1.2 Characteristics of effluent and manure

An understanding of the characteristics and quantity of effluent and manure generated by the cow is the starting point for assessing the suitability of effluent and manure management strategies for a dairy farm. The nature of excreta produced by the cow depends on breed, dry matter intake and composition of the diet. The nature of the effluent generated varies much more, depending on the number of hours on a cleaned surface, type of washdown systems, size of catchment area and climate. For this reason, it is preferable to work with estimates of the mass of 'as-excreted' manure (faeces + urine) and its components rather than to rely on 'typical' effluent analysis data.

Rates of faeces and urine production

Many guidelines have used data from the ASAE Standard 'Manure Production and Characteristics' (ASAE 1999) to characterise manure (a term usually taken to include both faeces and urine). That standard was based on 1960s and 1970s US data, so it presumably contained little, if any, data from grazing operations. Strategies for feeding cows in Australia, however, are diverse: from grazing with minimal supplementary feeding, through the broad group of grazing operations with varying degrees of increased supplementary feeding on feedpads, to completely ration-fed cows in freestalls (where the cows have a more predictable manure production). When the majority of the feed intake is sourced from pasture, variation in the forage consumed, both spatially and temporally, makes estimation of volume and composition difficult.

It is widely documented that milk production depends on feed intake: high-producing cows have a larger dry matter intake and consequently a larger volume of excreted manure than lower-producing cows. Nennich *et al*. (2003) found that milk production was a better indicator of the mass of faeces produced, and its constituents, than body weight; that work forms the basis of the updated ASAE Standard (ASAE 2005). Nennich et al. (2005) went on to define regression equations for estimating manure production based on either milk yield or dry matter intake and dietary concentrations. Although the latter were more accurate than milk yield alone, the difficulty in determining those parameters for grazing operations restricts their use to more intensive operations.

Table 1 compares the manure production predicted by the sources discussed above with the little data available from Australian and New Zealand sources. It is clear that there will be considerable variation in the volume and characteristics of manure produced from pasture-based operations, but little published research documents that range. In the absence of any more relevant data, the equations developed by Nennich *et al*. (2005) are the most useful tool available and may be adopted unless site-specific information is available.

Equations based on milk yield developed by Nennich *et al*. (2005):

$$\text{Total excreta (faeces + urine) (kg·day}^{-1}) = [\text{milk (kg·day}^{-1}) \times 0.616] + 46.2 \quad (1)$$

$$\text{Dry matter excretion (kg·day}^{-1}) = [\text{milk (kg·day}^{-1}) \times 0.0874] + 5.6 \quad (2)$$

$$\text{N excretion (g·day}^{-1}) = [\text{milk (kg·day}^{-1}) \times 2.82] + 346 \quad (3)$$

$$\text{P excretion (g·day}^{-1}) = [\text{milk (kg·day}^{-1}) \times 0.781] + 50.4 \quad (4)$$

$$\text{K excretion (g·day}^{-1}) = [\text{milk (kg·day}^{-1}) \times 1.476] + 154.1 \quad (5)$$

1.2 Characteristics of effluent and manure

Table 1. Comparing estimated manure production.

	ASAE (1999)	ASAE (2005)	Nennich *et al.* (2005)	Vanderholm (1984)	Victoria [d]	Victoria [d]
Relevance	USA	USA	USA	NZ (pasture)	Victoria (pasture + grain)	Victoria (pasture + protein)
Milk yield ($kg{\cdot}day^{-1}$)		*16.5*	*16.5*			
Body weight (kg)	*600*	*600*		*600*		
Total manure (faeces + urine) ($kg{\cdot}day^{-1}$)	52	54	56	65		
Urine ($kg{\cdot}day^{-1}$)	16	22		30	10–18	15–31
TS ($kg{\cdot}day^{-1}$)	7.2	6.6	7.0	5.3	3–5	4–6.6
VS ($kg{\cdot}day^{-1}$)	6.0	5.5 [a]	5.9 [a]	3.8		
N ($g{\cdot}day^{-1}$)	270	351	393	290	265 (113 dung, 152 urine)	394 (159 dung, 235 urine)
P ($g{\cdot}day^{-1}$)	56	58	63	30	48 (42 dung, 6 urine)	62 (59 dung, 3 urine)
K ($g{\cdot}day^{-1}$)	174	60	178	370	161 (30 dung, 131 urine)	203 (19 dung, 184 urine)
BOD_5 ($kg{\cdot}day^{-1}$)	1.0	0.9 [b]	0.9 [b]	1.2		
COD ($kg{\cdot}day^{-1}$)	6.6	6.1 [c]	6.5 [c]	5.2		
Moisture content (incl. urine) (%)	13.8	12.2	12.5	8.1		

[a] VS calculated as 0.83 × TS (ASAE 1999)
[b] BOD calculated as 0.16 × VS (ASAE 1999)
[c] COD calculated as 1.1 × VS (ASAE 1999)
[d] Personal communication, D. Daley 2003, DPI Ellinbank.
Note that numbers in italics are selected for enabling a comparison between sources. The milk yield of 16.5 $L{\cdot}day^{-1}$ was based on the estimated 2005–06 Australian average annual production of 5034 L (Dairy Australia 2006) and a 305-day lactation.

Minimising excreted nutrients

Powell (2006) suggests that 'manure management should start at the front, rather than the back end of the animal.' Dietary nutrient content in excess of requirements is excreted: excess protein (as urea) and K in urine, excess P in faeces. Adding excess salt to stimulate appetite can exacerbate problems with salinity management for the reuse area. Although the opportunity to manipulate pasture-based diets is limited and recommendations for minimum nutrient levels are beyond the scope of this manual, the issue is important when you are considering both whole-farm nutrient balances and opportunities for waste minimisation. In general, the formulation of supplementary feeds should be based on nutritional requirements to avoid overfeeding and thus to reduce the excretion of undigested components.

Proportion of daily manure output collected

Most existing guidelines assume that 10% to 15% of the daily manure output (equivalent to 2.4 to 3.6 h per day) is deposited onto surfaces from which effluent is collected. Although that is a reasonable estimate for the holding yard at the dairy, industry trends towards feeding increasing levels of supplements or mixed rations mean that such an assumption is no longer valid. On a farm with a feedpad, such an assumption can seriously underestimate the volume of manure and nutrients to be handled. The amount of time that cows are confined to a collected surface must be determined on each farm.

Dunging behaviour

As a general rule, the amount of manure deposited at any location is proportional to the time that the cows spend at that location. Although the frequency of defecation and urination increases after the cow rises from a resting or rumination period, White *et al*. (2001) found that when cows were given time to void themselves before being retrieved for milking, the volume of faeces and urine deposited at the dairy was proportional to the time that the cows were held.

As the amount of manure to be collected can be minimised by reducing the time spent on a confined surface, consider opportunities to improve dairy throughput and not hold cows after milking when planning or reviewing an effluent management system. To reduce the amount of manure collected in laneways, give cows sufficient time to stand and defecate in the paddock before being moved. Stress is one reason for an increase in the number of defecations and urinations at the dairy; avoid rough handing and crowding in holding yards. More detailed information on shed and yard configuration and its impact on throughput is provided by the CowTime program (http://www.cowtime.com.au/).

Time in the yard

The average time cows were held for milking ranged from 2.8 h per day until the last cow left the yard (40–100 cows) to 3.8 h per day (>150 cows), with an overall mean of 3.3 h per day (Wheeler 1996). Where cows are allowed to return to the paddock after milking, the time that the middle cow spends at the yard is more appropriate for calculations; Wheeler's results suggested a range of means from 1.6 to 2.1 h, with an overall mean of 1.8 h per day. Therefore, the rule-of-thumb for the proportion of manure collected from the holding yard should be 10% where cows return to the paddock immediately after milking, and 15% where cows are held until milking is complete.

Impact of supplementary feedpads on manure proportion

The adoption of feedpads to support more intensive feeding strategies and to alleviate environmental stresses significantly increases the time cows are restricted to a surface from which manure must be collected (see chapter 4.2 'Feedpads, calving pads and loafing pads'). It is no longer uncommon for cows to be on or around a feedpad for 8 to 12 h per day, particularly where it is covered.

Although the volume of manure collected will increase significantly under such condition, some assumptions need to made regarding its distribution around the feedpad. Dairy cows will eat for up to 8 h a day. Therefore, if given free access to a loafing area, cows fed on an uncovered feedpad may deposit one-third of the manure on the feedpad and the remainder on the loafing area (which may be handled separately as a scraped solid). If the feedpad is covered, the proportion collected may well be higher, particularly in summer.

Any summary of the design criteria for an effluent management system (the composite of the collection, storage and/or treatment, and reuse components) should clearly report the likely times when the herd is confined and the proportion of daily output to be collected that was adopted in developing the plan.

Water use in dairies

Most of the water used in and around the dairy ends up being collected by the effluent management system. An accurate estimate of the water usage by the dairy is needed in order to successfully design and manage an effluent system: not only to ensure sufficient storage (see chapter 2.6 'Effluent storage requirement'), but also to secure a supply with sufficient quality and quantity, and to identify opportunities for minimisation.

1.2 Characteristics of effluent and manure

There is no simple relationship between the amount of water used for cleaning yards and the number of cows milked or the area of the yard (Wheeler 1996). McDonald (2005) found that total water use in dairies can vary significantly between 1000 L and over 150 000 L day^{-1}, and that it is not necessarily the larger operations and dairy sheds that use excessive amounts of water.

Typical ranges in water use reported include 11 to 56 L day^{-1} per cow (NSW Dairy Effluent Subcommittee 1999) and 4 to 138 L day^{-1} per cow (Rogers and Alexander 2000). The survey of 114 Bonlac farms by Rogers and Alexander (2000) recorded an average water use of 33 L·day^{-1} per cow (Table 3).

Table 3. Reported water use (Rogers and Alexander 2000).

	Average (n = 114) L·day^{-1} per cow	Rotary L·day^{-1} per cow	Herringbone L·day^{-1} per cow
Yard	21	26	19
Pit	4.4		
Platform	1.3	10	n.a.
Cups	1.4		
Teats	0.1	n.a.	n.a.
Cold machine wash	1.6	1.9	1.6
Hot machine wash	2.0	2.3	1.7
Vat	1.0	n.a.	n.a.
Total	33	47	27

Water use audits

Producers tend to underestimate daily water use, so a thorough audit is required for an accurate estimate. A water use audit should include at least the following:

- yard washing (distinguishing between clean water and reuse of treated effluent)
- yard pre-wetting
- pit or platform wash
- cup sprays
- platform sprays
- teat wash
- milking machine wash
- vat wash
- platecooler
- cow cooling.

Planning for new dairies without an audit

Although it is preferable to base effluent volumes on data from the actual farm, planning for a new site often requires that 'typical' data be used, as an audit cannot be done. McDonald (2005) suggests that in the absence of any other data, reasonable estimates for water use can be based on the number of milking units (Figure 1).

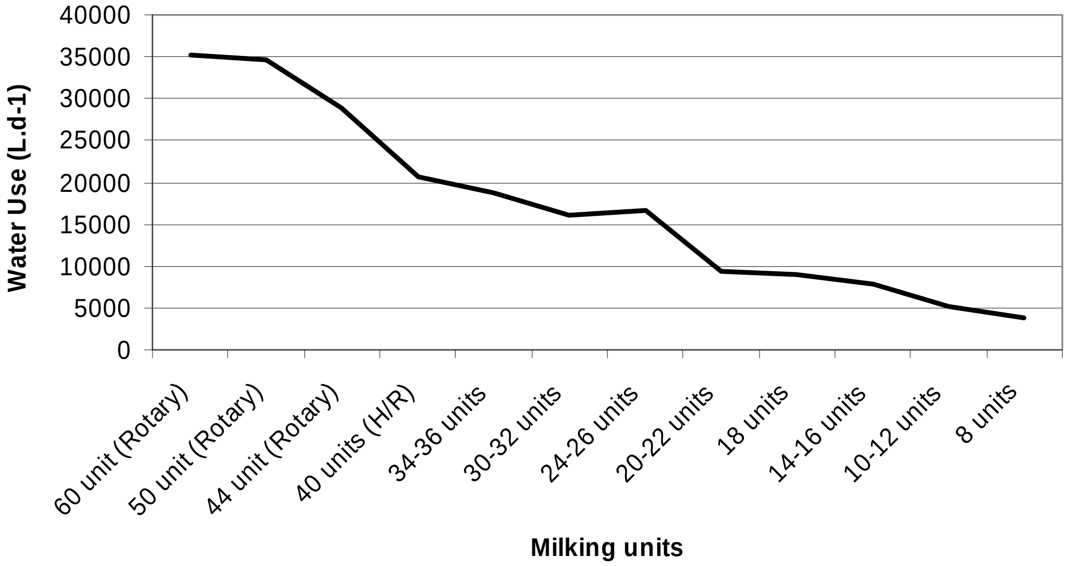

Figure 1. Total water use per day versus shed or milking units (McDonald 2005).

Minimising water use

The range in water use recorded by McDonald (2005) suggests that significant savings are possible without compromising plant hygiene or milk quality. For example, cup and platform sprays in rotary sheds represent up to 40% of total water use, but this component could be reduced by 70% to 80%.

To minimise the volume of effluent generated, Rural Solutions SA (2005) recommend reducing the cup spray flow rate to 10–15 L·min^{-1} for most of the milking; the fine spray is sufficient to prevent manure from sticking to the cups. On the last rotation, the flow rate can be turned on full to 70 to 80 L·min^{-1} for a final cup wash. They also recommend that the platform spray be used strategically (when there is manure that must be removed), but otherwise left off until the last rotation.

Water use for washing milking plant and vats should not be reduced below manufacturers' recommendations.

Floodwash systems represent the largest use of water around the dairy; where possible they should draw on treated effluent for supply and not clean water. Even if treated effluent is used, water use should be examined, as McDonald (2005) suggests that many farmers are dumping the entire tank volume when it may not be necessary. Shutting off the flow after the required flush duration will improve the performance of the solids trap and reduce the volume to be handled by any pumps. The volume of water required should be assessed by using appropriate flow depth, velocity and duration criteria (see chapter 1.4 'Floodwash systems').

Platecooler water use is 2.5 to 3 times the volume of milk cooled. As this water remains clean, it should be reused for washing or stock consumption. If excess platecooler water is generated, it should be directed to the effluent system only if its volume is allowed for in the calculation of storage requirement (see chapter 2.6 'Effluent storage requirement').

Although the volume of water used for cow cooling can be significant, the water is generally not needed during the storage period and should not affect the storage requirement.

Stormwater

Contaminated stormwater must be collected and treated, but diverting clean stormwater away from the effluent collection point will reduce the volume that the effluent management system must handle, decreasing the size of the storage pond and reducing the volume that has to be disposed of by irrigation. See chapter 2.6 'Effluent storage requirement' for further information on stormwater minimisation and yard runoff diversion.

In summary, all dairies should:

- collect and use roof runoff by directing gutters to the tank supplying platecooler or washdown water
- reuse platecooler discharge for washdown
- prevent runoff from entering the yards or effluent systems from upslope.

Typical raw effluent analysis

A table of 'typical' raw effluent analyses is provided for background information. For the reasons stated above, typical concentrations should not to used for design purposes unless site-specific information is not available.

Table 4. Typical dairy shed effluent concentrations.

Parameter	Units	Region	
		NZ [a] (*n* > 37)	Victoria (NE) [b]
Total solids (TS)	%	0.9 (typical range 0.5–1.2)	
BOD_5	$mg{\cdot}L^{-1}$		3200
Suspended solids (SS)	$mg{\cdot}L^{-1}$		2400
Total N	$mg{\cdot}L^{-1}$	269	187
Organic N	$mg{\cdot}L^{-1}$	219	
Ammonium + ammonia	$mg{\cdot}L^{-1}$	48	84
Total P	$mg{\cdot}L^{-1}$	69	26
K	$mg{\cdot}L^{-1}$	370	200
Total S	$mg{\cdot}L^{-1}$	65	
Electrical conductivity (EC)	$dS{\cdot}m^{-1}$		1.12
pH	–		8.0
Cl^-	$mg{\cdot}L^{-1}$		180
Mg^{2+}	$mg{\cdot}L^{-1}$		27
Na^+	$mg{\cdot}L^{-1}$		119
Sodium adsorption ratio (SAR)	–		4.3

[a] Longhurst *et al.* (2000)
[b] Wrigley (1994)

The N concentration may vary seasonally. Wang *et al.* (2004) suggest that N concentration reaches a peak within 1 month of the start of lactation and then gradually declines.

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