University of California
Cooperative Extension
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WATER QUALITY

Guidelines for Interpretation of Water Quality for Agriculture

(UC-Committee of Consultants)

Guidelines were originally distributed to Cooperative Extension staff in December 1973. Suggestions for needed changes, additions, and corrections have been made as received. The present "guidelines" are revised to January 15, 1975 and include -

1. Guidelines for Interpretation of Quality of Water for Irrigation.
2. Assumptions and Comments on "Guidelines".
3. Crop Tolerance and Leaching Requirement Tables - Field Crops.
4. " " " " " " - Vegetable Crops.
5. " " " " " " - Fruit Crops
6. " " " " " " - Forage Crops
7. Example - Use of Crop Tolerance Tables.
8. Boron in Irrigation Waters.
9. Tolerance of Ornamental Shrubs and Ground Covers to Salinity in Irrigation Water.
10. Recommended Maximum Concentrations of Trace Elements in Irrigation Waters.
11. Guide to Use of Saline Waters for Livestock and Poultry.
12. Guidelines To Levels of Toxic Substances in Drinking Water For Livestock.
13. Tables for Calculating pHc Values of Waters.

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GUIDELINES FOR INTERPRETATION OF QUALITY OF WATER FOR IRRIGATION

Interpretations are based on possible effects of constituents on crops and/or soils. Guidelines are flexible and should be modified when warranted by local experience or special conditions of crop, soil, and method of irrigation.

PROBLEM AND RELATED CONSTITUENT	WATER QUALITY GUIDELINES		
	No Problem	Increasing Problems	Severe Problems
Salinity[1]			
EC_w of irrigation water, in millimhos/cm	<0.75	0.75 - 3.0	>3.0
Permeability			
EC_w of irrigation water, in mmho/cm	>0.5	<0.5	<0.2
adj.SAR[2]	<6.0	6.0 - 9.0	>9.0
Specific Ion Toxicity[3]			
from ROOT absorption			
Sodium (evaluate by adj.SAR)	<3	3.0 - 9.0	>9.0
Chloride (me/l)	<4	4.0 - 10	>10
(mg/l or ppm)	<142	142 - 355	>355
Boron (mg/l or ppm)	<0.5	0.5 - 2.0	2.0 - 10.0
from FOLIAR absorption[4] (sprinklers)			
Sodium (me/l)	<3.0	>3.0	----
(mg/l or ppm)	<69	>69	----
Chloride (me/l)	<3.0	>3.0	----
(mg/l or ppm)	<106	>106	----
Miscellaneous[5]			
NH_4-N, NO_3-N (mg/l or ppm) for sensitive crops	<5	5 - 30	>30
HCO_3 (me/l) [only with overhead sprinklers]	<1.5	1.5 - 8.5	>8.5
HCO_3 (mg/l or ppm) [only with overhead sprinklers]	<90	90 - 520	>520
pH	normal range =	6.5 - 8.4	-----

1/ Assumes water for crop plus needed water for leaching requirement (LR) will be applied. Crops vary in tolerance to salinity. Refer to tables for crop tolerance and LR. (mmho/cm X640= approximate total dissolved solids (TDS) in mg/l or ppm; mmhoX1000= micromhos)

2/ adj. SAR (Adjusted Sodium Adsorption Ratio) is calculated from a modified equation developed by U.S. Salinity Laboratory to include added effects of precipitation or dissolution of calcium in soils and related to CO_3 + HCO_3 concentrations.

To evaluate sodium (permeability) hazard: $$\text{adj.SAR} = \frac{Na}{\sqrt{\frac{Ca + Mg}{2}}} \left[1 + (8.4 - pHc) \right]$$

pHc is a calculated value based on total cations, Ca+Mg, and CO_3+HCO_3. Calculating and reporting will be done by reporting laboratory. NOTE: Na, Ca+Mg, CO_3+HCO_3 should be in me/l.

Permeability problems, related to low EC or high adj.SAR of water, can be reduced if necessary by adding gypsum. Usual application rate per acre foot of applied water is from 200 to about 1000 lbs. (234 lbs. of 100% gypsum added to 1 acre foot of water will supply 1 me/l of calcium and raise the ECw about 0.1 mmho). In many cases a soil application may be needed.

3/ Most tree crops and woody ornamentals are sensitive to sodium and chloride (use values shown). Most annual crops are not sensitive (use salinity tolerance tables). For boron sensitivity, refer to boron tolerance tables.

4/ Leaf areas wet by sprinklers (rotating heads) may show a leaf burn due to sodium or chloride absorption under low-humidity, high-evaporation conditions. (Evaporation increases ion concentration in water films on leaves between rotations of sprinkler heads.)

5/ Excess N may affect production or quality of certain crops, e.g. sugar beets, citrus, avocados, apricots, grapes etc.
(1 mg/l NO_3-N = 2.72 lbs. N/acre foot of applied water).
HCO_3 with overhead sprinkler irrigation may cause a white carbonate deposit to form on fruit and leaves.

Symbol	Name
EC_w	Electrical Conductivity of water
mmho/cm	millimho per centimeter
<	less than
>	more than
mg/l	milligrams per liter
ppm	parts per million
LR	Leaching Requirement
me/l	milliequivalents per liter
TDS	Total Dissolved Solids

Symbol	Name	Equiv. Wt.
Na	Sodium	23.00
Ca	Calcium	20.04
Mg	Magnesium	12.16
CO_3	Carbonate	30.00
HCO_3	Bicarbonate	61.00
NO_3-N	Nitrate-nitrogen	14.00
Cl	Chloride	35.45

17.1 ppm = 1 grain per gallon

Assumptions and Comments on Guidelines for Interpretation of Quality of Water for Irrigation Developed by UC-Committee of Consultants.

1. These "guidelines" are flexible and intended for use in estimating the potential hazards to crop production associated with long term use of the particular water being evaluated. "Guidelines" should be modified when warranted by local experience and special conditions of crop, soil, method of irrigation or level of soil-water-crop management. Changes of 10 to 20 percent above or below an indicated guideline value may have little significance if considered in proper perspective along with all other variables that enter into a yield of crop.

2. It is assumed that the water will be used under average conditions - soil texture, internal drainage, total water use, climate, and salt tolerance of crop. Large deviations from the average might make it unsafe to use water which under average conditions, would be good, or might make it safe to use water, which under average conditions, would be of doubtful quality.

3. The divisions into "No problem - Increasing problem - Severe problem" is more-or-less arbitrary but based on large numbers of field studies and observations, as well as carefully controlled greenhouse and small plot research conducted by various researchers over the past 40 years or more. Guidelines of one sort or another have been proposed by U.S. Geological Survey, University of California, U.S. Salinity Laboratory and many others starting as early as 1911. As new research and observations have developed additional information for assessing water quality, guidelines have been modified.

4. These "guidelines" apply to surface irrigation methods such as furrow, flood, basin, sprinklers, or any other which applies water on an "as-needed" basis and which allows for an extended dry-down period between irrigations during which the crop uses up a considerable portion of the available stored water.

5. The guidelines incorporate some of the newer concepts in soil-plant-water relationships as recently developed at U.S. Salinity Laboratory. Uptake of water occurs mostly from the upper two-thirds of the rooting depth of crop (the "more-active" part of the root zone). Each irrigation normally will leach this upper soil area and maintain it at relatively low salinity. Salts applied in the irrigation water under reasonable irrigation management concentrate in the soil water in this active root zone to about three times the concentration of the applied irrigation water and the salinity of this root area is representative of the salinity levels to which the plant responds. The salinity of the lower root zone is of less importance as long as plants are reasonably well supplied with moisture in the upper, "more-active", root zone.

These guidelines represent the 1974 consensus of the UC-Committee of Consultants. It is recognized they are not perfect and it is expected they will be modified from time to time as further knowledge and experience dictate.

CROP TOLERANCE [illegible]ES[1] - FIELD CROPS

CROP	Expected Yield Reduction[2] at ECe or ECw indicated: 0% ECe[3]	0% ECw[4]	0% LR[5]	10% ECe	10% ECw	10% LR	25% ECe	25% ECw	25% LR	50% ECe	50% ECw	50% LR	MAXIMUM ECdw[6]
Barley[7] (Hordeum vulgare)	8.0[7]	5.3	10%	10	6.7	12%	13	8.7	15%	18	12	21%	56
Cotton (Gossypium hirsutum)	7.7	5.1	10%	9.6	6.4	12%	13	8.3	15%	17	12	21%	54
Sugarbeet (Beta vulgaris)	7.0[7]	4.7	10%	8.7	5.8	12%	11	7.5	16%	15	10	21%	48
Wheat[7] [8] (Triticum aestivum)	6.0[7]	4.0	10%	7.4	4.9	12%	9.5	6.4	16%	13	8.7	22%	40
Safflower (Carthamus tinctorius)	5.3	3.5	12%	6.2	4.1	14%	7.6	5.0	17%	9.9	6.6	23%	29
Soybean (Glycine max)	5.0	3.3	17%	5.5	3.7	18%	6.2	4.2	21%	7.5	5.0	25%	20
Sorghum (Sorghum bicolor)	4.0	2.7	7%	5.1	3.4	9%	7.2	4.8	13%	11	7.2	20%	36
Groundnut (Arachis hypogaea)	3.2	2.1	16%	3.5	2.4	18%	4.1	2.7	21%	4.9	3.3	25%	13
Rice (paddy) (Ozyza sativa)	3.0	2.0	9%	3.8	2.6	11%	5.1	3.4	15%	7.2	4.8	21%	23
Sesbania (Sesbania macrocarpa)	2.3	1.5	6%	3.7	2.5	8%	5.9	3.9	12%	9.4	6.3	19%	33
Corn (grain) (Zea mays)	1.7	1.1	6%	2.5	1.7	8%	3.8	2.5	13%	5.9	3.9	20%	20
Flax (Linum usitatissimum)	1.7	1.1	6%	2.5	1.7	8%	3.8	2.5	13%	5.9	3.9	20%	20
Broadbean (Vicia faba)	1.6	1.1	4%	2.6	1.8	7%	4.2	2.0	12%	6.8	4.5	19%	24
Cowpea (Vigna sinensis)	1.3	0.9	5%	2.0	1.3	8%	3.1	2.1	12%	4.9	3.2	19%	17
Beans (field) (Phaseolus vulgaris)	1.0	0.7	5%	1.5	1.0	8%	2.3	1.5	12%	3.6	2.4	19%	13

VEGETABLE CROPS

CROP	Expected Yield Reduction[2] at EC_e or EC_w indicated												MAXIMUM
	0%			10%			25%			50%			
	ECe	ECw	LR	ECe	ECw	LR	ECe	ECw	LR	ECe	ECw	LR	ECdw
Beets[7] (Beta vulgaris)	4.0	2.7	9%	5.1	3.4	11%	6.8	4.5	15%	9.6	6.4	21%	30
Broccoli (Brassica italica)	2.8	1.9	7%	3.9	2.6	10%	5.5	3.7	14%	8.2	5.5	20%	27
Tomato (Lycopersicon esculentum)	2.5	1.7	7%	3.5	2.3	9%	5.0	3.4	13%	7.6	5.0	20%	25
Cucumber (Cucumis sativus)	2.5	1.7	8%	3.3	2.2	11%	4.4	2.9	15%	6.3	4.2	21%	20
Cantaloupe (Cucumis melo)	2.2	1.5	5%	3.6	2.4	7%	5.7	3.8	12%	9.1	6.1	19%	32
Spinach (spinacia oleracea)	2.0	1.3	4%	3.3	2.2	7%	5.3	3.5	12%	8.6	5.7	19%	30
Cabbage (Brassica oleracea capitata)	1.8	1.2	5%	2.8	1.9	8%	4.4	2.9	12%	7.0	4.6	19%	24
Potato (Solanum tuberosum)	1.7	1.1	6%	2.5	1.7	8%	3.8	2.5	13%	5.9	3.9	20%	20
Sweet corn (Zea mays)	1.7	1.1	6%	2.5	1.7	8%	3.8	2.5	13%	5.9	3.9	20%	20
Sweet potato (Ipomea batatas)	1.5	1.0	5%	2.4	1.6	8%	3.8	2.5	12%	6.0	4.0	19%	21
Pepper (Capsicum frutescens)	1.5	1.0	6%	2.2	1.5	9%	3.3	2.2	13%	5.1	3.4	20%	17
Lettuce (Lactuca sativa)	1.3	0.9	5%	2.1	1.4	8%	3.2	2.1	12%	5.2	3.4	19%	18
Radish (Raphanus sativas)	1.2	0.8	4%	2.0	1.3	7%	3.1	2.1	12%	5.0	3.4	19%	18
Onion (Allium cepa)	1.2	0.8	5%	1.8	1.2	8%	2.8	1.8	12%	4.3	2.9	19%	15
Carrot (Daucus carota)	1.0	0.7	4%	1.7	1.1	7%	2.8	1.9	12%	4.6	3.1	19%	16
Beans (Phaseolus vulgaris)	1.0	0.7	6%	1.5	1.0	8%	2.3	1.5	12%	3.6	2.4	19%	12.5

FRUIT CROPS

CROP	Expected Yield Reduction[2/] at EC_e or EC_w indicated												MAXIMUM
	0%			10%			25%			50%			
	ECe	ECw	LR	ECe	ECw	LR	ECe	ECw	LR	ECe	ECw	LR	ECdw
Date palm (Phoenix dactylifera)	4.0	2.7	4%	6.8	4.5	7%	10.9	7.3	11%	17.9	12	19%	64
Fig (Ficus carica) Olive (Olea europaea) Pomegranate (Puncia granatum)	2.7	1.8	6%	3.8	2.6	9%	5.5	3.7	13%	8.4	5.6	20%	28
Grapefruit (Citrus paradisi)	1.8	1.2	8%	2.4	1.6	10%	3.4	2.2	14%	4.9	3.3	21%	16
Orange (Citrus sinensis)	1.7	1.1	7%	2.3	1.6	10%	3.3	2.2	14%	4.8	3.2	20%	16
Lemon (Citrus limonea)	1.7	1.1	7%	2.3	1.6	10%	3.3	2.2	14%	4.8	3.2	20%	16
Apple (Pyrus malus) Pear (Pyrus communis)	1.7	1.0	6%	2.3	1.6	10%	3.3	2.2	14%	4.8	3.2	20%	16
Walnut (Juglans regia)	1.7	1.1	7%	2.3	1.6	10%	3.3	2.2	14%	4.8	3.2	20%	16
Peach (Prunus persica)	1.7	1.1	9%	2.2	1.4	11%	2.9	1.9	15%	4.1	2.7	21%	13
Apricot (Pyrus armeniaca)	1.6	1.1	9%	2.0	1.3	11%	2.6	1.8	15%	3.7	2.5	20%	12
Grape (Vitis spp.)	1.5	1.0	4%	2.5	1.7	7%	4.1	2.7	11%	6.7	4.5	19%	24
Almond (Prunus amygdalus)	1.5	1.0	7%	2.0	1.4	10%	2.8	1.9	13%	4.1	2.7	20%	14
Plum (Prunus domestica)	1.5	1.0	7%	2.1	1.4	10%	2.9	1.9	14%	4.3	2.8	20%	14
Blackberry (Rubus spp.)	1.5	1.0	8%	2.0	1.3	11%	2.6	1.8	15%	3.8	2.5	21%	12
Boysenberry (Rubus spp.)	1.5	1.0	8%	2.0	1.3	11%	2.6	1.8	15%	3.8	2.5	21%	12
Avocado (Persea americana)	1.3	0.9	7%	1.8	1.2	10%	2.5	1.7	15%	3.7	2.4	20%	12
Raspberry (Rubus idaeus)	1.0	0.7	6%	1.4	1.0	9%	2.1	1.4	13%	3.2	2.1	19%	11
berry ia chiloensis)	1.0	0.7	8%	1.3	0.9	10%	1.8	1.2	15%	2.5	1.7	21%	8

FORAGE CROPS

CROP	Expected Yield Reduction[2] at ECe or ECw indicated: 0% ECe	0% ECw	0% LR	10% ECe	10% ECw	10% LR	25% ECe	25% ECw	25% LR	50% ECe	50% ECw	50% LR	MAXIMUM ECdw
Tall wheat grass (Agropyron elongatum)	7.5	5.0	8%	9.9	6.6	10%	13.3	9.0	14%	19.4	13	21%	63
Wheat grass (fairway) (Agropyron elongatum)	7.5	5.0	11%	9.0	6.0	14%	11	7.4	17%	15	9.8	22%	44
Bermuda grass [9] (Cynodon dactylon)	6.9	4.6	10%	8.5	5.7	13%	10.8	7.2	16%	14.7	9.8	22%	45
Barley (hay) [7] (Hordeum vulgare)	6.0	4.0	10%	7.4	4.9	11%	9.5	6.3	16%	13.0	8.7	22%	40
Perennial rye grass (Lolium perenne)	5.6	3.7	10%	6.9	4.6	12%	8.9	5.9	16%	12.2	8.1	21%	38
Trefoil, birdsfoot [10] narrow leaf (L. corniculatus tenuifolius)	5.0	3.3	11%	6.0	4.0	13%	7.5	5.0	17%	10	6.7	22%	30
Harding grass (Phalaris tuberosa)	4.6	3.1	9%	5.9	3.9	11%	7.9	5.3	15%	11.1	7.4	21%	36
Tall fescue (Festula elatior)	3.9	2.6	6%	5.8	3.9	8%	8.6	5.7	12%	13.3	8.9	19%	46
Crested Wh. grass (Agropyron desertorum)	3.5	2.3	4%	6.0	4.0	7%	9.8	6.5	11%	16	11	19%	57
Vetch (Vicia sativa)	3.0	2.0	8%	3.9	2.6	11%	5.3	3.5	15%	7.6	5.0	21%	24
Sudan grass (Sorghum sudanense)	2.8	1.9	4%	5.1	3.4	7%	8.6	5.7	11%	14.4	9.6	18%	52
Wildrye, beardless (Elymus triticoides)	2.7	1.8	5%	4.4	2.9	7%	6.9	4.6	12%	11.0	7.4	19%	39
Trefoil, big (Lotus uliginosis)	2.3	1.5	10%	2.8	1.9	13%	3.6	2.4	16%	4.9	3.3	22%	15
Alfalfa (Medicago sativa)	2.0	1.3	4%	3.4	2.2	7%	5.4	3.6	12%	8.8	5.9	19%	31
Lovegrass [9] (Eragrostis spp.)	2.0	1.3	5%	3.2	2.1	8%	5.0	3.3	12%	8.0	5.3	19%	28

FORAGE CROPS (continued)

CROP	Expected Yield Reduction[2] at EC_e or EC_w indicated: 0% ECe	0% ECw	0% LR	10% ECe	10% ECw	10% LR	25% ECe	25% ECw	25% LR	50% ECe	50% ECw	50% LR	MAXIMUM ECdw
Corn (forage) (zea mays)	1.8	1.2	4%	3.2	2.1	7%	5.2	3.5	11%	8.6	5.7	18%	31
Clover, berseem (Trifolium alexandrinum)	1.5	1.0	3%	3.2	2.2	6%	5.9	3.9	10%	10.3	6.8	18%	38
Orchard grass (Dactylis glomerata)	1.5	1.0	3%	3.1	2.1	6%	5.5	3.7	11%	9.6	6.4	18%	35
Meadow Foxtail (Alopecurus pratensis)	1.5	1.0	4%	2.5	1.7	7%	4.1	2.7	11%	6.7	4.5	19%	24
Clover, alsike, ladino, red, strawberry (trifolium spp.)	1.5	1.0	5.5	2.3	1.6	8%	3.6	2.4	12%	5.7	3.8	19%	20

CROP TOLERANCE TABLES[1]

1/ Based on data as reported by MAAS and Hoffman (in press); Bernstein ( ), and University of California Committee of Consultants ( ).

2/ Expected yield reduction for the particular crop due to indicated salinity of soil or salinity of irrigation water.

3/ ECe means electrical conductivity of the saturation extract of the soil ( ) reported in millimhos per centimeter at 25°C. Values reported are from MAAS and Hoffman ( ) and Bernstein ( ).

4/ ECw means electrical conductivity of the irrigation water in millimhos per centimeter at 25°C. This assumes a 15 to 20% leaching fraction and an average salinity of soil water equal to about three times that of the irrigation water applied ($EC_{sw} = 3\ EC_w$) or about twice that of the soil saturation extract ($EC_{sw} = 2\ EC_e$). From the above, $EC_e = 1.5\ EC_w$.

CROP TOLERANCE TABLES[1/] (continued)

5/ LR means leaching requirement or the minimum leaching fraction that can be relied upon to control salts within the tolerance of the particular crop grown and considering the quality of water used. LR is determined from the equation $LR = EC_w/EC_{dw}$[6/].

6/ Maximum ECdw is the maximum salinity of the percolating water draining from the root zone that can result due to removal of water by the particular crop to meet its water requirement for growth (if all the root zone soil water were at this maximum ECdw, yield reduction would be 100% since the crop would be unable to extract water from the very salty soil water). This is the value used as ECdw in the LR calculation ($LR = EC_w/EDdw$). For the given crop and quality of water indicated, application of irrigation water to exactly meet the evapotranspiration demand of crop plus the LR to control salt should result in maximum efficiency of water use. At this efficiency, percolating water draining from the root zone would be minimal as to quantity but at a maximum as to salinity and should approach the maximum EC_{dw} as shown on these crop tolerance tables.

7/ Barley, wheat, sugar beets and several other crops are less tolerant of salts during germination and early seedling growth. For germination of beets, salinity of soil in the seed area should not exceed $EC_e = 3$ mmhos/cm; for barley and wheat, EC_e should not exceed $EC_e = 4$ or 5 mmhos/cm.

8/ Tolerance data may not apply to semi-dwarf varieties of wheat. These are often more tolerant.

9/ An average of Bermuda grass varieties. Suwanee and Coastal are about 20% more tolerant; common and Greenfield are about 20% less tolerant.

10/ Average of Boer, Wilman, Sand, and Weeping Lovegrass. Lehman appears about 50% more tolerant.

11/ Broad-leaf birdsfoot trefoil appears to be less tolerant than narrow leaf.

EXAMPLE - Use of Crop Tolerance Tables

Crop = Alfalfa

Max. EC_{dw} = 31

$LR\% = \frac{EC_w}{EC_{dw}} \times 100$

$\left(\text{Applied water (needed to supply ET+LR)} = \frac{ET}{1-LR}\right)$

Max. EC_w - From Tables

for 0 yield loss = 1.3 mmho, LR = 4%
10% " " = 2.2 " , LR = 7%
25% " " = 3.6 " , LR = 12%
50% " " = 5.9 " , LR = 19%

**** 0 yield loss expected with $EC_w < 1.3$

EC_w = 0.2 mmho, LR = $\frac{0.2}{31} \times 100$ = .6%
EC_w = 0.5 " , LR = 1.6%
EC_w = 0.75 " , LR = 2.4%
EC_w = 1.00 " , LR = 3.2%
EC_w = 1.30 " , LR = 4.2%

**** From 0-10% yield loss expected with EC_w = 1.3-2.2 mmho

EC_w = 1.3 mmho, LR = 4.2%
EC_w = 1.5 " , LR = 4.8%
EC_w = 1.75 " , LR = 5.6%
EC_w = 2.0 " , LR = 6.5%
EC_w = 2.2 " , LR = 7.0%

**** From 10-25% yield loss expected with EC_w = 2.2-3.6 mmho

EC_w = 2.2 mmho, LR = 7.1%
EC_w = 2.35 " , LR = 7.6%
EC_w = 2.50 " , LR = 8.1%
EC_w = 2.75 " , LR = 8.9%
EC_w = 3.00 " , LR = 9.7%
EC_w = 3.30 " , LR = 10.6%
EC_w = 3.6 " , LR = 11.6%

**** From 25-50% yield loss expected with EC_w = 3.6-5.9 mmho

EC_w = 3.6 mmho, LR = 11.6%
EC_w = 3.80 " , LR = 12.3%
EC_w = 4.00 " , LR = 12.9%
EC_w = 4.50 " , LR = 14.5%
EC_w = 5.0 " , LR = 16.1%
EC_w = 5.3 " , LR = 17.1%
EC_w = 5.9 " , LR = 19.0%

BORON IN IRRIGATION WATERS

Boron toxicity in many areas is traceable to use of irrigation waters with boron content in excess of 1 ppm. The UC Ag. Extension laboratories are using the following interpretation as regards boron content of irrigation water:

Below 0.5 mg/l	Satisfactory for all crops.
0.5 - 1.0 mg/l	Satisfactory for most crops; sensitive crops may show injury (may show leaf injury but yields may not be affected).
1.0 - 2.0 mg/l	Satisfactory for semi-tolerant crops. Sensitive crops are usually reduced in yield and vigor.
2.0 -10.0 mg/l	Only tolerant crops produce satisfactory yields.

There is no economically feasible method of removing boron from irrigation water. Similarly, there is at present no chemical or soil amendment which can economically be added to the soil to render the boron nontoxic. However, growers in some areas are learning to live with marginal boron and salinity conditions by: 1) Maintaining fertility levels slightly above the usual "optimum," and 2) By irrigating a little more frequently than "normal."

RELATIVE TOLERANCE OF PLANTS TO BORON

(In each group the plants first named are considered as being more sensitive and the last named more tolerant)

SENSITIVE	SEMI-TOLERANT	TOLERANT
0.5 mg/l	1 mg/l	2 mg/l
Lemon	Lima Bean	Carrot
Grapefruit	Sweet Potato	Lettuce
Avocado	Bell Pepper	Cabbage
Orange	Tomato	Turnip
Thornless Blackberry	Pumpkin	Onion
Apricot	Zinnia	Broad Bean
Peach	Oat	Gladiolus
Cherry	Milo	Alfalfa
Persimmon	Corn	Garden Beet
Kadota Fig	Wheat	Mangel
Grape (Sultanina & Malaga)	Barley	Sugar Beet
Apple	Olive	Palm (Phoenix Canariensis)
Pear	Ragged Robin Rose	Date Palm (Phoenix Dactylifera)
Plum	Field Pea	Asparagus
American Elm	Radish	Athel (Tamarix Aphylla)
Navy Bean	Sweet Pea	10 mg/l
erusalem Artichoke	Pima Cotton	
Persian (English) Walnut	Acala Cotton	
Black Walnut	Potato	Adopted from
Pecan	Sunflower (Native)	USDA Tech. Bull. No. 448
1.0 mg/l	2 mg/l	

TOLERANCE OF ORNAMENTAL SHRUBS AND GROUND COVERS TO SALINITY IN IRRIGATION WATER [1/]

SENSITIVE [2/]	MODERATELY TOLERANT	TOLERANT
(ECw=.75-1.50 [3/])	(ECw=1.50-3.0)	(more than ECw=3.0)
Star jasmine (Trachelospermum jasminoides)	Pittosporum (P. tobira)	Oleander (Nerium oleander)
Pineapple guava (Feijoa sellowiana)	Viburnum (V.tinus v.robustum)	Pyracantha (P. graeberi)
Burford holly (Ilex cornuta Burford)	Texas privet (Ligustrum lucidum)	Rosemary (Rosmarinus lockwoodi)
Rose (Rosa sp.var.Grenoble on Dr. Huey root)	Lantana (L. camara)	Dracaena (D. endivisa)
Algerian ivy (Hedera canariensis)	Boxwood (Buxus microphylla v. japonica)	Euonymus (E. japonica v. grandiflora)
Hibiscus (H. rosa-sinensis cv. Brilliante)	Xylosma (X senticosa)	Natal plum (Carissa grandiflora)
Heavenly bamboo (Nandina domestica)	Arborvitae (Thuja orientalis)	Bougainvillea (B. spectabilis)
	Dodonea (D. viscosa v. atropurpurea)	
	Silverberry (Elaegnus pungens)	
	Spreading juniper (Juniperus chinensis)	
	Bottlebrush (Callistemon viminalis)	

1/ Source: L. Bernstein; L.E. Francois; R.A. Clark - 1972: Salt Tolerance of Ornamental Shrubs and Ground Covers, J. Amer. Soc. Hort. Sci. 97(4): 550-556

2/ Listed in decreasing order of sensitivity. ECw values shown are associated with generally satisfactory appearance and up to 25% decrease in top growth.

3/ ECw means electrical conductivity of irrigation water (in mmho/cm). Assumptions include the following:
ECe X 2 = ECsw, ECe = Electrical conductivity of soil saturation extract, representative of the more active part of the root zone.

ECsw=Electrical conductivity of soil water; ECwX3=ECsw,1/2ECsw=ECe,ECe=3/2ECw.

RECOMMENDED MAXIMUM CONCENTRATIONS OF TRACE ELEMENTS IN IRRIGATION WATERS [a]

ELEMENT	FOR WATERS USED CONTINUOUSLY ON ALL SOIL	FOR USE UP TO 20 YEARS ON FINE TEXTURED SOILS OF pH 6.0 TO 8.5
	mg/l	mg/l
Aluminum	5.0	20.0
Arsenic	0.10	2.0
Beryllium	0.10	0.50
Boron	0.75	2.0
Cadmium	0.010	0.050
Chromium	.10	1.0
Cobalt	.050	5.0
Copper	0.20	5.0
Fluoride	1.0	15.0
Iron	5.0	20.0
Lead	5.0	10.0
Lithium	2.5[b]	2.5[b]
Manganese	0.20	10.0
Molybdenum	0.010	0.050[c]
Nickel	0.20	2.0
Selenium	0.020	0.020
Vanadium	0.10	1.0
Zinc	2.0	10.0

[a] These levels will normally not adversely affect plants or soils. No data available for Mercury, Silver, Tin, Titanium, Tungsten.

[b] Recommended maximum concentration for irrigating citrus is 0.075 mg/l.

[c] For only acid fine textured soils or acid soils with relatively high iron oxide contents.

Source: Above data based on Environmental Studies Board, Nat. Acad. of Sci. - Nat. Acad. of Eng. Water Quality Criteria 1972 (U.S. Gov't. Print. Office, Wash. D.C. 20402) p. 339.

GUIDE TO THE USE OF SALINE WATERS FOR LIVESTOCK AND POULTRY[1/]

Total Soluble Salt Content of Waters (mg/l)	
Less than 1,000 mg/l (EC less than 1.5)[2/]	Relatively low level of salinity. Excellent for all classes of livestock and poultry.
1,000-2,999 (EC=1.5-5)	Very satisfactory for all classes of livestock and poultry. May cause temporary and mild diarrhea in livestock not accustomed to them or watery droppings in poultry.
3,000-4,999 (EC=5-8)	Satisfactory for livestock, but may cause temporary diarrhea or be refused at first by animals not accustomed to them. Poor waters for poultry, often causing water feces, increased mortality and decreased growth, especially in turkeys.
5,000-6,999 (EC=8-11)	Can be used with reasonable safety for dairy and beef cattle, for sheep, swine, and horses. Avoid use for pregnant or lactating animals. Not acceptable for poultry.
7,000-10,000 (EC=11-16)	Unfit for poultry and probably for swine. Considerable risk in using for pregnant or lactating cows, horses, or sheep, or for the young of these species. In general, use should be avoided although older ruminants, horses, poultry, and swine may subsist on them under certain conditions.
Over 10,000 (EC over 16)	Risks with these highly saline waters are so great that they cannot be recommended for use under any conditions.

1/ Environmental Studies Board, Nat. Acad. of Sci. - Nat. Acad. of Eng. Water Quality Criteria 1972 (U.S. Gov't. Print. Office, Wash. D.C. 20402) p. 308.

2/ EC values shown are reported as mmho/cm and are only approximations based on rough conversion of given mg/l to EC by mg/l ÷ 640= EC.

UC-Coop. Extension
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GUIDELINES TO LEVELS OF TOXIC SUBSTANCES IN DRINKING WATER FOR LIVESTOCK [1/]

Constituent	Upper Limit
Aluminum (Al)	5 mg/l
Arsenic (As)	0.2 mg/l
Beryllium (Be)	no data
Boron (B)	5.0 mg/l
Cadmium (Cd)	.05 mg/l
Chromium (Cr)	1.0 mg/l
Cobalt (Co)	1.0 mg/l
Copper (Cu)	0.5 mg/l
Fluoride (F)	2.0 mg/l
Iron (Fe)	no data
Lead (Pb)	0.1 mg/l [2/]
Manganese (Mn)	no data
Mercury (Hg)	.01 mg/l
Molybdenum (Mo)	0.5 mg/l
Nitrate + Nitrite (NO_3-N+NO_2-N)	100 mg/l
Nitrite (NO_2-N)	10 mg/l
Selenium (Se)	0.05 mg/l
Vanadium (Va)	0.10 mg/l
Zinc (Zn)	25 mg/l
Total Dissolved (TDS) Solids	10,000 mg/l [3/]

1/ Based primarily on Environmental Studies Board, Nat. Acd. of Sci. - Nat. Acad. of Eng. Water Quality Criteria 1972 (U.S. Gov't Print. Office, Wash. D.C. 20402) p. 309-317.

2/ Lead is accumulative and problems may begin at threshold value = 0.05 mg/l.

3/ See "Guide to Use of Saline Waters For Livestock and Poultry" included as separate "Guide"

January 15, 1975

TABLES FOR CALCULATING pHc VALUES OF WATERS

pHc can be calculated, using the table below; pHc= $(pK_2'-pK_c')$ + p (Ca+Mg) + pAlk where $pK_2'-pK_c'$ is obtained from Ca+Mg+Na
p (Ca+Mg)" " " Ca+Mg
pAlk " " " CO_3+HCO_3

Tables for Calculation pHc

Conct. Ca+Mg+Na (me/l)	$pK_2'-pK_c'$	Conct. Ca+Mg (me/l)	p(Ca+Mg)	Conct. CO_3+HCO_3 (me/l)	pAlk
.5 →	2.11	.05 →	4.60	.05 →	4.30
.7	2.12	.10	4.30	.10	4.00
.9	2.13	.15	4.12	.15	3.82
1.2	2.14	.2	4.00	.20	3.70
1.6	2.15	.25	3.90	.25	3.60
1.9	2.16	.32	3.80	.31	3.51
2.4	2.17	.39	3.70	.40	3.40
2.8	2.18	.50	3.60	.50	3.30
3.3	2.19	.63	3.50	.63	3.20
3.9	2.20	.79	3.40	.79	3.10
4.5	2.21	1.00	3.30	.99	3.00
5.1	2.22	1.25	3.20	1.25	2.90
5.8	2.23	1.58	3.10	1.57	2.80
6.6	2.24	1.98	3.00	1.98	2.70
7.4	2.25	2.49	2.90	2.49	2.60
8.3	2.26	3.14	2.80	3.13	2.50
9.2	2.27	3.90	2.70	4.0	2.40
11	2.28	4.97	2.60	5.0	2.30
13	2.30	6.30	2.50	6.3	2.20
15	2.32	7.90	2.40	7.9	2.10
18	2.34	10.00	2.30	9.9	2.00
22	2.36	12.50	2.20	12.5	1.90
25	2.38	15.80	2.10	15.7	1.80
29	2.40	19.80	2.00	19.8	1.70
34	2.42				
39	2.44				
45	2.46				
51	2.48				
59	2.50				
67	2.52				
76	2.54				

Example: To calculate adj.SAR of water from

$$\text{adj.SAR} = \frac{Na}{\sqrt{\frac{Ca+Mg}{2}}} \left[1+(8.4-pHc)\right]$$

With report of water analysis
Na = 3.5 me/l
Ca+Mg = 1.0 me/l
Ca+Mg+Na = 4.5 me/l
CO_3+HCO_3 = 3.0 me/l

pHc= 2.21+3.30+2.5= 8.01 (from tables)

$$\text{adj.SAR} = \frac{3.5}{\sqrt{1/2}} \left[1+(8.4-8.01)\right] = 4.95 \ (1+.39)$$

adj.SAR= 6.88

NOTE: Values of pHc above 8.4 indicate tendency to dissolve lime from soil through which the water moves; values below 8.4 indicate tendency to precipitate lime from waters applied.

(ref: L.V. Wilcox, U.S. Salinity Laboratory, mimeo Dec. 30, 1966)

IRRIGATION AND DRAINAGE PAPER

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water quality for agriculture

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