3.7 Sodicity

Sodicity is the presence of a high proportion of sodium ions relative to calcium plus magnesium ions in water or to the cation exchange capacity of a soil.

The potential for sodium to degrade soil structure, resulting in erosion, reduced permeability and subsequent waterlogging, and a decline in plant growth, in part determines the suitability of dairy effluent for land application. The sodium levels of dairy effluent and existing and potential soil sodicity levels can be used to calculate the risk associated with land application.

Elevated sodium levels in dairy effluent and the subsequent elevated soil sodicity levels can often be managed through a range of strategies, such as the application of gypsum or organic matter.

Sodium in dairy effluent

In relation to sodium, the suitability of water for application to land should be evaluated on the basis of a range of criteria that indicate the potential of the water to harm plant growth or to create soil conditions hazardous to plant growth or to animals or humans in contact with the plants or soil (ANZECC & ARMCANZ 2000). Dairy effluent sodicity levels are assessed through calculation of the sodium adsorption ratio (SAR), which is a measure of the amount of sodium present in the effluent relative to calcium plus magnesium (Rengasamy and Olsson 1993).

Calculation of SAR

The SAR is calculated with Equation 1; note that Na^+, Ca^{2+} and Mg^{2+} are measured in $cmol^+ \cdot kg^{-1}$. For this calculation the dairy effluent must first be analysed for all three ions.

$$SAR = Na^+ / \sqrt{((Ca^{2+} + Mg^{2+}) / 2)} \qquad (1)$$

The SAR can be adjusted (SAR_{adj}) by Equation 2 to take into account the effects of electrical conductivity (EC), carbonate and bicarbonate (Environment Protection Authority 1991). For this, Ca^{2+} is replaced by Ca_x, which is determined by the EC of the effluent and the bicarbonate-to-calcium ratio (HCO_3^-/Ca^{2+}) of the effluent (Table 2) (Environment Protection Authority 1991). Concentrations of Na^+ and Mg^{2+} in milliequivalents per litre ($mEq \cdot L^{-1}$) are determined from Table 1.

Table 1. Factors for conversion of ions from $mg \cdot L^{-1}$ to $mEq \cdot L^{-1}$ (Environment Protection Authority 1991).

		Conversion	
Na^+	$mg \cdot L^{-1}$	× 0·0435	$mEq \cdot L^{-1}$
Mg^{2+}	$mg \cdot L^{-1}$	× 0·0833	$mEq \cdot L^{-1}$
Ca^{2+}	$mg \cdot L^{-1}$	× 0·0500	$mEq \cdot L^{-1}$
HCO_3^-	$mg \cdot L^{-1}$	× 0·0164	$mEq \cdot L^{-1}$
$CaCO_3$	$mg \cdot L^{-1}$	× 0·0200	$mEq \cdot L^{-1}$

$$SAR_{adj} = Na^+ / \sqrt{((Ca_x + Mg^{2+}) / 2)} \qquad (2)$$

3.7 Sodicity

Table 2. Values of Ca_x determined by salinity (EC) and the bicarbonate-to-calcium ratio (HCO_3^-/Ca^{2+}) of the effluent—for use in Equation 2 (Environment Protection Authority 1991).

Ratio of HCO_3/Ca	Irrigation water EC (dS m^{-1})											
	0.10	0.20	0.30	0.50	0.70	1.00	1.50	2.00	3.00	4.00	6.00	8.00
0.05	13.20	13.61	13.92	14.40	14.79	15.26	15.91	16.43	17.28	17.97	19.07	19.94
0.10	8.31	8.57	8.77	9.07	9.31	9.62	10.02	10.35	10.89	11.32	12.01	12.56
0.15	6.34	6.54	6.69	6.92	7.11	7.34	7.65	7.90	8.31	8.64	9.17	9.58
0.20	5.24	5.40	5.52	5.71	5.87	6.06	6.31	6.52	6.86	7.13	7.57	7.91
0.25	4.51	4.65	4.76	4.92	5.06	5.22	5.44	5.62	5.91	6.15	6.52	6.82
0.30	4.00	4.12	4.21	4.36	4.48	4.62	4.82	4.98	5.24	5.44	5.77	6.04
0.35	3.61	3.72	3.80	3.94	4.04	4.17	4.35	4.49	4.72	4.91	5.21	5.45
0.40	3.30	3.40	3.48	3.60	3.70	3.82	3.98	4.11	4.32	4.49	4.77	4.98
0.45	3.05	3.14	3.22	3.33	3.42	3.53	3.68	3.80	4.00	4.15	4.41	4.61
0.50	2.84	2.93	3.00	3.10	3.19	3.29	3.43	3.54	3.72	3.87	4.11	4.30
0.75	2.17	2.24	2.29	2.37	2.43	2.51	2.62	2.70	2.84	2.95	3.14	3.28
1.00	1.79	1.85	1.89	1.96	2.01	2.09	2.16	2.23	2.35	2.44	2.59	2.71
1.25	1.54	1.59	1.63	1.68	1.73	1.78	1.86	1.92	2.02	2.10	2.23	2.33
1.50	1.37	1.41	1.44	1.49	1.53	1.58	1.65	1.70	1.79	1.86	1.97	2.07
1.75	1.23	1.27	1.30	1.35	1.38	1.43	1.49	1.54	1.62	1.68	1.78	1.86
2.00	1.13	1.16	1.19	1.23	1.26	1.31	1.36	1.40	1.48	1.54	1.63	1.70
2.25	1.04	1.08	1.10	1.14	1.17	1.21	1.26	1.30	1.37	1.42	1.51	1.58
2.50	0.97	1.00	1.02	1.06	1.09	1.12	1.17	1.21	1.27	1.32	1.40	1.47
3.00	0.85	0.89	0.91	0.94	0.96	1.00	1.04	1.07	1.13	1.17	1.24	1.30
3.50	0.78	0.80	0.82	0.85	0.87	0.90	0.94	0.97	1.02	1.06	1.12	1.17
4.00	0.71	0.73	0.75	0.78	0.80	0.82	0.86	0.88	0.93	0.97	1.03	1.07
4.50	0.66	0.68	0.69	0.72	0.74	0.76	0.79	0.82	0.86	0.90	0.95	0.99
5.00	0.61	0.63	0.65	0.67	0.69	0.71	0.74	0.76	0.80	0.83	0.88	0.93
7.00	0.03	0.50	0.52	0.53	0.55	0.57	0.59	0.61	0.64	0.67	0.71	0.74
10.00	0.39	0.40	0.41	0.42	0.43	0.45	0.47	0.48	0.51	0.53	0.56	0.58
20.00	0.24	0.25	0.26	0.26	0.27	0.28	0.29	0.30	0.32	0.33	0.35	0.37

Consequences of SAR

The SAR of dairy effluent can vary considerably and depends on the sodium levels in the water used in the dairy, on dairy shed and feedpad management and on effluent treatment. Typical and usually safe SAR levels for dairy effluent are 1 to 6, but levels up to 10 are not uncommon. The SAR can approach 20 in some cases, and values over 20 indicate severe sodicity problems.

In assessing the suitability of effluent for land application, you must also assess the propensity for sodium-related problems to develop. Some soils, especially those with a high clay content, poor subsoil structure or low permeability, can retain excessive exchangeable sodium, which breaks down soil structure and reduces permeability under rainfall or freshwater irrigation (Rengasamy *et al.* 1984). Figure 1 indicates the risk of permeability problems developing. However, the interaction between soil structure, exchangeable sodium and salinity is complex, and the permeability of the soil resulting from these interactions readily fluctuates, especially over the course of a season (Rengasamy and Olsson 1991, Rengasamy and Olsson 1993).

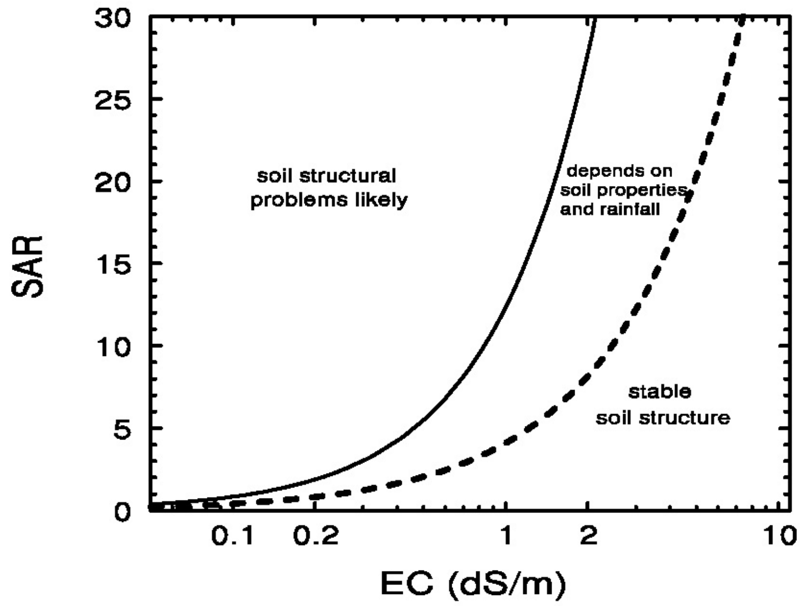

Figure 1. The risk of soil structural change in relation to the salt content of irrigation waters (ANZECC & ARMCANZ 2000).

Sodium in soils

Sodium at high concentrations in soils, especially at a high ratio to other cations, has a detrimental effect on soil structure and thus on plant growth (Rengasamy *et al.* 1984). Sodicity degrades soil structure by breaking down clay aggregates, which makes the soil more susceptible to erosion and dispersion (Rengasamy and Olsson 1991). The dispersed soil particles are then washed away by low-salinity water such as rainfall or irrigation (Rengasamy and Olsson 1993).

Calculating soil exchangeable sodium percentage

Where high soil sodium levels are likely (e.g. soils with high clay content, poor subsoil structure or low permeability), it is important to regularly assess soil exchangeable sodium percentage (ESP) levels to gauge soil structural stability.

The ESP considers the balance between sodium ions and the cation exchange capacity (CEC) of a soil. It is calculated by dividing exchangeable sodium by the CEC or, as the majority of the CEC is due to sodium, potassium, calcium and magnesium, the sum of these four exchangeable cations:

ESP = exch. Na ($cmol^{+}\cdot kg^{-1}$) × 100 / (exch. Na + exch. Mg + exch. Ca + exch. K) ($cmol^{+}$ or $cmol^{2+}\cdot kg^{-1}$)

Table 3 indicates the effects of the soil ESP.

Table 3. Suitability of soil by ESP.

ESP	Rating	Comments
<5	Satisfactory	Insufficient proportion of Na to cause dispersion
5–6	Marginal	Potentially sufficient Na to cause dispersion
6–15	Poor	Likely structural problems caused by high proportion of Na
>15	Very poor	Definite structural problems caused by high proportion of Na

In Australia, a soil with an ESP > 6 is technically termed a sodic soil, and soils with an ESP > 15 are considered to be highly sodic.

Effects of soil sodicity on soil

High concentrations of sodium in a soil create a state of easy dispersion, leading to poor soil physical conditions (Rengasamy and Olsson 1993) such as:

- low hydraulic conductivity, conceivably due to blockage of pores by dispersed colloids
- the downward movement of dispersed material, leading to the formation of a clay pan, which can limit root development and drainage
- unfavourable soil consistency: hard when dry and plastic-sticky when moist; such soils are difficult to work
- a low resistance to slaking, easily leading to the formation of surface crusts, which hamper water infiltration and plant emergence
- waterlogging resulting from the general deterioration of soil drainage associated with the above effects.

Take care in relating poor drainage in the soil to high ESP levels since, although high ESP frequently causes poor drainage, inherent poor drainage characteristics of the soil may also lead to high soil salinity and high ESP values (Rengasamy and Olsson 1993).

Effects of soil sodicity on plant growth

The mainly osmotic effects of salts on crop transpiration and growth are related to total salt concentration rather than to the individual concentrations of specific ions such as sodium. However, sodium typically plays a significant role in salinity, as it is a constituent of the harmful salt sodium chloride. The effects of salts on plants are generally evidenced as reduced transpiration and retarded growth, producing smaller plants with fewer and smaller leaves. Effects of high soil sodicity on plants growth can also materialise in the form of a toxicity or a nutritional imbalance. The effects of specific solutes, or their proportions, especially chloride, sodium and boron, can reduce plant growth. These effects are generally evidenced by leaf burn and defoliation.

Managing sodicity

In applying sodic waters to land it is important to ensure a high level of irrigation design, accurate irrigation infrastructure, proficient irrigation scheduling to match plant demands and regular detailed monitoring. Strategies for the management of sodicity are similar to those for managing salinity (Rengasamy and Olsson 1991):

- Minimise sodium levels in any applied water wherever possible. This is likely to include sourcing low-sodium dairy shed water and minimising sodium in feedstuffs and sanitisers.
- Regularly apply gypsum at rates determined from the results of regular soil chemistry analyses. Applications typically vary from 1 to 5 $t{\cdot}ha^{-1}$ every 1 to 5 years.
- Provide good surface drainage to divert excess irrigation and rainfall runoff.
- Grow crops that are more tolerant of elevated soil sodium levels.
- Raise soil organic levels.

Monitoring sodicity

Details on monitoring sodium levels are provided in chapter 7 'Monitoring and sampling'.

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