3.6 Salinity

Salinity is the presence of high levels of soluble salts in soils or waters. Management of salinity is important, as elevated salt levels can have detrimental effects on production and the environment. Elevated levels in dairy effluent are often a potential problem, as salts are ubiquitous in the production system and it is difficult to separate them from effluent. Best practice for the management of water, nutrients and salts in dairy effluent is land application. A range of methods are available to minimise salt loading and to manage land application areas.

Salinity units and conversions

The salinity level of water is typically reported as either electrical conductivity (EC) or total dissolved solids (TDS).

It is critical to note what units a water salinity measurement is reported in. Water EC can be measured in:

- microsiemens per centimetre ($\mu S \cdot cm^{-1}$)
- millisiemens per centimetre ($mS \cdot cm^{-1}$)
- decisiemens per metre ($dS \cdot m^{-1}$).

The TDS in water can be measured in:

- milligrams per litre ($mg \cdot L^{-1}$)
- parts per million (ppm).

Note that 1000 EC units = 1000 $\mu S \cdot cm^{-1}$ = 1.0 $mS \cdot cm^{-1}$ = 1.0 $dS \cdot m^{-1}$ = 640 $mg \cdot L^{-1}$ TDS = 640 ppm TDS.

To convert EC units to TDS: multiply by 0.64.

To convert TDS to EC units: multiply by × 1.5625.

Minimising salinity

Where there is a risk of salinity levels becoming elevated in the dairy effluent stream, it is prudent to minimise salt accumulation in this stream where possible. The following dairy management components should be assessed.

Salt importation

- Washdown water—one of the main determinants of effluent salinity levels is the salinity of water used for washdown, as the proportion of effluent generated by this process can be considerable.
- Water—stock drinking water may contain salts.
- Feed—feeds can also contain salts, especially by-products or supplements.
- Cleaning agents—milking shed sanitisers can often import significant levels of salts. Low-salinity or differing-salinity alternatives are available.

Salt accumulation

Salts can readily accumulate in dairy effluent where the effluent is recycled for washdown. Salts can concentrate in ponds through evaporation.

Storage risks

It is important to ensure that effluent storage salinity levels do not become excessive, as this can impede pond biological interactions (see chapter 2.3 'Anaerobic, aerobic and facultative ponds').

Applying effluent to land

Salinity risks

Care is required where dairy effluent with elevated salinity is applied to land, as salinity levels can influence production (e.g. pasture growth) and the environment. Table 1 indicates the risks associated with the application of water with elevated salt levels. Elevated salt loadings can result in an accumulation of salts in the pasture or crop rootzone that can affect yield and therefore water and nutrient use. In addition, the mobilisation of excess salts can have adverse off-site environmental impacts.

Table 1. Salinity classes of irrigation waters (Environment Protection Authority 1991).

Class	TDS* (mg·L^{-1})	EC* (μS·cm^{-1})	Comments
1	0–175	0–270	Can be used for most crops on most soils by all methods or water application with little likelihood that a salinity problem will develop. Some leaching is required, but this will occur under normal irrigation practices, except in soils of extremely low soil permeabilities.
2	175–500	270–780	Can be used if a moderate amount of leaching occurs. Plants with moderate salt tolerance can be grown, usually without special salinity management practices. Sprinkler irrigation with the more saline waters in this class may cause leaf scorch on salt-sensitive crops.
3	500–1500	780–2340	Do not use the more saline waters in this class on soils with restricted drainage. Even with adequate drainage, best practice management controls for salinity may be required, and the salt tolerance of the plants to be irrigated must be considered.
4	1500–3500	2340–5470	For use, soils must be permeable with adequate drainage. Water must be applied in excess to provide considerable leaching, and salt-tolerant crops should be grown.
5	>3500	>5470	Not suitable for irrigation except on well drained soils under good management, especially leaching. Restrict to salt-tolerant crops, or for occasional emergency use.

* See conversions at end of this chapter.

An indication of typical salinity levels found in dairy effluent storages is provided by (Waters 1999), who quotes levels from south-western Victoria measured in 1996 ranging from 2800 to 7700 EC units (μS·cm^{-1}).

Assessing application impacts

In assessing the risks associated with the application to land of effluent with elevated salinity levels, assess the following issues:

- The existing salinity status of the soils and the surface and groundwater in the region and on the farm.
- The potential salinity level on application, allowing for any dilution (refer to Table 1).
- The proposed method of effluent application (spray application of saline waters can cause leaf burn in certain crops or pastures depending on salinity levels, crop susceptibility, application timing and temperature).
- Climatic variables, especially rainfall–evaporation interactions (levels of water application to sustain crop or pasture growth, leaching attained from applied water or from rainfall).

An assessment of these factors will help determine whether there is a significant risk of adverse impacts on production or the environment resulting from salinity applied in effluent. In cases where Class 3, 4 or 5 water is to be applied (Table 1), where significant salinity effects exist in the region or on the farm, where site variables (including adverse drainage, or soil or groundwater conditions) indicate a risk, or where climatic variables indicate a risk of salt accumulation, use salinity budgeting to assess the risks.

The salinity status of the potential effluent reuse site must be considered in relation to several factors:

- Existing soil salinity levels are often variable and are of more value when recorded over time and assessed in conjunction with water application, rainfall, surrounding surface or groundwater depth and salinity level fluctuations.
- Groundwater depth and salinity levels: Shallow (typically <2.0 m below natural surface) and saline groundwaters can make site salinity management difficult.
- Groundwater beneficial uses and environmental interactions: Increased salinity levels can significantly affect other users. Impacts can result where groundwaters approach or broach the surface or interact with surface waters.
- Site surface drainage: Good surface drainage is preferable.
- Soil permeability: Soils with low permeability can make site salinity management difficult. In clayey soils, the impacts of irrigation, rainfall, salt and sodium on soil permeability need to taken into account.
- Soil profile potential leaching fraction: If the amount of leaching that can be achieved is low, salinity management will be more difficult.

Salinity budgeting

Where elevated salinity loadings to land are sustained or where there is significant risk of adverse effects on production and the environment resulting from salinity (see above), use salinity to budgeting assess the suitability of land application by considering a number of interactive factors. A number of salinity budgeting options are available (ANZECC & ARMCANZ 2000, Ayers and Westcot 1989). These typically calculate the estimated soil salinity level from applied water quality, any dilution, application rate, rainfall and the achievable leaching fraction. The predicted soil salinity is correlated with soil salinity tolerances of crops (Ayers and Westcot 1989), thereby providing an estimate of yield loss resulting from salinity for a particular plant species. Salinity budgeting can be used to indicate a leaching requirement that will maintain sufficiently low soil salinity to limit production losses to an acceptable level. A comparison between this leaching requirement and the perceived achievable leaching fraction provides one component of an assessment of dairy effluent application suitability.

Leaching of salts

Where there is significant risk of adverse production and environmental impacts from salinity (see above), some leaching of salts is typically required to maintain sufficiently low rootzone salinity levels. In addition to the site production aspects assessed through salinity budgeting, the fate of these leached salts must also be taken into consideration. The estimation of achievable leaching fraction is typically based on experience and needs to consider any soil drainage enhancement, soil physical characteristics, and the interactions of sodium, calcium and salinity with soil structure (Doorenbos and Pruitt 1984). The interactions of these factors dictate the changeable nature of leaching fractions and require that a range of leaching fractions be considered. Use rainfall data and water budgeting in the salinity budgeting. Typically leaching should be facilitated by rainfall. Where this is insufficient, additional water over and above plant water demands should be applied to facilitate leaching (Environment Protection Authority 1991). Monitoring of topsoil and subsoil salinity is typically recommended to ascertain the effectiveness of leaching (see chapter 7 'Monitoring and sampling').

Salinity budgeting process

Although a range of salinity assessment options are available, one process for assessment of the suitability of land application, sourced and adapted from ANZECC & ARMCANZ (2000), details five key steps:

Step 1

Identify the key interactive factors, including:

- salinity levels of waters to be applied
- shandying ratio and water application rates
- the resulting salt loadings
- climatic information, including rainfall and evaporation
- soil properties and relevant hydrological and hydrogeological features
- plant salt tolerances
- relevant site management.

Step 2

Estimate the achievable leaching fraction under the proposed water application regime (see ANZECC & ARMCANZ (2000)).

Step 3

Estimate the new average root zone salinity (see ANZECC & ARMCANZ (2000)). Average rootzone salinity is the key limitation to plant growth in response to the application of water with elevated salinity. However, poor soil structure resulting from salinity and sodium can also reduce plant yields by limiting aeration, water infiltration and root growth.

Step 4

Estimate relative plant yield loss due to salinity (see ANZECC & ARMCANZ (2000)).

Step 5

Consider salinity impacts within the broader catchment, such as regional water tables, groundwater pollution and surface water quality.

Steps 2 to 4 cover what is typically considered salinity budgeting. Further salinity budgeting examples are provided at the end of the chapter. Software such as SALF and SALF PREDICT can estimate the parameters necessary for a detailed assessment of irrigation water quality in relation to soil properties, rainfall, water quality and plant salt tolerance. This type of software is based on summer rainfall areas and should be used with some caution in winter rainfall areas (DPI 2001).

Salinity management and monitoring

Where there is significant risk of adverse effects on production and the environment from salinity, success is often determined by a combination of prudent site management and careful monitoring. The actual yield reduction due to salinity will vary considerably and will depend on a range of management factors, but will be dictated mainly by irrigation water salinity levels and the degree of leaching attained with rainfall and irrigation water. The following salinity management strategies can reduce the risk of adverse impacts:

- Good site design, the provision of good surface drainage and accurate water application infrastructure (such as sprinklers).
- Proficient water application scheduling to match plant demands and leaching requirements, in conjunction with regular climatic and soil moisture monitoring (see chapter 7 'Monitoring and sampling').
- The regular application of gypsum according soil monitoring results.
- Where salinity budgeting indicates a risk, monitor management practices, soils, crop production levels, groundwater and surface runoff. Assess monitoring results in conjunction with the results from the monitoring of all site environmental, management and production parameters.
- Where salinity risks are suspected, a hand-held electrical conductivity meter can be a valuable and relatively cheap tool providing for easy field assessment of water (e.g. water source, effluent pond), the effluent application site (e.g. paddock runoff), the farm (e.g. runoff recycling dam, groundwater) and within the broader catchment (e.g. neighbouring creeks).
- Risks can be reduced by spreading small amounts of effluent over a large area (Waters 1999).

Example salinity budget calculations

Example 1—Leaching requirements for perennial pasture

What leaching fraction is required and what will the yield loss be, if any, if saline bore water (2000 EC units = 2000 $\mu S \cdot cm^{-1}$ = 2.0 $dS \cdot m^{-1}$ = 1280 ppm TDS) is applied to a perennial ryegrass–clover pasture (*Lolium perenne* and *Trifolium repens*) where the bore water is shandied in a ratio of 1:1 with irrigation water at 300 EC units (= 300 $\mu S \cdot cm^{-1}$ = 0.3 $dS \cdot m^{-1}$ = 192 ppm TDS) and effective leaching winter rainfall (Ayers and Westcot 1989)?

Bore water salinity	2000 EC units = 2.0 $dS \cdot m^{-1}$
Irrigation water	300 EC units = 0.3 $dS \cdot m^{-1}$
Dilution ratio	1:1
Applied water salinity	1150 EC units = 1.15 $dS \cdot m^{-1}$
Irrigation application rate	7.0 $ML \cdot ha^{-1}$*
Average irrigation season rainfall	300 mm*

* Values typically derived from water budgeting—see chapter 3.9 'Hydraulic application rate and scheduling'.

Estimated rainfall salinity	50 $dS \cdot m^{-1}$
Average irrigation + rainfall salinity	0.8 $dS \cdot m^{-1}$

Soil salinity thresholds and yield reductions (Ayers and Westcot (1989):

Perennial ryegrass:	No yield reduction = 5.6 dS·m^{-1}
	10% yield reduction = 6.9 dS·m^{-1}
	25% yield reduction = 8.9 dS·m^{-1}
White clover:	No yield reduction = 1.5 dS·m^{-1}
	10% yield reduction = 2.3 dS·m^{-1}
	25% yield reduction = 3.6 dS·m^{-1}

Calculate leaching requirement as (irrigation water salinity) / (5 × soil salinity threshold – irrigation water salinity) (Ayers and Westcot 1989):

Ryegrass:	0.8 / (5 × 5.6 – 0.8) × 100% ≈ 3%
Clover:	0.8 / (5 × 1.5 – 0.8) × 100% ≈ 12%

Additional water required for leaching to achieve no yield reduction:

Ryegrass leaching requirement of 3%	0.21 ML (i.e. 3% of 7 ML·ha^{-1} annual irrigation application)
Clover leaching requirement of 12%	0.84 ML

This calculation indicates that a 3% leaching fraction will be required to avoid yield loss in perennial ryegrass, and 12% for white clover. If we assume that the soil could accommodate a leaching fraction of 12%, an additional 0.84 ML of irrigation water would need to be applied over and above plant water requirements to sufficiently leach salts from the pasture rootzone for white clover.

Let's say that an examination of the soil profile on this dairy farm indicates an achievable leaching fraction of 5%. Example 2 below shows how calculate the yield loss from this water application scenario.

Example 2—Estimated yield reduction at set leaching fraction

What will the yield loss be, if any, if irrigation water diluted to 1150 EC units (= 1150 µS·cm^{-1} = 1.15 dS·m^{-1} = 736 ppm TDS) is applied to a perennial ryegrass–clover pasture where the achievable leaching fraction is 5% (Ayers and Westcot 1989)?

Applied water salinity	1150 EC units = 1.15 dS·m^{-1}
Irrigation application rate	7.0 ML·ha^{-1}*
Average irrigation season rainfall	300 mm*

* Values typically derived from water budgeting—see chapter 3.9 'Hydraulic application rate and scheduling'.

Estimated rainfall salinity	50 dS·m^{-1}
Average irrigation + rainfall salinity	0.8 dS·m^{-1}
Achievable leaching fraction	5%

Calculate resulting soil salinity as (irrigation water salinity / leaching fraction) + irrigation water salinity) divided by 5 (Ayers and Westcot 1989):

Resulting soil salinity	(0.8/0.05 + 0.8) / 5 = 3.36 dS·m^{-1}

The application of water with a salinity level of 1150 EC units at 7.0 ML·ha^{-1}, under average annual rainfall and a leaching fraction of 5%, will give the soil a salinity level of 3.36 dS·m^{-1}.

3.6 Salinity

Soil salinity thresholds and yield reductions (Ayers and Westcot 1989):

Perennial ryegrass:	No yield reduction = 5.6 dS·m^{-1}
	10% yield reduction = 6.9 dS·m^{-1}
	25% yield reduction = 8.9 dS·m^{-1}
White clover:	No yield reduction = 1.5 dS·m^{-1}
	10% yield reduction = 2.3 dS·m^{-1}
	25% yield reduction = 3.6 dS·m^{-1}

A soil salinity level of 3.36 dS·m^{-1} will not cause any yield reduction in perennial ryegrass, as the soil salinity threshold for yield reduction in ryegrass is 5.6 dS·m^{-1}. However, in the more salt-sensitive white clover, it will cause a predicted yield reduction of 23% (by interpolation).

The managers of the example dairy farm need to decide whether they can tolerate a 23% loss in white clover production and, if not, will have to reduce the amount of salt applied through, for example, further dilution with the bore water.

The impacts of leaching these salts with irrigation water and winter rainfall need to be taken into consideration, especially in relation to other areas of the farm and in the broader catchment, notably regional water table depth, groundwater quality and surface water impacts.

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