3.10 Land application of manure and pond sludge

Manure can be readily used as fertiliser. As a result of increasing resource scarcity and fuel costs, the price of chemical fertilisers is increasing, in turn increasing the value of the nutrients in manure. However, the value of manure is not just limited the macro and micro-nutrients, but extends to the organic matter, which has beneficial effects on soil health and structure.

The level of dairy farm experience with successful manure and sludge reuse, as well as processing of manure and sludge, are growing. However, environmental policies developed to minimise risk tend to limit the off-site use of solids. With obvious opportunities for using manure to support pasture and crop production, land application is currently the favoured option for reuse.

Accumulation and collection of solids

The milking shed is not the only part of a farm where manure accumulates: feedpads, calving pads and loafing pads accumulate manure too. Whenever animals congregate and generate manure at levels in excess of the capacity of a site, the manure must be harvested and reused. Surfaces that drain to effluent storages or sumps will export manure too. This accumulated manure, solids or sludge will need to be removed periodically. Of key concern in harvesting solids for reuse is the presence of extraneous material such as rocks, clay and sand, and care is required to limit contamination. More information is provided in chapter 2.8 ‘Desludging and pond closure’.

Storage of solids

The amount of manure or sludge yielded and how quickly it is harvested obviously exert major control on the prospects for solids storage. However, typically, solids are generated year-round but are applied only sporadically, and so need to be stored. Storage has the potential for generating contaminated runoff, odours and groundwater contamination. It is preferable to have a dedicated area or structure for the storage of solids where they will have minimal impacts. It is critical to manage any contaminated runoff emanating from storage and handling. Runoff can emanate from the product, from rainfall ingress or from surfaces covered with spilt solids. All contaminated runoff around the solids storage and works areas should be contained. Runoff is typically directed to the dairy shed effluent system. The storage area needs to provide room for the movement of vehicles bringing and taking materials. Solids storage provides a potential breeding or feeding ground for flies, rodents, birds and microbes, so these must be excluded or controlled.

Because the land application of moist material can present difficulties, solids can be dried in heaps, windrows or broad areas. Research is currently under way to examine techniques for drying to increase nutrient density. A dewatered product obviously weighs less and takes up less room for transport and application.

Transporting solids

Transporting solids can lead to complaints, particularly in towns and cities. Loads must be covered to minimise the risks of spillage and complaints.

Land application

Nutrient loadings

Typical phosphorus levels in manure range from 0.3% to 2.0% of total solids, compared with 9% in single superphosphate and 19% in triple superphosphate. The potassium content ranges from 0.3% to 3.0% of total solids, compared with 52% in potassium chloride. Comparisons with nitrogenous fertilisers are difficult to make, but assuming a total Kjeldahl nitrogen concentration of 2.0% to 4.0% of total solids, this is less than one-tenth of the nutrient content of urea (which contains 47% N) on a dry-matter basis. In addition, the moisture content of manure and sludge is often significant, so these materials have a relatively low nutrient density and require high application rates to meet nutrient requirements. When the variable nature of organic nutrient availability is taken into account, there is often a tendency to apply solids too intensively, sometimes resulting in a smothering of the pasture or crop or an inability to incorporate the solids into the soil.

Application rates

Application rates are usually determined by phosphorus or nitrogen loadings (see chapter 3.1 'Nutrient budgeting'), although the presence of heavy metals and pathogens can restrict reuse options (see chapters 3.5 'Trace elements' and 3.11 'Microbial risks'). The concentrations of nutrients in manure and their availability are highly variable. Although pond sludge is generally stabilised to non-volatile, non-odorous material after extended storage, manure can still be dominated by putrescible organics, particularly when it has recently been harvested: age and moisture content can markedly influence characteristics. A lack of reliable data on manure and sludge characteristics dictates the need to adopt a very conservative approach to land application.

Spreading

The limitations and availability of spreading equipment pose major impediments to solids reuse. Only larger farms have manure spreaders, whereas typical farms rely on contract spreaders or their own gypsum or super spreaders, which block if the manure is clumped or too wet. By far the most common technique for land application is the use of a tipping trailer or dumper, which applies manure in dollops across a paddock. The manure is then incorporated during cultivation. Chain-activated spreaders are more effective for conveying manure and sludge with a dry matter content over 30%. Tanker transport with soil injection is another option, relying on the use of material with a dry matter content of 15% or less. Liquid application to the land surface from a tanker followed by spreading is a further option. The major impediment to this practice is the need to apply a large amount to a small area during a short time frame. Table 1 shows the association between solids content and handling method. Manure and sludge with a solids content of between 20% and 30% are defined as semi-solid, warranting the use of scrapers, loaders and muck spreaders.

Table 1. Association between solids content of manure and sludge and conveyance method.

Type	Solids content (%)	Handling methods
Liquid	1–10	Gravity flow, pump, tanker
Semi-solid ('wet' solids)	8–30	Conveyor, auger, truck transport (watertight box), solid-waste hopper
Solid ('dry' solids)	25–80	Conveyor, bucket, truck transport (box)

Other options for spreading include:

- application of dewatered material and incorporation by cultivation

- application of liquid to the land surface by tanker
- application of liquid by subsurface injection
- spreading with a vacuum tanker and spray line
- high-capacity solids-handling pump to high-flow effluent sprinklers
- excavator to drying bed and truck application of dry material
- excavator to dump truck with land application by tipping.

Organic matter loading and degradation

Whenever effluent enters a farm channel, dam or pond, aquatic microorganisms build up and consume the organic matter and the dissolved oxygen. Similarly, land application of manure with elevated COD or BOD will reduce the oxygen level in the soil. Low levels of soil oxygen inhibit plant growth and may produce unpleasant odours (associated with anaerobic conditions). Maintenance of aerobic conditions in the plant root zone under wastewater irrigation is best achieved through sound scheduling practice.

Guidelines for the disposal of effluent to land include a limit on maximum BOD loading. The NSW EPA's BOD limit is 300 $kg{\cdot}ha^{-1}{\cdot}week^{-1}$. The ability of a soil–plant system to assimilate biodegradable organic matter depends on the maintenance of aerobic conditions for rapid microbial degradation. Plant roots also must have oxygen; the requirement varies widely among species. For oxygen levels to be maintained, the BOD must be balanced by oxygen diffused from the atmosphere at a rate that depends on the concentration gradient and the oxygen diffusion coefficient, the latter of which depends on soil characteristics and moisture content.

With good site management, the soil–plant system has a considerable capacity for assimilating organic waste. The organic matter in manure adds to the soil organic matter levels directly and through enhancing plant production and the building of microbial biomass. This organic matter is valuable for maintenance of a healthy soil and protecting the soil from erosion. It also improves soil cation exchange capacity, which reduces heavy metal availability and buffers sodicity.

Accumulation

Heavy metals, which are relatively immobile and do not degrade, can be permitted to accumulate in soils until a critical concentration is reached; they are not commonly present at high concentrations in dairy manure and sludge (see chapter 3.5 'Trace elements'). The critical level is usually associated with phytotoxicity or constraints determined by material entering the food chain. Phosphorus applied as a component of manure or sludge can also accumulate but is rarely implicated in plant toxicity. Soil pH is a major controller of the bioavailability of heavy metals, most of which are available to plants at neutral to low pH levels. Increasing pH allows for the accumulation of heavy metals.

Migration of manure components

Waste constituents can migrate with water movement. The capacity of a soil to assimilate them is based on using enough land to ensure that the concentration of the constituent in the recipient groundwater or surface water conforms with established water quality standards. Nitrate is prone to migrate from manure-treated land that is not actively growing a crop or pasture. However, salts must migrate with runoff or leachate to maintain optimum conditions for growth on the application sites.

Crop use

Land use options are many and varied. Table 2 shows typical rates of macro- and micronutrient uptake by a range of crops. The land-limiting constituent dictates the area of land required for a balance (see chapter 3.1 'Nutrient budgeting'), and top-up fertilisers are then required to meet deficiencies in other nutrients. Tabulated data on crop nutrient uptake rates are indicative only, being highly influenced by management and yield, and additional amounts are often applied to cater for lack of homogeneity, lack of uniformity of application, gaseous and leaching losses, and limitations on nutrient availability in soils. Only nutrients in the harvested portion of the plant are listed in the table.

Table 2. Nutrient requirements for broadacre crops in kg·ha^{-1}(FAO 2000).

Crop	Yield (kg·ha^{-1})	Nitrogen (N)	Phosphorus (P)	Potassium (K)	Ca	Mg	S
Rice (paddy)	3000	50	11	66			
	6000	100	22	133	19	12	10
Wheat	3000	72	12	54			
	5000	140	26	108	24	14	21
Maize	3000	72	16	45			5
	6000	120	22	100	24	25	15
Potatoes	20 000	140	17	158	2	4	6
	40 000	175	35	257		23	16
Onions	35 000	120	22	133	–	–	21
Tomatoes	40 000	110	13	125	–	17	54
Cucumber	35 000	60	20	83	–	36	–
Lucerne (hay)	7000	215*	26	108	164	19	19
Soybeans	1000	160*	15	66	–	–	–
	2400	224*	19	81	–	18	–
Beans	2400	155*	22	100	–	–	–
Cotton—seed	1700	73	12	46	6	4	5
—lint	5000	180	27	105		35	30
Tobacco (dry leaf)	1700	90	10	107	48	6	4

–: Data not available.
The table lists plant nutrients contained in the above-ground part, and in the below-ground harvested portion where appropriate, at the indicated yields. Note that these are not the same as fertiliser requirements.
* Legumes can secure most of their nitrogen from the air.

Plant harvest is the most desirable way of exporting the nutrients in manure, but not all of the nutrients are available directly after application, and some can take years. Usually there is an upper limit to the concentration of a constituent within the plant–soil system below which there is no adverse plant response. Once it is applied, no further application should be made until the concentration in the soil has been reduced to about 10% to 20% above the natural level.

References

FAO 2000, *Fertilizers and their use*, Food and Agriculture Organization & Ineternational Fertilizer Industry Association, Rome.