3.3 Phosphorus

For general management guidelines pertinent to all nutrients, see chapter 3.1 'Nutrient budgeting'. Most issues pertinent to P are dealt with in that chapter, but some additional issues specific to P are dealt with here.

As P is essential for rapid pasture and crop growth and is not naturally abundant in Australian soils (Moody and Bollard 1999, Price 2006), the significant amounts found within dairy effluent can be used to supply pasture and crop P requirements (McDonald *et al.* 2005, Wang *et al.* 2004), thus reducing fertiliser inputs and bringing substantial savings (Skerman *et al.* 2006).

Although P is relatively immobile in soils, it can be lost in surface runoff or by leaching, particularly in association with rainfall or irrigation (McCaskill *et al.* 2003). The P collected through a dairy effluent management system therefore needs to be managed prudently.

Phosphorus in dairy effluent

Phosphorus collection

Minimal P is lost throughout collection and conveyance of dairy effluent, and it can be assumed that all P collected will be available for reuse, providing that solids from separation, sludge from effluent ponds and liquid effluent are all considered. The quantity of P within dairy effluent will vary with location and feed type, and particularly with dietary P forms and levels (Ebeling *et al.* 2003). The amount of P entering an effluent storage pond depends on the amount of solids separated from the effluent stream and varies considerably. See chapters 2.3 'Anaerobic, aerobic and facultative ponds' and 2.8 'Desludging and pond closure' for typical P concentrations in dairy effluent and sludge. Although these chapters can provide a guide, it is more accurate to analyse the dairy effluent in each individual case (Waters 1999).

Phosphorus uptake by plants

P in dairy effluent is excreted in both organic and inorganic forms. Organic P (unavailable to plants) becomes inorganic (available) through mineralisation. This process varies with both time frame and output (Moody and Bollard 1999). The removal of P from soils is almost entirely due to plant uptake and harvest, which depends on nutrient availability and soil pH. Sites with a long-term history of dairy effluent application, in particular solids application, typically have adequate soil P levels. Intensive hay production can significantly reduce available P levels in soil. However, the interactions between available P and the total soil P pool is complex, and is discussed in more detail below.

Phosphorus losses

P is readily fixed to soils, especially clayey soils, and is far less mobile within soils than other nutrients, moving very little from initial placement (Price 2006). The likelihood of leaching is highest in coarse, sandy, well drained soils, but leaching can also occur where loadings are excessive or through bypass flow mechanisms (Redding 2001). Excess P may be retained by soil and only slowly released through diffuse surface runoff processes, or alternatively lost in significant amounts during episodic erosion events (Gourley *et al.* 2007b, Nash and Murdoch 1997). The quantity of P required to reduce water quality is very small, especially in comparison to N, so the movement of very small quantities of P off site can have adverse environmental impacts (Nash and

Murdoch 1997, Redding 2001). When effluent is applied to paddocks, surface runoff is the most likely method of P loss in both soluble and particulate forms, typically in association with rainfall or irrigation (Drewry *et al.* 2006, Holz 2007, McCaskill *et al.* 2003, Nash and Murdoch 1997, Redding 2001). Higher concentrations of P in surface runoff are associated with sites with a greater use of P fertiliser or effluent application, especially where soil incorporation does not occur (Fleming and Cox 2001, McCaskill *et al.* 2003). Fleming and Cox (2001) found that 98% of P loss over a 3-year period was due to overland flow. To help minimise the risks of P loss in surface runoff, careful monitoring of soil and effluent P levels is required, along with responsive management. In addition, surface runoff should flow into drainage lines and recycling ponds so that no contaminated runoff leaves the farm (Drewry *et al.* 2006, Nash and Murdoch 1997). The risk of P loss from effluent application areas can be assessed through use of the Farm Nutrient Loss Index (FNLI) (Gourley *et al.* 2007a)—see chapter 3.1 'Nutrient budgeting'.

Phosphorus management

Phosphorus in soils

Most Australian soils are naturally low in P, so pastures and crops require P applications for optimum production (Moody and Bollard 1999). Although much of the P pool remains unavailable as fixed or adsorbed P (Figure 1), P can become available in the soil solution from plant and microbial processes (Barrow and Shaw 1975, Moody and Bollard 1999). Most P is taken up in the upper few mm of the soil profile, and the availability for uptake varies with the soil P buffering index (PBI), soil texture, temperature, time, pH, rainfall, plant species, management, microbial populations and mineralisation rates (Barrow and Shaw 1975, Burkitt *et al.* 2002, Gourley *et al.* 2007a, Moody and Bollard 1999).

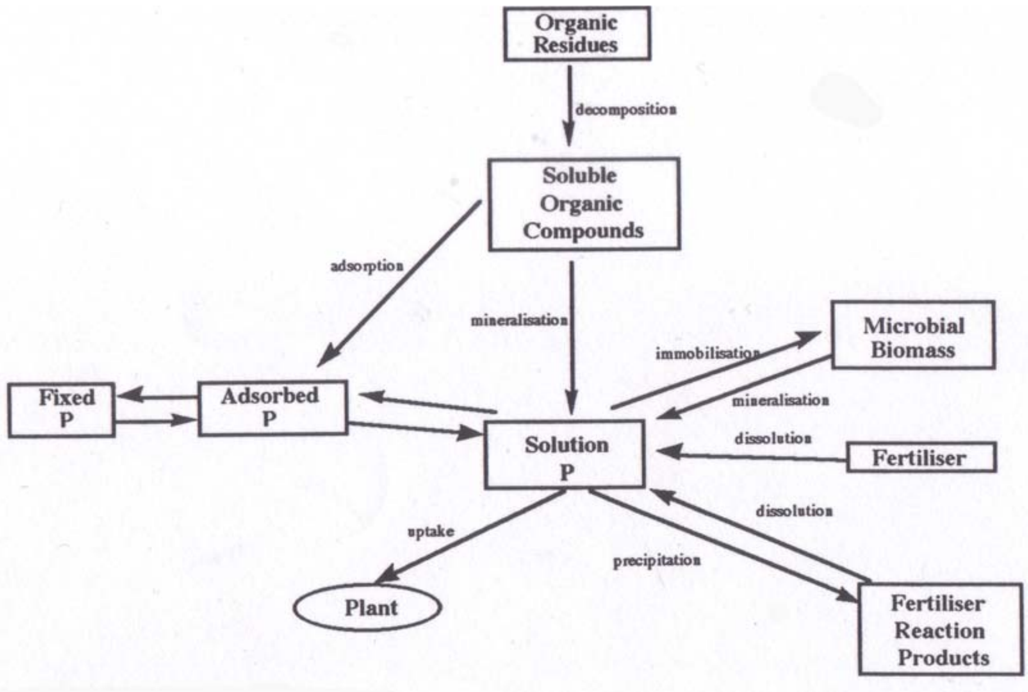

Figure 1. Phosphorus cycling in soils (Moody and Bollard 1999).

Phosphorus and soil analysis

P in soils is typically measured as plant-available P by a range of methods, the most common being Colwell P and Olsen P. Both tests are relatively accurate and reliable, but soil-available P can be affected by a range of factors, as listed above (Moody and

Bollard 1999). These soil analysis results, especially Colwell P, need to be interpreted in association with an estimate of the soil's P-fixing capacity (Gourley *et al.* 2007a). Although soil texture or other measures have long been used as surrogates for soil P-fixing capacity, the recently developed PBI is now the national standard (Burkitt *et al.* 2002, Gourley *et al.* 2007a).

Soil phosphorus levels

Soil analysis for P is a reliable method of assessing soil P requirements. The soil should be analysed before effluent or fertiliser is applied to assist in determination of appropriate P loadings (Gourley *et al.* 2007a, Moody and Bollard 1999). Gourley *et al.* (2007a) found that critical available P levels for pastures measured as Olsen P were applicable Australia-wide regardless of region, soil texture or PBI. The critical soil-available P level to achieve 95% of maximum pasture production across Australia, measured as Olsen P, was 15 $mg \cdot kg^{-1}$.

Gourley *et al.* (2007a) also found that critical available P levels for pastures measured as Colwell P depended significantly on PBI, but not on region or soil texture. They developed an equation enabling determination of critical Colwell P values when the PBI of a soil is known and used this to calculate critical Colwell P values for commonly used PBI categories, as detailed in Table 1.

Table 1. From Gourley *et al.* (2007a).

Predicted critical Colwell P soil test values for standard PBI categories, derived from the national data set.

PBI category		Critical value for mid point of PBI category (range)[1]
<15	Extremely low	23 (20 – 24)
15-35	Very very low	26 (24 – 27)
36-70	Very low	29 (27 – 31)
71-140	Low	34 (31 – 36)
141-280	Moderate	40 (36 – 44)
281-840	High	55 (44 – 64)
>840	Very high	n/a[2]

[1] Critical Colwell P value (mg/kg) at the mid-point of PBI category. Values in parenthesis are critical Colwell P values at the lowest and highest PBI values within the category.

[2] Insufficient data to derive a response relationship.

Phosphorus fixation and buffering

The amount of phosphorus sorbed in a soil and the subsequent P available for plant growth will largely depend on the soil type and its sorption capacity (Burkitt *et al.* 2002, Gourley *et al.* 2007a, Kruger *et al.* 1995, Moody 2007, Slattery *et al.* 2002). P sorption capacities can be obtained by using the isotherm method (DPI 2001, Kruger *et al.* 1995); however, as this method is detailed, time consuming and costly, the PBI is the preferred method of assessing a soil's propensity to retain P (Burkitt *et al.* 2002, Gourley *et al.* 2007a). This propensity should be assessed in conjunction with Colwell P or Olsen P soil analysis, and the P requirement should be interpreted according to the PBI range, as detailed in Table 1 (Burkitt *et al.* 2002, Gourley *et al.* 2007a, Moody and Bollard 1999).

3.3 Phosphorus

The PBI can be used to indicate the amount of P that could theoretically be sorbed by the portion of the soil profile that effluent will infiltrate before significant leaching of P occurs. Experience and research on soils treated with piggery effluent indicate that the actual amount of P sorbed in the field before leaching occurs is typically one-third of the total P sorption capacity. This information, combined with the results of nutrient budgeting and proposed P loadings, can be used to estimate the sustainable life of an effluent application area. This is based on the $kg{\cdot}ha^{-1}$ of P that can be sorbed in the soil before soil P saturation is reached in comparison with the accumulated P loadings and estimated P export in crops and pastures. Note that P sorption and buffering are theoretical parameters, and any interpretation must tempered by operational experience and monitoring of available P and total P levels in both effluent and soils. This process is detailed in Kruger et al. (1995).

Monitoring phosphorus

Details on monitoring P throughout a dairy effluent management system are provided in chapter 7 ‘Monitoring and sampling’.

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