Evaluation of rapid buffer methods to estimate pH buffer capacity of highly weathered soils from south west of Western Australia

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Abstract

Information on the pH buffer capacity (pHBC) of a soil is important in the management of soil acidification and in soil monitoring. The pHBC of a soil is a key determinant of its lime requirement and of its time left to critical pH when production loss is likely. It enables the difficult to measure net acid addition rates to be determined from changes in soil pH over time or in spatially different treatments. In spite of its importance, there is an acute lack of pHBC data for soils in Australia and elsewhere. The problem is the length of time (normally >1 week) required for direct measurement of pHBC by standard incubation or titration methods and the consequence of slow measurement procedures on availability of this soil test in commercial laboratories and on cost.

Measurement of pH of highly weathered soils from the south west of Western Australia after 1 h equilibration in Mehlich, Adams and Evans and Woodruff buffers allowed us to calculate for each buffer, the soil pHBC from the change in buffer pH and the buffering capacity of the buffer solution (giving us the amount of acidity neutralised from the acid soils) and from the change in soil pH (allowing us to calculate the amount of acidity neutralised per unit soil pH change and per unit mass). Comparison buffer-based measurements of pHBC with direct measurement by standard titration method showed that all three buffers could be used to lower the time to estimate PHBC from a week to an hour. These buffer methods are therefore more easily adoptable by commercial laboratories and for routine work. The simplicity of these methods means that they could be used in the field simply with a pH meter and pH buffer solutions to determine soil pHBC. In addition, strong correlations of pHBC measured by titration and buffer methods with soil organic carbon content open the way to estimate pHBC by pedotransfer. The buffer and pedotransfer approaches to estimating pHBC should alleviate current scarcity of this important data on soils in Australia and elsewhere.

Key Words

Adams and Evans, buffer, Mehlich, organic, pHBC, pedotransfer function, titration, Woodruff

Introduction

Information on the pH buffer capacity (pHBC) of a soil is important in the management of soil acidification and in soil monitoring. The pHBC of a soil is its ability to resist pH change on addition of acidity or alkalinity. Its value determines both the amount of lime required to raise the pH of a soil layer from its initial acid condition to a near optimal pH for plant growth (lime requirement) and the time to critical pH. This is the time available under current net acid addition rate (NAAR) until the soil layer acidifies to a critical pH defined as the pH value when production losses are likely. These losses can be severe depending on crop, soil and seasonal conditions (Wong and Asseng 2007). In other scenarios, accurate values of pHBC can also be used to estimate NAAR from observed changes in soil pH over time or over spatially different treatments (Wong *et al.* 2004). This time to critical pH helps forward planning and to prioritise resource allocation and management interventions needed to address the urgency of the soil acidification problem. In spite its importance, very few pHBC measurements are available for soils in Australia and elsewhere.

The lack of data is so acute that it is currently not possible to make reliable indirect estimates of pHBC across Australia from its correlation with other more readily available surrogate soil properties such as clay and organic matter contents. Ability to develop and test this pedotransfer function approach with sufficient data is important to enable us to use existing national soil data to estimate pHBC. It is also important to allow use of in-field soil data for high spatial resolution estimates of pHBC used in precision agriculture to manage localised soil acidity (Wong *et al.* 2008). This localised soil acidity occurs due to soil textural differences and localised acidification processes such as nitrate leaching and crop removal of ash alkalinity (Wong *et al.* 2006) across the field resulting in a preference for site specific management.
Moist incubation of soil with incremental additions of calcium carbonate is a reliable method to measure pHBC but this method takes two or more weeks to complete. The quicker titration method uses suspension

and agitation of the soil slurry to increase the rate of reaction between soil and acid/alkali. The results of this measurement are often not significantly different from those of incubation. Titration is therefore also considered a reliable way of determining pHBC (Aitken and Moody 1994; Aitken *et al.* 1990). It is completed in about a week (Aitken *et al.* 1990), which is still too slow for routine soil testing. Our aim is to address this scarcity of data by (1) assessing rapid buffer methods of measuring pHBC that could be adopted for routing soil testing and (2) assessing the correlation between pHBC and more readily available soil organic carbon content so that pHBC can also be estimated indirectly by the pedotransfer function approach.

Methods

Sixty nine acid topsoil samples with depth down to a maximum of 15 cm were collected mainly across cropping and some pasture areas south-west of Western Australia. These soil samples were chosen to cover a wide range of organic matter contents and hence a likely broad range of pHBC values. Soil organic matter content was measured by Walkley and Black wet oxidation method and pH was measured in 1:5 soil to 10 mM $CaCl_2$ suspension.

Soil pH was also measured in the supernatant of 10 g soil shaken and equilibrated for 1 h as 1:2 suspensions with the following buffer solutions (1) Mehlich buffer (Mehlich 1976) (2) 1:2 Woodruff buffer (Brown and Cisco 1984) (3) Adams and Evans buffer (Adams and Evans 1962). Soil pHBC was calculated for each buffer solution from the change in buffer pH, the buffer capacity of the buffer solution (thus giving the amount of acidity consumed from the soil) and change in soil pH (thus enabling us to calculate amount of acidity released to buffer solution per unit pH change and unit mass of soil which is in effect the pHBC of the soil sample). These buffer-derived values of pHBC were compared with direct measurement by titration. Titration was carried out using 8 g soil suspended in a ratio of 1:5 in 2 mM $CaCl_2$ and with toluene (not chloroform which reacts with NaOH) added to suppress microbial growth. Incremental amounts of either HCl and/or NaOH were added and equilibrated with occasional shaking over a period of 7 days at room temperature before measuring final pH (Aitken and Moody 1994).

Results

The soil organic carbon content ranged from 0.47 to 10.0% and pH in 10 mM $CaCl_2$ ranged from 3.9 to 5.5. Values of pHBC measured by what is regarded to be the standard titration method by which other methods are compared ranged from 0.48 in soils low in organic matter to 6.60 $cmol_c$ $(kg\ pH)^{-1}$ in soils with larger organic matter content. PHBC measured by all three buffer methods was strongly correlated with measurement by titration (Figure 1). The Mehlich buffer gave the tightest correlation and largest correlation coefficient with $r^2 = 0.87$. PHBC measured by direct titration and indirect buffer methods was strongly correlated with soil organic matter content (Figure 2). The tightest correlation was again obtained with Mehlich buffer which returned an r^2-value of 0.89. This provides a simple pedotransfer function to estimate pHBC from nationally available data for cropping and pasture areas of south west of Western Australia and for farms and fields in this region.

Conclusions

There is an acute lack of pHBC data in Australia and elsewhere due to the length of time required for its direct measurement by incubation or titration and the consequence of slow measurement procedures on cost. This work shows that buffer methods can be used lower measurement time from a week to an hour. These methods are therefore more easily adoptable by commercial laboratories and for routine work. The simplicity of these buffer methods means that they could be used in the field simply with a pH meter and pH buffer solutions to determine soil pHBC. In addition, soil organic carbon content can be used to estimate pHBC through the pedotransfer function approach. These two ways of estimating pHBC should alleviate current scarcity of this important data on soils in Australia and elsewhere.

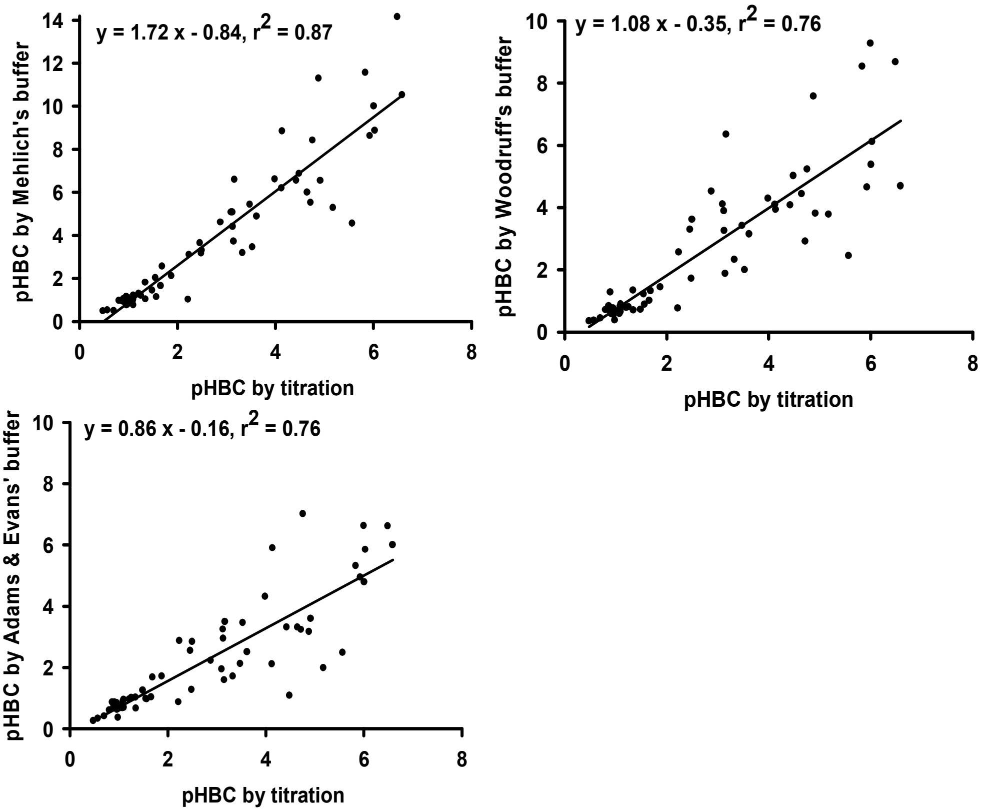

Figure 1. Regressions of pHBC measured by Mehlich buffer (Mehlich 1976), Woodruff buffer (Brown and Cisco 1984) and Adams and Evans buffer (Adams and Evans 1962) methods on pHBC measured by titration. All pHBC values are expressed as cmol$_c$ (kg pH)$^{-1}$.

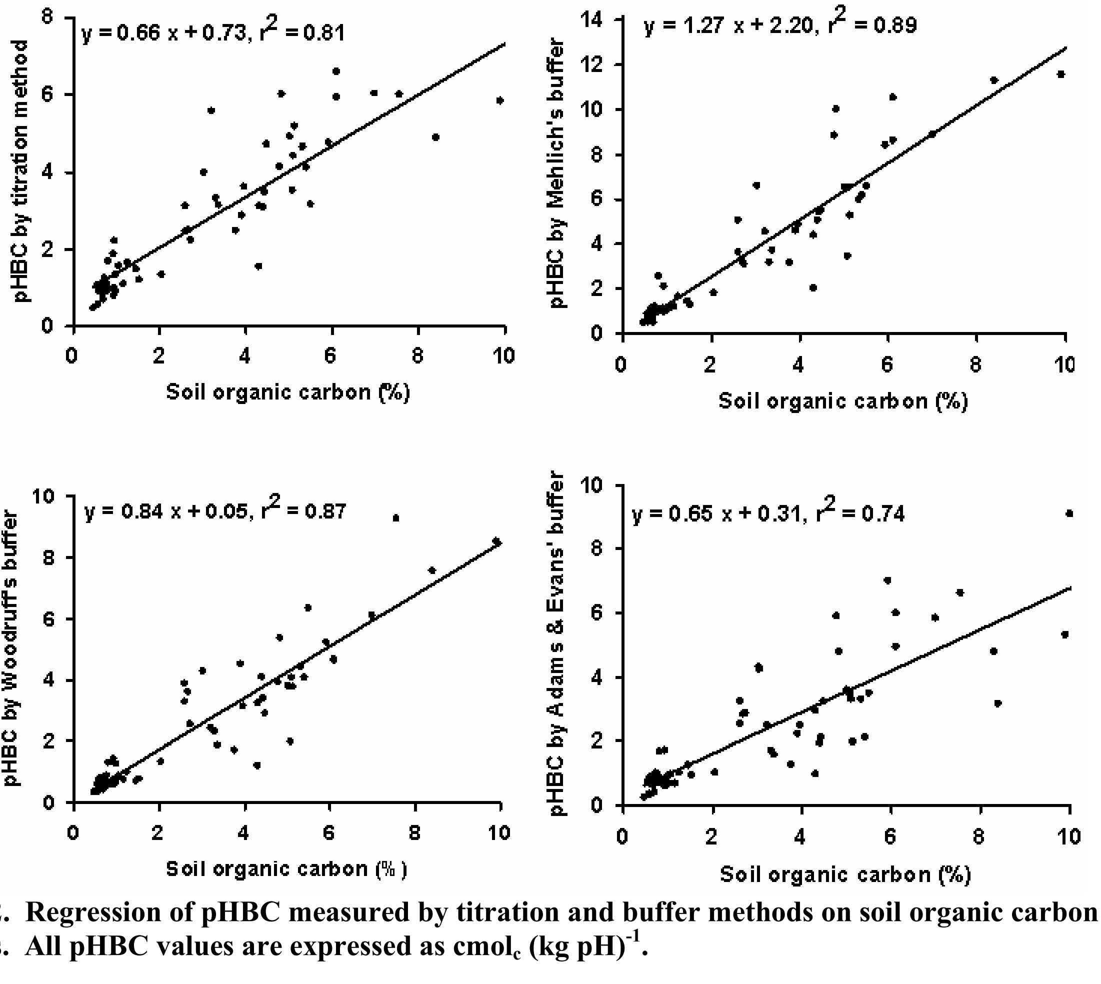

Figure 2. Regression of pHBC measured by titration and buffer methods on soil organic carbon contents. All pHBC values are expressed as cmol$_c$ (kg pH)$^{-1}$.

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