1.1 Physical, biological and chemical components of effluent and manure

Terminology

Collectively, urine and dung are called **excreta**. This excreta is typically mixed with wash water produced by cleaning yards; with wash water, chemicals and residual milk from cleaning equipment; with waste feed or bedding material; and occasionally with rainwater. The resulting liquid is usually referred to as **effluent** (or dairy shed effluent or wastewater).

Excreta that dries before being collected (for example, by scraping from feedpads or loafing yards) and is handled as a semi-solid or solid is called **manure**. Manure can also contain waste feed or bedding material and soil removed by scraping non-concrete areas.

The characteristics of effluent and manure need to be understood before a suitable option for management can be selected. The relevant characteristics can be described by the following physical, biological and chemical parameters.

Physical—solids

The solids in effluent and manure can be partitioned into different physical components, as described by the following matrix adapted from Taiganides (1977):

TS	=	VS	+	FS
‖		‖		‖
SS	=	VSS	+	FSS
+		+		+
TDS	=	VDS	+	FDS

where TS = total solids
VS = (total) volatile solids
FS = (total) fixed solids
SS = (total) suspended solids
VSS = volatile suspended solids
FSS = fixed suspended solids
TDS = total dissolved solids
VDS = volatile dissolved solids
FDS = fixed dissolved solids.

The characteristics of effluent and manure can be described by these components and other biological and chemical parameters, as explained below.

Total solids (TS)

The choice of effluent management system is constrained by the total solids content of the material to be handled. Figure 1 shows generally accepted TS limitations for different manure handling options.

The TS content of manure 'as-excreted' may range from 8% to 15% and can therefore be described as a liquid or semi-liquid (a slurry). Material of this concentration is usually conveyed by augers or manure tankers. After yard and plant wash is added, the TS content of the diluted effluent is usually between 0.5% and 1.2% (Longhurst *et al.* 2000).

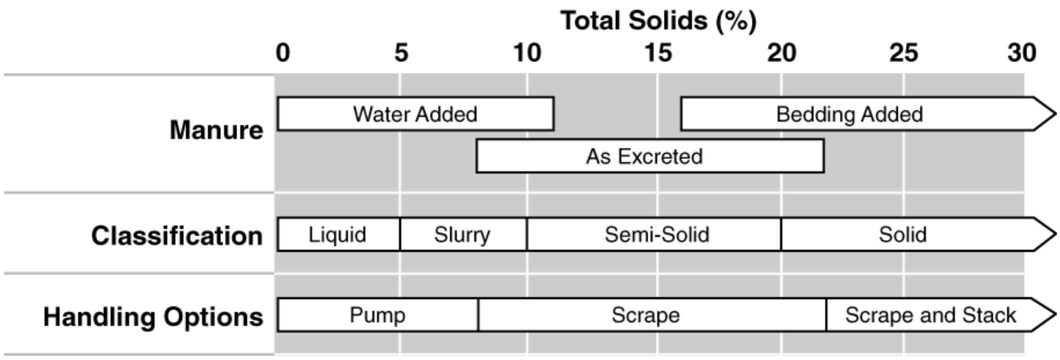

Figure 1. TS and manure handling options (USDA-NRCS 1996).

Note that a TS concentration of 10 000 mg·L^{-1} (or 10 g·L^{-1}) is equivalent to 1% solids; the density of manure is almost the same as that of water up to around 10% TS (Taiganides 1977).

Volatile solids (VS)

The volatile solids component is the organic matter or degradable component that must be removed or stabilised during treatment. The VS component of dairy cattle faeces is generally 80% to 86% of TS, the remainder being ash (FS) (Zhang *et al.* 2003, Wright 2005, ASAE 2005). Any extraneous material such as laneway material walked in on hooves, soil washed from earthen pads or sand bedding entering the effluent stream will reduce the ratio of VS to FS.

Fixed solids (FS)

The fixed solids constitute the residual inorganic compounds (N, P, K, Ca, Cu, Zn, Fe etc.) in a suspended or dissolved state. In dilute effluents, these minerals are mainly dissolved, and their removal from the effluent stream is difficult.

Suspended solids (SS)

The content of total SS ranges from 62% to 83% of TS Loehr (1984), and sets the theoretical limit of performance for separation systems (see chapter 2.1 Solid-liquid separation systems). The majority of SS is volatile (VSS): approximately 80% according to Longhurst *et al*. (2000); the rest is fixed (FSS).

Total dissolved solids (TDS)

All dissolved solids (TDS) are ions. There is a strong correlation between TDS and the electrical conductivity (EC) of effluent.

Biological oxygen demand (BOD)

Biological oxygen demand is an index of the oxygen-demanding properties of biodegradable material in water. It is a useful measure for assessing the strength of effluent and its pollution potential. The BOD curve in Figure 2 illustrates the typical two-stage characteristic: the first stage is related to demand for carbon, and the second to nitrification. Because the reproductive rate of the bacteria responsible for nitrification oxygen demand is slow, it normally takes 6 to 10 days for them to influence the BOD measure (Metcalf & Eddy Inc. 2003).

Unless specified otherwise, BOD values usually refer to the standard 5-day value (BOD_5), measured within the carbon demand stage. Note that the BOD_5 of animal effluents cannot be compared to that of sewage, as BOD_5 of sewage represents 68% to

80% of the ultimate BOD, whereas that of animal effluents is only 16% to 26%. (Having already undergone anaerobic fermentation in the rumen, the effluent contains a higher proportion of slowly degradable organic matter.)

Typically, dairy effluent (unless substantially diluted) has a BOD_5 of the order of 2500–4000 $mg \cdot L^{-1}$. Although much of the organic matter in dairy effluent is derived from manure, the contribution from spilt milk or flushing milk lines cannot be ignored. Raw milk has a BOD_5 of 100 000 $mg \cdot L^{-1}$ and has the potential to be a powerful pollutant if inappropriately managed.

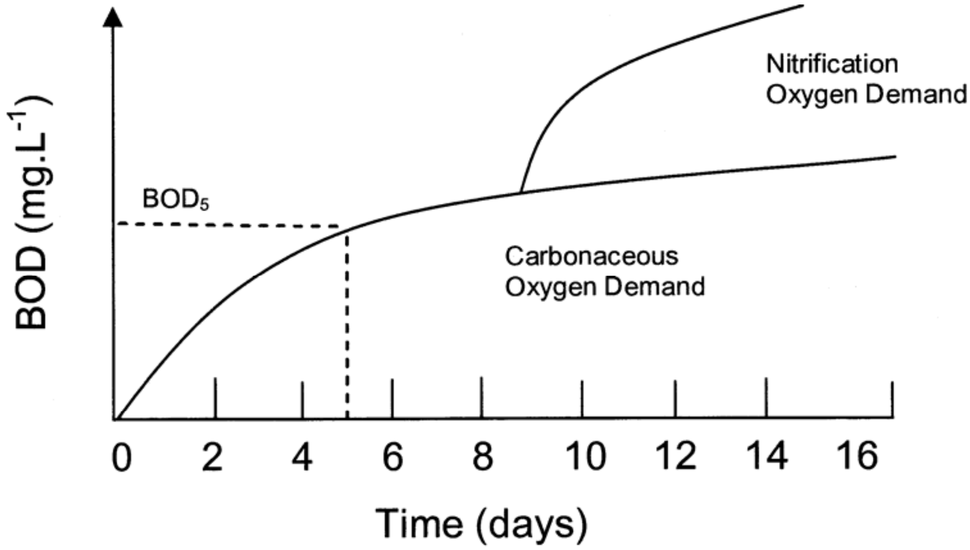

Figure 2. Typical BOD response with time.

Chemical oxygen demand (COD)

Chemical oxygen demand is the amount of oxygen consumed during the oxidation of organic carbon under a high-temperature, strongly acidic chemical digestion process. COD is frequently used in monitoring treatment processes, as it can be completed in 1 to 3 h (rather than the 5 days for BOD_5). However, since it is a chemical process, the biodegradability prospects for the material are not given.

The COD:BOD_5 ratio is frequently used as an indicator of biological degradability: ratios exceeding 5:1 indicate low digestibility. The COD:BOD_5 ratio of dairy effluent is typically 7:1 to 12:1.

Nutrient content and distribution by manure particle size

Particle size distribution (PSD) is important when we are considering nutrient balances and the impact of separation systems (see chapter 2.1 ‘Solid-liquid separation systems’). The limited data regarding particle size distribution of dairy manure comes mainly from ration-fed animals in the USA. Meyer *et al*. (2007) reported the results of a PSD study of four lactating cows fed a diet of coarsely chopped lucerne, whole cottonseed and a concentrate mix (intake averaged 21.9 kg DM day^{-1} with a nutrient composition of 2.7% N, 0.4% P and 1.5% K). It is expected that the distribution of particle sizes in manure will vary with diet.

Meyer *et al*. (2007) identified that around half of the mass and most of the nutrients in fresh dairy manure are associated with particle sizes smaller than 125 µm: 50% of TS, 85% of N, 87% of P and 99.8% of K. Just 37% of TS, 10% of N and P and negligible K were associated with particles larger than 1000 µm—a size range that may be removable by mechanical screens. Wright (2005) reported similar results.

Table 2. Particle size distribution for ‘as-excreted’ dairy manure (Meyer et al. 2007).

Particle size (µm)	Percentage of total solids	Percentage of N	Percentage of P	Percentage of K
2000	30	9.0	9.0	0.1
1000	7	1.5	0.8	0.0
500	6	1.6	1.1	0.0
250	5	1.7	1.4	0.0
125	3	1.4	1.4	0.0
<125	50	84.9	86.7	99.8

Meyer *et al*. (2007) confirmed the commonly assumed partitioning of nutrients between faeces and urine from dairy cattle: N, 48% faecal, 52% urine; P, 97% faecal, 3% urine; K, 30% faecal, 70% urine.

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