints are probably suitable if they are certified as biodegradable. In older buildings there may be lead paint. For wallpaper applications on plasterboard an oil-based sealer is recommended by plasterboard manufacturers and most wallpapers contain more than just paper (eg, vinyl). Although unsuitable for composting (unless the process strips the coverings away), many reprocessing operations can accept all of these products (although they will limit the uses of the recycled paper content) as the coverings are stripped away.

Winstone Wallboards have not yet updated their literature to contain directions as to suitable paints or plasters to use with GIB® plasterboard so that it can be composted (as required under the Environmental Choice Certification, see Appendix 4). Low VOC paints are not the same as biodegradable paints (only the latter should be included in a composting process).

Dioxin/furans

There is some difference of opinion as to the danger of possible dioxin and furan levels in plasterboard paper (Harker, n.d.), but generally this has been found to be insignificant. Public health officials and academics in Washington State (USA) did not believe there was an issue (Harker, n.d.). UK research also found insignificant amounts (Coning and Bareham, 2007) and the Gypsum Association has stated in conversation with John Reindl (reference 15 in Reindl, 2003) that claims of dioxin issues are unfounded and may be an attempt to ‘corner the market’ for remanufacture.

Radioactivity

Environmental Choice certification of plasterboard precludes the use of phosphogypsum (see section 2.1.2). Phosphogypsum can have significant impurities (Nature’s Way Resources, n.d.) including some hazardous and/or radioactive substances, which may not be suitable for composting (one might argue that they are not suitable for plasterboard manufacture either). New Zealand manufactured plasterboard is not currently manufactured from phosphogypsum and has not been in the past (Mark Jury, Market Manager of Winstone Wallboards, personal communication, 4 August 2008). Winstone Wallboards is committed to not using phosphogypsum in the future under the Environmental Choice Certification scheme. However, some imported plasterboards might contain phosphogypsum, or might have done so in the past (or could in the future). In this case it would be important to know what impurities the phosphogypsum contained. When applied to the soil the radioactivity might well be extremely minor compared to background levels (and it is noted that fertiliser is manufactured from the same source and is also radioactive) but consideration should be given to the risks posed to those working with the material, for example inhalation of dust may increase exposure.

Barium

The Environmental Choice certification includes all of Winstone Wallboard's GIB® plasterboard of 13mm or thicker, including GIB® X-Block. X-Block contains more than 50% barium sulphate, which is quite insoluble in water and most acids and would not be expected to break down during composting nor move through soil. Although many barium compounds are quite toxic, barium sulphate is not, so break down would in fact be undesirable. No research was found to show that it is a suitable constituent of compost. Indeed no research at all was found relating to barium sulphate and compost. Caution would be advised in this context as barium has the potential to bioaccumulate in legumes, mushrooms and brazil nuts. Barium sulphate dust inhalation leads to baritosis, which is a benign pneumoconiosis that shows up as marked shadowing on the lungs in x-rays. Note: GIB® X-Block is a specialist plasterboard used primarily in small volumes in medical facilities.

3.2 Collection

3.2.1 Issues (storage, transportation, education etc)

On the building site the challenges involve keeping the plasterboard separate and dry and then storing and transporting it to a processing facility. The location of the processing facility will obviously be an issue. It might require storing the plasterboard until a sufficient amount has been collected to make the trip to the processing facility economical.

From the starting point of actually having the waste plasterboard at a processing facility, the challenges include:

- inspection to ensure that the load meets specifications
- separation of metals (eg, nails) – probably with a magnet
- separation of contaminants (if required) such as:
    - – other materials (other than plasterboard)
    - – unusable types of plasterboard/plasterboard composites (eg, wet area plasterboards)
    - – demolition plasterboard
- separation of the paper if required (which can be difficult if the plasterboard is wet)
- shredding or chipping the gypsum to the right particle size, whilst controlling the generation of dust.

Note that the factors will vary considerably depending on the eventual use of the recycled gypsum and indeed the particular process used by each facility. For example the moisture and paper content is likely to be critical for reuse in plasterboard production (eg, less than 2% paper content), whereas it will be less important for agricultural and/or composting purposes (where the paper will biodegrade and may even be viewed as beneficial as it assists in moisture absorption). (Integrated Waste Management Board, 1996).

Additionally, one type of composite panel (available in the US) is made from a blend of gypsum and recycled newspaper fibres (Ince, 1996) which might be suitable for inclusion in compost but possibly is not suitable for recycling to produce new plasterboard (unless perhaps of the same type). This is a speculative example to demonstrate that it is important to consider how easy (or important) it will be to separate out potential new products as well as existing products.

Note that as with all solid waste management this separation is much easier/cheaper to achieve if it is performed at the source (eg, a separate bin for standard waste plasterboard only, preferably kept dry) and if contaminated material is screened out prior to acceptance. Customer education is an important factor in this.

In order to ensure that plasterboard is separated from other construction and demolition waste as close as possible to source (ie, on the building site), it will be necessary to make it economically viable, or indeed beneficial for the building industry to do so. Where there is no such incentive it is unlikely there will be much interest in making the effort to separate it out, which could lead to inefficiency, waste and possible contamination of the recycled product. For example, in a project undertaken to classify the waste from builders' skips, 24% of the material was considered to be a 'residue' (too small to sort) (McKendrie, 2001). With appropriate incentive levels in place, the preferred solution on-site would be to have a separate, dry bin for collecting plasterboard scraps. It is worth noting however that one study found that it was not landfill fees in Canada which led to successful recovery operations, but the total ban on plasterboard waste going into landfill (Van Seters and Hill, 1991).

In contrast to the study above, research from the UK on the collection and segregation of plasterboard waste at three construction and demolition sites found that where there was an organisational commitment to segregate for recycling, legislative barriers became less important than the site-based factors in determining the success of schemes (Emery et al., 2008).

One example of how collection of waste plasterboard can be organised can be found in the UK. British Gypsum operates a take-back scheme (in the UK only) in which it supplies housing development sites with containers (a choice of either bags or skips) for plasterboard and other gypsum construction materials waste. It then collects the containers and reuses the waste in its manufacturing process and claims that the service could save customers money in waste handling and transport costs (British Gypsum, n.d.)

It is also worth noting that plasterboard is colour-coded according to type. This makes for easy identification when separating the plasterboard however it appears that colour-coding is not consistent across the industry.

3.2.2 Methods used here and overseas

Gypsum Recycling International (Gypsum Recycling International, n.d.; The Waste & Resources Action Programme, n.d.(b))

Gypsum Recycling International uses containers which are placed at a wide range of civic amenity facilities and waste transfer centres, as well as construction sites. The containers are emptied on demand by a specially designed truck which can take loads from up to six containers at once. The trucks, once full, take the contents to a warehouse where it is stored until there is sufficient material for the mobile recycling machine to be sent in. This method maximises the number of collection points for the plasterboard whilst minimising the investment in infrastructure and transportation distances. The process can be viewed as a video on the Gypsum Recycling International website (Gypsum Recycling International, n.d.).

New West Gypsum (The Waste & Resources Action Programme, n.d.(a))

New West Gypsum has been in business for over 20 years, originating in Canada, but now with plants in Canada, the United Kingdom, France and the United States.
It locates its facilities close to its market (plasterboard manufacturing plants) and collects waste plasterboard from three sources, in roughly equal quantities:

- mosquito fleets (small vehicles collecting directly from construction sites, which are very effective at providing high quality waste materials)
- larger waste management contractors
- production waste from plasterboard manufacture.

Contamination is reduced by charging for loads based on quality. Where sources of waste are located at a distance from the reprocessing plant, bulking and storage is used before transport. Annual production worldwide is approximately 250,000 tonnes of recycled material, which is remanufactured back into new plasterboard.

Wiltshire County Council (UK):

Wiltshire County Council (UK) contract Hills Minerals & Waste Limited to carry out the disposal of municipal waste, including recycling. Hills began separating out and collecting plasterboard following the introduction of new legislation. The legislation requires businesses to assess, classify and treat their waste prior to disposal, and for waste management companies to treat and dispose of gypsum waste in separate cells in the absence of biodegradable waste (to minimise the production of hydrogen sulphide gas) (The Environment Agency, n.d.). The plasterboard is stored in waste bays and then sent (all types mixed up and with screws and nails allowed) to Mid UK Recycling Ltd for reprocessing once there is enough to fill an articulated lorry. The system works well, with Hills not needing to do much with the material, nor storing it for long periods of time [personal communication].

Once the plasterboard reaches Mid UK Recycling (which accepts a full range of plasterboards and doesn’t mind if the material is wet) it is reprocessed into a soil amendment (and possibly has other uses and markets).

It is of note that Hills’ account manager initially felt disadvantaged because his company had committed to the system on the basis of a draft version of the Hazardous Waste Regulations (final version published in 2005) which indicated that no plasterboard would be allowed in landfill. However the final version was watered down to allow landfill to contain 10% sulphurous products, so competitors have been able to continue to landfill plasterboard (The Environment Agency, n.d.; Emery et al., 2008]. Since then new legislation has come in (on 1 April 2008) requiring the construction industry to prove segregation of waste and file quarterly waste returns which are checked by the Environment Agency. Hills now feel that they have an advantage because they have an established system to segregate gypsum waste which they send to a “proven reprocessor” [personal communication].

California (USA)

There are approximately 44 drywall pickup sites and/or processors in California (fifteen of these are local Habitat for Humanity chapters, which take large reusable sheets). Most processors take clean construction drywall only (California Integrated Waste Management Board, 2007).

3.3 Benefits and limitations

3.3.1 Benefits

Adding gypsum plasterboard to composting processes is technically possible and appears to be compatible with most aerobic composting systems. Waste plasterboard almost certainly has a neutral or beneficial effect on the soils to which the compost is applied (Wallace & Wallace, 2003) because gypsum from plasterboard alone improves the tilth and permeability of clay soils (Yost, 1998) or can ameliorate excess sodium (Sojka et al, 2004). Application rates achieved by the addition of compost will be much lower than agricultural application rates so there is little likelihood of introducing harmful levels of trace elements. However, the only real benefit derived from adding it during the composting process as opposed to direct application (either to finished compost or to the land) is that composting degrades the paper fraction. Otherwise it is likely to be better to add crushed plasterboard directly to obtain the correct volume for the application in question.

Composting plasterboard is a relatively simple process which requires little or no additional capital investment. In many cases an acceptable product can be obtained by passing plasterboard through normal compost shredders but to obtain a fine particle size a hammer mill may be required.

Composting plasterboard is preferable to landfilling and sea dumping due to the environmental issues associated with these disposal methods (Matrix Management Group, 1990). There is an argument that perhaps composting is not the most appropriate technology, as explained in figure 1.

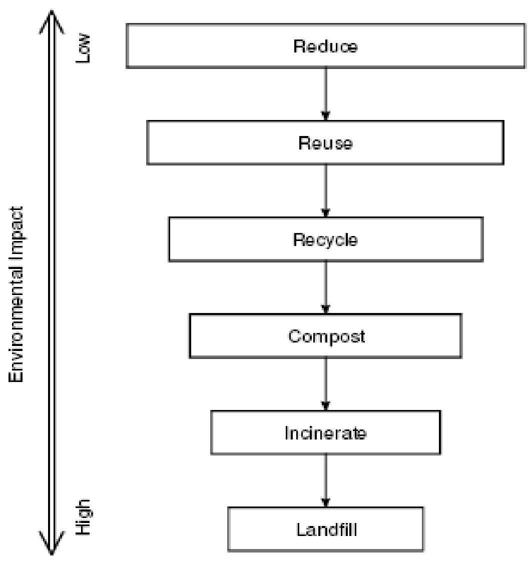

Figure 1. Hierarchy of Construction and Demolition waste materials disposals.

Peng et al. (1997) note that composting is a lower cost alternative than recycling but regard it as having a higher environmental impact. However, this is a general hierarchy for construction and demolition waste which may not apply to plasterboard. For example, Japanese research has concluded that it is 48% more energy intensive to recycle plasterboard to new plasterboard than using virgin ore in Japan, “because considerable energy must be invested to convert the recycled plasterboard into a consistent starting material” (Gao et al., 2001). However, it should be noted that Japan mines gypsum locally for use in plasterboard production whereas New Zealand imports all of its gypsum, which may alter the equation dramatically (Founie, 2006). A full consideration of the benefits and drawbacks of the various options outlined in section 3.6 would be required to draw further conclusions.

3.3.2 Limitations

The limitations of composting plasterboard are that demolition plasterboard is not suitable for composting due to contamination and specialist plasterboards with additives (eg, fibreglass) may also be unsuitable, or at least not universally suitable. In contrast many plasterboard recycling companies claim to be able to take demolition waste and specialist plasterboards, such as vinyl, foam, fibre enriched and foil backed board (Roy Hatfield Ltd, n.d.). One notable exception to this is the trial of mixed demolition and construction waste plasterboard for the manufacture of mushroom compost that was reported in the UK (Coning & Bareham, 2007).

Conceivably there could be future issues with imported or local plasterboard that has been manufactured using recycled gypsum, as they may contain a small quantity of impurities that were previously added for the manufacture of specialist types of plasterboard and which were recycled into new standard plasterboards. This is not likely to be a significant problem however.

Organic compost producers may not wish to use plasterboard as organic certification precludes the use of manufactured products, so compost with added plasterboard would not be able to achieve certification (Marvin, 2000; Moyle & MacGillivray, 2005; Wallace, 1998). Bio-Gro New Zealand has only had one application relating to composting plasterboard which did not proceed due to lack of information on product composition [personal communication].

It is possible that some customers may prefer not to have gypsum (or prefer not to have gypsum from plasterboard) in their compost.

The Environmental Choice criteria for recyclability include information on acceptable paint types for diversion to composting as the intention is that decorating GIB® plasterboard should not be an impediment to recycling. It is not likely that many paints are suitable for composting and this information could not be found on the Winstone Wallboards website.

Winstone Wallboards have been reported to have estimated the ratio of demolition to construction waste at 10:1 (Sinclair Knight Merz, 2005) which if accurate, means that less than 10% of plasterboard would be diverted from waste by composting. However this figure is so divergent from reported data elsewhere that it must be treated with caution. South Australian figures put the ratio at more like 1:2 (nearly twice as much construction plasterboard waste as demolition) (Moyle & MacGillivray, 2005). In a US study demolition/renovation plasterboard only accounted for 26% of all plasterboard waste, with 74% coming from manufacturing and construction, a factor of 1:3 (Marvin, 2000). UK figures currently show a ratio of 2:1 (twice as much demolition as construction waste) (Fisher, 2008). There is clearly considerable variation in the figures, but a 10:1 figure (which unlike the others is not backed by data) is outside of the expected range. Of course over time there is the question of what happens to all the plasterboard which has been installed – eventually that figure could prove to be correct. Whatever the balance proves to be, either currently, or indeed in the future, it is certainly true that a very significant portion of plasterboard waste is not able to be composted due to contamination, at least under present conditions. Demolition plasterboard is generally considered to be too contaminated for reuse in agriculture/compost (Macozoma, 2000).

A dissenting view on composting (Musick, 1992) states that chelating agents in the gypsum and trace dioxins in the paper will limit agricultural options and that high pH means composters can only accept a small percentage of feedstock. This view, put forward by a company which recycles plasterboard to provide feedstock for new plasterboard, ie, a competing use, states that contaminants include: furans, dioxins (in paper) and soaps, boric acid, silicone glue, starches, potassium sulphate, fibreglass, chelating agents, water dispersants and asphalt wax emulsions. However, the view presented is not well supported in the literature, except insofar as many of the contaminants listed are only added to specialist plasterboard, which should be kept separate (eg, plasterboard for wet areas, which has a different colour paper) until it is established that it is safe to include in the particular process employed.

A study by Washington State Department of Ecology (Matrix Management Group, 1990) found that the best option was to recycle back to new plasterboard, followed by agricultural applications, then sea dumping or 'best practise' landfill. It stated that "use of waste gypsum as a fertiliser seems like an ideal way to solve existing problems…However the literature only mentioned this alternative in passing, with no in depth analysis found." This lack of evidence presumably resulted in the lower scores for technical viability. In contrast, this review (conducted some 18 years later) found substantial research to attest to the viability of agricultural applications of recycled plasterboard. Furthermore, the Washington State study did not appear to consider the energetic costs of the different options. Caution is recommended in interpretation of the results of this study, due to the specificity of many factors to Washington State and the age and limitations of the data.

3.4 Compost processing

The main method used for composting plasterboard appears to be windrows, covered and open. However in-vessel composting systems are also being used to compost plasterboard in New Zealand (see 3.6.1).

Provided that the process is aerobic and the pieces of plasterboard are less than 25mm in size, the gypsum is almost completely broken down (to a point where it can't be seen) and can be regarded as a bulking agent (Clean Washington Center, 1997), which is beneficial for nearly all soils (Wallace & Wallace, 2003). Larger pieces, greater than 25mm in size, can remain visible in finished compost but this is primarily an issue of aesthetics. In terms of benefits for the composting process itself, gypsum may reduce odours associated with ammonia. The process responsible for this may also result in more nitrogen being retained in the compost, but further research is needed in this area (Saludes et al, 2008). Gypsum may also help balance the nitrogen and carbon ratios in biosolids composting, increasing the porosity and absorbing excess water. Greenwaste composting facilities which receive high volumes of grass and insufficient woody bulking material may also find that chipped plasterboard improves aeration and reduces odour generation (Clean Washington Center, 1997).

The following is from Marvin (2000):

> Composting gypsum drywall does present several challenges. First, temperature, moisture, and oxygen within the compost mixture must be monitored to avoid anaerobic decomposition. Gypsum wallboards' tendency to absorb moisture can be problematic, as well. If the drywall is wet before it is processed moisture will be added to the compost rather than absorbed. Thus, drywall should be stored indoors and ground on an as-needed basis. The final product should be monitored for the presence of paper pieces because consumers generally dislike seeing such flecks. The Clean Washington Center has found that the pieces are unnoticeable in compost mixtures containing less than 30% gypsum drywall.
>
> PROCESS
> 1. Separate drywall from other forms of construction waste
> 2. Transport gypsum drywall to the composting facility
> 3. Shred or chip the drywall
> 4. According to the Clean Washington Center shredding is best done when mixed with yard debris to prevent dust
> 5. Add the shredded or chipped drywall to other ingredients of the compost mixture
> 6. Monitor the compost's temperature, moisture, and oxygen levels

Practical detail from Vermont (see reference 43 in Reindl, 2003)

Dust was not really found to be a big problem as the gypsum isn't ground up too small, however crystalline silica can lead to silicosis (a serious lung disease) and fibreglass could be an irritant, so it's important for employees to wear protective gear and to take steps to retain the dust on the site. Once incorporated into the soil it is unlikely to be a concern. If the plasterboard is wet then it adds water to the process, but if dry it takes it away.

Note: the volume of crystalline silica in New Zealand manufactured plasterboard is below the level which can be analysed in New Zealand (less than 0.1%) and below the level which requires labelling (Mark Jury, Market Manager of Winstone Wallboards, personal communication, 15 September 2008).

Separation

One issue for composters to consider will be that of separating specialist boards (if indeed necessary as suggested in Marvin (2000) such as wet area or fibreglass reinforced boards, or X-board. It is likely that this will not be a major concern due to large sized scraps being easy to identify and smaller scraps which could contaminate being insignificant in terms of the total content. Clearly the issues of separating plasterboard from other waste streams and contamination of the plasterboard waste is something that needs management. An unfortunate situation would be for composters' requirements and builders practice to be incompatible, so consideration should be given to planning any collection system and how communication should be facilitated between the composters and the waste generators.

3.5 Economic/financial analysis

3.5.1 Overseas data

The dates of the following references should be noted when considering quoted figures. A clear picture emerges that situations vary depending on local economic drivers, such as the availability of markets for recycled gypsum (generally agricultural application or remanufacture of plasterboard), landfill costs and raw material costs.

USA

Recycled gypsum is cheaper per ton in California ($15-20 for reclaimed vs $30 for mined) (Integrated Waste Management Board, 1996). There is a wide range of recycling options pursued across the United States, with many being agricultural applications, although the viability of different options is dependent on disposal costs, distance to market, etc. (Reindl, 2003).

Canada

A landfill ban on plasterboard in the Greater Vancouver area in 1984 followed a study by Hardy Associates (1978) Ltd into the deleterious effects of hydrogen sulphide production in landfill. As a result it became viable for New West Gypsum to set up its operation which recycles gypsum back to plasterboard manufacturers. The company has since expanded to Ontario and the Northern States of the USA and then into Europe (which it has been able to do even without a landfill ban). The company always sets up its operation close to plasterboard manufacturing plants, which are its customers (The Waste & Resources Action Programme, n.d.(a)).

Australia

A survey of Australian manufacturers of plasterboard (Moyle and MacGillivray, 2005) found that there were no post-consumer waste processing systems in place and that the reason for this was that market forces did not make it beneficial to the manufacturer to do so. For example, there was low cost for raw gypsum and moderately low landfill costs, whereas the main drivers overseas (eg, Canada) were said to be high raw material costs and landfill costs. Moreover in South Australia there were no plasterboard manufacturers to accept reprocessed gypsum and the economics of sending it to geographically removed plants did not stack up, given that there was a significant existing market for gypsum as a soil amendment (there being extensive problems with sodic and/or hardpan soils). The suggested options were as a soil conditioner or as a civil construction stabiliser. It is noted that the estimated costs of processing plasterboard with a trommel screen are similar to the raw material costs of mined gypsum available direct to farmers. One assumes that the extra costs of collection would make this uneconomic unless these were balanced by a reduction in disposal costs. Agricultural suppliers would need to be able to accept waste plasterboard at a lower cost than landfills to make the separate handling attractive to construction companies, then the reprocessing and distribution costs would need to be low enough to ensure that the finished materials were competitive with raw gypsum. To underline the significant impact made by market and legislative forces, the report also notes that in Sydney several plants were reportedly discussing the need to set up a reprocessing plant due to the higher landfill costs and inaccessibility of agricultural markets.

3.5.2 New Zealand data

Little data was found on the costs in New Zealand. The following is based on the general economic outlook. Oil prices are historically high (higher than the Ministry for Economic Development's (2006) worst case scenario) and there is a reasonable likelihood that they will remain so or indeed increase further (Financial Times Economists' Forum, 2008). Given that New Zealand imports its raw gypsum, higher oil prices will significantly impact on the affordability of raw gypsum. An increase in the number of coal fired power stations in New Zealand, along with scrubbing operations to reduce sulphur emissions, could result in increased availability of flue gas desulphurisation gypsum, but otherwise the only other significant source of gypsum for plasterboard manufacture or agricultural application (or any other use) will be from imports. When this scenario is considered in conjunction with the environmental costs of landfill (which will increasingly be reflected in the financial costs of landfill as levies increase), the imperative to reuse the gypsum from waste plasterboard is clear. It is important to select a method for recycling which is beneficial in terms of resource conservation. Given the vast quantities of gypsum which exist in many parts of the world, including Australia, the important resource to be conserved is energy. The energetic costs of importing gypsum should be considered against the energetic costs of reprocessing it. It is beyond the scope of this report to conduct such an analysis, but the following points are noted:

1) Future scenarios (eg, higher oil prices) should be considered as part of the consideration of any investment in infrastructure.
2) Composting is really a disposal option in that it does nothing to reduce the demands for raw gypsum. To reduce these demands would require processing plasterboard into a format which could replace an existing use, such as bulk application to agricultural land or remanufacture back into plasterboard. Moreover, this level of reprocessing could accept more waste as demolition plasterboard could be suitable.
3) Notwithstanding the above, composting may be the better option presently because it requires little infrastructure investment, it diverts plasterboard from landfill (but not demolition plasterboard), and requires less processing than for remanufacturing, and less transportation (assuming that multiple composting operations are willing to accept the plasterboard and that there would only be a few remanufacturing operations). The critical question is whether the reduced processing and transportation costs of composting, in energetic terms, outweigh the increased costs associated with remanufacturing and with importing raw gypsum.
4) In favour of composting is that it is not an irreversible commitment. Should the balance change in future, little by way of investment will have been made and it should be no more difficult to introduce remanufacturing facilities.

It is therefore important that policy makers attempt to ensure that real environmental costs are reflected in landfill costs, or alternatively where this is not feasible or practical, that legislation is enacted to promote or enforce more desirable actions. In this case the imperatives are to keep plasterboard out of landfill and to reduce energy consumption in its remanufacture or reprocessing. Care should be taken not to create conditions which distort environmental realities, making less desirable outcomes economically attractive.

Plasterboard manufacturers should consider carefully the current and likely future scenarios in terms of supply costs (including transportation and processing) for raw and recycled materials and expect that the status quo (where most plasterboard is landfilled) becomes unaffordable throughout the industry, for builders, their clients and for the manufacturing industry. Alternative disposal, by composting or remanufacture, is increasingly and quite rapidly going to become the norm. Opportunities exist for manufacturers to demonstrate good product stewardship to customers, specifiers and legislators and to possibly secure competitively advantageous relationships with recyclers, or indeed diversify into that market.

3.6 Plasterboard composting operations

3.6.1 New Zealand

Composters

Wastebusters Canterbury
Sheryl Stivens
Telephone (03) 308 9998
Wastebusters Canterbury initially crushed plasterboard and supplied it to local wormfarmers but now crush it and add it to compost which is processed in windrows. They set up a C&D site in 2005 and have not sent any plasterboard to landfill since that time. They add Effective Micro-organisms (EM) to the compost to stop sulphurous smells which can develop if compost isn't aerated properly. Every batch (250-500 m^3) is tested prior to screening with nothing going off site without testing. An education programme is being developed to encourage local farmers to apply the compost to farmland. Contamination with chlorpyralid herbicide is a major problem for South Island composters. Wastebusters did their own research, backed up by independent laboratory testing, which indicated waste plasterboard in compost may help break down chlorpyralid.

MacKenzie District Council
John McGartland, Solid Waste Manager
Telephone (03) 435 0630
MacKenzie District Council have been shredding waste plasterboard and putting it through their Vertical Composting Unit (VCU) with greenwaste and foodwaste. The shredder breaks the plasterboard into 50mm pieces which break down fully after the compost has gone through a screening process. They have been working by trial and error but so far there have been no problems and it seems that the plasterboard is giving porosity and texture to the compost. Only standard plasterboard is added to the compost, other types are screened out. They have a stockpile of plasterboard for which composting is only a partial solution. It would be preferable to crush and screen the plasterboard and add it at the end of the composting process to enable more precise application, however extra equipment, such as a hammer mill, would be required to produce a fine enough particle size.

Timaru District Council
Brain Gallagher (Timaru District Council), Geoff Hemm (Trans Pacific Industries),
Telephone (03) 687 7200
Trans Pacific Industries (TPI) are contracted to compost organic material from Timaru District Council's greenwaste and foodwaste collection. Plasterboard has been added to improve the quality of the compost which is processed in covered, aerated windrows. Plasterboard is put through the shredder and quickly disappears during the composting process. As an added bonus plasterboard has been found to help clean the shredder when it is put through after foodwaste.

Living Earth
George Fietje
Telephone (09) 574 3607
Living Earth have done experiments on plasterboard composting at their Wellington in-vessel composting plant. They've found composting to be quite feasible as long as aerobic conditions are maintained. The major issue is keeping contaminants out of the compost. From a composter's perspective the driver for adding waste plasterboard must be to add value rather than diverting waste from landfill.

Soil and Compost Amendment

TerraNova
Jim Forsman
Telephone (03) 336 0063
TerraNova bought what was formerly the Crusaders Landscaping plant and are crushing waste plasterboard for agricultural land application and as a compost additive. Crushing commences once a stockpile of 1,200 to 1,500 tonnes has accumulated. It has to be done over a long dry spell as wet crushed plasterboard clogs spreaders. All processed plasterboard is sold. Crusaders started their plasterboard crushing operation in response to the introduction of Christchurch City Council's Cleanfill Licensing Bill in 2004 (Sinclair Knight Merz, 2005).

Envirofert
Gary McGuire
Telephone (09) 236 8483
Envirofert do not compost plasterboard because of the problems they believe it causes. Instead they process it for incorporation into compost as an additive and as soil amendment products.

Hall Bros Transport Ltd
Doug Hall
Telephone (03) 477 1141
Hall Bros are currently trialling stockpiling and chipping waste plasterboard in Dunedin. They intend recovering both construction and demolition plasterboard from transfer stations and from skips located on construction sites. They intend spreading the processed material onto agricultural land.

3.6.2 Overseas

The Clean Washington Center
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Seattle, WA 98121
Telephone 206 464 6282 Fax 206 464 6902
E-mail eduardou@cted.wa.gov
Internet www.cwc.org

Study 1

Cedar Grove Composting located in Maple Valley, WA and the Clean Washington Center experimented with incorporating gypsum drywall into their compost mixture. The drywall was chipped along with yard debris at a one to one ratio. Dust generation was a problem. The operators found that grinding yard debris with the gypsum reduced the dust. They also found that when the loader was kept full the escaping dust was only from the discharge chute. Another recommendation was to keep the drywall under cover to protect the gypsum from becoming wet. Cedar Grove composting found that the volume of drywall increases after chipping or shredding. Since completion of the Clean Washington Center project Cedar Grove has not continued to compost gypsum drywall because Cedar Grove produces organic compost.

Study 2

A study was undertaken in Washington (Clean Washington Center, n.d.) to examine the feasibility of recycling scrap plasterboard as a bulking agent in the composting process. Four mixes were examined with different mix ratios of gypsum, yard debris, and biosolids. There were no significant differences in odour production. Fine pieces of paper (less than a quarter inch) degraded nearly completely whereas larger pieces of paper (approximately 2 inch diameter) degraded by an average of 40% by weight during the process. The product quality was not hindered from the addition of the gypsum. Calcium content rose in direct proportion to the gypsum fraction and the organic content dropped as more gypsum was added. Boron content was not affected, nor was germination. The screened end product had some noticeable differences, such as the presence of gypsum powder in greater quantities as the mix ratio increased. There was no paper present in the screened product. Two different methods (crushing by hand and grinding with a chipper) showed that the material volume increased after processing. The best way to control dust from the processing seemed to be to grind the board simultaneously with a prescribed volumetric ratio of yard debris, and to keep the hopper full to limit the escape of dust from the top.
For composting facilities which receive biosolids, gypsum wallboard, with its paper content, is useful as a bulking material in order to provide the necessary porosity, to attain a good carbon to nitrogen ratio and to absorb the excess water present in the biosolids. The report concluded no detrimental effects (aside from minor aesthetic issues) in the product or in the off-gasses.

City of Columbia City MO
Mark Russell
Telephone 573 886 0722
Internet http://www.gocolumbiamo.com/PublicWorks/Solidwaste/compost-mulch.php

During March 1999, the city of Columbia, Missouri began a one year pilot project composting drywall at the city's composting facility. The composting project was advertised through construction waste haulers and construction supply companies in the area. Individuals received a decreased tipping fee of $16.25, approximately one half the fee charged for placing the waste in the landfill, if they brought in clean drywall to be composted. The composting facility has collected and composted approximately 700 tons of gypsum drywall. Quarterly water samples are taken to test for runoff; the results of these tests have not shown composting of gypsum drywall to have any negative side effects. The compost is currently being used as landfill cover. Based on the success of the pilot project the city of Columbia has decided to continue composting gypsum drywall and the city's website still advertises the same "$16.25/ton disposal fee for composting" of clean drywall, the same fee as for green waste. The web page above has links to downloadable analyses of the compost. Note that the landfill fee is double, at $32.50/ton.

Michael J. Hill
Thelin Recycling Company
5225 Thelin St
Fort Worth, Texas 76115
Telephone 817 926 5626
Thelin Recycling composts gypsum drywall with chipped wood and horse manure in windrows. The drywall is ground with wood, because it is too powdery to be ground alone. Water is added to the windrows. The composting process takes approximately 18 months. Thelin's composting facility has been composting drywall for nearly 4 years. The end product is sold on the retail market to homeowners, landscapers, and gardeners.

Maui Earth Compost Company
Hansen & Pulehu Road
Maui, Hawaii
Telephone 808 877 0403
Maui Earth Compost (Hawaii) found that the addition of recycled plasterboard made for a compost which they could sell at a premium due to its ability to improve the clay soils and ameliorate the sodicity of the soil. The compost sold for $65 per cubic yard, as opposed to other composts which range from $20/cy to $45/cy. The company produced a brochure informing local plasterboard handlers that they could avoid disposal fees by bringing waste plasterboard to them for free. The company had no problems getting the gypsum to break down, using windrows and a Scarab turner. The composting process was not elongated and was not prevented from reaching the requisite temperature. Other elements of the compost were rotten bananas, ferns and palm fronds. Note that the company does not currently process gypsum due to the paperwork (Welda, 2008).

Wright Composting Facility
Percy Lane & N Beal Extension
Okaloosa County
Florida
Telephone 850 651 7399
Okaloosa County investigated using ground plasterboard as an ingredient in composting for application to local peanut farms (Townsend et al., 2001). Plasterboard was collected from several large construction projects in Okaloosa County. Poor economic incentive for contractors to separate plasterboard from the C&D waste stream left only two contractors willing to take part. The chute system

which was used for collecting non-residential construction waste was found to discourage separation of materials. The County processed the collected plasterboard using an existing hammer mill. Since the paper did not have to be separated prior to composting, this system worked well. Two types of composting systems were utilised: a containerised system and a windrow system. The final compost was applied to a peanut farm and no significant increase in yield was observed. It was agreed that future application should utilise only the ground gypsum. Both an Ag-Bag and a windrow system were used, without much care as to the composition. A tub grinder was used to break up the gypsum and no odours were noted.

Waste & Resources Action Programme
The Old Academy, 21 Horse Fair
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OX16 0AH, United Kingdom
Telephone 01295 819 900 Fax 01295 819 911
E-mail info@wrap.org.uk

An estimated 100 tonnes of gypsum is used each week in the UK for composting purposes (Coning and Bareham, 2007). Research was carried out by consultants, a university horticultural research centre, a commercial compost producer and a commercial mushroom grower to determine if shredded waste plasterboard would make a suitable alternative to standard mushroom compost. It was necessary to shred the waste into sufficiently small pieces as unsatisfactory yields were found with coarse sizes. The size of particles was larger than normal gypsum as the need for small particles for high yield was balanced against dust handling issues. Construction and demolition waste was used and screening was carried out to remove metal, glass, plastic and other debris, which initially caused major breakages. The method by which this was accomplished isn't described. Only paper pieces larger than 75mm were removed. No significant amounts of VOCs, dioxins or heavy metals were found during chemical analysis (ie, they were well below permitted limits, which with regard to heavy metals are well below the levels found in wild mushrooms). The trials included equal amounts of new build waste and demolition waste plasterboard, which were processed together. Similar yields were obtained as from agricultural gypsum and heavy metal levels in the compost and mushrooms were comparable to the control groups. The waste plasterboard had higher levels of water retention than the mined and flue gas desulphurisation gypsum. The paper has good tables of data presenting the results.

Section IV: Alternative/competing uses for waste plasterboard

4.1 Alternative/competing uses

Composting is just one of a number of methods by which waste plasterboard can be diverted from landfills and cleanfills.

4.1.1 Product to product recycling

Gypsum Recycling International (GRI) is recycling both construction and demolition plasterboard waste in Denmark, Sweden, Norway, The Netherlands, Ireland, United Kingdom and United States. Its process, for which it is looking for new markets in other countries, accepts all types of plasterboard, including waste contaminated with nails, screws and wall coverings and up to 2% contamination from non-plasterboard products. It has a fully developed system for collection of waste and distribution of the recycled material, which can be used for new plasterboard production at rates of one part recycled gypsum to three parts virgin gypsum. The metal contamination is directed into a separate container and the remaining waste is divided into the paper (and whatever coverings were on it) and into recycled gypsum powder. GRI claim that there is very little contamination of the gypsum or paper fraction at the end of the process and that the top five plasterboard companies in the world (USG, BPB Group, Knauf, LaFarge Gypsum and National Gypsum) purchase recycled gypsum from them. In Denmark they have almost 500 collection points around the country and claim to save waste owners typically more than 25% of their costs and are recycling approximately 65% of all Denmark's gypsum waste. The system is voluntary (ie, there is no ban on landfilling of plasterboard), but clearly the economics are favourable as the plasterboard manufacturers also obtain materials at a discount and the company is able to service its operation and make a profit (Gypsum Recycling International, n.d.). In a paper by the CEO at the global gypsum conference in May 2008 (Lund-Nielsen, 2008) it was noted that New Zealand has a shortage of cheap available gypsum and the manufacturer was looking at recycling gypsum to reduce costs and in response to customer pressure (which was motivated by increasing disposal costs and fear of global warming).

New West Gypsum, as already noted in 3.3.2, operates gypsum plasterboard remanufacturing plants in Canada, the United Kingdom, France and the United States (New West Gypsum Recycling, 2003a).

Domtar Gypsum in Michigan (US) were (in 1994) selling plasterboard which contained 20% post-consumer recycled gypsum and 10% post-industrial (pre-consumer) recycled gypsum. (reference 82 in Reindl, 2003). The plant is now closed (Waste and Hazardous Materials Division, 2007).

In the UK, a comprehensive Life Cycle Analysis (LCA) was undertaken to investigate the benefits of recycling plasterboard for remanufacture (other uses were excluded from the study) as this was the predominant use of recycled plasterboard (Fisher, 2008). The LCA found that there were benefits across a range of environmental issues for doing this, but that the benefits were comparatively small (between -4% and 12%, with a negative figure indicating a net cost) and not outside the boundaries of uncertainty that would enable the study to state categorically that recycling is a net benefit. The study found that efforts would be better focussed on minimising wastage so that less plasterboard was manufactured and needed to be disposed. The results would change if greater percentages (than 25%) of recycled gypsum were able to be reused.

4.1.2 Cleanfill/land-banking

Plasterboard is generally not allowed in cleanfills in New Zealand (due to leachate and off gassing during decomposition) however Envirofert (a greenwaste and cleanfill disposal operation in Tuakau) is permitted to accept loads of 100% plasterboard which is then quarantined in separately lined cells (Envirofert Ltd, n.d.).

Monocell disposal sites are the only option in the UK where sulphurous wastes amount to more than 10% of that disposed, although currently landfill operations are exploiting the 10% rule quite effectively meaning that there is only one monocell site (Fisher, 2008).

4.1.3 Land application

Land application of plasterboard waste has been demonstrated to be nearly identical to application of agricultural gypsum (Yost, 1998). Options include grinding the gypsum up into powder, or chipping it to form a mulch. The paper is potentially beneficial as a carbon source and to retain moisture, although it can be screened out if required.

It should be noted that much confusion surrounds the use of gypsum as a soil amendment, with some authors claiming almost universal benefits (Wallace and Wallace, 2003) and others stating that gypsum is effective at ameliorating only sodic soils (soils high in sodium). It is often used in New Zealand (where sodic soils are less of a problem) for improving the structure of heavy clay soils. It also alleviates problems of high aluminium and manganese in some clay subsoils (Winstone Gypsum, n.d.(b)).

Both calcium and sulphur are provided by gypsum and both are essential nutrients for plants. Additionally, it has been claimed that recycled plasterboard often works better than agricultural gypsum due to a wider profile of trace elements that are beneficial to plant life (Nature’s Way Resources (n.d.).

A number of organisations in New Zealand are currently processing plasterboard for agricultural land application (see 3.6.1).

4.1.4 Disposal at sea

Gypsum breaks down in the sea and both sulphate and calcium occur naturally in sea water (Matrix Management Group, 1990). However, there are some significant problems with sea disposal, namely large amounts of waste paper may accumulate on the surface, destruction of life on the seabed due to smothering in the dumping area and significant energy expenditure in transporting the waste to the dumping area.

4.1.5 Reduction in waste

A potentially very effective way to reduce environmental effects of plasterboard use is to design buildings so that cutting of plasterboard is minimised. The Waste & Resources Action Programme (UK) LCA (Fisher, 2008) gives an example (assumed hypothetical) for a $750,000 contract for the installation of plasterboard where wastage rates were reduced from 15% to 5%. The resulting reduction in CO_2 equivalent emissions amounted to 158 tonnes, or 62 kg CO_2 equivalents per tonne of plasterboard used.

Further reductions could be achieved by using off-cuts above doors, although this may lead to cosmetic cracking (Mark Jury, Market Manager of Winstone Wallboards, personal communication, 4 August 2008) or in wardrobes where the finish is less important and retaining scraps for use between jobs. It is possible to order specific size sheets in from Winstone Wallboards when the order is for 100 sheets or more. It may be simpler to design to standard wall heights.

4.1.6 Reuse by charities

In the US, many affordable building charities accept plasterboard remainders that are half size sheets or larger (Marvin, 2000).

4.1.7 On-site reuse or disposal options

The National Association of Home Builders (USA) suggests placing plasterboard scraps within the stud walls to achieve low cost disposal (at least until the building is demolished) (Yost & Lund, n.d.). Another option which is mentioned frequently in the literature (although some localities have rules which forbid this) is to grind up waste plasterboard on-site for land application on the site itself. A plasterer in Christchurch was reportedly investigating the option of offering this grinding service as a contractor (Sinclair Knight Merz, 2005).

4.1.8 Animal bedding

Chipped/mulched plasterboard is suitable for use as animal bedding (eg, in poultry farms) (Wyatt & Goodman, 1992) if the dust issue can be managed, although some have reported problems (Harker, n.d.). It is effective at absorbing ammonia (Global Repair, 2008). Gypsum is a major component of many cat litters for this reason.

A study in the UK by the Waste & Resource Action Programme (Holt-Martyn, 2007) found no issues with using recycled plasterboard paper as an animal bedding material for cows. The resultant slurry was able to be dealt with (spread) in the same way as with straw bedding. There were two advantages. Firstly farmers did not need to add lime to absorb excess moisture, which is a cost saving and may be an improvement to animal health as lime can lead to rashes on the udders (which then require treatment). Secondly, the underfoot conditions were improved, which may help reduce the incidence of ‘slip, trip and fall’ injuries. Potential problems could occur if bedding material included excess gypsum or was used in such a way as to represent waste disposal (ie, excessively high usage) rather than beneficial reuse or if processing did not involve adequate screening (Harker, n.d.) but no problems should be expected if used as described in Holt-Martyn (2007).

4.1.9 Cement additive

Gypsum is used to influence the setting time (Resource Efficiency in Building and Related Industries, 2005c) and hardening reactions of cement. High purity gypsum is required for this purpose, although the real issue is with the paper content, not the additives and impurities in the parts per million (Waste and Hazardous Materials Division, 2007; Allcorn and Welch, 2007). One recycler of plasterboard in the US was cited by John Reindl as supplying gypsum to cement compounders in 1994 (reference 75 in Reindl, 2003). The major problem was that they needed such a large supply. A study by the Waste & Resource Action Programme (Allcorn and Welch, 2007) found that two cement manufacturers in the UK are using recycled gypsum, one at 100% and the other at 50%. This scoping study concluded that having a level of quality assurance that recyclers and purchasers could specify would build confidence and facilitate greater levels of recycling.

In New Zealand Geocycle, a subsidiary of Holcim Cement, have undertaken trials with TerraNova to investigate 'de-papering' waste plasterboard [personal communication].

4.1.10 Plaster

Gypsum is a major ingredient in bagged plasters and recycled gypsum from plasterboard could be appropriate for use in their manufacture. A product suitable for interior or exterior application is listed in reference 82 in Reindl (2003).

4.1.11 Novel cementitious or plaster products for construction

There are numerous research papers and reports (Pouya et al, 2007; Waste & Resources Action Programme, n.d.(c)) which show that novel plaster or cement-type materials can be made from recycled plasterboard, often in conjunction with other construction waste materials, for a range of purposes, including road construction. Recycled gypsum has also been used in roofing (reference 82 in Reindl, 2003).

4.1.12 Wastewater treatment

Gypsum flocculates suspended solids, causing them to settle. It can be used in wastewater treatment although other additives are used more frequently, like alum. However, there may be additional benefit of using gypsum (or recycled plasterboard) as a wastewater additive when the wastewater is to be applied to land due to its ability to ameliorate the effects of high sodium concentrations in wastewater (eg, from laundry products) which can be damaging to the soil (for example clay soils could be subject to dispersion leading to tunnel erosion or else clogging of the pores and reduced porosity, leading to failure of the wastewater system and run-off). This would apply to both municipal waste and to on-site treatment plants.

Furthermore, for the same reason, it may be beneficial to apply gypsum to the wastewater land application area directly; indeed this is recommended in AS/NZS1547:2000 as an option for dispersive soils.

Section V: Conclusions

5.1 Viability of composting gypsum wallboard in New Zealand

Composting waste plasterboard is a viable, low cost option. In its favour are that it avoids the negative effects of other disposal options and it can be performed in a wide range of locations which can reduce the distance which waste plasterboard needs to travel. There are many compost making companies and it is highly likely that the process can be made to work safely and effectively by the majority of them. It may be the case that including plasterboard does not suit low involvement/low technology composting techniques as well as it does the higher input/more technically advanced systems.

It has not been fully established what the health and environmental effects are of fibreglass and other additives included in specialist plasterboards (such as for wet areas). Depending on the process and the preferences of the composting company it is possible to identify non-standard boards by their colour and side markings. This may be more difficult with very small scraps but it is anticipated that adequate processes could be developed to achieve the desired separation.

Composting is not perhaps the best diversion technique to be adopting over the longer term as it is not as flexible as systems which produce high quality recycled gypsum powder, which can be put to a wider range of uses. It might be that remanufacturing currently requires more energy expenditure than using virgin gypsum ore (though this has not been determined for New Zealand) but this may not remain the case and remanufacturing processes are likely to become more efficient. There are several successful models to consider and attention should be given to these in the New Zealand context. Furthermore, Winstone Wallboards have been reported to have estimated the ratio of demolition to construction waste at 10:1 which, if accurate, means that less than 10% of plasterboard would be diverted from waste through composting (Sinclair Knight Merz, 2005). However as discussed in 3.12, this figure is likely to be an overestimation. Whatever the balance proves to be either currently, or indeed in the future, it is certainly true that a very significant proportion of plasterboard waste cannot be composted due to contamination, at least under present conditions.

Notwithstanding the above, there appears to be few disadvantages in proceeding with the composting option now, as it requires little investment in infrastructure and does not preclude the development of other options in the future. Indeed, it may be the case that in the future it is most efficient to fully reprocess a percentage of plasterboard from some waste streams and locations, and to compost the rest.

5.2 Best case options from product stewardship/economic perspectives

From a product stewardship perspective the best solution is likely to be one which can take both demolition and construction waste and can strip off the paper and crush the gypsum. This could be used for remanufacture, agricultural application and a host of other uses in building materials, roads, etc, and could still be added to compost as well. The paper, if from construction waste, could be used in remanufacturing, added to compost or recycled as animal bedding, but demolition waste paper would most likely need to be disposed of due to the presence of contaminants.

Remanufacturing may require a costly investment in infrastructure, but given the right conditions it is likely that an established overseas company would want to set up in partnership with a manufacturer. For this to happen a manufacturer would have to be willing to accept recycled gypsum (which a large number of manufacturers are now doing around the world) creating the necessary market, along with landfill fees and/or legislation to encourage the separation of plasterboard waste. Given that landfill fees are going to increase (and one must assume increased costs or landfill bans are possible for plasterboard to reflect its bad behaviour in landfill), manufacturers have an interest in finding solutions that won't raise costs for installers to the point they look for alternative materials. At the same time, accepting recycled gypsum for manufacturing is potentially a cost saving exercise as costs for imported gypsum rise.

Given this scenario and being mindful of the potential for overseas products ending up in the remanufacturing process, it would seem beneficial for Winstone Wallboards, as New Zealand's only manufacturer, to operate the scheme. It would benefit from the recycled materials and the ability to maintain quality control, as well as being able to 'blow the whistle' on imported product which might cause problems for recycling due to contamination, etc.

Successful remanufacturing schemes in Scandinavia are able to utilise a small number of mobile reprocessing plants to cover a wide area, whereas the Canadian system has been successful at setting up plants near large populations and manufacturing plants. Given that the two plants in New Zealand are both near large populations (Auckland and Christchurch), it may make more sense to set up reprocessing operations close to these sites and to centralise collection from as wide an area as feasible to these points. Outside of the areas from which it is feasible to store and periodically ship waste plasterboard to the plants (which may well cover most of the country), the best option may be to compost the remainder in association with existing compost producers.

It may be possible for plasterboard distributors to set up collection points and for delivery trucks to backload with scrap plasterboard (reference 29 in Reindl, 2003). Contractors installing the plasterboard might also be able to return the scrap without making additional journeys.

In the short term there appears to be no great drawback in developing the composting option until remanufacturing systems are initiated, but certainly it would be prudent to plan for the likelihood that this will become an economic and indeed a commercial imperative.

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Section VII: Appendices

Appendix 1 – Composition of Winstone Wallboards' Plasterboard

Ingredients

Material		Content %	TLV mg m^{-3}	CAS No.
Gypsum		>85	10	13397-24-5
Or Calcium Sulfate Dihydrate			10	101101-41-4
Paper (Cellulose Fibre)		<15	10	9004-34-6
Starch		<3	10	9005-25-8
Sucrose		<0.1	10	57-50-1
Alkyl Ether Sulphate		<0.1	NE	8061-52-7
Poly-napthalene sulfonic acid salt		<0.1	NE	37293-74-6
May Contain The Following:				
Wax, Paraffin		<10	5	8002-74-2
Vermiculite		<10	10	1318-00-9
Glass Fibre		<1	NE	65977-17-3
Boric Acid		<0.5	NE	10043-35-3
Crystalline Silica (Total From Above)		NE	0.1(R)	14808-60-7

R Respirable
NE Not Established
NA Not Available

Further information can be found at:
http://www.gib.co.nz/Literature/pdf/Performance%20Board.doc

Appendix 2 – Composition of BPB plasterboard

BPB Plasterboards are not classified hazardous under CHIP 2 Regulations 1994 (refer to Section 15).

- General composition: calcium sulphate dihydrate encased in paper liners. Natural constituents may include clay, limestone and minor amounts of quartz.
- Minor additives may include starch, foaming agents, dispersants and boric acid.
- Firestop boards include small quantities of chopped man made mineral glass fibre.
- Moisture Resistant Boards include a silicone and/or a wax additive for moisture control.

Further information can be found at:
http://www.bpb.co.nz/PDFs/BML-Safety-data.pdf

Appendix 3 – Composition of BGC's plasterboard

BGC's plasterboard contains the following ingredients:

Chemical Name	CAS Number	Proportion	Exposure Limits
Calcium sulphate dihydrate	10101-41-4	> 95%	-
Paper facing (cellulose)	9004-34-6	4-6%	10 mg/m3 measured as inspirable dust
Paraffin wax	8002-74-2	0-3%	-
Clay	-	0-8%	-
Vermiculite (mica)	12001-26-2	0-4%	2.5 mg/m3 measured as inspirable dust
Starch	9005-25-8	< 1%	10 mg/m3 measured as inspirable dust
Paper pulp (cellulose)	9004-34-6	< 1%	10 mg/m3 measured as inspirable dust
Continuous filament glass fibre	65997-17-3	0-0.4%	-
Boric Acid	10043-35-3	< 0.2%	-

Note: The silica quartz content of BGC Plasterboard is less than 0.1%.

Further information can be found at
http://www.bgcplaster.com/pdfs/msds.pdf

Appendix 4 – Excerpt from The New Zealand Ecolabelling Trust

Gypsum Plasterboard Specification

Some disposal of gypsum products can occur through application as a fertiliser on agricultural land in compost or cement manufacture, as well as other possible alternatives.

Disposal in compost can, in the case of gypsum that has been painted or treated in some way during installation and if not managed correctly, result in hydrogen sulphide being produced, potentially lowering the pH conditions in the compost and causing odour. Accordingly, the environmentally preferable approach is to either recycle and reprocess wallboard products or compost unpainted and untreated waste from the manufacturing process or unpainted and untreated offcuts from installation sites.

Gypsum plasterboard must not be impregnated, labelled, coated or otherwise treated in a manner which would prevent recycling and / or composting in New Zealand or in the country where the product is used.

Information on paint types that are acceptable and will not hinder the recycling or diversion process must be available to purchasers of the Gypsum Plasterboard to avoid the product being painted in substances that will stop it being diverted from landfill sites.

Gypsum plasterboard must contain at least 5% (by weight) recycled gypsum board; or 5% of waste gypsum board (based on annual production tonnage) must be diverted to a composting facility, for use as either a soil amendment or bulking agent, or be utilised in cement manufacture or an equivalent diversion use (to be approved by Environmental Choice New Zealand).

The option for composting or cement diversion has been added, as it has been adequately demonstrated by Gypsum manufacturers that the 5% recycled content requirement is technically extremely difficult to achieve in New Zealand. As the intent of this requirement is to actively divert waste from landfill, it is considered that, as the composting or cement alternative achieves this intent, it should be accepted. The original 5% recycled content requirement has been left as an alternative, rather than removing it altogether. In line with ISO 14024, this 5% requirement is expected to increase over time and manufacturers must demonstrate plans to actively increase this amount.

Further information can be found at:
http://www.enviro-choice.org.nz/specifications/EC-19-07GypsumPlasterboardProducts.pdf