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The decay of wood in landfills in contrasting climates in Australia

Fabiano Ximenes [a,*], Charlotte Björdal [b], Annette Cowie [c], Morton Barlaz [d]

[a] Forest Science, Agriculture NSW, New South Wales Department of Primary Industries, Level 12, 10 Valentine Ave, Parramatta, NSW 2150, Australia
[b] Department of Conservation, Gothenburg University, Guldhedsgatan 5A, Box 130, SE-405 30 Göteborg, Sweden
[c] NSW Department of Primary Industries, Beef Industry Centre, Trevenna Rd., University of New England, Armidale, NSW 2351, Australia
[d] Dept. of Civil, Construction, & Environmental Eng., North Carolina State University, Box 7908, Raleigh, NC 27695-7908, USA

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ABSTRACT

Wood products in landfill are commonly assumed to decay within several decades, returning the carbon contained therein to the atmosphere, with about half the carbon released as methane. However, the rate and extent of decay is not well known, as very few studies have examined the decay of wood products in landfills. This study reports on the findings from landfill excavations conducted in the Australian cities of Sydney and Cairns located in temperate and tropical environments, respectively. The objective of this study was to determine whether burial of the wood in warmer, more tropical conditions in Cairns would result in greater levels of decay than occurs in the temperate environment of Sydney. Wood samples recovered after 16–44 years in landfill were examined through physical, chemical and microscopic analyses, and compared with control samples to determine the carbon loss. There was typically little or no decay in the wood samples analysed from the landfill in Sydney. Although there was significant decay in rainforest wood species excavated from Cairns, decay levels for wood types that were common to both Cairns and Sydney landfills were similar. The current Intergovernmental Panel on Climate Change (IPCC, 2006) default decay factor for organic materials in landfills is 50%. In contrast, the carbon loss determined for *Pinus radiata* recovered from Sydney and Cairns landfills was 7.9% and 4.4%, respectively, and 0% for *Agathis* sp. This suggests that climate did not influence decay, and that the more extensive levels of decay observed for some wood samples from Cairns indicates that those wood types were more susceptible to biodegradation. Microscopic analyses revealed that most decay patterns observed in samples analysed from Sydney were consistent with aerobic fungal decay. Only a minor portion of the microbial decay was due to erosion bacteria active in anaerobic/near anaerobic environments. The findings of this study strongly suggest that models that adopt current accepted default factors for the decay of wood in landfills greatly overestimate methane emissions.

1. Introduction

Approximately 48% of the total waste generated in Australia is disposed in landfills, with solid waste disposal on land estimated to contribute 9.0 Mt CO_2-e to Australia's greenhouse gas emissions (GHG) in 2012 (Dept. of Environment, 2014). It has been estimated that prior to 2008, 1,457,000 tonnes of wood waste were deposited in landfills annually in Australia (FWPA, 2008). This value is well-aligned with that provided in the National Waste Plan 2020 (Department of the Environment, Water, Heritage and the Arts, 2010), which suggests that 1,470,000 tonnes of wood waste were deposited in landfills in Australia for a similar period. Approximately 70% of the total waste generated in Australia is in the construction and demolition (C&D) and commercial and industrial (C&I) streams, in which wood is a component, accounting for 13% of the C&I waste and 6.0% of the C&D waste by mass (Dept. of Environment, 2014). In the United States, it is estimated that wood products account for as much as 40% of the C&D waste stream by mass (Staley and Barlaz, 2009). Wood products are generally also found in the municipal solid waste (MSW) stream, although in smaller quantities. In Australia, even when wood products are re-used or recycled, unless they decay naturally (e.g. mulch), they are typically disposed in landfills, as this is the common form of waste management in Australia. Anaerobic decay of organic materials in landfills results in the generation of carbon dioxide and methane (IPCC, 2006). Knowledge on the decay of specific components of the organic waste stream – such as wood products – assists in the understanding of the biology of anaerobic decay in landfills and the management of GHG emissions. As C&D landfills generate only small quantities of GHG due to the lack of the more easily degradable organic materials, there are typically

* Corresponding author. Tel.: +61 2 0458 760 812.
E-mail address: fabiano.ximenes@dpi.nsw.gov.au (F. Ximenes).

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no regulatory requirements for capping or capturing methane in C&D landfills.

There have been only a few studies that have quantified decay of wood products in landfills. Available studies differ greatly in their methodology, approach, climatic coverage and whether they are based on field data, laboratory data or theoretical values. Early studies suggested that 56% of the carbon in wood would be lost in landfills (Bingemer and Crutzen, 1987, based on stoichiometric calculations). However, Micales and Skog (1997) suggested much lower levels of decay (0–3%), based on published estimates of methane yields. Ximenes et al. (2008) described the results of two excavations in Sydney where large volumes of wood and wood products were recovered. The carbon loss in the samples analysed ranged from zero in two sites in one landfill where samples had been buried for between 19 and 29 years, to an average 17.5% in a landfill where samples had been buried for 46 years. However it was not possible to determine what proportion of the decay happened prior to deposition in landfill. More recently, Wang et al. (2013) assessed the decay of a range of wood products that were buried in an active landfill with leachate recirculation for 1.5–2.5 years. No decay was observed in the hardwood and softwood samples included in the experiment. The biodegradability of wood products has also more recently been tested in laboratory-scale bioreactors. Wang et al. (2011) measured methane yields from bioreactors filled with a range of wood products, including red oak (*Quercus rubra*), blackbutt (*Eucalyptus pilularis*) from Australia, spruce (*Picea* sp.) and radiata pine (*Pinus radiata*) from Australia. No carbon loss was observed for the wood from Australia, with minor carbon losses recorded for spruce and red oak (1.8% and 7.8%, respectively).

There is a need for more research to better understand the dynamics of the decay of wood products in landfills, given the uncertainty in the range of values suggested and the low number of data points reported. If confirmed, the low decay rates suggested by recent research will have important implications for models that estimate methane generation from landfills and GHG accounting for inventory and emissions trading.

Biodegradation of wood has long been of interest to wood scientists and has been of special interest for wood biologists focussing on durability, preservative treatment and service life of wood products (Eaton and Hale, 1993). Aerobic biodegradation in above ground conditions and in contact with soil is caused primarily by specialized wood-degrading fungi grouped as brown rot and white rot fungi. Soft rot fungi as well as two types of bacteria are efficient degraders in more humid and waterlogged environments with limited access to oxygen (Blanchette, 2000; Blanchette et al., 1990; Eaton and Hale, 1993). Previous studies have shown that microbial degradation in anoxic or near anoxic waterlogged environments was caused by specialised bacteria (Daniel and Nilsson, 1986; Kim and Singh, 2000). Erosion bacteria degrade and utilise the holocellulose-rich part of the wood cell walls, leaving behind a lignin-rich and unaltered skeleton (Björdal, 2000, 1999; Pedersen et al., 2013). This process is extremely slow and may take hundreds or even thousands of years (Björdal, 2012; Björdal et al., 2000). Studies show that erosion bacteria probably belong to Cytophaga or Flavobacteria, but their identity and therefore also metabolism, including respiration products, is still unknown (Landy et al., 2008; Nilsson et al., 2008).

The objective of this study was to recover wood that had been buried for a long period of time in landfills in contrasting environments, to determine whether warmer, more tropical conditions in Cairns would result in greater levels of decay relative to the temperate environment of Sydney. This study is focussed on the chemical, physical and microscopic analyses of wood samples recovered from one municipal solid waste (MSW) landfill in Sydney, New South Wales, and from two landfill sites in Cairns, Queensland, Australia. The analyses were focussed on solid wood products, rather than composite wood products (e.g. particleboard, plywood) or paper products.

2. Material and methods

2.1. Sites description

2.1.1. Sydney (Meadowbank)

Meadowbank is located approximately 15 km north-west of the Sydney central business district. The Meadowbank landfill was located adjacent to the Parramatta River, and was one of the largest landfills in Sydney, receiving primarily household waste and operating between the early 1950's until 1968. The landfill was not capped and was not fitted with leachate collection systems. Four holes were dug using an excavator fitted with a bucket (Fig. 1) in a section of the landfill currently used as sport fields. Three of the holes revealed large volumes of waste (including a wide range of wood products), whereas one of them had little waste. Only a small quantity of paper products was recovered, most likely because of the common practice of that period to burn

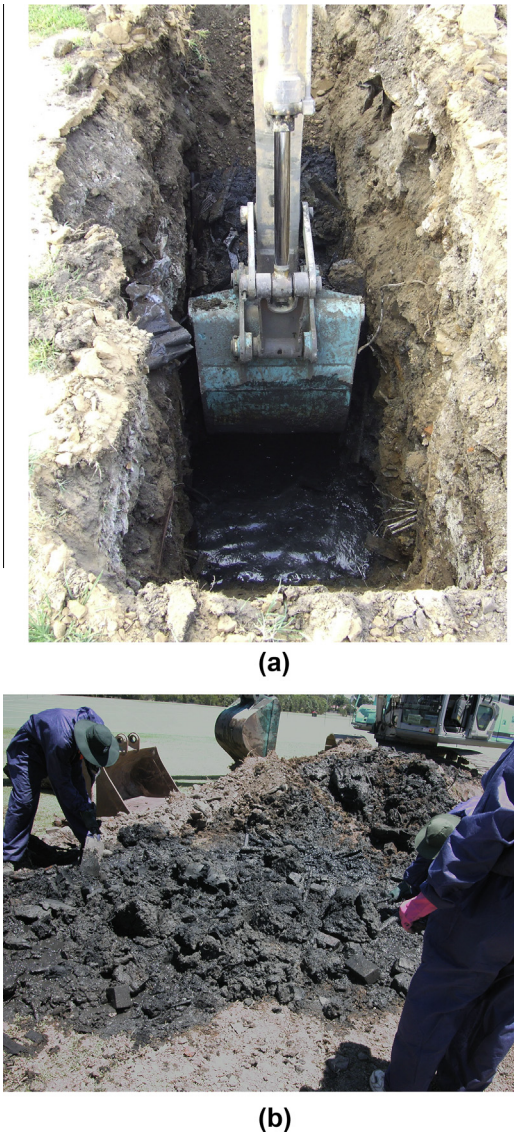

Fig. 1. (a) Bottom of cell, Meadowbank landfill and (b) excavated waste, Meadowbank landfill.