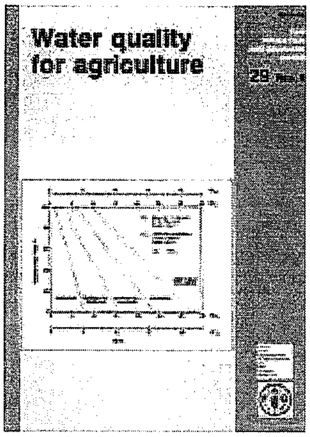

Water quality for agriculture

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by
R.S. Ayers
Soil and Water Specialist (Emeritus)
University of California
Davis, California, USA

and
D.W. Westcot
Senior Land and Water Resources Specialist
California Regional Water Quality Control Board
Sacramento, California, USA

FAO IRRIGATION AND DRAINAGE PAPER

29 Rev. 1

Reprinted 1989, 1994

M-56
ISBN 92-5-102263-1

	Vetch	
	(Vicia sativa)	
	Wheat	
	(Triticum vulgare)	

Adapted from data of FAO-Unesco (1973); Pearson (1960); and Abrol (1982).

The approximate levels of exchangeable sodium percentage (ESP) corresponding to the three categories of tolerance are: sensitive less than 15 ESP; semi-tolerant 15–40 ESP; tolerant more than 40 ESP. Tolerance decreases in each column from top to bottom. The tolerances listed are relative because, usually, nutritional factors and adverse soil conditions stunt growth before reaching these levels. Soil with an ESP above 30 will usually have too poor physical structure for good crop production. Tolerance in most instances were established by first stabilizing soil structure.

Particular care in assessment of a potential toxicity due to SAR or sodium is needed with high SAR water because apparent toxic effects of sodium may be due to or complicated by poor water infiltration. As shown in Table 15, only the more sensitive perennial crops have yield losses due to sodium if the physical condition of the soil remains good enough to allow adequate infiltration. Several of the crops listed as more tolerant do show fair growth when soil structure is maintained and, in general, these crops can withstand higher ESP levels if the soil structure and aeration can be maintained, as in coarse textured soils.

4.1.3 Boron

Boron, unlike sodium, is an essential element for plant growth. (Chloride is also essential but in such small quantities that it is frequently classed non-essential.) Boron is needed in relatively small amounts, however, and if present in amounts appreciably greater than needed, it becomes toxic. For some crops, if 0.2 mg/l boron in water is essential, 1 to 2 mg/l may be toxic. Surface water rarely contains enough boron to be toxic but well water or springs occasionally contain toxic amounts, especially near geothermal areas and earthquake faults. Boron problems originating from the water are probably more frequent than those originating in the soil. Boron toxicity can affect nearly all crops but, like salinity, there is a wide range of tolerance among crops.

Boron toxicity symptoms normally show first on older leaves as a yellowing, spotting, or drying of leaf tissue at the tips and edges. Drying and chlorosis often progress toward the centre between the veins (interveinal) as more and more boron accumulates with time. On seriously affected trees, such as almonds and other tree crops which do not show typical leaf symptoms, a gum or exudate on limbs or trunk is often noticeable.

Most crop toxicity symptoms occur after boron concentrations in leaf blades exceed 250–300 mg/kg (dry weight) but not all sensitive crops accumulate boron in leaf blades. For example, stone fruits (peaches, plums, almonds, etc.), and pome fruits (apples, pears and others) are easily damaged by boron but they do not accumulate sufficient boron in the leaf tissue for leaf analysis to be a reliable diagnostic test. With these crops, boron excess must be confirmed from soil and water analyses, tree symptoms and growth characteristics.

A wide range of crops was tested for boron tolerance by using sand-culture techniques (Eaton 1944). Previous boron tolerance tables in general use have been based for the most part on these data. These tables reflected boron tolerance at which toxicity symptoms were first observed and, depending on crop, covered one to three seasons of irrigation. The original data from these early experiments, plus data from many other sources, have recently been reviewed

(Maas 1984). Table 16 presents this recent revision of the data. It is not based on plant symptoms, but upon a significant loss in yield to be expected if the indicated boron value is exceeded. Table 17 presents recent data on citrus and stone fruit rootstocks and are listed in order of increasing boron accumulation.

4.2 MANAGEMENT OF TOXICITY PROBLEMS

Obviously, the most effective method to prevent occurrence of a toxicity problem is to choose an irrigation water that has no potential to develop a toxicity. But if such water is not available, there are often management options than can be adopted to reduce toxicity and improve yields.

Table 16 RELATIVE BORON TOLERANCE OF AGRICULTURAL CROPS [1,2]

Very Sensitive (<0.5 mg/l)	
Lemon	*Citrus limon*
Blackberry	*Rubus spp.*
Sensitive (0.5 – 0.75 mg/l)	
Avocado	*Persea americana*
Grapefruit	*Citrus X paradisi*
Orange	*Citrus sinensis*
Apricot	*Prunus armeniaca*
Peach	*Prunus persica*
Cherry	*Prunus avium*
Plum	*Prunus domestica*
Persimmon	*Diospyros kaki*
Fig, kadota	*Ficus carica*
Grape	*Vitis vinifera*
Walnut	*Juglans regia*
Pecan	*Carya illinoiensis*
Cowpea	*Vigna unguiculata*
Onion	*Allium cepa*
Sensitive (0.75 – 1.0 mg/l)	
Garlic	*Allium sativum*
Sweet potato	*Ipomoea batatas*
Wheat	*Triticum eastivum*
Barley	*Hordeum vulgare*
Sunflower	*Helianthus annuus*
Bean, mung	*Vigna radiata*
Sesame	*Sesamum indicum*
Lupine	*Lupinus hartwegii*
Strawberry	*Fragaria spp.*
Artichoke, Jerusalem	*Helianthus tuberosus*
Bean, kidney	*Phaseolus vulgaris*
Bean, lima	*Phaseolus lunatus*

Citrus		
Alemow	*Citrus macrophylla*	Low
Gajanimma	*Citrus pennivesiculata or Citrus moi*	
Chinese box orange	*Severinia buxifolia*	
Sour orange	*Citrus aurantium*	
Calamondin	*X Citrofortunella mitis*	
Sweet orange	*Citrus sinensis*	
Yuzu	*Citrus junos*	
Rough lemon	*Citrus limon*	
Grapefruit	*Citrus X paradisi*	
Rangpur lime	*Citrus X limonia*	
Troyer citrange	*X Citroncirus webberi*	
Savage citrange	*X Citroncirus webberi*	
Cleopatra mandarin	*Citrus reticulata*	
Rusk citrange	*X Citroncirus webberi*	
Sunki mandarin	*Citrus reticulata*	
Sweet lemon	*Citrus limon*	
Trifoliate orange	*Poncirus trifoliata*	
Citrumelo 4475	*Poncirus trifoliata X citrus paradisi*	
Ponkan mandarin	*Citrus reticulata*	
Sampson tangelo	*Citrus X tangelo*	
Cuban shaddock	*Citrus maxima*	
Sweet lime	*Citrus aurantiifolia*	High
Stone Fruit		
Almond	*Prunus dulcis*	Low
Myrobalan plum	*Prunus cerasifera*	
Apricot	*Prunus armeniaca*	
Marianna plum	*Prunus domestica*	
Shalil peach	*Prunus persica*	High

[1] Data taken from Maas (1984).

The potentially toxic ions sodium, chloride and boron can each be reduced by leaching in a manner similar to that for salinity, but the depth of water required varies with the toxic ion and may in some cases become excessive. If leaching becomes excessive, many growers change to a more tolerant crop. Increasing the leaching or changing crops in an attempt to live with the higher levels of toxic ions may require extensive changes in the farming system. In cases where the toxicity problem is not too severe, relatively minor changes in farm cultural practices can minimize the impact. In a few cases, an alternative water supply may be available to blend with a poorer supply to lower the hazard from the poorer one.

Alternatives for management of toxicity and to maintain production are discussed in the following sections.

4.2.1. Leaching

supplies frequently serve as a drinking water source for live-stock, salinity and trace element drinking water limitations for livestock are presented in section 6.

It is beyond the scope of this publication to go into drinking water standards, but this aspect should, nevertheless, be considered during the planning of an irrigation scheme. This is important, because irrigation supplies are also commonly used, either intentionally or unintentionally, as human drinking water. The World Health Organization (WHO) or a local health agency should be consulted for more specific information.

Laboratory determinations and calculations needed to use the guidelines are given in Table 2 and Figure 1, along with the symbols used. Analytical procedures for the laboratory determinations are given in several publications: USDA Handbook 60 (Richards 1954), Rhoades and Clark 1978, FAO Soils Bulletin 10 (Dewis and Freitas 1970), and Standard Methods for Examination of Waters and Wastewaters (APHA 1980). The method most appropriate for the available equipment, budget and number of samples should be used. Analytical accuracy within ±5 percent is considered adequate.

Table 1 GUIDELINES FOR INTERPRETATIONS OF WATER QUALITY FOR IRRIGATION[1]

Potential Irrigation Problem					Units	Degree of Restriction on Use		
						None	Slight to Moderate	Severe
Salinity *(affects crop water availability)*[2]								
	EC_w				dS/m	< 0.7	0.7 – 3.0	> 3.0
	(or)							
	TDS				mg/l	< 450	450 – 2000	> 2000
Infiltration *(affects infiltration rate of water into the soil. Evaluate using EC_w and SAR together)*[3]								
SAR	= 0 – 3		**and EC_w**	=		> 0.7	0.7 – 0.2	< 0.2
	= 3 – 6			=		> 1.2	1.2 – 0.3	< 0.3
	= 6 – 12			=		> 1.9	1.9 – 0.5	< 0.5
	= 12 – 20			=		> 2.9	2.9 – 1.3	< 1.3
	= 20 – 40			=		> 5.0	5.0 – 2.9	< 2.9
Specific Ion Toxicity *(affects sensitive crops)*								
	Sodium (Na)[4]							
	surface irrigation				SAR	< 3	3 – 9	> 9
	sprinkler irrigation				me/l	< 3	> 3	
	Chloride (Cl)[4]							
	surface irrigation				me/l	< 4	4 – 10	> 10
	sprinkler irrigation				me/l	< 3	> 3	
	Boron (B)[5]				mg/l	< 0.7	0.7 – 3.0	> 3.0
	Trace Elements (see Table 21)							
Miscellaneous Effects *(affects susceptible crops)*								
	Nitrogen (NO_3 - N)[6]				mg/l	< 5	5 – 30	> 30

1. WATER QUALITY EVALUATION

1.1 INTRODUCTION

Irrigated agriculture is dependent on an adequate water supply of usable quality. Water quality concerns have often been neglected because good quality water supplies have been plentigul and readily available. This situation is now changing in many areas. Intensive use of nearly all good quality supplies means that new irrigation projects and old projects seeking new or supplemental supplies must rely on lower quality and less desirable sources. To avoid problems when using these poor quality water supplies, there must be sound planning to ensure that the quality of water available is put to the best use.

The objective of this paper is to help the reader to a better understanding of the effect of water quality upon soil and crops and to assist in selecting suitable alternatives to cope with potential water quality related problems that might reduce production under prevailing conditions of use.

Conceptually, water quality refers to the characteristics of a water supply that will influence its suitability for a specific use, i.e. how well the quality meets the needs of the user. Quality is defined by certain physical, chemical and biological characteristics. Even a personal preference such as taste is a simple evaluation of acceptability. For example, if two drinking waters of equally good quality are available, people may express a preference for one supply rather than the other; the better tasting water becomes the preferred supply. In irrigation water evaluation, emphasis is placed on the chemical and physical characteristics of the water and only rarely are any other factors considered important.

Specific uses have different quality needs and one water supply is considered more acceptable (of better quality) if it produces better results or causes fewer problems than an alternative water supply. For example, good quality river water which can be used successfully for irrigation may, because of its sediment load, be unacceptable for municipal use without treatment to remove the sediment. Similarly, snowmelt water of excellent quality for municipal use may be too corrosive for industrial use without treatment to reduce its corrosion potential.

The ideal situation is to have several supplies from which to make a selection, but normally only one supply is available. In this case, the quality of the available supply must be evaluated to see how it fits the intended use. Most of the experience in using water of different qualities has been gained from observations and detailed study of problems that develop following use. The cause and effect relationship between a water constituent and the observed problem then results in an evaluation of quality of degree of acceptability. With sufficient reported experiences and measured responses, certain constituents emerge as indicators of quality-related problems. These characteristics are then organized into guidelines related to suitability for use. Each new set of guidelines builds upon the previous set to improve the predictive capability. Numerous such guidelines have become available covering many types of use.

There have been a number of different water quality guidelines related to irrigated agriculture. Each has been useful but none has been entirely satisfactory because of the wide variability in field conditions. Hopefully, each new set of guidelines has improved our predictive capability. The guidelines presented in this paper have relied heavily on previous ones but are modified to give more practical procedures for evaluating and managing water quality-related problems of

	Bicarbonate (HCO_3)				
	(overhead sprinkling only)	me/l	< 1.5	1.5 – 8.5	> 8.5
	pH		**Normal Range 6.5 – 8.4**		

[1] Adapted from University of California Committee of Consultants 1974.

[2] ECw means electrical conductivity, a measure of the water salinity, reported in deciSiemens per metre at 25°C (dS/m) or in units millimhos per centimetre (mmho/cm). Both are equiva-lent. TDS means total dissolved solids, reported in milligrams per litre (mg/l).

[3] SAR means sodium adsorption ratio. SAR is sometimes reported by the symbol RNa. See Figure1 for the SAR calculation procedure. At a given SAR, infiltration rate increases as watersalinity increases. Evaluate the potential infiltration problem by SAR as modified by ECw.Adapted from Rhoades 1977, and Oster and Schroer 1979.

[4] For surface irrigation, most tree crops and woody plants are sensitive to sodium and chlor-ide; use the values shown. Most annual crops are not sensitive; use the salinity tolerance tables (Tables 4 and 5). For chloride tolerance of selected fruit crops, see Table 14. With overhead sprinkler irrigation and low humidity (< 30 percent), sodium and chloride may be absorbed through the leaves of sensitive crops. For crop sensitivity to absorption, see Tables 18, 19 and 20.

[5] For boron tolerances, see Tables 16 and 17.

[6] NO_3 -N means nitrate nitrogen reported in terms of elemental nitrogen (NH_4 -N and Organic-N should be included when wastewater is being tested).

Assumptions in the Guidelines

The water quality guidelines in Table 1 are intended to cover the wide range of conditions encountered in irrigated agriculture. Several basic assumptions have been used to define their range of usability. If the water is used under greatly different conditions, the guidelines may need to be adjusted. Wide deviations from the assumptions might result in wrong judgements on the usability of a particular water supply, especially if it is a borderline case. Where sufficient experience, field trials, research or observations are available, the guidelines may be modified to fit local conditions more closely.

The basic assumptions in the guidelines are:

Yield Potential: Full production capability of all crops, without the use of special practices, is assumed when the guidelines indicate no restrictions on use. A "restriction on use" indicates that there may be a limitation in choice of crop, or special management may be needed to maintain full production capability. A "restriction on use" does not indicate that the water is unsuitable for use.

Site Conditions: Soil texture ranges from sandy-loam to clay-loam with good internal drainage. The climate is semi-arid to arid and rainfall is low. Rainfall does not play a significant role in meeting crop water demand or leaching requirement. (In a monsoon climate or areas where precipitation is high for part or all of the year, the guideline restrictions are too severe. Under the higher rainfall situations, infiltrated water from rainfall is effective in meeting all or part of the leaching requirement.) Drainage is assumed to be good, with no uncontrolled shallow water table present within 2 metres of the surface.

Methods and Timing of Irrigations: Normal surface or sprinkler irrigation methods are used. Water is applied infrequently, as needed, and the crop utilizes a considerable portion of the available stored soil-water (50 percent or more) before the next irrigation. At least 15 percent of the applied water percolates below the root zone (leaching fraction [LF]≥15 percent). The guidelines are too restrictive for specialized irrigation methods, such as localized drip irrigation, which results in near daily or frequent irrigations, but are applicable for subsurface irrigation if surface applied leaching satisfies the leaching requirements.

Water Uptake by Crops: Different crops have different water uptake patterns, but all take water from wherever it is most readily available within the rooting depth. On average about 40 percent is assumed to be taken from the upper quarter of the rooting depth, 30 percent from the second quarter, 20 percent from the third quarter, and 10 percent from the lowest quarter. Each irrigation leaches the upper root zone and maintains it at a relatively low salinity. Salinity increases with depth and is greatest in the lower part of the root zone. The average salinity of the soil-water is three times that of the applied water and is representative of the average root zone salinity to which the crop responds. These conditions result from a leaching fraction of 15–20 percent and irrigations that are timed to keep the crop adequately watered at all times.