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The Use of Softened Colorado River Water for Home Gardens

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WITH the completion of the Metropolitan Water District's aqueduct and distribution system, Colorado River water will he available in Southern California. On the basis of exhaustive tests, methods and cost of softening this water for industrial and home use have been determined. A description of the process was given in June, 1939, by Julian Hinds, Assistant Chief Engineer of the Metropolitan Water District of Southern California (1). He states that for agricultural purposes it is better to use the water without softening, and to this the author believes all soils men and agriculturists will agree. Additional information about the softening plant is given by Montgomery and Aultman (2). The present paper will discuss the USC of treated Colorado River water on the lawns, gardens, and shrubbery of home owners in the Metropolitan Water District.

The water reaching Cajalco Reservoir will closely approximate the composition of Colorado River water at Yuma. Table 1, giving the composition of Colorado River water, is based on 43 weekly samplings and analyses during the calendar year 1939, omitting 4 samplings in January because of a flood in the Bill Williams River and 4 samples in September and October because of heavy local rains. The analyses were made by the Division of Irrigation Agriculture, Bureau of Plant Industry, and supplied by C. S. Scofield. The United States Geological Survey has furnished the author with analyses and discharges at Willow Beach since 1934, from which a weighted five-year average, from September 30, 1934, to September 30, 1939, yields 690 p.p.m. dissolved solids. Adding 5 per cent for evaporation loss between

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Willow Beach and the softening plant, this value becomes 724 p.p.m., nearly equal to that given in Table 1.

Values for 1940 at Willow Beach and Yuma are said to exceed slightly the 1939 values of Table 1. Hinds (I) and Montgomery and

TABLE 1

Estimated Composition of Colorado River Water at Cajalco Reservoir

COMPONENT	QUANTITY	
	e.p.m.*	p.p.m.
Cations:		
Calcium	5.15	103
Magnesium	2.32	28
Sodium.	4.62	106
Total	12.09	
Anions:		
Carbonate	.14	8
Bicarbonate.	2.45	149
Sulfate	7.09	341
Chloride	2.43	86
Total	12.12	
Sodium.	33%	
Boron		.14
Total dissolved solids		746
Total hardness as $CaCO_3$		374
Total carbonate hardness		123
Total non-carbonate hardness		251
Conductance K X 10^5 @ 25°C		115

* "An equivalent per million (e.p.m.) is a unit chemical equivalent weight of solute per million unit weights of solution. Concentration in equivalents per million is calculated by dividing concentration in parts per million (p.p.m.) by the chemical combining weight of the substance or ion.

"This unit has also been called 'milliequivalents per liter' and 'milligram equivalents per kilogram.' The latter term is precise, but the former will be in error if the specific gravity of the solution is not exactly 1.0." A.S.T.M. Standards-1940; Part III, p. 541.

Aultman (2) give the estimated concentration of Cajalco Reservoir water as 609 p.p.m. total dissolved solids. Their analyses were based mainly on records obtained at Grand Canyon prior to 1930. Causes for the increased salinity figures of recent years may be the trans-mountain diversion of fresh water, subnormal rainfall, or inadequate data for the original estimate. At any rate it would seem that the water reaching the softening plant would have about 750 p.p.m. total dissolved solids, 38 per cent sodium and 350 to 400 p.p.m. total hardness computed as calcium, carbonate.

The boron concentration in Colorado River water is 0.14 p.p.m. as compared with 0.62 p.p.m. in the Los Angeles aqueduct water. On this score, the Colorado River water is almost ideal, having enough boron for good growth of most plants, yet not too much for even the most sensitive.

Effect of Prolonged Irrigation With Saline Water

A portion of the irrigation water applied to land evaporates from the surface; a large part seeps into the soil from which it is removed by transpiration from plants; and some drains downward below the root depth. Runoff under good irrigation practice is usually not large. About. 500 lb. of water is transpired for each pound of dry matter produced. In the past it was considered good agriculture practice to reduce runoff, surface evaporation and root zone drainage to a minimum and to utilize all the water, or as much of it as possible, for plant growth. It is now realized that in irrigated regions some root zone drainage is necessary.

Irrigation water such as that from the Colorado contains about 1 ton of salt for each acre-foot of water. In the Imperial Valley about 5 acre-ft. of water per acre is required each year for alfalfa. It is readily understandable then that, with 5 tons of salt per acre added annually, there must be some provision for removing this salt or so much would accumulate in the surface soil that agriculture would be impossible. For this purpose, drainage is necessary-a fraction of the irrigation water should drain downward beyond the root depth to carry away the accumulated salt.

Irrigation Water and the Soil Solution

The soil solution, which is thought of loosely as the water bathing the soil particles, even though it may be only a thin film of water in cases of soils near the wilting point, varies greatly in composition, depending upon the naturcof the original water, the composition of the soil colloid, and presence or absence of previously accumulated salts in the soil. Kelley (3) has shown that on a sandy loam, near Riverside, with good drainage the concentration of salts in the soil solution (calculated at a moisture content corresponding to the field capacity) was about three times as great as the concentration of the original irrigation water. On less permeable soils, drainage is impaired and salts tend to accumulate so that the concentration of the soil solution may become very great. Heavy rains or heavy irrigation will tend to push these concentrated soil solutions downward below the root zone. Gilman (4) shows that on Ramona Loam after several years of low rainfall and light applications of irrigation water (1.77 ft. per acre), the concentration of chloride was found to be:

0- 3 ft. horizon	from	1.2	to	2.4	M.E.	or	42.6	to	85.2 p.p.m.
3- 6 " " "	"	2	"	25	"	"	71.0	"	887.5 "
6-10 " " "	"	4	"	81	"	"	142.0	"	2,875.5 "

The soil solution in this well drained soil, he states, contained from 2 to 150 times as much chloride as the original irrigation water. After a winter of heavy rainfall, new samplings indicated that the concentration of the soil solution had been very much reduced. Thus, it may be seen that on well drained soils, copiously irrigated, the concentration of the soil solution may be as low as two or three times that of the irrigation supply, while on heavy soils, with small additions of irrigation water and low rainfall, the concentration of the soil solution may be 50 or 100 times as great as that of the irrigation water.

Since the soil colloids are bathed in the downward moving irrigation water, it is understandable that chemical reactions will occur between these colloids and the salts present in the water. One of the principal types of reaction is that of base exchange in which cations exchange between the colloid and the water until both are in equilibrium. This process is chemically similar to 'that used in water softening by zeolites. If the water is hard, and contains a large amount of calcium and magnesium, and the soil has a relatively largd store of absorbed sodium, some sodium will go into solution. Usually the process goes the other way around, the soil being relatively high in calcium and magnesium compared with the solution, and sodium enters the soil colloid. Kelley, et al. (5) state: "The ratio of Na to Ca in the solution has relatively great influence on the absorption of Na. If this ratio is not greater than 2 to 1, very little Na will be absorbed, but as this ratio exceeds 2 to 1 the absorption of Na tends to increase proportionately." There are, however, other reactions, such as precipitation as calcium carbonate, sometimes as the sulfate, or by plant absorption, which tend to remove calcium from solution.

All these reactions tend to increase the Na : Ca + Mg ratio and when the soil solution is concentrated by evaporation or transpiration, the ratio may increase markedly. Under these conditions, when the soil solution is concentrated, it is most likely that there will be sodium entering the soil colloid.

Sodium saturated soils are very greasy to the feel. The colloid swells and the soil pores close up. Aeration is diminished. If the soil colloid becomes relatively saturated with sodium, the pH value of the soil solution may become dangerously high and all these factors are injurious to plant growth. The process is a steadily cumulative

TABLE 2

The Principal Soil Types and Areas in the Los Angeles and Pasadena District

SOIL TYPE	WEST LOS ANGELES	EAST LOS ANGELES	PASADENA
	acres	acres	acres
Hanford fine sandy loam..	13,082	1,299	1,363
Ramona loam..	10) 598	3,885	7,411
Chino silt loam..	4,602	320	
Altamont loam..	3,616	211	256
Chino clay loam..	2,989	51	
Altamont clay loam..	2,778	3,674	79
Ramona clay loam.	2,778	1,696	
Rarnona sandy loam..			7,501
Miscellaneous	8,381	4,621	8,260
Total..................	49,824	15,757	24,870

one because, with swelling of the soil, colloid drainage is impaired and the soil solution becomes more concentrated.

For consideration of the nature of the soils in the Los Angeles and Pasadena areas, there have been obtained, from soil maps, the principal soil types in three areas: (1) the City of Los Angeles west of the river, south of Los Feliz Boulevard and following city limits, except at La Ciencga Boulevard, and excluding the harbor and harbor strip; (2) Los Angeles east of the river; and (3) Pasadena from Foothill Boulevard, on the north, to the Southern Pacific Railroad on the south and San Gabriel on the east. The principal soil types found in these areas are given in Table 2.

Hanford fine sandy loam is the major soil type in West Los Angeles. It is of recent alluvial origin and is usually underlaid by stratified deposits of sand, silt or gravel. This loam is, therefore, fertile, porous, easily drained, and well suited to irrigation agriculture.

At the other extreme are the Altamont soils which are residual, derived from shales. The Altamont, clay loam, for example, is dark gray to black in color and usually has a heavier subsoil. On such a soil, of which there are over 5,000 acres in Los Angeles, drainage is poor. The Altamont loam is more permeable.

The Ramona soils are older than the Hanford and are derived from old unconsolidated water-laid deposits. The subsoil is usually heavier than the surface soil and may have compact layers which impede drainage.

Chino soils, like the Hanford, are of recent alluvial origin derived from granite and schistose igneous rocks. This soil may contain some lime. The subsoils are usually heavier than the surface soil and drainage is often restricted.

Effect of Irrigation on Los Angeles Soils

For lawn and garden purposes, people are prone to water the soil too lightly. Many people do not have sprinkler installations and it is too tedious to hold the hose or move it about. Delivery rates are apt to be low because of few or small nozzles. As a result it is estimated that the average householder in the region applies less than 2 ft. of water annually, whereas twice this amount would be more nearly adequate.

The average annual rainfall of the Los Angeles district is about 15 in. This precipitation sometimes comes in heavy downpours and because of surface runoff, is not effective for leaching purposes.

The probable result of a continual irrigation of Los Angeles soils with softened Colorado River water is an interesting speculation. Eaton (6) states that waters having a sodium percentage of 65 are of doubtful quality while waters with less than 50 per cent are satisfactory. Kelley (5) would put the limit a little lower, in the general region of 1 equivalent of sodium to 1 of calcium plus magnesium, that is, a sodium percentage of 50. With the relatively high total salt concentration of Colorado River water, and with a sodium percentage below 50 or 60, it would seem that this water could probably be used continuously on the well drained Hanford soils, but there would be a decided probability of disastrous results on the heavy soils such as the Altamont clay loam. This statement is based on the assumption that softened Colorado River water is used continuously, which eventuality is very improbable.

Effect of Saline Water on Plants

Although investigators have studied the tolerance of agricultural plants to alkali since the time of Hilgard, on the whole but few precise data have been accumulated. In general, experiments have been conducted in such manner that the actual concentrations at the plant roots have been unknown or extremely variable or such that there has been little assurance that the plant was supplied with the accessory elements now known to bc essential.

A summary of results was published in 1936 by Kearney and Scofield (7). They indicate that sugar beets, strawberry clover, Bermuda grass and Rhodes grass are most likely to succeed on strongly saline soil, containing 0.8 to 1.0 per cent salts. Among ornamental and shade trees, they list cottonwood, black locust, honey locust, Chinese elm, Russian mulberry and some eucalyptus varieties as suitable on moderately saline soils, and recommend pomegranate and tamarisk as shrubs.

Eaton (8) pointed out that plants growing in salt solutions often appeared normal and that only by comparing them with others grown under similar non-saline conditions could one establish the amount of growth reduction which had occurred. Thus, a farmer or householder may believe his plants on saline soil to be healthy, yet they may, nevertheless, be stunted. More recently, at the U. S. Regional Salinity Laboratory, it has been demonstrated that salty conditions may change the internal anatomy of plants before external symptoms are visible.

Considerable acreages of irrigated lands have been abandoned, and a large fraction of land in the west, now irrigated, is in danger of having yields reduced to unprofitable levels because of saline conditions. To gather more information on the action of irrigation waters on soils, and on the joint action of water and soil on the plant, a regional laboratory was established at Riverside, Calif., in December, 1937. This Federal laboratory is part of the Bureau of Plant Industry. Building the laboratory and obtaining a staff took most of the time in 1938 and 1939, but results on some phases arc now becoming available. The laboratory is co-operating with the western states, and their appointed representatives confer with the laboratory staff on the problems and research program.

While the work program to date has dealt mainly with plant and soil studies in the greenhouse and laboratory, the employment of an irrigation engineer will permit the staff to undertake field experiments in the near future.

Thus far in the plant studies at the laboratory, it has been learned that the quality of the irrigation water is of extreme importance. Crop plants have been grown in various synthetic salt solutions and their growth and behavior measured. During the 1939 season, experiments were conducted with cowpeas, squash, cotton, milo, sugar beets, tomatoes, and alfalfa in sand cultures of varying salt concentrations. At Riverside the average dry weights of the entire plant minus roots were as follows: (In the case of sugar beets, roots were included and tops discarded.)

Treatment	*Average Relative Yield*
1 Basal nutrient solution	100
2 Base solution + 50 e.p.m. Cl, 10 Ca, 15 My, 25 Na..	86
3 Base solution + 100 e.p.m. Cl, 10 Ca, 30 Mg, 50 Na	56
4 Base solution + 100 e.p.m. SO_4, 20 Ca, 30 Mg, 50 Na..	70
5 Base solution + 200 e.p.m. SO_4, 20 Ca, 80 Mg, 100 Na	32
7 Base solution + 100 e.p.m. Cl, 90 Ca, 5 Mg, 5 Na...	65
8 Base solution + 100 e.p.m. Cl, 5 Ca, 90 Mg, 5 Na..	52
9 Base solution + 50 e.p.m. Cl, 2.5 Ca, 2.5 Mg, 45 Na..	70
13 Base solution + 200 e.p.m. SO,, 10 Ca, 180 Mg, 10 Na	38
14 Base solution + 200 e.p.m. SO_4, 10 Ca, 10 Mg, 180 Na.	31

It must be borne in mind that the concentration in sand beds shown above should be compared with soil solution concentration and not that of irrigation waters. We see from the data above that on an equivalent basis, sulfates are less toxic to plants than chlorides. Eaton (9) on the basis of earlier work stated that "a tendency is shown for sulfate to be about half as toxic as chloride to some plants, but the lemon is apparently four or more times as tolerant to sulfate as chloride."

As regards cations, comparing Treatments 7 and 8, plants arc more tolerant to calcium than magnesium. Again, comparing Treatments 3 and 7, it may be noted that Treatment 3 with 50 per cent sodium does not give as good yields in a perfectly drained sand culture as does Treatment 7 with 5 per cent sodium. The reduction is not so great and emphasizes the belief that sodium is harmful not so much *per se* as by its effect on the soil, resulting in turn in poorer drainage, more concentrated soil solutions, and a higher sodium percentagc. Confirmation of this is available in a study of two 13-year old grapefruit groves, as reported by Eaton (9). Both were irrigated with Colorado River water (12 e.p.m.). In the first, on Superstition sand, the displaced soil solution of the third foot (considered representative) contained 20.6 e.p.m. and gave a yield, in 1936, of 546 lb. of fruit per tree. In the second, on Holtville silty clay loam, a yield of less than 100 lb. per tree was obtained in the same year. The displaced soil solution of the third foot contained 178.4 e.p.m. of which 56 per cent was sodium. On the sand, little salt accumulated and the grove produced well, while on the silty clay soil, salt accumulated in the subsoil and the grove suffered very seriously.

It is known that there are tremendous differences among plant species as regards their tolerance to salinity. Thus, at Riverside, in 1939, the following yields were determined in a sand culture tank containing 100 e.p.m. of chloride salt plus basal nutritent solution as compared with the yield in a control bed the base nutrient solution of which is taken as 100.

Cotton.................	83.9	Tomatoes.................	51.4
Sugar beets	82.0	Milo maize	34.8
Alfalfa..	60.0	Squash	20.0
Cowpeas.	51.8		

From these figures it may be seen that 100 e.p.m. of chloride reduced the yield of sugar beets 18 per cent in a sand culture as compared with an 80 per cent reduction of yield with squash in the same sand bed and under identical conditions.

Use of Colorado River Water

The discussion to this point has been on the thesis that treated Colorado River water would be used to the exclusion of any other irrigation water throughout the year. The need for additional water in the Los Angeles area at the present time is not great, and for the next few years most of the cities in the District will probably require only a relatively small quantity of additional water from the Colorado River Aqueduct. The water from the Los Angeles Aqueduct, with a total dissolved solid content of 311 p.p.m., total hardness of 109, and 48 per cent sodium (10) is undoubtedly superior to the softened Colorado River water and should be used as long as it is available. To mix treated Colorado River water and Los Angeles Aqueduct water would be desirable, but perhaps impracticable, at least for Pasadena. It may be assumed, then, that not so many years hence certain districts of Pasadena and other cities will use Colorado River water almost exclusively. A suggestion is made at this time that insofar as is practicable, the use of Colorado River water be confined to the areas of permeable soils, such as the Hanford fine sandy loam. It would also be desirable to have more information on the possibility of blending the Los Angeles Aqueduct water and the Colorado River water, both from the standpoint of boron content and salt content.

Studies should be made concerning household "hardeners" as well as "softeners." Home or estate owners who could afford to do so would certainly be interested in hardening the water to be used in the garden. Possibly the District could install and service these units very cheaply with the calcium and magnesium compounds they obtain in the softening cycle at the softening plant.

The softening plant will produce large quantities of lime. Probably the District could convert this to calcium sulfate and apply it on the gardens of those who request and pay for the service. The soil itself will work as a zeolite, but the materials must not be so drastic in reaction, or in concentration, that plant growth is inhibited. For this reason, calcium sulfate, calcium silicates, and, in general, calcium salts of weak bases or relatively insoluble salts are used as soil applications to combat an increasing Sodium percentage in the base exchange complex of the soil.

A whole new approach to water softening has been made possible by the use of anion exchangers (10). The process seems to be too expensive in its present state, but although it is new and costly, a few years research may well make the process economically feasible. There has also recently become available a new carbonaceous zeolite (10) which has the ability of removing sodium as well as calcium and magnesium from waters. This cation type of exchanger operates on a hydrogen cycle and its USC on high sodium waters may be feasible.

Summary

In closing, the author should like to plead for facts and more facts. Just as the Metropolitan District made such a fine study of methods of softening water, a thorough study of the effect of this water on the particular soil types to be encountered is now needed, together with information about the effects of the water on a host of plant species ranging from shade trees to small flowers. It is true the U. S. Regional Salinity Laboratory at Riverside is doing work in this field, but it has a limited budget and will have to restrict its work to agricultural crops. Additional work by the state or by the Metropolitan Water District would be highly desirable.

Probably further study would indicate that "we can have our cake and eat it too"-that soft water for the bath and kitchen, with a hard-

ness below 100 p.p.m., and water with a sodium percentage below 50 or 60, which will not have an appreciably deleterious effect on soil and vegetation in the garden, will both be available. In the light of present knowledge, this does not seem entirely probable in the case of Colorado River water, so some compromise will undoubtedly have to be made.

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