Recycled Organics Unit

A Literature Review on the Composting of Composite Wood Products

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Executive Summary

This review examines issues relating to the size reduction and composting of *composite wood products*. The composting of these materials is not widespread, possibly due to concerns pertaining to the potentially toxic effects of some constituent chemicals (resins and preservatives) used during the manufacture of composite wood products. Although many of these fears are understandable, existing practices of placing these materials into *landfill* do not exploit the highest net resource value of composite wood products. Consequently, it is important to develop economic and environmentally appropriate methods of recycling these materials, while at the same time alleviating stresses on *landfill sites*. Scientific literature and case studies, indicate that composting *wood and timber residuals* in combination with other materials is possible, subject to the adoption of a number of safety measures throughout the manufacturing process (principally during size reduction and composting stages). These precautions are required to mitigate possible human, animal and plant health problems during the composting process and from end-products.

The size reduction of composite wood materials requires similar machinery to that used for non-treated *wood and timber* residuals. However, additional safety measures are required, as size reduction procedures may expose operators of machinery and nearby workers to contaminated particulates or *aerosols* from the composite wood *feedstocks*. It is therefore recommended that operators of equipment use respirators and protective clothing while size reducing these materials. Workers in areas adjacent to size reduction equipment should adopt similar measures.

The composting of composite wood products in isolation is not a viable option due to their very high carbon to nitrogen ratios and possible chemical (e.g. resins and preservatives) and physical (e.g. fasteners and plastic coatings) *contamination*. It is therefore recommended that composite products are blended/mixed with other nitrogenous (non-toxic) materials to facilitate the composting process and to avoid potential contamination problems.

Feedstocks comprising a high proportion of composite wood products are not suitable for application to land or soil unless they have been fully composted. The *pasteurisation* of these products alone may not be sufficient to degrade persistent toxic chemical constituents of composite wood products. It is therefore recommended that in addition to pasteurisation, these materials are fully composted and matured as a means of reducing possible contamination problems.

Although research indicates that most chemicals in composite wood products readily degrade in a compost pile, there are some chemicals (e.g. organochlorines) in older materials, which are resistant to this process. It is therefore recommended that operators of facilities minimise the proportion of older composite wood products used, as a means of avoiding contamination problems. The blending of these contaminated products with non-contaminated feedstocks will also help reduce associated heavy metal (e.g. As, Cu and Cr) concentrations in the composted product.

The burning of composite wood residuals could result in the release of toxic emissions. It is therefore recommended that facilities composting these feedstocks adopt additional pre-emptive safety measures to minimise the risk of fire. These safety measures may include a reduction in pile heights in pile/windrow systems (i.e. < 2.5 m) and an increase in separation distances between individual piles or windrows. In addition, extra care should be taken during size reduction processes to reduce the risk of fire at this stage in the manufacturing process.

Formaldehyde (resin used in the manufacture of composite wood products) emissions from composite products could have an adverse effect upon human health in enclosed areas. It is therefore recommended that adequate ventilation be provided in composting facilities where composite wood products are stored or composted in enclosed environments.

Products manufactured from composted composite wood feedstocks (and their blends) should be similar to those manufactured from other (non-composite) wood products in terms of physical and chemical composition. However, it is recommended that products created from these feedstocks comply with the Australian Standard AS 4454 (1999) for *composts*, *soil conditioners* and *mulches* if they are to compete on the basis of quality against more established recycled organics products that are currently available.

Section 1 Introduction

1.1 Background

Wood and timber residuals incorporate any contaminated or uncontaminated, treated or untreated, solid or *composite wood* material. These materials are predominantly produced by construction and demolition (C&D) sources, commercial and industrial (C&I) sources and primary and secondary timber processing mills.

Existing practices of burning or putting wood and timber residuals into (Inert Waste Class 1) landfill sites (NSW EPA, 1999) are inconsistent with the principles of the Waste Hierarchy (Waste Minimisation and Management Act, 1995), as there are alternative management strategies which utilise the highest net resource value of this material. The reprocessing of these residuals will help alleviate increasing pressures on landfill sites, while at the same time converting materials that have been considered '*waste*' into a 'resource'.

Some possible reprocessing opportunities include the re-manufacturing of higher quality residuals (McKeever, 1999), or the size reduction (*grinding*/*shredding*) of a product for such purposes as boiler fuel or (more recently) as mulch or artificially coloured mulch and *compost* (BioCycle Staff, 2000). Although the composting of these *feedstocks* may require additional precautions, there are many instances where these materials are recycled overseas.

Recently, Warnken (1999) estimated that approximately 19 000 tonnes/year of wood and timber residuals were generated by small timber related businesses in western Sydney. Of this material, 67% comprised *composite wood* products. The report alluded to the potential re-use of these materials by adopting size reduction and composting procedures.

Unfortunately, at present, detailed scientific information on the composting of composite wood material is limited, as the majority of information is presented as case studies in industry based journals. The absence of solid information has significant implications, as composite wood products often possess a range of physical attributes and chemical ingredients that may affect handling requirements and end-product application. Consequently, significant caution and awareness of feedstock variability is required prior to establishing an operation for the composting of composite wood products.

1.2 Objectives

This review has addressed the following objectives:

1.2.1 Primary objectives

To: inform the development of safe and effective processes for handling and recycling of composite wood waste materials by reviewing documented international and national experience.

1.2.2 Secondary objectives

- Composite wood waste material size reduction options;
- Composting of composite wood waste materials; and
- Occupational health and safety issues associated with the composite wood waste material size reduction and composting operations.
- Potential use of composts manufactured from composite wood residuals

Detailed information describing the chemical effects of resins and preservatives used in the manufacture of composite wood products are complex and are beyond the scope of this review.

1.3 Terminology

The Recycled Organics Unit has submitted a range of compostable organics material descriptions and sub-categories for inclusion in the Australian Waste Database. These material descriptions have already been adopted as a standard by the NSW Waste Boards (Recycled Organics Unit 2000d).

This review has identified material description subcategories for wood and timber residuals, and identifies this breakdown in the Appendix for the purpose of identifying the scope of this research paper (Appendix, Table 3).

"Composite wood" is used in this document to describe wood materials that have been manufactured from other wood-based products, as defined in the glossary (Appendix, Table 3). This terminology is based upon those used by Eaton and Hale (1993) and Standards Australia AS 4491 (1997). This is also the term most consistently used throughout the literature reviewed to describe and identify the relevant materials.

Section 2 Composite Wood Products

2.1 Definitions

Materials that are classified as 'composite wood products' have wide-ranging chemical and physical properties. This variation originates from the fast paced development of technologies that aim to make these products more resilient to physical, chemical and biological stresses. In general terms however, composite wood products may be constructed using wood fibres, flakes, chips or shavings, *veneers* or paper. During the manufacturing process, these materials are often combined with different glues, resins, water repellents and preservatives to produce sheet boards. Some examples of major composite wood products include (Eaton and Hale, 1993) (see appendix for detailed definitions):

- *Fibreboard* (constructed from fibres of wood)
- *Particleboard/chipboard* (constructed from wood flakes, shavings or splinters)
- *Plywood* (constructed from one or more *veneers*)

Each of these composite wood product types can be manufactured in a variety ways, comprising different physical or chemical attributes that may affect composting procedures and end-product applications. Furthermore, the prior use of these wood products will determine the presence or absence of such components as fasteners, nails, screws, bolts, plastic coatings and paint. It is therefore critical for the production of quality compost to be aware of how a wood residual was manufactured, its prior use, and its condition at time of recycling (e.g. presence of fasteners, paint etc. and *moisture content*).

2.1.1 Chemicals used in the manufacture of composite wood products

The manufacture of composite wood products requires the use of bonding resins such as urea-formaldehyde (UF), melamine-formaldehyde (MF), melamine-urea-formaldehyde (MUF), phenol-formaldehyde (PF) and isocyanates (Table 1) (Eaton and Hale, 1993). In addition, to protect these products from biological degradation (e.g. fungal induced decay), preservatives (insecticides and/or fungicides) are combined with resins or applied separately to the composite material (Tables 2). Other property-modifying chemicals such as waxes and fire retardants (Yalinkilic *et al.*, 1998) may also be used. Chemical processes such as acetylation are in some instances used to increase the water repellency of fibres in composite wood products (Eaton and Hale, 1993). Many of these products are detrimental to human health and caution should therefore be exercised by operators endeavouring to process composite wood products (Yeates, 1994; Mclaren and Smith, 1996).

Table 1. Resins and preservatives used in different composite wood products. Adapted from Eaton and Hale, (1993).

Board type	*Resin type*	*Preservative used*
Plywood	UF PF	Insecticide
Particleboard	MF MUF Isocyanate	Combination insecticide/fungicide
Fibreboard	Tannin F	Insecticides and fungicides

Table 2. A partial list of biocides used for composite wood protection. Adapted from Eaton and Hale, (1993).

Principal biocidal action		*Combined*
Fungicide	*Insecticide*	*fungicide/insecticide*
• Didecyl dimethyl ammonium chloride • Didecyl dimethyl ammonium chloride + copper • Didecyl dimethyl ammonium chloride + carbamate • 3-ido-2-propynyl butyl carbamate • Azaconazole • (Pentachlorophenol)	• Chlordane • Fenvalerate • Fenitrothion • Pirimiphos-methyl • (DDT) • (Lindane) • (Dieldrin) • (Aldrin)	• Copper naphthenate • Copper chromium arsenic • Sodium fluoride • Ammonium hydrogen bifluoride • Borates • Copper + borates • (Creosote) • (Arsenic trioxide)

Names in brackets () indicate restricted use or banned in a number of countries (including Australia).

The banning of certain chemicals in Australia does not necessarily preclude their presence in composite wood products that were produced prior to a chemical's prohibition. Furthermore, the expansive range of chemicals that may be added to these products illuminates possible problems involved with the future production of compost. However, reviews by Buyuksonmez *et al.*, (1999); BioCycle Staff, (2000); and Buyuksonmez *et al.*, (2000) indicate that the majority of biocides in various feedstock materials (not necessarily composite wood based) do not cause contamination problems, as most of these chemicals readily degrade in compost piles. Similarly, work by Peltola *et al.*, (2000) showed that the biocides and resins present in a number of composite wood products posed no environmental threat for landfill following composting under high and low oxygen conditions. Although considerable work has been done in this area, there is scope for further research in the composting context. More detailed discussion pertaining to the effect of these chemicals is beyond the scope of this review.

Section 3 Composting of Composite Wood Products

3.1 Feedstock quality, condition and selection

There are very few instances where composting operators have solely worked with composite wood materials. In many instances, they receive a mix of composite and solid wood products from C&D, C&I and municipal sources. Because of this variety, the source and age of feedstock are important factors influencing processing methods and end-product manufacture. Composite wood material originating from new construction sites may be more predictable and manageable than material from the demolition of older buildings, where (older) lead-based paints or toxic banned chemicals (e.g. pentachlorophenol) may be present (McKeever, 1999). Work by Beebe and England (1998) indicated that leachable lead in stockpiled wood residuals from C&D sources were generally above safe levels for drinking water in Connecticut, USA. It was concluded that "…any land application, composting or blending of products containing C&D fine wood material cannot be supported." It was suggested that the removal of the fine wood fraction or blending lead-contaminated with non-lead based feedstocks would help reduce lead levels. Even with newer materials, composting facilities will have to consider health and safety issues associated with the possible dispersal of their chemical constituents (Section 2.1.1) during size reduction procedures.

The emergence of plastic composite materials adds another level of complexity to the processing and composting of composite wood products. Some manufacturers are combining recycled wood fibre with plastic for the construction of composite products (Lavendel, 1996). The presence of plastic in feedstock generated from these wood-plastic composites may affect end-product quality, in terms of visual appearance and compliance with the Australian Standard AS 4454 (1999) for composts, soil conditioners and mulches. Therefore, it is in the interest of composting facilities to limit or prevent wood-plastic composite materials from entering the site.

Some companies go through rigid sorting/separation processes prior to placing any material in size reduction machinery. Material may be excluded if such contaminants as paints, plastics or metals are present (Rynk *et al.*, 1992; Steuteville, 1997). This level of sorting is required if end-products are to be of sufficient quality to meet customer demand and to attract higher prices. In some instances, *treated wood products* are removed (if readily identified visually) from the feedstock, as these are considered to be contaminated materials.

Information on the actual processes used by many companies to process composite wood is limited due to the industry-based sources of information. Moreover, as the information is of a non-scientific nature, any detailed interpretations on efficiency and quality of end-products are difficult to make. Further discussion with individual firms is required to obtain more detailed information.

3.2 Size reduction of the composite wood products

Size reduction options for composite wood products are similar to those for other solid wood-based materials. However, unless a composting facility is receiving uniform, clean or standardised composite wood, size reduction equipment needs to be robust enough to manage materials of different sizes, shapes and densities, incorporating a range of possible contaminants.

3.2.1 Generic technology types

There are a number of basic technology types used in the size reduction of residual wood and timber materials (composite or solid). These are used interchangeably to suit material quantity, size, shape and hardness. Machinery size largely depends upon the size of the feedstock materials a facility receives, and the amount of material to be processed (Williams and Engel, 1997). Other factors to consider when selecting appropriate size reduction technology:

- Quantity of material to be processed and its intended use (Glenn, 1997);
- Where the processing is to occur (mobile or not);
- Type of material to be processed;
- Type of end-product produced;
- Safety features; and
- Capacity to detect or remove contaminants such as ferrous metals (Williams and Engel, 1997).

Price of machinery reflects capacity and maintenance requirements. Cheaper machines generally have lower processing capacities and higher maintenance requirements, as they may not have features that allow them to manage some contaminants (BioCycle Staff, 2000). Size reduction machinery types include hammer-mills/tub grinders and shredders/chippers. Each has its advantages and disadvantages depending upon situation, feedstock and end-product type. These machines may be mobile (trailer-mounted and towed behind a truck) or fixed. The following summarises some of these features.

i. Hammer Mills and Tub grinders

Grinders smash and crush large pieces of wood into smaller pieces, relying on a screen or grate to control the maximum particle size of the size-reduced material (Rynk *et al.*, 1992). These machines (appropriately sized) are capable of grinding a range of materials including pallets, railway sleepers and composite wood products. Stationary grinders can process between 10 and 50 tonnes of material per hour, depending upon the size of machinery used, screen size, type of material processed and moisture content (Rynk *et al.*, 1992). As these machinery types are usually gravity fed (top-loading), some types of materials (in particular those of low density), may not move through a grinder efficiently. As material is fed into the top of a grinder, it may, in some instances, be expelled from the grinder, creating additional safety hazards for operators and workers in the vicinity of the machinery. Also, due to their relatively short feed openings, long pieces of wood cannot be processed easily. Size-reduced material produced by tub grinders may be of variable sizes. This range in size may be a problem if uniformity of particle size is a requirement of an end-product (Glenn, 1997).

Alternatives to gravity fed grinders include horizontal feed grinders. These machines address the previously mentioned safety issues, as material is fed into enclosed compartments. In addition, their horizontal layout allows these grinders to accept longer pieces of wood than do vertical feed grinders.

ii. Shredders/chippers

Shredders or chippers differ from tub grinders in that they use a sharp edge to perform size reduction (Glenn, 1997). Materials are dropped directly into a shredder, which usually consists of two or three counter-rotating shafts fitted with fixed knives or rippers (Rynk *et al.*, 1992). The wood is sheered and cut as it is drawn down through the machine (Williams and Engel, 1997). Chippers usually generate a more uniform product than grinders, but they may not have the throughput capacity of grinders (Glenn, 1997). Horizontal shredders are typically used for primary size reduction. Further grinding and screening may be required for the production of higher quality wood chips. This may not be necessary for the manufacture of compost, as a range of particle sizes will facilitate the *decomposition* process (Rynk *et al.*, 1992).

3.3 Approaches to composting

Wood is not as degradable as other compostable organic materials (Rynk *et al.*, 1992) due to the presence of organic compounds such as *lignin* and lignocellulose that are relatively resistant to decomposition (Recycled Organics Unit, 2000). This resistance to degradation may be somewhat enhanced in preservative and biocide treated composite wood products. In addition, the high carbon to nitrogen (C:N) ratio of woody materials impacts upon the efficiency of microbial processes. High C:N ratios slow the decomposition process, extending the composting time required (Recycled Organics Unit, 2000). The blending of high C:N feedstocks with low C:N feedstocks is one strategy used to increase decomposition rates (see Section 3.3.1).

In Australia, softwood and hardwood *sawdust* and pinebark have been used since the early 1970's for the manufacture of composts, soil mixes and potting mixes (Rochfort, 1998). Wood chips are also used as bulking agents to adjust the physical properties of a composting mix. Adjustments are usually made to improve the porosity, structure, texture and particle size characteristics of compost (Rynk *et al.*, 1992; Recycled Organics Unit, 2000). Moisture contents of windrows are in some instances adjusted with sawdust.

Unlike the aforementioned products, the composting of treated timbers and composite wood products is not widespread. In fact, many sources indicate that preservative treated or painted wood products should not be used at all (Rynk *et al.*, 1992; Steuteville, 1997). Therefore information pertaining to the use of these products for composting is limited, and is often based upon anecdotal evidence or case studies.

There are many manufacturers reprocessing and composting wood and timber residuals (e.g. Earth 'n Wood, Ohio, USA; Greenvalley Enterprises, USA; L.R. Higgins Company, USA) for the production of different end-products (e.g. mulches, soil conditioners etc.). Composting facilities usually create a blend of wood material (may include composites) with *garden organics*. Unfortunately, specifics relating to the wood and timber residuals are not reported in the literature and will require direct communication with specific facility operators and are beyond the scope of this review.

Case studies from the United States and Europe indicate that a significant number of facilities are located on farms. This allows for the utilisation of blending materials that may not be readily available in city based composting facilities (e.g. agricultural manures). For example, an on-farm manufacturer of compost in the United States (Greenvalley Enterprises) blends crop residuals from corn, soybean and wheat straw with wood chips, saw dust, other wood residuals (not specified), cardboard and egg cartons (Block, 1998). Similarly, facilities such as that of the L.R. Higgins Company process 7500 to 9000 m^3 of C&D debris (including wood) every month using windrow systems (Section 3.4.1). Over 50 % of this material is recycled or composted, with the remainder being sent to landfill (Block, 1997).

3.4 Compost Production

Aerobic composting is primarily achieved through the actions of microorganisms under specified levels of air, water, food and temperature (Recycled Organics Unit, 2000). There are many approaches to the creation of quality compost and these are influenced to a large extent by the type of feedstock used and the end-product to be generated. The following section outlines some approaches to the composting of wood and timber residuals, with reference to composite materials where information is available.

3.4.1 Process control (windrow *turning*, forced aeration, aerated static piles etc.)

There a number of methods that may be utilised for the composting of wood and timber residuals. Some of these methods include (Recycled Organics Unit, 2000c):

- Turned windrow (aeration is achieved with a front-end loader or specialised equipment);
- Passively aerated windrow (windrows constructed over perforated plastic pipes, which serve as air ducts for passive aeration);
- Aerated static piles (aeration is achieved by a blower moving air through perforated plastic pipes located beneath a pile);
- Aerated covered windrow (similar to an aerated static pile, with a cover over the feedstock);
- Rotating drum (mixing and aeration occur with the rotation of a drum and forced aeration);
- Agitated bed or channel (forced aeration and mechanical mixing are used in fully enclosed buildings); and
- *In-vessel* systems (composting is achieved in an enclosed chamber subject to mechanical aeration).

From several case studies presented in industry based journals, open-air windrows appear to be the dominant method for composting wood and timber residuals (in combination with other feedstocks). Although this method of composting is not the most efficient, operations are relatively cheap to establish compared with alternatives including in-vessel systems or rotating drums. Companies such as Greenvalley Enterprises (USA) utilise windrows that are 2.5 m in height, 4.5 m wide, and 90 m long. A pond is used to collect runoff from the compost, and piles are turned approximately every three days using specialised windrow turning machinery (Block, 1998). In general, the height and width of a pile can be increased if the windrow is force aerated. However, windrow size may need to be regulated due to possible fire hazards (BioCycle Staff, 2000) (see Section 4.2).

3.4.2 Addition of amendments to size reduced wood

A carbon to nitrogen ratio of 25 to 30:1 (Golueke, 1994; Recycled Organics Unit, 2000) has been identified as the optimum level for the facilitation of decomposition for most feedstock types. Consequently, as most wood materials have very high carbon to nitrogen ratios (200-750:1) (Recycled Organics Unit, 2000b), it may be necessary to add or blend nitrogenous materials (e.g. non-woody *garden organics* or *food organics*) with wood-based feedstock, to lower the carbon to nitrogen ratio (Rynk, 1998). Some approaches are quite innovative, allowing for the use of on-site complementary material to amend the compost mix. For example, Greenvalley Enterprises (USA) composts approximately 100 000 tonnes of material annually (mentioned in previous section). This facility grows a hybrid of Sudan grass and sorghum for its high nitrogen content and then blends it into the compost mix to suit the requirements of customers. The crop itself is fertilised with surplus compost, improving the efficiency of the enterprise (Block, 1998). Similar blending procedures are discussed by Rynk *et al.* (1992) and Rynk (1998).

3.4.3 Pasteurisation

As the effective composting of composite wood materials requires the addition of nitrogenous materials such as non-woody garden organics or *food organics*, it is possible that pathogens or weed propagules are present in the mixed feedstock. To address these documented risks, the *pasteurisation* of compost is required. Pasteurisation is a heat derived process used during composting to kill *pathogens* or weed propagules in feedstock (Standards Australia, 1999). All compost materials should be maintained at temperatures of approximately 55°C or greater (from microbial activity) for a minimum period of three days (Recycled Organics Unit, 2000a). In windrow systems, the outer surface of the compost pile does not reach these temperatures, and should therefore be turned on a regular basis in order to achieve effective pasteurisation for all the material.

3.4.4 Fate of resins and other chemical constituents

As mentioned in Section 2.1.1, composite wood products comprise different resins, fungicides and pesticides. As a result, the use of these chemicals in feedstock material has been met with caution by individuals in the composting industry (e.g. Rynk *et al.*, 1992) because of the potentially harmful effects these chemicals have on humans and other organisms. The effect of the composting process on some of these chemical has been evaluated by a number of researchers, including Buyuksonmez *et al.*, (1999); Buyuksonmez *et al.*, (2000); BioCycle Staff, (2000); and Peltola *et al.*, (2000). Some of these findings are summarised below.

In a study investigating the biodegradability of (new) composite wood materials (chipboard, plywoods and laminates), Peltola *et al.*, (2000) concluded that "the materials studied were aerobically biodegradable and there was no toxicity towards photobacteria (bacteria associated with plants) or substances of environmental concern in the biodegradation". Similarly, in a review of literature, Buyuksonmez *et al.*, (1999) reported on a large number of physical, chemical and biological mechanisms that contributed to the biodegradation of pesticides in composts. These mechanisms included mineralisation, abiotic transformations, adsorption, leaching, humification and volatilisation. Buyuksonmez *et al.*, (1999) suggested that biodegradation in compost was accelerated by high temperatures, increased *organic matter* content, and vigorous biological activity. Although the majority of chemicals were found to readily degrade, Buyuksonmez *et al.*, (1999) indicated that organochlorine compounds (such as dieldrin and DDT) were resistant to degradation. This is important as wood and timber residuals may in some instances originate from demolition sites containing materials that were treated with these chemicals. Therefore, significant caution is warranted if a composting facility receives older wood and timber residuals, as they may be treated with resistant chemicals. In these instances, the blending of old and new materials may help reduce possible contamination of end-products. Because of these chemical contamination issues, it is important for a facility to conduct regular testing of compost material generated from composite wood products. On the basis of such testing, it may be found that the only valid/safe/reliable approach is to accept wood and timber residuals exclusively from known and controlled sources. In this way, the operator knows likely risks and can develop appropriate management, monitoring and testing regimes. In addition, it may be necessary to fully compost and mature feedstocks, to allow microorganisms sufficient time to degrade possible toxins present in the material.

Section 4 Health and Safety Issues

4.1 Size reduction (OH&S)

By their nature, shredders and grinders have the potential to cause severe damage to an operator (and bystanders) if care is not taken while using the equipment. This can occur through the release of airborne projectiles, generation of dust, aerosols and noise. As highlighted by BioCycle Staff (2000), complete safety for any machine on the market has not been achieved. Consequently, it is the responsibility of the operator to adopt risk characterisation procedures that pre-empt situations where injury may result. Precautions to consider are as follows [based upon a review by BioCycle Staff (2000)]:

- Follow guidelines for operation and maintenance given by the product manufacturer;
- Discuss safety issues on an on-going basis with operators and adjust practices accordingly;
- Establish regular follow-up training programs to re-enforce good operational practices and to eliminate any possible lapses in procedure;
- Position size reduction equipment in locations where pedestrians or other employees are not affected by possible projectiles. In one instance, a projectile was found to travel over 30 m from a tub grinder. Keeping a grinder full of material for the entire period of operation should help reduce these types of problems (Glenn, 1997);
- Avoid placing equipment close to power lines.
- Remove possible contaminants prior to operating machinery. This will protect machinery from damage caused by resilient material (e.g. metal). Use of machinery with protective mechanisms, such as metal detectors or magnets should be considered;
- Wearing protective clothing (hard hats, safety goggle, gloves, steel-toed boots, ear plugs) and respirators are required to avoid possible health hazards from dust and aerosols (this is particularly important for composite wood feedstocks where resins and biocides may be present);
- Monitor fatigue in operators of loading and grinding equipment; and
- Conduct daily safety inspections of equipment (Glenn, 1997).

4.2 Composting (OH&S)

4.2.1 Fire related hazards

Fire presents significant problems to all composting facilities, as heat is a major by-product of aerobic decomposition processes. The risk of fire in these situations is influenced by the following factors:

- Feedstock type
- Particle size and *density* of feedstock
- Moisture content
- Aeration
- Temperatures
- Height of pile (Glen, 1998; BioCycle Staff, 2000)

The height of a compost pile should reflect the particle size and density of feedstock material used. Feedstocks with larger particle sizes can be placed in higher piles than those with lower densities, as aeration will be more efficient. Moisture content of feedstock is another factor that should be considered when determining pile height. Materials with lower moisture contents can be piled higher than those with high moisture contents (BioCycle Staff, 2000). Fires from piles composed of composite wood products may create additional health problems due to the presence of resins, preservatives and other chemicals (Section 2). Therefore, extra measures to minimise the risk of fire during the composting of composite wood products may be required. Glenn (1998) indicated that at one facility, the Wood Recycle and Composting Center (USA), fire hazards were present at all levels of processing. To reduce the risk of fire, the facility lowered the height of piles and increased distances between individual piles to minimise the risk of fire transmission from one pile to another. Even with these additional measures, fires still occur.

4.2.2 Human health (formaldehyde emissions)

The type of feedstock used during composting operations may have an impact upon human health. While the composting of non-chemically treated wood materials may not contribute to any significant health problems, the resins, glues and other chemical compounds used in composite wood products can cause problems. Therefore, in some instances, it may be necessary for employees to take extra precautions (protective clothing and breathing apparatus) when composting composite materials.

Kazakevics and Spedding (1979) amongst many others suggest that formaldehyde emissions from composite wood products can be significant. In high enough concentrations (e.g. indoor areas), formaldehyde emissions have been reported to cause irritation to eyes and respiratory tracts, nausea, headache, tiredness, and thirst (National Research Council, 1981). Similar problems may arise in enclosed composting facilities where feedstock is stored or composted in poorly ventilated areas.

Formaldehyde emissions should not cause any significant problems in a well-ventilated facility or in an outdoor composting facility. Furthermore, as microbial breakdown of formaldehyde usually takes between 30-72 hours (National Research Council, 1981), emissions from compost piles may not be a serious problem after a prescribed period (dependent upon microbial activity, process control and quality of feedstock). Nevertheless, testing for formaldehyde concentrations in air may be prudent in enclosed facilities processing significant volumes of composite wood products. Guidelines and methodology for testing are presented in the Australian Standard AS 2365.6 (1995), Methods for the Sampling and Analysis of Indoor Air.

Section 5 Potential Uses and Markets

Contrary to general statements made by Merz (1999), the composting of composite wood residuals can be economically viable. Putting chemical issues of composite wood residuals aside, compost produced from these feedstocks (or their mixes) can be used for the production of a variety of end-products. Given that composite wood composts comply with Australian Standard AS 4454 (1999) for soil conditioners and mulches, composite wood-based composts should attract similar markets to other composts made from more traditional feedstocks. Manufacturers such as Universal Wood Recycling (U.S.A.) and Weaver Industries Inc. (U.S.A) process wood and timber residuals (with other feedstocks) for composts and mulches (in addition to a number of other products) that are used for a range of end-products (Farrell, 1998). The manufacture of compost can be targeted towards low and high value markets depending upon the composting process and quality of feedstock used. The following two sections outline some of these products.

5.1 High value products

High value products require quality feedstock, good screening processes for the removal of physical contaminants, and effective size reduction and composting procedures. Monitoring of compost quality and chemical composition during the composting process is necessary to maintain standards and also to avoid possible contamination issues associated with the resins and preservatives used in composite wood products. Some examples of end-products and applications for compost include soil conditioners, mulches, potting mixes and soils for landscaping and garden use. Descriptions of each are given below.

- Soil conditioner (Pasteurised with incomplete or complete composting. These products should not have more than 15% of particles greater than 15 mm in size) (Standards Australia AS 4454, 1999).
- Mulch (Any pasteurised organic material with complete or incomplete composting suitable for placing on soil surfaces. To comply with Standards Australia AS 4454 (1999), 75 % of material must be greater than 15 mm in size) (Standards Australia AS 4454, 1999).
- Potting mixes (General or specialised growing mediums for the establishment of plants in containers. Potting mix quality can be either regular or premium grade. Regular grade potting mix requires a balanced fertiliser, whereas premium grade does not) (Standards Australia AS 3743, 1996).
- Soils for landscaping and garden use (Manufactured by combining organic materials (including composts) with natural soil. Depending upon the end-use, soil-organic matter blends must fall within certain ranges for organic matter composition, nutrient contents and bulk densities) (Standards Australia AS 4419, 1998).

5.2 Low value products

Compost that has been manufactured from lower quality feedstocks, comprising higher physical and chemical contaminant levels can be used for the *bioremediation*[*] of degraded areas. For these end-products, the manufacturing process is less extensive, giving reduced production costs, and product prices that are markedly less than those for high quality products. Composts utilised in this way do not require extensive screening, size-reduction or fully matured compost, as they are applied to areas (e.g. mine-site rehabilitation) to assist with the biological breakdown of hazardous organic contaminants.

[*] Terminology from Market Strategy (2000), EC Sustainable Environment Consultants.

Section 6 Conclusions and Recommendations

6.1 General

The composting of composite wood products is an important issue that requires clarification, as there are individuals in the composting industry with serious concerns regarding the suitability of these materials. This apprehension stems from the presence of potentially toxic substances, including glues, resins and preservatives in composite wood products. In their original state, these chemicals may impact upon the health of humans and other organisms if applied to the environment. The purpose of this review was therefore to evaluate the potential use of composite wood materials, and to identify problems and safety measures associated with the handing of these materials as compost feedstocks.

Existing literature indicates that there are a large number of overseas facilities processing wood and timber residuals. Unfortunately, the proportion of feedstocks comprised by composite wood products is unclear due to anecdotal or case study based sources of information. Although a large information gap exists, there is evidence to support the composting of composite wood products in combination with other feedstock materials. However, as these materials are treated with a range of chemical substances, operators of composting facilities should adopt additional safety measures. The following sections summarise the main findings and recommendations of this review.

6.2 Size reduction

The size reduction of composite wood products presents problems other than those experienced for the size reduction of non-treated timber materials. The size reduction process may expose machinery operators and nearby workers to particulates or aerosols containing glues, resins and biocides in the composite wood materials. This exposure may have detrimental effects upon the health of workers if exposed for an extended period. It is therefore recommended that operators of size reduction machinery wear protective clothing other than that generally required for the operation of such equipment, including respirators and clothing that covers the entire body. Workers located near size reduction equipment should informed of the hazards and made to wear protective clothing and respirators where required.

6.3 Composting

Composting of composite wood materials in isolation is not a viable option for the following reasons:

- The carbon to nitrogen ratio of these materials is generally too high to facilitate effective decomposition, and
- The presence of persistent biocides in older wood and timber residuals may result in compost that exhibits toxic effects on plants and animals and therefore may not comply with the Australian Standard AS 4454, (1999) for composts, soil conditioners and mulches.

It is recommended that if composite wood materials are to be used as feedstock, that they be combined with other feedstock materials (e.g. food organics, non-woody garden organics) comprising low levels of chemical contaminants, to optimise the carbon to nitrogen ratio and to mitigate possible contamination issues.

Compost products comprising a high proportion of composite wood materials are not suitable for use unless they have been fully composted and matured. The pasteurisation of these products alone may not be sufficient to degrade all toxic chemical constituents of composite wood products. It is therefore recommended that in addition to pasteurisation, these materials are fully composted and matured as a means of reducing possible contamination problems.

6.4 Biodegradability of chemical constituents

Considerable work has been done investigating the biodegradability of chemicals present within composite wood products. The rate at which these chemicals degrade is related to chemical type and also the period in which a product was manufactured. In general, modern chemicals used in the manufacture of composite wood products readily degrade in the environment. In the context of a compost pile, the rate of degradation is significantly faster than that observed in soil, due to increased temperatures, moisture levels and biological activity. However, substances such as organochlorines (DDT, dieldrin etc.), used in the manufacture of older composite products, are not readily degraded and may pose considerable health risks if present in sufficient concentrations. It is therefore recommended that operators of facilities minimise the proportion of older composite wood products used, particularly from the C&D sector, as a means of avoiding contamination problems.

6.5 General Safety Issues

The presence of toxic chemicals in composite wood products raises issues of fire safety at all levels of production, and also issues of air quality during the composting process. These concerns are summarised below.

The control of fire in a composting facility is an important issue that merits more attention if composite wood products are a dominant material used in the feedstock mix, or are stockpiled on site in any significant quantity. In the event of a fire, constituent toxic chemicals may be released into the atmosphere, impacting upon the health of individuals in a facility and in neighbouring areas. To minimise the risk of fires, it is recommended that operators of composting facilities reduce the height of compost piles below that usually recommended for similar non-treated wood feedstocks and increase separation distances between piles (where appropriate). Extra precautions are also required during size reduction processes, where fires may arise from inappropriate use of machinery or from contaminated (physical) feedstocks.

Formaldehyde (resin used in the manufacture of composite products) emissions from composite products could have an adverse affect upon human health in enclosed areas. Therefore, it is recommended that where composite wood products are composted or stored in an enclosed facility, adequate ventilation to dissipate formaldehyde fumes be provided. Facilities with external composting piles do not require such precautions.

6.6 End-products

The production of composite wood derived compost that complies with Australian Standard AS 4454, (1999) should allow manufacturers the flexibility of creating end-products similar to those made from other non-treated wood materials.

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Glossary

All terms listed in the glossary are from the Recycled Organics Dictionary and Thesaurus (Recycled Organics Unit, 2000d). Other references not in this dictionary are appropriately referenced below.

Aerobic In the presence of, or requiring, oxygen.

Aerosols Suspension of particles in airborne water droplets (Brock and Madigan, 1991)

Anaerobic In the absence of oxygen, or not requiring oxygen. Composting systems subject to anaerobic conditions often produce odorous compounds and other metabolites that are partly responsible for the temporary phytotoxic properties of compost. Anaerobic conditions are important for anaerobic digestion systems.

Bioremediation Process by which microorganisms are stimulated to rapidly degrade hazardous organic contaminants to environmentally safe levels in soils, sub-surface materials, water, sludges, and residues.

Bulk Density Weight or mass per unit of volume of a material comprised of many individual particles. For example, the weight of a pile of wood chips divided by the volume of the pile is the bulk density. This is different from the particle density (which, in this case, equals the weight of a single wood chip divided by its volume.

Bulking Agent An ingredient in a mixture of composting raw materials included to improve the structure and porosity of the mix. Bulking agents are usually rigid and dry and often have large particles (for example, straw or wood chips). The terms “bulking agent” and “amendment” are often used interchangeably. See also composting amendment.

Chipboard See particle board.

Composite wood Composite wood products may be constructed from wood fibres, flakes, chips or shavings, veneers or paper. During the manufacturing process, these materials are often combined with different glues, resins, water repellents and fungal inhibitors to produce sheet boards.

Compost A stable and pasteurised material, high in organic matter, that is the product of an aerobic composting process. Compost is suitable for the use as soil conditioner or mulch and can improve soil structure, water retention, aeration, erosion control, and other soil properties

Compostable wood Any uncontaminated wood waste material produced by domestic, C&D and C&I sources, including: off-cuts; crates; pallets and packaging; saw dust and timber shavings. Residual Wood is one of the primary component materials of the Compostable Organics stream.

Contamination (Compost) Contaminants within this context include physical inorganic materials (metals, glass etc.), non-biodegradable organic materials (plastics), chemical compounds and/or biological agents that can have a detrimental impact on the quality of any recycled organic products manufactured from source separated compostable organic materials.

Decomposition The breakdown of organic waste materials by micro-organisms.

Feedstock Organic materials used for composting or related biological treatment systems. Different feedstocks have different nutrient concentrations, moisture, structure and contamination levels (physical, chemical and biological).

Fibreboard Sheet material manufactured from lignocellulosic fibres with the primary bond deriving from the felting of the fibres and their inherent adhesive properties. Bonding or impregnating agents may be added during manufacture. When heat and pressure are used to cure the adhesive, fibreboard of increased density is produced (Standards Australia AS 4491, 1997).

Food Organics Food Organics includes organics generated by any one of the following activities: the manufacturing, preparation or consumption of food (including beverages); the processing of meat, poultry or fish, and the manufacturing of edible grocery products. Such materials may be derived from domestic or commercial and industrial sources. The definition does not include grease trap waste. Food organics is one of the primary components of the compostable organics stream.

Garden Organics Any garden derived organic (plant) materials generated by domestic, C&D and C&I sources. Garden Organics is defined by its component materials including: putrescible garden organics (grass clippings); non-woody garden organics; woody garden organics; trees and limbs, and stumps and rootballs. Garden organics is one of the primary components of the compostable organics stream.

Grinding Operation which reduces the particle size of materials. Grinding implies that particles are broken apart largely by smashing and crushing rather than tearing or slicing.

In-vessel A containerised unit in which vermiculture, compost or anaerobic digestion-based processes are performed. Containers vary in size, configuration, degree of automation and level of process control. In-vessel systems are often used for treatment of putrescible organics in populated areas as they have minimal or no significant impact on the environment (e.g. through the generation of odour, leachate or attraction of pests or vermin).

Landfill Solid or liquid material disposed of by burial in the ground .

Landfill Site A waste facility used for the purpose of disposing waste to land (EPA 1999).

Lignin A substance that, together with cellulose, forms the woody cell walls of plants and the cementing material between them. Lignin is resistant to decomposition

Moisture Content The fraction or percentage of a substrate comprised of water. Moisture content equals the weight of the water portion divided by the total weight (water plus dry matter portion)

Mulch Any pasteurised organic product (excluding polymers which do not degrade such as plastics, rubber and coatings) that is suitable for placing on soil surfaces. Mulch has at least 70% by mass of its particles with a maximum size of greater than 15 mm.

Organic Matter Chemical substances of animal or vegetable origin, consisting of hydrocarbons and their derivates.

Particleboard A generic term for a panel manufactured from lignocellulosic materials (usually wood) primarily in the form of discrete particles, flakes, strands or fibres and bonded together with synthetic resin, or other binder, under heat and pressure, until cured (Standards Australia AS 4491, 1997).

Pasteurisation The process whereby organic materials are treated to kill plant and animal pathogens and weed propagules

Pathogens Microorganisms capable of producing disease or infection in plants or animals. Pathogens can be killed by heat produced during thermophilic composting. Modified from EcoRecycle Victoria (1998).

Ply Each of the individual layers of veneer or core plate in a sheet of plywood (Standards Australia AS 4491, 1997).

Plywood An assembled product made up of two or more plies bonded together with the direction of the grain in alternate plies usually at right-angles (Standards Australia AS 4491, 1997).

Sawdust Any untreated, uncontaminated wood fibre produced by the saw milling of timber. Particles of sawdust are less than 3 mm in size.

Shredding An operation which reduces the particle size of materials. Shredding implies that the particles are broken apart by tearing and slicing.

Soil Conditioner Any composted or pasteurised organic material that is suitable for adding to soils. This term also includes 'soil amendment', 'soil additive', 'soil improver' and similar terms, but excludes polymers which do not biodegrade, such as plastics, rubber and coatings. Soil conditioners may be either 'composted soil conditioners' or 'pasteurised soil conditioners'. Soil conditioner has not more than 15% by mass of particles with a maximum size above 15 mm.

Treated wood products Wood products that have been chemically treated with resins or preservatives. May include composite or non-composite wood products.

Turning A composting operation which mixes and agitates material in a windrow pile or vessel. Its main aeration effect is to increase the porosity of the windrow to enhance passive aeration. It can be accomplished with front-end loaders or specially designed turning machines.

Veneer A thin sheet of wood of uniform thickness produced by slicing, rotary cutting, semirotary cutting or sawing (Standards Australia AS 4491, 1997).

Waste NSW Waste Minimisation and Management Act (1995) to include:

any substance (whether solid, liquid or gaseous) that is discharged, emitted or deposited in the environment in such volume, constituency or manner as to cause an alteration in the environment, or any discarded, rejected, unwanted, surplus or abandoned substance, or any otherwise discarded, rejected, unwanted, surplus or abandoned substance intended for sale or for recycling, reprocessing, recovery or purification by a separate operation from that which produced the substance, or any substance prescribed by the regulations to be waste for the purposes of this Act.

A substance is not precluded from being waste for the purposes of this Act merely because it can be reprocessed, re-used or recycled.

Wood and Timber (Residuals)

Wood and Timber residuals include any contaminated or uncontaminated, treated or untreated, solid or composite wood material produced by domestic,and C&I sources.

Appendix

As a result of this project, a submission will be made to the Australian Waste Database regarding the range of wood and timber residuals that may be processed into marketable products (Table 3).

Table 3. Australian waste database material descriptions and sub-categories.

AWD code	Broad description	Material description	Material description sub category 1	Material description sub category 2	Material description sub category 3
C	Other Organic				
C01		Wood & timber			
C011			Transport pallets		
C012			Untreated timber (no plastic laminate and/or paint)		
C0121				No fasteners (Grade A)	Sawdust, shavings, woodchips, off-cuts, other
C0122				Some fasteners (Grade B)	Sawdust, shavings, woodchips, off-cuts, other
C013			Untreated timber (with plastic laminate and/or paint)		
C0131				No fasteners (Grade A)	Sawdust, shavings, woodchips, off-cuts, other
C0132				Some fasteners (Grade B)	Sawdust, shavings, woodchips, off-cuts, other
C014			Treated timber		
C0141				Treatment type (resins, pesticides, fungicides, fire retardants)	
C015			Composite wood (no plastic laminate and/or paint)		
C0151				Fibreboard (No fasteners, Grade A)	Low Density Fibreboard (LDF), Medium Density Fibreboard (MDF), High Density Fibreboard (HDF)
C0152				Fibreboard (Some fasteners, Grade B)	Low Density Fibreboard (LDF), Medium Density Fibreboard (MDF), High Density Fibreboard (HDF)
C0153				Particleboard/ chipboard (No fasteners, Grade A)	Wood flakes, paper
C0154				Particleboard/ chipboard (Some fasteners, Grade B)	Wood flakes, paper
C0155				Plywood (No fasteners, Grade A)	Veneers
C0156				Plywood (Some fasteners, Grade B)	Veneers
C016			Composite wood (with plastic laminate and/or paint)		
C0161				Fibreboard (No fasteners, Grade A)	Low Density Fibreboard (LDF), Medium Density Fibreboard (MDF), High Density Fibreboard (HDF)
C0162				Fibreboard (Some fasteners, Grade B)	Low Density Fibreboard (LDF), Medium Density Fibreboard (MDF), High Density Fibreboard (HDF)
C0163				Particleboard/ chipboard (No fasteners, Grade A)	Wood flakes, paper
C0164				Particleboard/ chipboard (Some fasteners, Grade B)	Wood flakes, paper
C0165				Plywood (No fasteners, Grade A)	Veneers
C0166				Plywood (Some fasteners, Grade B)	Veneers