7 Monitoring and sampling

As part of ongoing farm management, it is prudent to regularly monitor a range of aspects related to the effluent management system. The results of this monitoring can provide feedback to management and support decisions relating to system optimisation, including maximising enterprise production and viability while minimising risks to the environment, stock health and human health. In addition, the results of regular monitoring should enable management to fulfil any obligations under regulatory authority requirements.

A detailed account of the requirements of sampling and monitoring for intensive livestock industries is provided by Redding (2003); that document should be used as a basis for the parameters to monitor and the procedures for sampling. However, the document was prepared mainly for intensive livestock systems where effluent was being applied to cultivated land, not to intensively grazed pastures such as those used for dairy production. More research is needed to establish acceptable levels of monitoring for the dairy industry. The use of overall farm monitoring such as that outlined in chapter 3.1 'Nutrient budgeting' and the use of a nutrient management plan or the Farm Nutrient Loss Index (FNLI) (Gourley *et al.* 2007) are recommended.

A simple but important and often overlooked aspect of monitoring is the recording of the location and timing of sampling and the appropriate storage of results.

What to monitor?

Base parameters to monitor

The actual monitoring required may differ from that detailed by Redding (2003), depending on the type of effluent management system used, the risks involved, strategies developed to minimise these risks, and specific recommendations from appropriate guidelines such as Tasmania's State Dairy Effluent Working Group (1997), or regulatory authority requirements such as the relevant Environment Protection Act or State Environment Protection Policy (for example, SA's Environment Protection Authority (2003)). This section presents the most comprehensive list possible of parameters to monitor in an attempt to cover most situations, so not all of the parameters listed may have to be monitored on any one particular enterprise.

Recording production information and environmental variables

Typical dairy management will include regular monitoring and recording of general farm management procedures, inputs and production levels. This practice will provide important information for assessing the results of effluent system monitoring. Keep records of any management changes that are likely to change production levels or effluent quality, along with details of:

- farm infrastructure—water storage and drainage system levels, surface runoff quantity and quality, pumping volumes
- pasture and crop monitoring—plant growth rates, plant symptoms (e.g. of salting or soil nutritional imbalances), crop yields or production levels, applications of fertiliser or soil ameliorants; irrigation quantity and water quality; a paddock walk is a useful way to identify these things
- stock performance—stocking rates, stock health, milk quantity and quality
- public amenity—to maintain a certain level of public and neighbour amenity.

Environmental variables should also be recorded as part of dairy management. Rainfall, weather (evaporation, wind, temperature etc.), groundwater levels and drainage line flows are all important parameters to record.

Monitoring of storage and treatment lagoons

The parameters that require monitoring in effluent storage and treatment processes are described in detail in chapter 2.3 ‘Anaerobic, aerobic and facultative ponds’.

Monitoring of effluent reuse area

- Soils—The intensity of monitoring will vary. Divide areas treated with effluent (both solids and liquids) into management areas, segregating those areas that have significantly differing management, soil type, crop or pasture, stocking rate, irrigation or effluent application rate. Each management area should then have at least one soil monitoring point on a representative area. Topsoil and subsoil samples should be analysed annually to assess for nutrient deficiencies or excesses. Take samples are selected from the same monitoring points over time for comparison.
- Groundwater—Install groundwater monitoring bores (or piezometers) within and next to reuse areas. Determine the number and location of bores in association with an assessment of local shallow hydrogeological conditions. These bores should be used to monitor fluctuations in shallow (0–3 m) groundwater levels and groundwater salinity content twice a year. A simple piece of slotted PVC pipe makes an effective monitoring bore. A simple hand-held EC meter will facilitate regular, easy, cheap assessment of water salinity levels. Assess variations in groundwater level and quality in conjunction with seasonal conditions and effluent application practices.
- Surface water—Collect any excess surface water from the reuse area for reuse and divert uncontaminated rainfall runoff to local natural drainage lines. Monitor surface runoff for quantity and quality.

Example parameters to be monitored

An example of some of the variables that may require monitoring as part of an effluent management system are listed in Tables 1 and 2. These tables provide the most comprehensive list possible of parameters that may need to be monitored. The degree of monitoring on any particular site will need to be assessed on an individual basis considering all effluent system facets and management. The list of parameters that will require monitoring will vary considerably from site to site.

Table 1. Comprehensive list of parameters that might have to be monitored (not all of these will be required on any one site).

Parameter	Specifics	Frequency	Timing
Effluent	Effluent generated	monthly	
	Effluent lagoon water quality	monthly	
	Salinity (hand-held meter)	weekly	
	Additional water onto farm	monthly	
	Dilution rates	at irrigation	
	Salt & nutrient loadings	annually	
	Water budgeting information	bi-annually	Feb & Oct
Climate	Rainfall	daily	
	Evaporation	weekly	
	Growing conditons (wind, temp etc.)	weekly	
Irrigation	Irrigation applications	at irrigation	
	Area irrigated	at irrigation	
	Reuse sump capacity	at irrigation	
	Waterlogging	continual	
	Salinity (surfae evidence)	continual	
	Surface ponding	continual	
	Soil moisture	continual	
Soil physics	Channel or drain erosion	continual	
	Physical deterioration (slaking etc.)	continual	
Soil chemistry	General	twice a year	Mar & Oct
	Detailed	every 2 years	March
	Salinity (hand-held meter)	as required	
Crop production	Crop health	continual	
	Production—product removed	as occurs	
	Product nutrient levels	annually	Mid season
	Leaf analysis	as required	
	Fertiliser and gypsum rates	as applied	
	Leaf analysis	as required	
Runoff	Off site runoff—quanitity & quality	as occurs	
Groundwater	Depth to water table	twice a year	Mar & Oct
	Chemical parameters	twice a year	Mar & Oct
Native vegetation	Tree health—mature trees on site	continual	
	Tree health—adjoining stands	continual	
	Tree health & mortality—plantations	continual	
Other	Record contractors onto farm	as occurs	

Table 2. Technical parameters that may need monitoring in a dairy effluent management system.

Characteristic	Parameters	Characteristic	Parameters
Wastewater	pH	**Soils – detailed**	Aluminium
	Total nitrogen		Boron
	Total phosphorus		Copper
	Total dissolved solids		Zinc
	Biological oxygen demand		Iron
	Salinity (EC)		Sulphur
	Na		Manganese
	Ca	**Soils – physical**	Slaking
	Mg		Dispersion
	K		Cracking
	Cl		Moisture
	Sodium adsorption ratio		Pugging
Soils – general	pH (H_2O)		Erosion
	pH ($CaCl_2$)		Waterlogging
	Salinity ($EC_{1:5}$)	**Groundwater**	EC
	Chloride		Chloride
	Organic carbon		Calcium
	Total nitrogen		Potassium
	Olsen phosphorus		pH
	Total phosphorus		Total nitrogen
	Exchangeable Na		Sodium
	Exchangeable K		Magnesium
	Exchangeable Ca		Total dissolved solids
	Exchangeable Mg		Phosphorus
	Ca:Mg		Depth
	CEC	**Crop**	Nitrogen
	Exchangeable sodium %		Phosphorus
	Skene potassium		Potassium

Instrumentation

Wireless sensor technology for feedback and control systems, GPS guidance systems, GIS mapping techniques and computer-based farm planning tools allow more precise measurement, support record keeping and reduce labour on the farm. Dedicated instruments can be used to measure important parameters of dairy waste management systems. The purpose of instrumentation is to:

- collect data for comparison with predicted or modelled outcomes
- maintain records for regulatory purposes and adjustment of systems to improve performance
- yield information for research and innovation.

Instruments are available to measure and record feed and water use, rainfall and evaporation, stock movement patterns, milking times, disease incidence, milk volumes and chemical usage, much of it at regular time intervals. Even basic instruments such as water meters, thermometers and pressure gauges can be handy.

Monitoring effluent

Water use and effluent conveyance can be monitored to reveal volumetric flow rate, power consumed, pipe and pump pressure, and volumes. Ultrasonic meters, magnetic flow meters and pressure gauges are by far the most common devices installed for effluent monitoring. The recording of information for subsequent analysis when time is available is important.

Load cells, depth gauges and level sensors can be used to control discharge from pump sumps to stabilisation ponds. Float sensors are commonly used to control sump pumps and ponds and can be used to actuate surface aerators. Effluent quality sensors are uncommon. pH and chemical conductivity gauges can be used, but rarely are nutrient or dissolved oxygen sensors used.

Paddock monitoring

Sites on which manure and effluent are applied can be monitored. Although sap flow meters and leaf turgor sensors are available, by far the most common instruments are soil moisture meters such as tensiometers, ceramic and gypsum blocks, capacitance probes, neutron moisture probes, and time domain reflectometry meters.

A key objective is to capture spatial characteristics. Remote sensing devices can be used to aid this objective by monitoring temperature and canopy radiation from suspended points, satellites or high vantage points.

The range of devices available and their ease of use, accuracy and compatibility with computers, mobile phones and radio networks is extensive. As new technologies prove their worth, the take-up rate will increase and the unit cost will decrease.

Examples of suitable instruments

Rather than try and measure a host of variables with a range of specialist instruments, experience indicates that the simpler the instrumentation, the more robust will be the data. For example, rather than monitor effluent discharge, it is easier to use an off-the-shelf water meter to record water consumption; if all the water used becomes effluent, the results will be reliable. If necessary, a rain gauge and accurate surface area computations will accurately indicate additional runoff volumes. The characteristics of the effluent and changes in its characteristics over time can be gauged with an off-the-shelf conductivity meter. Very common instruments include water meters, pressure gauges, level sensors and soil moisture sensors. Equipment quality can usually be gauged by price. Although the accuracy of instruments for measuring effluent parameters can be dubious, case studies confirm that relative performance is critical: reliability and consistency of reading are usually of greater significance than accuracy.

Table 3 lists instruments that have well-established utility for dairy effluent use.

Table 3. Potentially useful instruments.

Parameter	Instrument
Flow rate	Bucket & stop watch, volumetric tank, load cell & stop watch, magnetic flow meter, weir plate & flume
Change in concentration	Conductivity meter, turbidity gauge, flask & stop watch, colorimetric test
Rainfall	Ramped gauge
Evaporation	Class A pan
Wind speed and direction	Anemometer
Soil moisture	Gypsum or ceramic block, neutron moisture probe, tensiometer, time domain reflectometry probe, capacitance probe, SENTEC meter, gravimetric sampler
Soil nutrient status	pH kit, hydrogen peroxide test, hydrometer

Although flow meters, hand-held pH and EC meters, level sensors, pressure gauges and visual observations are commonly used, more specialised instruments are under study. Kizil (2006) documents the evaluation of a gas sensor to estimate the nitrogen, phosphorus, potassium and ammonium content of cattle manure. Van Kessel and

Reeves (2000) evaluated cheap and simple techniques for assessing nitrogen levels in manure, using hydrometers, EC meters, colorimetry and a hand-held nitrogen gas meter.

The hydrometer proved to be the only quick test available for measuring total N in effluent. Singh and Bicudo (2004) found that a conductivity meter and conductivity pens gave more reliable results for ammonium than hydrometers. Provolo and Martinez-Suller (2007) demonstrated the value of EC for assessing total Kjeldahl nitrogen (TKN) and total ammoniacal nitrogen (TAN), the limited value of using EC to determine potassium, and no value at all for phosphorus (P) assessment. Lugo-Ospina et al. (2005) studied quick tests for P in dairy manure. Both dissolved P and total P could be determined reasonably accurately with a hand-held reflectometer in association with specific gravity tests.

To reduce the cost of analytical tests, instruments can be used to determine solids content and infer P and N levels. Higgins et al. (2004) found that knowledge of animal growth stage (which can be measured) and solids content could be used as proxies to predict the total N and total P contents of liquid animal manure.

The use of quick tests must be investigated under Australian conditions, as the quality of surface water and groundwater sources is variable (particularly EC) and may alter results.

Assessing results and reviewing performance

An annual revision of the performance of the dairy enterprise and of the effluent management system is recommended. Assess the preformance of the effluent management system in conjunction with the results from the monitoring of all site environmental, management and production parameters. Some results may need to be assessed by suitably qualified personal.

Record the results of all monitoring and store them to ensure that they are readily accessible. It is also important to:

- assess management variations proposed or instigated in response to monitoring results
- review the effectiveness of the monitoring process and any variations that are required.

System selection issues

The accuracy and frequency of the required measurements and the cost must be considered in equipment selection. Sensors must be compatible with coupling and output devices as well as with other sensors being used. The user should have experience with the technology.

Calibration

Calibration of any system is necessary. Blind reliance on numbers can be misleading. Instruments are best calibrated by applying a range of known static conditions to the sensor. Where this is not feasible, test each component of the instrumentation system; equipment suppliers will often do this.

Often it is necessary to develop another measurement system of greater precision to act as a standard for comparison of the main system. The data collected in calibration experiments must be analysed, and system errors must be evaluated. Regression analysis usually yields a calibration curve with confidence limits or tolerance levels.

Data quality, completeness and decisions

Check all instruments to see that they are functioning properly before collecting data for analysis. An equipment malfunction can cause loss of data or inaccuracies. Often some data are missing, or evidence suggests that the data should be adjusted. A vital step after monitoring is to check the reasonableness of the results; assumptions in design, equipment malfunction or misuse, or errors in the analysis can cause results to be unreliable. This step should not wait until after all of the data have been collected. Rather, it must be done early.

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