# The effect of P fertiliser application strategy and soil P sorption properties on 'incidental' P fertiliser characteristics using laboratory techniques and long term Bayesian risk modelling

**Warwick Dougherty**[A], Lucy Burkitt[B], Ross Corkrey[C] and Deirdre Harvey[D]

[A]Science and Innovation, Industry and Investment, Richmond NSW Australia, Email warwick.dougherty@industry.nsw.gov.au
[B]Tasmanian Institute of Agricultural Research, University of Tasmania, TAS, Australia, Email Lucy.Burkitt@utas.edu.au
[C]Tasmanian Institute of Agricultural Research, University of Tasmania, TAS, Australia, Email stephen.corkrey@utas.edu.au
[D]Science and Innovation, Industry and Investment, Richmond NSW Australia, Email deirdre.harvey @industry.nsw.gov.au

## Abstract

The occurrence of rainfall and runoff soon after phosphorus (P) fertiliser application (fertiliser 'incidental' effect) can increase P exports. In this paper we firstly use a laboratory study to examine the effect of soil properties on the duration of the incidental fertiliser effect. Secondly we examine the effect of P fertiliser strategy – single v split applications – on long-term runoff P risk using laboratory and catchment runoff data in a Bayesian risk model. We found that soil P buffering characteristics have a large effect on the duration of incidental fertiliser effect. Despite the disproportionately large effect of a single application on runoff P concentration compared to split applications, the increased likelihood of runoff and fertiliser application coinciding when fertiliser applications were split, mean that the overall risk of runoff P loss is increased with split fertiliser applications. Farmers should therefore apply P fertiliser in a single annual application and apply this when risk of runoff is low, the importance of this strategy being greatest for farmers on soils with moderate to low P buffering.

## Key Words

Phosphorus, incidental, risk, Bayesian, runoff, fertiliser**.**

## Introduction

The export of phosphorus (P) in surface runoff from intensively managed pasture is often greater than is desirable and can contribute to eutrophication of waterways. The concentration of P in runoff is a function of systematic and incidental factors. The systematic components include unavoidable factors (e.g. optimal soil P status and grazing activity) and avoidable factors (e.g. soil P in excess of plant requirements). The incidental components – also referred to as avoidable (Hart *et al*. 2004) - include the effect that fertiliser and dung application have when they are followed shortly by runoff.

The occurrence of runoff in the days following fertiliser application can result in increases in runoff P concentrations of 10-100 mg/L (Bush and Austin 2001; Hart *et al*. 2004; Nash *et al*. 2005). Although the 'incidental' fertiliser effect only lasts for a short period - typically less than 30 days (Hart *et al*. 2004) and its contribution to P loss relies on the coincidence of this effect and runoff, the high concentrations of P in runoff, should this occur, means that it has the potential to make a major contribution to P export.

As a result of increasing basal soil P status under dairy pastures, there is a trend of increasing use of split fertiliser applications, i.e. applying the annual P fertiliser application in several smaller amounts equal to the equivalent total. This may reduce the incidental runoff P concentrations should they occur, but the risk of coincidence of runoff and fertiliser application may also increase.

In this paper, we report results from laboratory investigations examining the effect of soil P properties on the duration of the incidental fertiliser effect and the effect of single vs split fertiliser applications using a combination of laboratory and Bayesian runoff risk modelling.

## Methods

Soils under pasture were collected from six sites located at a range of locations in New South Wales and Tasmania to a depth of 0-2 cm. They were selected to provide a wide range of P buffering indices (PBI) (Burkitt *et al*. 2008) ranging from extremely low (Richmond) to extremely high (Avoca) (Table 1). The soil samples were then dried at 40°C under forced draft before being sieved to <2mm to remove plant and particulate debris.

*The effect of soil P buffering on incidental fertiliser effects*

We firstly examined the effect of soil P buffering on the changes in extractable P following fertiliser addition (40 kg P/ha) using the six soils described in Table 1. The soils were packed in to 40 mm internal diameter tubes to a bulk density of 1.0 g/cm$^3$, with moisture adjusted to 0.3 bars and fertiliser granules added. $CaCl_2$-P was determined by shaking the soil in the tubes at a 1:5 soil:solution ratio with 0.01M $CaCl_2$, centrifuging (1300 g), filtering (<0.45 µm) and determining molybdate reactive P using colorimetry (Murphy and Riley 1962). Fertiliser half-lives were determined and the relationship with soil PBI examined. The use of $CaCl_2$-P as a surrogate for runoff P concentrations is based on a highly significant linear relationship between $CaCl_2$-P and runoff P we previously found on a range of Australian soils (unpublished).

**Table 1. Selected soil properties**

| Soil | Australian classification (Isbell 1997) | pH ($CaCl_2$) | Total P | Colwell P | PBI |
|---|---|---|---|---|---|
| | | | mg/kg | | |
| Avoca (NSW) | Ferrosol | 4.9 | 670 | 12 | 730 |
| Elliott (Tas) | Ferrosol | 5.1 | 1200 | 51 | 550 |
| Camden (NSW) | Brown Chromosol | 5.2 | 640 | 52 | 95 |
| Mt Hicks (Tas) | Brown Dermosol | 4.7 | 750 | 76 | 200 |
| Richmond (NSW) | Dermosol | 5.4 | 210 | 31 | 26 |
| Togari (Tas) | Hydrosol | 5.1 | 760 | 150 | 110 |

*Incidental fertiliser risk under two fertiliser application strategies*

We then compared the cumulative risk of two fertiliser application strategies, namely a single application of fertiliser (40 kg P/ha) or split applications (3×13.3 kg P/ha) to achieve the same total P application on one of the six soils. In order to compare these risks, $CaCl_2$-P (as per previously described methods) was determined under the two fertiliser strategies and a control (0 kg P/ha). The two fertiliser strategies were triple superphosphate applied as either one application of 40 kg P/ha at T0, or three applications of 13.3 kg P/ha at 25 day intervals (T0, T25, T50). These treatments were applied to the Togari soil and soil moisture was controlled as described previously. The extractions were undertaken at day 0, 1, 3, 6, 12, 25, 26, 28, 31, 37, 50, 51, 53, 56, 62, 75 and 127, with four replicates per treatment.

In order to consider the potential impact of these two fertiliser strategies on P loss in a temporally variable runoff context, we used a Bayesian modelling approach that combined the area under the $CaCl_2$-P curve and long term runoff data. The long term modelled surface runoff data (1961-2008) was from two catchments in Tasmania. Two catchments were selected to represent contrasting rainfall/runoff patterns which commonly support dairying in Australia. Average annual rainfall for the Montagu catchment (far north west Tasmania) is 1125 mm and the rainfall pattern is highly winter dominant. In contrast, the Ansons Bay catchment (north east Tasmania) receives an average annual rainfall of 786 mm and although rainfall in this catchment is higher in winter, rainfall and surface runoff patterns are more erratic and less winter dominant than the Montagu catchment.

## Results

*The effect of soil properties on incidental fertiliser effects*

For all soils, there was a rapid decrease in $CaCl_2$-P with time since fertiliser application. The exponential decay relationship between PBI and half life was highly significant ($P < 0.001$) and is shown in Figure 1. This study is the first to our knowledge that shows this affect of PBI on half life. The effect of PBI is particularly pronounced in the <150 PBI range, typical of a large number of dairy farms in Australia. These findings may explain the wide range of half lives reported by Hart *et al.* (2004). The data suggest that on soils with high P buffering capacities, incidental fertiliser effects are likely to be generally unimportant.

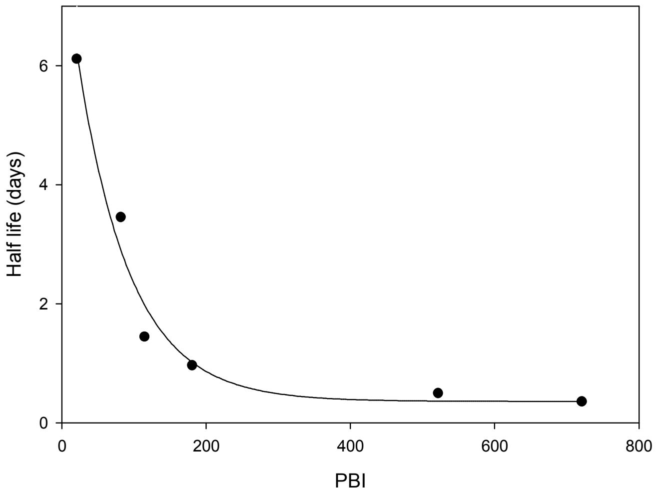

**Figure 1. The relationship between soil phosphorus buffering index and fertiliser half lives.**

*Incidental fertiliser risk under two fertiliser application strategies*

The $CaCl_2$ extractable P concentrations for the control, single and split P applications are shown in Figure 2. The addition of P fertiliser increased the extractable P concentration. The addition of 40 kg P/ha resulted in a disproportionately large increase in extractable P concentration compared to the first application of 13 kg P/ha immediately after P fertiliser application. The first application of 13 kg P/ha increased extractable P concentration from ~5 to 25 mg/kg (~5 fold increase), whereas the addition of 40 kg P/ha increased extractable P concentration from ~5 to 205 mg/kg (~41 fold increase). For each of the three split P additions, $CaCl_2$¬P measured immediately after each successive addition (T0, T25 and T50) significantly increased ($P < 0\ 05$; LSD = 7) with each subsequent addition (25, 56 and 75 mg/kg respectively). This increase in $CaCl_2$-P with repeated applications is consistent with a declining P sorption capacity with each additional P addition (Barrow *et al.* 1998).

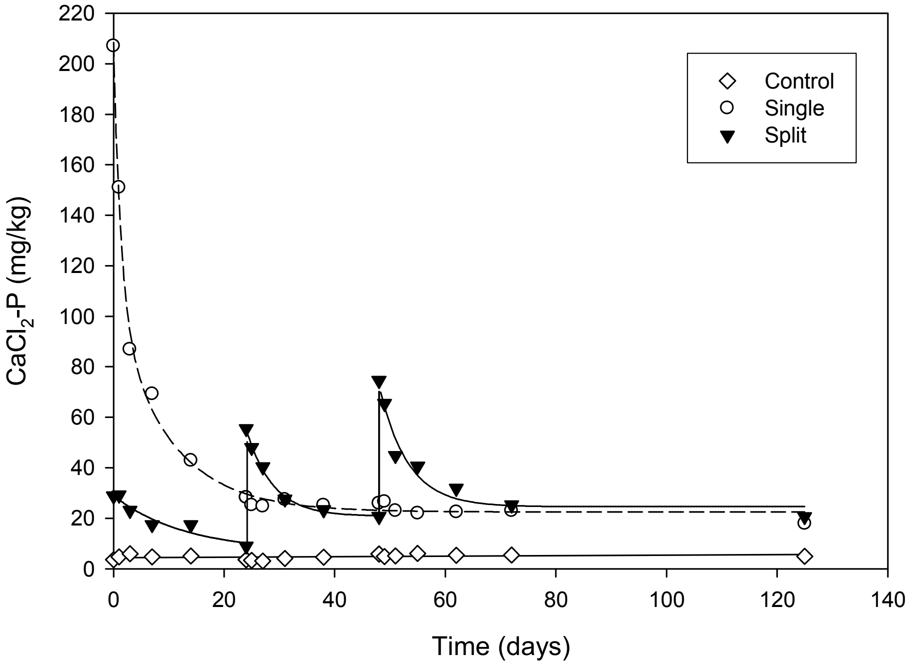

**Figure 2. The change in $CaCl_2$ P with cumulative number of days for the control (◊), single application of 40 kg P/ha (○) and 3 split applications of 13.3 kg P/ha (▼). Values presented are a mean of six replicates. Phosphorus fertiliser was added at T0 (single and 1st split treatments) and T25 and T50 (2nd and 3rd split treatments).**

Our Bayesian risk model revealed that 3 applications of 13.3 kg P/ha resulted in a greater risk compared to a single application of 40 kg P/ha and was significant in both catchments (posterior probability $P > 0.95$).

From a nutrient management perspective, single, annual applications of P fertiliser are likely to result in lower P runoff losses, especially if P fertiliser application can be applied when the chances of surface runoff are less likely (i.e. early autumn or late summer). This could represent a practical P management option considering that Burkitt *et al.* (unpublished) concluded that the timing or number of split applications of P fertiliser had no effect on pasture production when soil extractable P concentrations were already apparently adequate based on published agronomic soil test P values.

## Conclusion

This study, has for the first time, demonstrated that the duration and hence importance of the fertiliser incidental effect is a function of soil P buffering properties. These findings will have important implications for the identification of soils at highest risk of P runoff and have demonstrated that particular attention needs to be paid to timing of fertiliser application on soils with low PBI. The strategy of splitting fertiliser applications increases the overall risk of runoff P loss and should be avoided in favour of single applications at low runoff risk times of the year.

## References

Barrow NJ, Bolland MDA, Allen DG (1998) Effect of previous additions of superphosphate on sorption of phosphate. *Australian Journal of Soil Research* **36,** 359-372.

Burkitt LL, Sale PWG, Gourley CJP (2008) Soil phosphorus buffering measures should not be adjusted for current phosphorus fertility *Australian Journal of Soil Research* **46,** 676-685.

Bush BJ, Austin NR (2001) Timing of Phosphorus Fertilizer Application within an Irrigation Cycle for Perennial Pasture. *Journal of Environmental Quality* **30,** 939-946.

Hart MR, Quin BF, Nguyen ML (2004) Phosphorus runoff from agricultural land and direct fertilizer effects: A review. *Journal of Environmental Quality* **33,** 1954-1972.

Isbell RF (1997) *The Australian Soil Classification,* CSIRO Publishing, Melbourne, Victoria.

Murphy J, Riley JP (1962) A modified single solution method for the determination of phosphate in natural waters. *Analytica Chimica Acta* **27,** 31-36.

Nash D, Clemow L, Hannah M, Barlow K, Gangaiya P (2005) Modelling phosphorus exports from rain-fed and irrigated pastures in southern Australia. *Australian Journal of Soil Research* **43,** 1-11.