INTERPRETATION OF ANALYSES OF IRRIGATION WATERS, and the RELATIVE TOLERANCE OF CROP PLANTS

by

L. V. WILCOX, Agronomist,
Division of Irrigation Agriculture

and

C. C. MAGISTAD, Director
U. S. Regional Salinity Laborntory

Bureau of Plant Industry, Soils and Agr. Engineering,
Agricultural Research Administration,
U. S. Department of Agriculture, Riverside, California

May 1943.

EXPLANATION AND INTERPRETATION OF ANALYSES OF IRRIGATION WATERS

I. Explanation of Analyses of Irrigation Waters

A report of an analysis of an irrigation water may include some or all of the following items:

SPECIFIC ELECTRICAL CONDUCTANCE ($K \times 10^5$ @ 25°C). This measurement is reported in reciprocal ohms per cm., multiplied by 10^5 (100,000) to avoid awkward decimals. The electrical conductivity of waters is dependent upon the number and kinds of dissolved salt constituents and accordingly provides an index of total salinity,

Knowing the conductance of a water sample ($K \times 10^5$ @ 25°C) an approximation of the total equivalents per million (e.p.m.) of the anions (acid radicals) or of the cations (bases) may be had by dividing the conductance by 10. If the conductance is multiplied by 7, the resulting value approximates total dissolved solids expressed in parts per million. Thus: in a water with a. conductance of 100, the sum of the e.p.m. of CG3, HCO_3, SO_4, Cl, and NO_3 will be about 10 and total dissolved'solids will be about 700 parts per million.

TOTAL DISSOLVED SOLIDS. The total dissolved **matter** carried by the water. It is determined by evaporating a filtered sample of the water to dryness and weighing the residue. **Closely** agreeing results can be obtained by calculation from the results of analyses for the individual ions, Results are: reported as p.p.m. or t.a.f. (tons per acre foot.)

BORON. The concentration of boron is expressed in parts per million **(p.p.m.)** Of the element,

PERCENT SODIUM. This value is defined by the expression:

$$\text{Percent Na} = \frac{\text{Na} \times 100}{\text{Ca}+\text{Mg}+\text{Na}+\text{K}}$$

Concentrations in terms of e.p.m. are used in making the above calculations.

CATIONS: Calcium (Ca), Magnesium (Mg), Sodium (Na), Potassium (K).

ANIONS: Carbonate (CO_3), Bicarbonate (HCO_3), Sulfate (SO_4), Nitrate (NO_3), Chloride (Cl).

All are expressed in equivalents per million (e.p.m.). This unit of measurement, which involves the number of ions, is adopted in the interest of an understanding of the chemistry of natural waters and the interpretation of analyses. In waters of low salinity, such as most irrigation waters, the unit e.p.m. is numerically the same as the unit milligram equivalents per liter (m.e./l)* . For practical purposes, they can be considered identical. Concentrations expressed in units of weight as parts per million (p.p.m.) are sometimes desired for a particular purpose and for that reason the conversion factors are supplied. Those conversion factors are sot forth in the following table. Thus, the equivalent weight of chloride is 35.5 and 5 e.p.m. of chloride is the same as 177.5 p.p.m. The equivalent weight of the sulfate ion (SO_4) is 48 and 5 e.p.m. of sulfate is the same as 240 p.p.m.

Conversion Factors

Multiply concentrations in equivalents per million by the equivalent weight of the ion to convert to parts per million,

Cations		Equivalent weight	Anions		Equivalent weight
Calcium	(Ca)	20	Carbonate	(CO_3)	30
Magnesium	(Mg)	12.2	Bicarbonate	(HC03)	61
Sodium	(Na)	23	Sulfate	(SO_4)	48
Potassium	(K)	33.1	Chloride	(Cl)	35.5
			Nitrate	(NO_3)	62

To convert parts per million to equivalents per million, divide by tho above factors.

II Interpretation of Analyses of Irrigation Waters

The nature of an irrigation water has a dcfinitc influence on the salinity status of a soil, but the naturo of the soil has an even greater influcncc. Heavy soils which have a low rate of permeability to water will not drain readily and when irrigated, even with a low-salt water, salt will accumulate by evaporation of tho irrigation water faster than salt is lost in the drcinagc water. Sandy soils will remain permeable and will not be affected adversely to any great extent except whore the sodium percentage of tho water is- very high, above 80 percent. For general agricultural use, irrigation waters can be classified, bzscd on the following four characteristics,

*Refer to definitions of these terms, p. 6.

1. Specific electrical conductance,

2. Boron concentration

3. Sodium percentage

4. Chloride concentration

. Three classes of waters may be delimited in terms of these characteristics.

Class I Excellent to good. Suitable for most plants under most conditions.

Class II Good to injurious. Probably harmful to the more sensitive crops,

Class III Injurious to unsatisfactory. Probably harmful to most crops and unsatisfactory for all but the most tolerant.

	Class I Excellent to good	Class II Good to Injurious	Class III Injurious to Unsatisfactory
$K \times 10^5$ @25°C	Less than 100	1.00 - 300	More than 300
Boron p.p.m.	0.5	C.5 - 2.0	" " 2.0
Sodium Percentage	60	60 - 75	" " 75
Chloride e.p.m.	5	5 - 10	" " 1.0

PLANT TOLERANCES

The following lists are compiled from results presented in U. S. Dept. of Agr, Tech, Bull. 448, U. S, Dept. of Agr. Circ. 404, and from unpublished data from the U, S, Regional Salinity Laboratory, Riverside, California. These lists are provisional and subject 'co revision.

The plants considered here are divided into three groups) based on their tolerance to neutral salts. Plant growth is governed by the concentration of salt constituents in the soil solution rather than that of the irrigation water, Often there is little relation between the two, and the soil solution may be many times as concentrated as the irrigation water. The list of crops is arranged in the order of increasing tolerances. Those prefixed by the letter B in parentheses, (B) -; are somewhat sensitive to boron and probably would suffer from higher boron concentration of each class of water.

As a measure of *tolerance, it is* assumed that, under favorable conditions of climate, soil and fertilization, fair to good yields will be obtained.

Relative Tolerance of Crop Plants to Salt Constituents in the Soil Solution.

Group I Crops which may be grown on soils of weak salinity	Group II Crops which may be grown on soils of medium salinity	Group III Crops which may be grown on soils of strong salinity
Beans, wax, pods		
Beans, navy, tops		
Red clover		
Field peas		
Horsebean		
Vetch		
Pros0		
Oats (grain crop)		
Emmer (grain crop)		
Wheat (grain crop)		
Onions	Onions	
Squash	Squash	
Carrots	Carrots	
Ladino clover	Ladino clover	
Sunflower	(B) -Sunf lower	
Rice	Ric e	
Rye (grain crop)	Rye (grain crop)	
Barley (grain crop)	(B) -Barley (grain crop)	
Oats (hay crop)	Oats (hay crop)	
Wheat (hay crop)	'Wheat (hay crop)	
Grain sorghums	Grain sorghums	
Foxtail millet	Foxtail millet	
Strawberry clover	Strawberry clover	
Asparagus	Asparagus	
Cowpeas	Cowpeas	
Flax	Flax	
Sweet Clover	Sweet Clover	
Barley (hay crop)	Barley (hay crop)	
Tomatoes	(B) -Tomatoes	
Cotton	(B) -Cotton	Cotton
Alfalfa	Alfalfa	Alfalfa
Sorgo	Sorgo	Sorgo
Kale	Kale	Kale
Rape	*Rape*	Rape
Meadow fescue	Meadow fescue	Meadow fescue
Italian ryegrass	Italian ryegrass	Italian ryegrass
Crested wheatgrass	Crested wheatgrass	Crested wheatgrass
Slender wheatgrass	Slender wheatgrass	Slender wheatgrass
Tall oatgrass	Tall oatgrass	Tall oatgrass
Smooth bromegrass	Smooth bromegrass	Smooth bromegrass
Bluestem	Bluestem	Bluestem
Bermuda grass	Bermuda grass	Bermuda grass
Rhodes grass	Rhodes grass	Rhodes grass
Sugar Beets	Sugar Beets	Sugar Beets
Milo, tops and grain	Milo, tops and grain	Milo, tops and grain
Garden beets	Garden beets	Garden beets

↓ Tolerant

Representative analyses

Lab. Sample No.	$K \times 10^5$ @25°C	Total Solids		Boron	Percent		Equivalents per million								
		P.p.m.	T.a.f.	P.p.m.	Na	Cl	Ca	Mg	Na	K	CO_3	HCO_3	SO_4	Cl	NO_3
7487	21.7	145	0.20	0.11	28	15	0.84	0.83	0.67	0.07	0	1.90	0.15	0.34	0.01
16283	61.1	406	0.55	0.09	40	12	2.76	0.86	2.41	--	tr	2.25	3.19	0.75	0.01
17121	36.2	229	0.31	0.18	51	19	1.44	0.27	1.84	0.09	tr	2.14	0.76	0.65	0.01
8865	122	719	0.98	0.12	69	69	2.32	1.21	8.01	--	0	2.87	0.58	7.84	0.01
16487	274	1830	2.49	0.24	51	50	8.49	5.15	14.43	--	tr	2.33	12.02	14.03	0.04
17006	144	1090	1.48	0.23	23	16	7.39	4.89	3.78	0.11	0	3.91	9.79	2.35	0.27
8709	451	2725*	3.71	0.87	59	69	9.78	8.23	25.73	--	0.10	5.06	8.65	30.77	0.29
△1	786	5640	7.67	--	49	52	29.55	16.45	45.48	0.51	--	1.98	42.03	47.04	0.03
8148	474	2660*	3.62	0.14	53	88	12.63	8.71	24.15	0.22	0	3.00	2.54	39.91	0.24

* Calculated.

Sample No.	Description
7487	Sacramento River at Tisdale Weir, California. July 15, 1933.
16283	Rio Grande at Elephant Butte, New Mexico. February, 1942.
17121	City Water, Riverside, California. March 1, 1943.
8865	Salt River at Stewart Mountain Dam, Arizona. June 28, 1934.
16487	Rio Grande at Rio Grande City, Texas. February, 1942.
17006	Well, Santa Barbara County, California. January 8, 1943.
8709	Buckeye Canal near Buckeye, Arizona. May 28, 1934.
△1	Pecos River at Orla, Texas. Weighted mean for 1939-40. Analyses by U. S. Geological Survey, National Resources Planning Board, Pecos River Joint Investigation. Page 127. (1942).
8148	Well, San Diego County, California. December 9, 1933.

Definitions

Specific Electrical Conductance ($K \times 10^5$ @ 25°C)

The specific electrical conductance of a solution or soil suspension expressed as reciprocal ohms per *cm.* multiplied by 100,000. The value is determined at 25°C. or corrected to this temperature.

Equivalent, (gram-equivalent-weight)

The equivalent weight of an ion or molecule in grams is referred to as an "equivalent". The equivalent weight is obtained by dividing the atomic or molecular weight by the valence. One equivalent of a cation combines with or is chemically equal to one equivalent of an anion. Thus: one equivalent of sodium ion (23 grams) combines with one equivalent of chloride ion (35.5 grams) to form one equivalent of sodium chloride (58.5 grams). The number of equivalents of cations (positively charged ions) in a water is equal to the number of equivalents of anions (negatively charged ions).

A milligram equivalent or milliequivalent is l/1000 of an equivalent,

Milliequivalents per liter. (m.e./l.)

The number of equivalents per liter ~~divided~~ MULTIPLIED by 1000.

Equivalents per million. *(e.p.m.)*

One grem-equivalent-weight of an element, ion, or salt present in one million grams of solution. This quantity multiplied by the equivalent weight expresses the concentration in p.p.m. In solutions 1 e.p.m. is equal to 1 m.e./l. when the specific gravity is unity.

Miner's inch

A unit for the measurement of flow of irrigation water, whose value is not the same in all stctcs. The "Southern California" miner's inch, l/50 cu.ft. per sec., is the statute "miner's inch" in Idaho, New Mexico, Oregon, Utah, and Washington. In Arizona, Nevada, and Montana, the California "statute inch", l/40 cu.ft. per sec., is the statute inch. In Colorado, the miner's inch is l/38.4 cu.ft, per sec. (Univ. of Calif. Bul, 588).

Constants and Conversion Factors

1 acre = 43560 square feet.
1 acre foot soil weighs 4,000,000 pounds (Approx.)
1 acre foot water weighs 2,720,000 pounds (Approx.)

1 cubic foot per sec. (c.f.s.) = 50 miners inches (Southern California)
1 c.f.s. for 24 hours = 1.98 acre foot.
Gallons per minute (gpm) x 0.002228 = c.f.s.

1 U. S. gallon = 231 cubic inches
= 8,345 pounds water
= 0.1337 cubic feet

1 cubic foot = 7.4805 gallons at 59° Fahrenheit.
= 62.374 pounds water

Soil in place weighs 70 to 105 pounds per cubic foot,
Soil particles, specific gravity = 2.65

58417 grains per U. S. gallon.

Grains per U. S, gallon x 17.l. = parts per million,

P.p.m. x 0.00136 = Tons per acre foot (t.a.f.)

As detailed water analyses ere expensive, samples should be carefully taken and the data indicated in the form below should accompany the sample so that the analyses may be of greatest use not only for the immediate purpose but also for future reference. The Bureau of Plant Industry, Soils and Agricultural Engineering does not analyze waters except in the course of its own investigations, or for those of other governmental agencies.

Collector's Description of Water Sample

Collector's No.; ____ Lab.No. ______; Date __________; Collector ______________

Name and/or Owner ____

Spring, Stream, Lake, Well?

____ ____________

County Miles _ Direction nearest town U. S. G. S. Sheet

Location: ____ l/4, sec., ____ T. ______, R. ______, ______________

Distance & direction from l/4 cor. or landmark

Other description ____

Depth _______; Depth to upper perforations ______; Casing Diameter ___________

Discharge ____________; Static level ________; Draws down to ______________

cfs, gpm, in,?

Temp. ______________; Odor ________________ _; Gas ________; Color ________

°C. or °F.

Use: Irrig., Municipal, Ind., Stock, Dom. ______ ___ ____________________

Approximste acreage served, and kind of crops ___________________________

Condition or symptoms of land or crops __________________________________

Owner's opinion of water quality ____

Collector's remarks ____

____

____

(It is expected that the collector may not be able to obtain in each instance all the information requested.)