Fate of nutrients and heavy metal contaminants in biosolids applied to contrasting soils and cropping systems in southeast Queensland

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Abstract

Land application of biosolids is occurring in all mainland states of Australia, with broadacre crops, pastures and trees utilising the high nutrient content of these materials in place of artificial fertiliser. Studies of the nutrient and heavy metal balance in three southeast Qld field sites shows that crop removal of added nutrients and metals is small relative to the addition in biosolids applied at standard agronomic rates. These strongly positive nutrient and metal balances represent significant future risks due to off-site movement (N and P), phytotoxicity (Zn and Cu) or food safety (Cd). Careful agronomic management and soil specific nutrient/metal loading rates hold the key to long term sustainability of biosolids land application programs.

Key Words

Biosolids, nitrogen, phosphorus, heavy metals, nutrient balance

Introduction

There have been many studies on the fertiliser value of biosolids, which are the organic by-product of wastewater treatment (eg. Osborne 1996; Binder *et al*., 2002). Inputs of nitrogen (N) and phosphorus (P) are the most significant benefits, although the response to trace elements like Zinc (Zn) and Copper (Cu) can also be substantial. Accumulation of heavy metals such as cadmium (Cd), Zn and Cu may also be a concern, with unacceptable concentrations of Cd a food safety risk and excessive concentrations of Zn and Cu causing phytotoxic responses in plants and soil biota. This paper reports the results of three field experiments in which nutrient and heavy metal balances were calculated over a 3 year period following biosolids applications in southern Qld.

Methods

Experiments used dewatered cake (dwc) biosolids generated by either anaerobic or aerobic digestion processes in different sewage treatment plants. The nutrient and metal concentrations of biosolids varied between products and applications. Biosolids contained 4.5-7.5% N, 2.2-5.2% P, 380-2380 mg Zn/kg, 240-1040 mg Cu/kg and 1.5-4.8 mg Cd/kg on a dry weight basis. Application rates were based on multiples of the N Limiting Biosolids Application Rate (NLBAR - NSW EPA 1997), with a target N mineralisation of 150-180 kg N/ha during the initial crop season after application.

Biosolids were applied to an acidic Yellow Chromosol soil at Bundaberg (pH_C 4.7), a slightly acidic Red Ferrosol soil at Kingaroy (pH_C 5.4) and an alkaline Black Vertosol at Cecil Plains (pH_C 7.0) during 2002. Crop sequences differed between sites, with successive crops of sugarcane (Plant and 1st ratoon) and peanuts at Bundaberg, millet, maize, peanuts, sorghum and wheat at Kingaroy and sorghum, cotton and wheat at Cecil Plains. Soil samples were collected at least annually, and in the case of mineral N, twice per calendar year. Full analyses were conducted on the top 30cm, while mineral N was measured to 150-200cm. Samples of harvested produce were collected to determine nutrient removal by each treatment. The additional nutrient derived from biosolids in soil or plant material was determined as the difference between the nutrient content in that treatment and that in an Unfertilised Control that was maintained at all sites throughout the studies.

Results and Discussion

There was no evidence of phytotoxic effects of Zn or Cu in biosolids at any site, despite application rates as high as 4.5 NLBAR, or the equivalent of 15-20 years worth of biosolids applications. Similarly, except for the Bundaberg peanut crop, there were no instances where harvested produce in plots receiving biosolids had Cd concentrations exceeding food safety standards (0.1 mg/kg for wheat and peanut). All peanuts at Bundaberg, even the unfertilized control, exceeded the Cd food standard. Biosolids applications had no significant impact on kernel Cd concentration. The main issue with biosolids and heavy metal availability appeared to be acidification and increased metal bioavailability with high biosolids rates where N leaching was significant.

An analysis of the cumulative removal of Zn, Cu and Cd in harvested produce was conducted, with an example of the results for NLBAR applications at Kingaroy shown in Table 1. The net removal of all metals over the 3-4 year study period was extremely low relative to the quantities applied in biosolids, and given that farmers were interested in reapplication after 4 years (due to declining N and P responses), accumulation of metals in the soil profile is a likely outcome. Soil specific metal loading rates, based on metal bioavailability and sensitive ecological endpoints (eg. microbial function and earthworm activity, rather than plant phytotoxicity) are being developed to ensure long term sustainability of land application programs.

Table 1. Cumulative balances for Cd, Cu and Zn added in NLBAR applications of two biosolids after three consecutive grain/grain legume crops at Kingaroy.

Dewatered cake biosolid	Metal added in NLBAR application			Metal removed in harvested produce			Metal load remaining in soil		
	Cd (g/ha)	Cu (kg/ha)	Zn (kg/ha)	Cd (g/ha)	Cu (g/ha)	Zn (g/ha)	Cd (g/ha)	Cu (kg/ha)	Zn (kg/ha)
Anaerobic	62	20.7	25.6	0.12	44.2	333.0	61.9 (99.8%)	20.7 (99.9%)	25.3 (98.8%)
Aerobic	24	5.3	6.6	0.09	39.1	282.0	24.0 (99.6%)	5.3 (99.9%)	6.3 (95.5%)

The situation for N and P was similar to that for the metals, with additional N and P removal in harvested product in the biosolids-amended plots representing a very small fraction of the nutrient added in NLBAR applications of biosolids. Crop removal only accounted for (3-13%) of N and 1-3% of P added in biosolids, with the large residual amounts of N and P a risk for offsite movement (due to leaching or runoff and erosion), or in the case of N, gaseous loss. Despite these apparent large residual amounts of N and P, crop productivity was declining in the NLBAR treatments at all sites by the 3rd or 4th crop after application – due mainly to leaching of N deeper in the soil profile. While the leached N had not yet left the crop root zone at either Kingaroy or Cecil Plains, it was deep enough to prevent vigorous early growth and resulting crop yields were generally less than those in fertilised control treatments (Bell *et al*., 2006). Commercial farms would be considering re-application after 3-4 crops at most sites, resulting in further nutrient and metal loading issues.

Table 2. Cumulative nitrogen and phosphorus removal in harvested product (kg/ha) from experimental sites at Kingaroy, Bundaberg and Cecil Plains. Values are cumulative for 3 (Bundaberg and Cecil Plains) or 4 (Kingaroy) successive crops, with additional removal from biosolids shown as % nutrient added in brackets.

	Nitrogen (kg/ha)			Phosphorus (kg/ha)		
Treatment	Kingaroy	Bundaberg	Cecil Plains	Kingaroy	Bundaberg	Cecil Plains
Unfertilised Control	321	335	223	34.1	51.1	42.6
Anaerobic biosolids	361 (3%)	445 (9%)	314 (8%)	44.5 (2%)	58.7 (1%)	58.2 (3%)
Aerobic biosolids	342 (3%)	430 (12%)	325 (13%)	40.2 (1%)	61.7 (2%)	59.0 (3%)
Lsd (0.05)	***29***	***58***	***81***	***9.2***	***14.7***	***13.6***

Conclusion

Biosolids are a source of nutrients and trace elements that can be utilised in fertility management programs in broadacre cropping systems. However, nutrient and trace elements, as well as heavy metal contaminants like Cd, can impact adversely on long term sustainability if nutrient removal and loading rates are not considered. Removal rates of both nutrients and heavy metals are low relative to current application rates, with careful management required to avoid off site impacts (N and P) or metal accumulation and subsequent issues of phytotoxicity or food safety.

References

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