Chemical Characterisation and Compost-Recycling of a Pulp and Paper Mill Sludge

by

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Abstract

Australian Newsprint Mills is a pulp and paper mill located in southern Tasmania. This company produces approximately 50 000 tonnes of pulp and paper mill sludge (PMS) per year, all of which is currently landfilled. As the current landfill site is nearing full capacity, this study was developed to assess whether composting could potentially replace landfilling, with use of the resulting material as a mulch in radiata pine *(Pinus radiata)* plantation forestry or as a component in horticultural growing media.

The suitability of PMS (produced by a primary treatment system) as a substrate for composting was assessed. Elemental analyses revealed it to be nutrient poor, indicating that significant quantities of nitrogen, phosphorus and potassium would need to be added to initiate composting. The PMS consisted primarily of cellulose polymorph type I, as in ordinary pulp, with a minor lignin and uronic acid contribution. Since the PMS was highly fibrous and not contaminated with chlorinated organic substances or heavy metals, the material was considered suitable for compost-recycling.

Optimal conditions for composting PMS with mineral nutrient supplements were determined in laboratory scale reactors designed to simulate conditions in a large-scale periodically turned windrow. This study showed that composting proceeded faster under thermophilic conditions (relative to mesophilic conditions), and that pH control (to less than 7.5) was necessary to prevent excessive nitrogen loss through volatilisation of ammonia. This could be achieved by substituting some of the mineral nitrogen requirement (as urea) with a non-alkali forming nitrogen source, such as ammonium sulfate or ammonium nitrate.

A large scale windrow composting trial was undertaken, based on the optimum conditions determined in laboratory scale composting experiments. Performance of the process, assessment of product quality, and economics of composting relative to landfilling were addressed. The effectiveness of periodic turning as an aeration mechanism was assessed by monitoring spatial and temporal changes in the gas phase. The study showed that periodic turning was ineffective in maintaining aerobic conditions in the PMS windrows, suggesting that a reduction in pile height, addition of a bulking agent to improve porosity and/or the installation of open-ended perforated plastic pipes could improve aeration during the static phase. The chemical changes occurring during the composting process, and their relationship to maturity was assessed by solid state carbon-13 nuclear magnetic resonance with cross polarisation and magic angle spinning, and fourier transformed infrared spectroscopy.

The mechanism of aluminium retention in PMS and composted PMS was investigated, as the presence of soluble aluminium may have affected the ability of the material to support plant growth. Results provided by solid state aluminium-27 nuclear magnetic resonance with magic angle spinning and chemical extraction techniques showed that aluminium was bound in a monomeric, octahedrally coordinated, non-exchangeable form to the organic matrix. Since aluminium was strongly retained in both the non-composted and composted PMS forms, the potential of this element to deleteriously affect plant growth in the short term, even under low pH conditions (pH < 5), was considered to be low.

The effect of PMS compost on the growth, nutrition, water relations and weed suppression in a three year old radiata pine plantation for a twelve month period was studied. Compost applied at rates of 20 to 60 t ha^{-1} (dry matter) without incorporation on a relatively infertile podosol soil markedly improved the growth of radiata pine after twelve months, due to the release of soluble nitrogen from the compost and to decreased water stress. The compost, however, had little effect on soil water availability or weed suppression. The application of PMS compost to young radiata pine was found to be an environmentally acceptable method of improving plantation productivity, capable of utilising large quantities of this material.

The germination and growth of various agricultural and horticultural plant species in growing media formulated with PMS compost and perlite without nutrient addition was assessed. Media consisting of between 60 and 90% compost by volume had excellent levels of air-filled porosity and water holding capacity (at container capacity), however, plant growth could be improved by adding a slow nutrient releasing fertiliser (including trace elements), increasing pH and by reducing the calcium to magnesium ratio. Use of PMS compost as a component in horticultural growing media was considered to be a potentially profitable and an environmentally acceptable method of utilising this organic waste.

Declaration

This thesis contains no material which has been accepted for any other degree or diploma in any university, and to the best of my knowledge, contains no copy or paraphrase of material previously published or written by any other person, except where due reference is made in the text of this thesis.

Signed,

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Publications

A proportion of this thesis has been published. The following refereed publications have been included in a pocket on the inside back cover of the thesis.

- Jackson, M.J. and M.A. Line (1997). Organic composition of a pulp and paper mill sludge determined by FTIR, ^{13}C CP MAS NMR, and chemical extraction techniques. *Journal of Agricultural and Food Chemistry* 45(6): 2354-2358.

- Jackson, M.J. and M.A. Line (1997). Composting pulp and paper mill sludge - effect of temperature and nutrient addition method. *Compost Science and Utilization* 5(1): 74-81.

- Jackson, M.J. and M.A. Line (1997). Windrow composting of a pulp and paper mill sludge: process performance and assessment of product quality. *Compost Science and Utilization* 5(3): 6-14.

- Jackson, M.J. and M.A. Line (1998). Assessment of periodic turning as an aeration mechanism for pulp and paper mill sludge composting. *Waste Management and Research* 16(4): 312-319.

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Introduction

Sustainable industrial development and the utilisation of natural resources in an efficient manner has become the preferred method of reducing the rate of degradation of the global environment. Over the last few decades the environmental performance of many industries has improved, mainly through the implementation of more efficient manufacturing cycles and by recovering wastes which are normally disposed of to air, water and soil. Although these improvements have been largely driven by market forces and government legislation, the challenge for industry is to continue to improve its environmental performance whilst maintaining economic viability in an increasingly competitive global market place.

The environmental performance of the pulp and paper industry has long been the subject of community debate. Increasing paper consumption rates have put greater demands on our renewable resources, and as a consequence, the long term sustainability of the industry has been questioned. Paper plays an important role in our lives - in education, communication, packaging and hygiene. Although market based pressures have lead to many improvements in the industry, other economic factors have also come into play in recent times. For example, for the last three to four decades landfilling of sludge recovered from the waste water stream of pulp and paper mills has lead to shortages in landfill space in some regions. Rising tipping costs and difficulties in siting new landfills have encouraged many companies to seek other more cost effective sludge disposal methods.

Australian Newsprint Mills is a company seeking alternatives to the landfill disposal of sludge, as their current landfill is nearing full capacity. For this reason, this study investigated whether the sludge could be converted into a value-added compost, suitable for use in horticultural and agricultural applications. The primary focus of this study was to assess the practical and economic feasibility of compost-recycling pulp and paper mill sludge.

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