Sodium Adsorption Ratio

The relationship between sodium, calcium, and magnesium ions in irrigation water is expressed by Sodium Adsorption Ratio (SAR), where:

$$SAR = \frac{[Na^{+}]}{\sqrt{\frac{[Ca^{+2}]+[Mg^{+2}]}{2}}}$$

All ion concentrations are expressed as milliequivalents per liter (meq/l). To convert meq/l to mg/l (or ppm), multiply the specific ion by its equivalent weight:

meq/l x equivalent weight = mg/l or ppm

Equivalent weights for sodium, calcium, and magnesium are 23, 20, and 12.2, respectively (Table 18). Guidelines for correlating SAR values with potential problems are provided in Table 19.

Exchangeable Sodium Percentage

An additional soil parameter to measure is exchangeable sodium percentage (ESP). This indicates the percent of sodium that occupies cation exchange sites of a soil (or soil sodium saturation):

$$ESP = \frac{\text{Exchangeable sodium (meq/100 grams)}}{\text{Cation exchange capacity}} \times 100$$

ESP indicates the impermeability of soil to water and air. Usually little or only minor problems occur when ESP values are less than 15 percent. Over 15 percent, soil physical changes occur which may cause impermeability to water and air, especially if EC_w of irrigation water is less than 2 dS/m (Table 20). Increasing problems occur with values approaching 80 percent. Symptoms of reduced permeability include waterlogging, reduced infiltration rates, crusting, compaction, and poor aeration.

BICARBONATES

Water that is low in sodium and dissolved salts but high in bicarbonates (HCO_3^-) may result in increasing soil pH to an approximate maximum pH of 8.0 to 8.5. Calcium carbonate and magnesium carbonate may then precipitate out as lime. An increase in effective sodium percentage of the water in place of calcium and magnesium then occurs. In this way, calcium- or magnesium-dominant soils can become a sodium-

Table 18. Laboratory analysis to determine water quality.

Analysis	Reporting symbol	Reporting unit	Equivalent weight
Electrical conductivity	EC_w	mmhos/cm	--
Calcium	Ca	meq/l	20
Magnesium	Mg	meq/l	12.2
Sodium	Na	meq/l	23
Carbonate	CO_3	meq/l	30
Bicarbonate	HCO_3	meq/l	61
Chloride	Cl	meq/l	35.4
Sulphate	SO_4	meq/l	48
Boron	B	mg/l	--
Nitrate-nitrogen	NO_3-N	mg/l	14
Acidity	pH	pH	--
SAR	---		--
Potassium	K	meq/l	39.1
Lithium	Li	mg/l	7
Iron	Fe	mg/l	--
Ammonium-nitrogen	NH_4-N	mg/l	14
Phosphate phosphorus	PO_4-P	mg/l	31