Effects of biosolids on P sorption and phosphorus buffer capacity

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Abstract

Biosolids from sewerage treatment works represents a potentially valuable source of plant nutrients, particularly P. The application of biosolids to land can add P, change pH and increase the organic matter in the soil, all of which may affect the P sorption capacity. The objectives of the experiments described here were to determine the effects of biosolids application on P sorption capacity for two soils. Soils from farms at Tichborne, and Manildra, were used from biosolids treated and adjacent untreated sites on the same farm. The addition of biosolids reduced the P sorbed at a solution concentration of 0.2 mg P/L in each soil. There was desorption of P at a solution concentration of 0.2 mg P/L in the Tichborne biosolids treated soil and the sorption at a solution concentration of 0.2 mg P/L was lower in the non-treated Tichborne soil than in the non-treated Manildra soil. The PBC, measured as the P sorbed on increasing the P concentration of the equilibrium solution from 0.2 to 0.3 mg P/L, decreased in the Manildra soil and increased slightly in the Tichborne soil. For both soils the isotherms shifted along the x axis indicating that less P was adsorbed at a solution concentration of 0.2 mg/L.

Shifting of the isotherms on adding biosolids seems to be more important than changing their slope (PBC). With future application of biosolids, P sorption should be monitored to ensure that any decreased capacity of the soil to sorb P does not result in groundwater or surface water P pollution.

Key Words

Pollution, residual value, fertilizer

Introduction

Sewage wastewater contains mostly water (99%), human waste and chemicals which have been disposed of down the sewer. This wastewater is treated at a sewage treatment plant (STP) where effluent (liquid) and biosolids (solid) are produced. Once considered waste, sewage sludge or biosolids were disposed of into the ocean, incinerated or put into landfill, which potentially created problems for the environment. An awareness of the potential for health risks, pollution of waterways and contamination of land has resulted in the production of less noxious sewage effluent and biosolids. Biosolids are potential fertilisers or soil conditioners in soils deficient in nutrients and organic matter. Presently, with tighter restrictions being placed on the disposal of biosolids, they are beneficially used in agriculture, land rehabilitation, forestry and composts with only a small percentage going into landfill.

There are several treatments used by STPs to remove the nutrients from the effluent to meet discharge limits. Treatments include the addition of metal salts such as those of iron (Fe), aluminium (Al) and calcium (Ca) to remove P, and biological nutrient removal where microbes in the sewage remove the nutrients such as N and P. Some STPs use both techniques as it has been found to be most effective. Digestion of the sewage may also occur in some STPs under aerobic, anaerobic or anoxic conditions. Aerobic digestion involves the aerating of wastewater and the microbial breakdown of organic matter in biosolids into carbon dioxide and water. At this stage oxidation of chemicals applied to the wastewater for removal of P may occur, such as the oxidation of Fe(II) to Fe(III), which improves the capacity to remove P. Nitrification also occurs in the wastewater. This is followed by the anoxic process in which denitrification occurs so that N originally present in the wastewater is lost as N_2 gas. During the anoxic process sedimentation of solids also occurs. Anaerobic micro-organisms decompose the organic matter in the sewage biosolids into methane gas and carbon dioxide. As a result of the addition of chemicals to improve the quality of the effluent for discharge, high concentrations of Fe, Al and P may occur in the biosolids.

Sorption reactions in the soil are affected by pH. In high pH soils P sorption occurs on Fe and Al hydrous oxides, clay minerals, Ca and Mg carbonates and phosphates and Ca organic matter complexes but in low pH soils P sorption occurs on Fe and Al hydrous oxides, clay minerals, Fe and Al phosphates and Al organic matter complexes (Holford 1989). Organic matter, in the form of organic compounds (eg. humic acid), may compete with the P for P sorption sites, which may lower phosphate sorption and increase P availability in the soil (Iyamuremye and Dick 1996).

The application of biosolids to land can change both the pH of the soil and increase the organic matter in the soil, both of which may affect the P sorption capacity of the soil. The main objectives of the experiments described here were to determine the effects of biosolids application on P sorption capacity for a range of soils and to determine the residual effects of biosolids application on the P characteristics of soils.

Materials and Methods

The soil samples were provided by NSW Agriculture and were taken from the top 15 cm of the soil profile in February 1999. There were no replicate samples so statistical analysis of the results was not possible.
Soils from farms at Tichborne, and Manildra, were collected from biosolids treated and adjacent untreated sites on the same farm. The history of the biosolids application and the type of the biosolids are presented in Table 1. The treated soils received one application of lime amended biosolids (biosolids that have been treated with lime) and dewatered biosolids applied together.

Table 1. History of biosolids application to the soils.

Location	Biosolids application
Tichborne	August 1997: Lime amended biosolids (10 dry t/ha) and aerobically and anaerobically digested biosolids (10 dry t/ha).
Manildra	September 1995: Lime amended biosolids (6 dry t/ha) and aerobically digested, dewatered biosolids (10 dry t/ha).

Soil analyses

Phosphorus sorption isotherms were measured on the soils using Rayment and Higginson's (1992) method. Known concentrations of KH_2PO_4 solutions in a background of 0.01M $CaCl_2$ were equilibrated with the soil. The concentrations of the equilibrating solutions were chosen so that 50 mL aliquots of solution P added to the soil were at rates of 0, 5, 10, 15, 20 and 25 mg P/kg soil. 50mL of equilibrating solution was added to approximately 5 g air-dried soil (<2mm) in 100mL extraction bottles. The bottles were shaken end-over-end for 17 hours at 25 °C. The solutions were then filtered through Whatman 42 filter papers and P determined colorimetrically with a Shimadzu UV-120-01 spectrometer using the Murphy and Riley (1962) method. Isotherms were used to determine the amount of P that was sorbed at a solution concentration of 0.2 mg P/L, which is assumed adequate for the growth of a range of crops (Beckwith 1965).
The phosphorus buffering capacity (PBC) was calculated by:
PBC (mg P/kg) = P sorbed at 0.3 mg P/L (mg P/kg soil) – P sorbed at 0.2 mg P/L (mg P/kg soil).

Results

The addition of biosolids reduced the P sorbed at a solution concentration of 0.2 mg P/L in each soil (Table 2). There was desorption of P at a solution concentration of 0.2 mg P/L in the Tichborne biosolids treated soil and the sorption at a solution concentration of 0.2 mg P/L was lower in the non-treated Tichborne soil than in the non-treated Manildra soil (Table 2).
The PBC, measured as the P sorbed on increasing the P concentration of the equilibrium solution from 0.2 to 0.3 mg P/L, decreased in the Manildra soil and increased slightly in the Tichborne soil (Table 2). In both soils the isotherms have shifted along the x axis indicating that less P is adsorbed at a solution concentration of 0.2 mg/L (Figure 1).

Table 2. Soil pH, P sorption at a soil solution concentration of 0.2mg P/L and phosphorus buffer capacity for soils with and without biosolids.

Location	pH $CaCl_2$		P Sorption (mg P sorbed/kg soil at solution concentration of 0.2 mg P/L)			Phosphorus buffering capacity (mg P sorbed/kg/0.1 mg/L)	
	Minus biosolids	Plus biosolids	Minus biosolids	Plus biosolids	% Change in Sorption	Minus biosolids	Plus biosolids
Tichborne	5.4	5.9	5.9	-0.2	-103	3.7	5.4
Manildra	5.0	5.6	63.0	6.5	-90	32.7	8.1

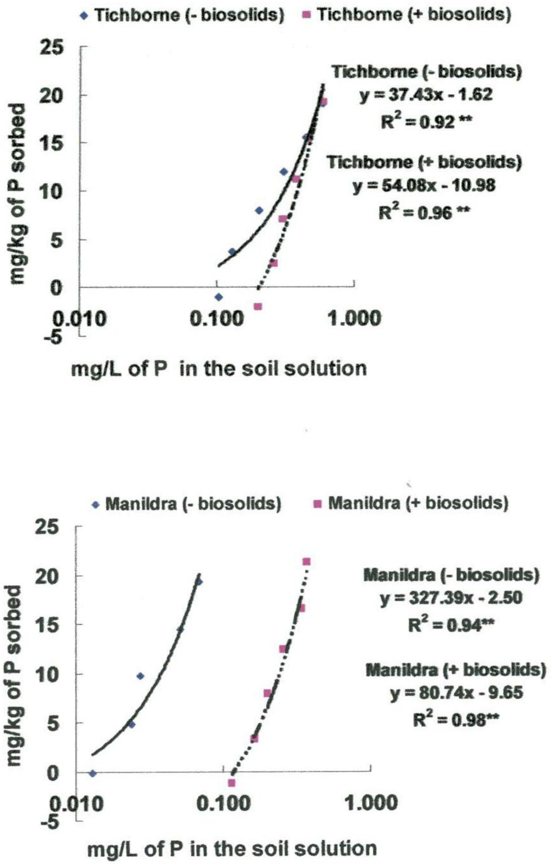

Figure 1. Effect of biosolids addition on P sorption isotherms in soils from Tichborne and Manildra.

Discussion

The changes in P sorption capacity of soils up to 6 years after biosolids application indicate the considerable residual benefits of applying biosolids to these soils. In all soils analysed there was a decrease in the P sorbed by the soil following the application of lime amended and dewatered biosolids, although the extent of the decrease varied. The results are in agreement with those of Barrow (1974) who reported that previous additions of P on phosphate adsorption of soils displaced isotherms to the right, reduced the slope of the isotherms (PBC) and P adsorption of the soil.

In a previous study (Davis, unpublished) there was an increase in bicarbonate P following addition of biosolids. At an application rate of 7.5 dry t/ha, 50% of the bicarbonate P was derived from biosolids and at 60 dry t/ha this increased to approximately 90%. The reduced P sorption following the addition of biosolids could be due to P derived from the biosolids occupying sorption sites or to organic matter blocking P sorption sites. The most noticeable feature of the paired isotherms (Figure 1) is the shift to the right along the x-axis when biosolids were added to the soil, rather than a large change in the slope of the isotherms. This indicates that P is being sorbed from the added biosolids to a much greater degree than a decrease in sorbing sites which would change the slope of the isotherms. ∅gaard (1996) reported that the application of animal manure resulted in a reduction in P adsorption, and that desorption occurred in soils with high available P. The soils in the present study were all deficient in P prior to biosolids application, but in some instances desorption still occurred. The adsorption of P from biosolids would shift the equilibrium between P in solution and P sorbed to the extent that desorption occurred when determining the isotherms.
The reduction in the soils capacity to adsorb P could limit further biosolids application as saturation of P sorption sites could lead to P being leached or removed by surface runoff. This hazard is unlikely to eventuate with the application practices currently used in NSW.

Conclusions

There is a residual P effect from biosolids application affecting P sorption. The application of biosolids decreased the sorption of P and shifts the P sorption isotherm thereby decreasing the P sorption of the soil at a particular concentration. Shifting of the isotherms on adding biosolids seems to be more important than changing their slope (PBC). With future application of biosolids, P sorption should be monitored to ensure that any decreased capacity of the soil to sorb P does not result in groundwater or surface water P pollution.

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