Biosolids: black gold in Western Australia

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ABSTRACT

Of the three major wastewater treatment plants in the capital city of Perth, Western Australia, two produce dewatered biosolids cake (DBC) and the third produces lime-amended biosolids (LAB). The total production of both DBC and LAB in the 2004/2005-year was approximately 20,000 tonnes dry solids (t DS) and is increasing at a growth rate of 4% yr^{-1}. The demand for Perth's biosolids as a low-grade fertiliser has outweighed supply and has achieved an average of 94% beneficial use for the past four years. The use of biosolids in Western Australia is strictly regulated by the '*Western Australian Guidelines for Direct Land Application of Biosolids and Biosolids Products 2002*' (DEP *et al*. 2002).

The three major users of biosolids in Western Australia include agriculture, forestry and composting accounting for 74%, 5% and 17% of the total biosolids production, respectively. Within the agricultural sector, the application of DBC commenced in 1996, mostly to wheat and canola crops in a dryland farming system. Local farmers have often referred to the biosolids as 'black gold' due to improvement in their crop yield and income following application. In forestry, biosolids research was commenced in 1998 on a 17 year-old pine plantation on the Swan Coastal Plain. Tree growth has improved significantly following the application of biosolids compared with inorganic fertiliser application, with no detrimental impact on groundwater quality. The composting of biosolids with other materials for domestic use and bagging has been practiced for more than 17 years.

This paper summarises the evolution and current use of biosolids in Western Australia and highlights the main research programs instigated by the Water Corporation to ensure that Perth's biosolids are used beneficially and safely in the environment. Research has concentrated mostly on plant and tree nutrient uptake, particularly nitrogen and phosphorus, heavy metals, composting of biosolids, flies and pathogens. Much of the research data has been collected within the Australian National Biosolids Research Project (NBRP).

KEYWORDS

Dewatered biosolids cake (DBC), lime-amended biosolids (LAB), agriculture, forestry, composting, flies

INTRODUCTION

In Perth during the early 1970s, sewage sludge produced by Wastewater Treatment Plants (WWTPs) was pumped into drying beds and then predominantly used by market gardens for growing vegetables. This practice continued until the late 1980s when associated health risks led to the construction of three incinerators to handle a large proportion of the sludge. By 1990 all three units were shut down due to high costs and odour issues. During this period, the sludge was also used in compost or land filled. A number of problems associated with the sludge drying beds, such as the lack of space, odours, flies and risks to groundwater contamination, resulted in them being progressively decommissioned. As a result, wastewater treatment plants were amplified or in some cases, newly constructed to process sludge.

The most recent wastewater treatments now use established processes that achieve significant pathogen reduction, such as anaerobic or aerobic digestion or thermal drying. Biosolids are defined as the stabilised organic solids produced by wastewater treatment processes, which in most cases can be beneficially recycled (NRMMC 2003). Perth's two major WWTPs, Woodman Point and Beenyup, stabilise their sludge by mesophilic anaerobic digestion. These secondary WWTPs are located along the coast and discharge effluent via outfalls to the ocean. Biosolids are rapidly dewatered by the use of enclosed centrifuges to approximately 20% total solids, and as such are a suitable consistency for transporting. The Subiaco WWTP stabilises raw sludge by the addition of lime, although previously it produced pelletised biosolids by thermal drying using an indirect rotary drum dryer, with pellets used for energy recovery at the plant (Bridle *et al.* 2000).

In total, these three WWTPs treated 280 ML/d of raw wastewater and produced 20,000 t DS of biosolids in 2004/2005, comprising 10,700 t DS DBC and 9,300 t DS LAB. All of the biosolids products meet minimum use criteria of Pathogen Grade P3 and Contaminant Grade C2 or better, as described in the Western Australian Guidelines (DEP *et al*. 2002), making them suitable for direct land application or reprocessing to improve quality. The Water Corporation has been monitoring biosolids quality (contaminant and pathogen) for a number of years with some parameters being reported at levels of less than detection. This has meant a less stringent monitoring program for the parameter listed in the guidelines, which then allows the Corporation to focus on other potential contaminants such as dioxins and alkyl-phenols.

The Water Corporation has achieved 100% beneficial use of DBC for the past four years. The demand for DBC currently out-weighs supply with indications from the current markets that they could handle supply well into the future. The three main outlets include direct land applications to agriculture and forestry plantations (79% of production) and production of an unrestricted product via composting (17% of production). The balance of production (5%) has been used in research. Current research relating to the constraints and beneficial use DBC will be discussed further in the scope of this paper.

RESEARCH PROGRAMS RELATING TO THE BENEFICIAL USE OF BIOSOLIDS

Agriculture

The agricultural region surrounding Perth consists of highly leached and infertile soils, which require regular applications of fertiliser to maintain productivity. In south-western Australia, the majority of rainfall (70%) falls within a seven month growing period over a typically Mediterranean climate. Soils have formed from landscapes that are generally very old by world standards, are low in organic matter and nutrients, complex and highly variable. The most cost effective and beneficial option for DBC for the Water Corporation in Western Australia is through land application in agriculture, with approximately 14,800 t DS being applied to farms in 2004/05. The nitrogen (N) and phosphorus (P) in biosolids is used as a substitute for commercially applied fertiliser.

Western Australia has participated in the Australian National Biosolids Research Project (NBRP) since 2002 (McLaughlin *et al.* 2002). The research is conducted by Curtin University under the leadership of CSIRO Land and Water in Adelaide, South Australia. Other State research units exist in New South Wales, South Australia, Queensland and Victoria. The group's expertise centres on the impact of land applied biosolids on Australian soils and knowledge on how best to reuse these products of wastewater treatment in the context of the various issues raised by this practice http://www.awa.asn.au/Content/NavigationMenu/Information/SpecialInterestGroups/BiosolidsManagement/Biosolids_Management.htm.

Agricultural land application rates of biosolids are commonly applied at rates necessary to satisfy the crop nutrient uptake requirement of N, referred to as the nitrogen limiting biosolids application rate (NLBAR). In Western Australia, the NLBAR has been estimated at 8 t DS/ha for wheat, which is equivalent to 70 kg of plant available N ha^{-1}. Research data concluded that grain yield of wheat grown in biosolids at NLBAR were comparable to yields obtained using farmer rates of commercial inorganic fertiliser. Canola yields, however, were significantly higher ($P<0.05$) in biosolids, substantiating the anecdotal yield increase claims by many farmers. Biosolids applied at NLBAR, resulted in soil concentrations in the surface (0-10 cm) well below the maximum allowable soil contaminant concentration (MACC) of metals such as zinc (Zn), copper (Cu) and cadmium (Cd) in the year of application (Pritchard & Collins 2005). The risk of pathogens transferring to cereal grains is under investigation (Crute *et al.* 2004).

A concern with using the NLBAR to determine land application rates is that the loading rate of P is higher than typically applied through a commercial fertiliser application, i.e. 180 kg P ha^{-1}. Excessive N and P have the potential to contaminate water bodies through runoff and/or leaching and lead to eutrophication of water bodies. Pritchard (2005) examined the impact of high loading rates of P in Western Australia following the application of biosolids at NLBAR in a number of glasshouse, field and laboratory experiments between 1999 and 2003. In the field, in the year of application biosolids were 68% as effective as inorganic P fertilisers as a source of P. In addition, the P in biosolids was of minimal risk of leaching in the current soils used for land application, and lower than for comparable rates of inorganic P fertilisers. Consequently the P limiting biosolids application rate (PLBAR) is under review to ensure crop requirements will be met (Pritchard and Penney 2003).

Forestry

Forestry plantations are a large potential market for biosolids use in Western Australia with 5,500 ha of softwood plantations south of Perth possibly suitable for the application of biosolids. In plantations on the Swan Coastal Plain, the current fertiliser management usually includes the application of inorganic fertilisers of N and P at various stages throughout the rotation. The Department of Conservation and Land Management (DCLM) (now the Forest Products Commission FPC) has been investigating the response of pines to the application of biosolids since 1998, given the increases in tree growth following the application of biosolids in countries elsewhere.

Biosolids (DBC) were applied in 1998 to a 17 year-old *Pinus pinaster* plantation on deep Karrakatta sand in a 920 mm yr^{-1} rainfall area, 120 km south of Perth. The experiment included a control, standard mineral fertiliser (500 kg ha^{-1} di-ammonium phosphate + 250 kg ha^{-1} urea) and two rates of biosolids applied at 17 and 34 t DS ha^{-1}. The experiment investigated the value of biosolids as a fertiliser replacement in plantations; assessed the potential for movement of pathogens, nutrients and heavy metals from the applied biosolids into groundwater beneath the highly permeable coarse sands; and determined operational constraints to the viability of routine biosolids applications.

Compared with the nil fertiliser control, the mineral fertiliser and both biosolids treatments initially increased the tree volume increment by 19%, 27% and 55%, respectively, over three years ($2m^3$ ha^{-1} yr^{-1}, $3m^3$ ha^{-1} yr^{-1}, $6m^3$ ha^{-1} yr^{-1}). The mineral fertiliser treatment produced the largest volume increment in the first year only relative to the control treatment. Relative volume increments in the biosolids treatments increased greatly in the second year and continued to increase in the third year, while the response in the MF treatment was constant and then declined. Biosolids applied at 34 t DS significantly increased foliar concentrations of N, P, zinc (Zn) and manganese (Mn) above all other treatments over three years. Both the mineral fertiliser treatment and biosolids treatment at 17 t DS significantly increased foliar concentrations of N for two years and P for three years above the control treatment (Dumbrell and M^{c}Grath, 2002). Eight years after start of the experiment, the trees in the biosolids treatments have continued to grow at a faster rate than the trees in both the nil and mineral fertiliser treatments, with the longevity of response yet to be determined. See the separate paper by Dumbrell (2006) within the proceedings of this conference.

Surface soil (0-10 cm) samples and groundwater did not detect any indication of pathogens (thermo-tolerant coliforms or salmonella), pesticides, and total N or P from any treatment. Concentrations of heavy metals in the 0-10 cm surface soil were less than the DEP *et al.* (2002) 1% MACC. The mineral fertiliser treatment was the only treatment to significantly ($P<0.05$) increase bicarbonate extractable P in the surface soil after treatment. Concentrations of nitrate in groundwater remained unchanged in samples taken from bores within the plantation. The nitrate was however, increased above acceptable limits for drinking water (ANZECC, 1992) in bore samples taken from beneath the stockpile area outside of the plantation at two sampling dates, eight months apart (Dumbrell and M^{c}Grath, 2003). It is suggested that trees within the plantation are either utilising all available nitrate within the soil profile or completely drying the soil profile so as to prevent recharge and nitrate movement to the groundwater. No attempt had been made to quantify total nutrient uptake by the trees.

The major constraints identified from this study relate to the high cost of transport and application, on site storage provisions, and the time required for stockpiling and application. The minor constraints were related to the social aspects, such as odour and public access, and the required operational condition of the plantation.

Composting

Companies in the Perth metropolitan area further process biosolids and produce products suitable for use in domestic markets. Approximately 2,400 t DS $yr^{-1}$of DBC is transported direct from the WWTP and used in this market. In addition, processing a further 500 t DS @17% total solids is sourced from a temporary biosolids stockpile, which is slowly being depleted. Until recently the percentage of compost being utilised in areas such as horticulture and turf was minimal, however with changes to the availability of raw materials such as chicken litter, this market is also expanding.

There are many methods available for composting and blending material to produce a product that meets the market demands. However, a typical composting process can be divided into three distinct sections: initial blending of raw materials; windrowing to control temperature; and mixing and final blending. During the first stage, biosolids are blended with other products such as sawdust and green waste. The mix is windrowed for approximately 10 to 16 weeks, during which time the rows are turned at least twice a week. Once the biosolids mix has met the unrestricted use requirement (DEP *et al*. 2002), aliquots of the mix are taken and depending on market demand are blended with peat, sand, loams or mulch.

CONSTRAINTS TO BIOSOLIDS PRODUCTION

Vector attraction

Areas along the Swan Coastal Plain have reported excessive fly breeding over the past decade. Although all flies can be described as a nuisance, the one of most concern is the blood sucking *Stomoxys calcitrans* (stable fly). The stable fly, which prefers to breed in organic mediums including manures, has proved a particular menace in the regions of Wanneroo, Kwinana and Gingin (Penney and Dadour 2002). These fly epidemics have the potential to force the closure of the Water Corporations current programs for beneficial reuse of biosolids, typically land applied throughout the agricultural region.

In 2002, the Water Corporation commenced a project to determine the attractiveness and breeding capacity of flies in DBC over a 12-month period at the Nowergup Biosolids Facility, 30 km north of Perth. The project recorded the seasonal variation and response of fly breeding in fresh and aged DBC, identified the chemical and physical components that rendered biosolids attractive as a fly breeding medium by examining the relationship between the moisture level, pH, the ammonia content and specific organic content; and correlated the above information to determine guidelines for covering biosolids stockpiles and/or evaluated the potential for reducing the attractive factors through modification of WWTP operating procedures. The experiment supported previous studies that covering of the stockpiles during fly breeding season was the most effective control method and consequently have been implemented in the guidelines for the storage of biosolids. Alternatively minimising the stockpile time to less than 7 days also reduces fly breeding , however this is not always practical and is dependant on land availability.

Storage facility proposal

The Water Corporation has limited facilities to store DBC at the WWTPs with the current storage capacity of overhead hoppers of 150 to 300 t DS, which on average provide 36 hr holding. Biosolids are transported by truck and trailer to agricultural properties daily, which are unloaded and stockpiled in earthen bunds. Depending on the application area there may be several stockpiles scattered throughout the paddocks. There are a number of problems associated with stockpiling of biosolids, including the potential for nutrient rich leachate to contaminate groundwater and the attractiveness of the biosolids to vectors (flies). To minimise the environmental and public health impacts of stockpiling biosolids and for the continued success of the biosolids land application program, the Corporation has undertaken development of a Biosolids Storage Facility. This will be the first biosolids storage facility of its kind in Australia and possibly the world.

CONCLUSIONS

The positive benefits of biosolids as a fertiliser and a soil amendment have created a demand for a resource, which has often been ‘wasted’. Research initiated by the Water Corporation in conjunction with Curtin University and the Forest Products Commission has targeted both agriculture and forestry as beneficiaries for the majority of DBC, with composting already established as a sound long-term market. Farmers have benefited from crop and soil improvement as a result of biosolids application with much anecdotal evidence and research data available to support this. Tree volume growth in pine plantations has increased significantly following biosolids application. Further research is required to establish the longevity of the increased growth within these coastal plantations. Under typical land application rates, no increases in N and P in ground water were measured on typically leaching coastal sands after three years beneath pine plantations. Laboratory studies showed that the solubility of P to be lower in biosolids amended soils compared with inorganic P fertiliser.

The agricultural land application rates are being fine tuned to ensure biosolids loading rates consider both the nutrient needs of the crop and the environmental risk. Consideration has been given to the unique soil and climatic conditions in Western Australia. Continuing research is being conducted in metal bioavailability and pathogens. The fly breeding program has highlighted solutions to prevent the breeding of flies in biosolids and influenced the design of the Biosolids Storage Facility. Overall, the use of biosolids, or 'black gold' as commonly referred to by farmers, has improved crop yields and increased sustainability within specific land use areas.

REFERENCES

ANZECC 1992. Australian Water Quality Guidelines for Fresh and Marine Waters. Chapter 4 Raw Water for Drinking Water Supply. Australian and New Zealand Environmental and Conservation Council, Canberra, A.C.T.

Bridle, T.R., Molinari, L., Skrypski-Mantle, S., Ye, D.P. and Mills, J. 2000. Start-up of the Subiaco Enersludge™ Plant, *Water Science and Technology,* 41 (8), 31-36.

DEP, WRC and DOH 2002. Western Australian guidelines for direct land application of biosolids and biosolids products, Biosolids Working Group, Department of Environmental Protection (DEP), Waters and Rivers Commission (WRC), Department of Health (DOH), Perth, W.A.

Crute, K., Toze, S., Pritchard, D. and Penney, N. 2004. Proposed research to determine risk from microbial pathogens in grains due to land application of biosolids. *In proceedings: "Biosolids specialty conference II",* Sydney, June 2-4, 2004. Australian Water Association, N.S.W.

Dumbrell, I. 2006. Biosolids produce significant long-term growth increases in Western Australian pine plantations without adverse impacts. *In proceedings: New Zealand Land Treatment Collective's 27th Conference,* March 14-17, Nelson, New Zealand.

Dumbrell, I.C. and McGrath, J.F. 2002. Biosolids produce significant increases in growth and nutrient status in a Western Australian pine plantation without contamination of groundwater. *In proceedings: "Biosolids Specialty Conference"*, Sydney, June 19 – 20, 2002. Australian Water Association, Artarmon, N.S.W.

Dumbrell, I.C. and McGrath, J.F. 2003. Plantation water use prevents contamination of groundwater following application of biosolids. *In proceedings: "Innovations in Water"* Ozwater Convention and Exhibition. Perth, Western Australia, April 6-10 2003. Australian Water Association, Artarmon, NSW.

McGrath, J.F., Crombie, D.S., Dumbrell, I.C. and Mungham, K. (in prep). Comparative water use and water relations of *Pinus radiata* and *Pinus pinaster* in a Mediterranean climate.

McLaughlin, M. J., Stevens, D. P., Barry, G., Bell, M., Whatmuff, M. and Warne, M. 2002. A national research program for beneficial reuse of biosolids and other wastes in agriculture; and scientifically defensible guidelines for metals. *In proceedings: Biosolids Specialty Conference I*, Sydney, Australia, Australian Water Association, Artarmon, N.S.W.

Natural Resource Management Ministerial Council 2003. Draft Guidelines for Sewerage Systems Biosolids Management. National Water Quality Management Strategy.

Penney, N. and Dadour, I. 2002. Biosolids and flies. *In Proceedings: Biosolids Specialty Conference I,* June 19-20, 2002, Sydney, N.S.W, Australian Water Association.

Pritchard, D.L. 2005. Phosphorus bioavailability in land applied biosolids in south-western Australia, PhD Thesis, Muresk Institute, Curtin University of Technology, Western Australia.

Pritchard, D.L. and Collins, D. 2005. 2005 Progress Report to Water Corporation, Western Australian National Biosolids Research Program, Curtin University of Technology, Perth, W.A.

Pritchard, D. L. and Penney, N. 2003. Validation of land application biosolids in W.A. through innovative research. *In proceedings: 'Innovations in Water' Ozwater Convention and Exhibition*, Perth, WA, April 6-10 2003, Australian Water Association, Artarmon, N.S.W.