IRRIGATION WATER QUALITY

The irrigation water quality guidelines presented in this chapter serve as a management tool and, as with all laboratory methods and interpretative tools in agriculture, they are developed to help the trained SCS technician better understand, characterize, and interpret the plant responses under a given set of conditions. The user must constantly be on guard against drawing any unwarranted conclusions based strictly on laboratory results alone. Laboratory data must be adequately related to field conditions or confirmed by field trials or experience. If used in this spirit and remembering the basic assumptions, these irrigation water quality guidelines should be a useful tool for the preliminary evaluation of the suitability of a water supply for irrigation.

In determining water availability for irrigation, information is required on both the quantity and quality; however, the quality has often been neglected. Quality should imply how well a water supply fulfills the needs of the intended user and must be evaluated on the basis of its suitability for the intended use.

Experience in the use of various irrigation water qualities gives rise to degrees of acceptability which allow an assessment of the suitability of the various irrigation waters for particular use. With sufficient reported experience, this knowledge can be organized into guidelines. The following guidelines presented in this chapter of the Irrigation

Guide for New Mexico are guidelines which have been formulated not only by experience in New Mexico but also by the United States Salinity Lab in Riverside, California, and worldwide experience of the Food and Agricultural Organization of the United Nations.

Water used for irrigation always contains measurable quantities of dissolved substances which, as a general collective term, are called salts. These include relatively small but important amounts of dissolved solids originating from the weathering of rocks and soil and disolving of lime, gypsum, and other salt sources as water passes over or percolates through them.

The suitability of a water for irrigation will be determined by the amount and kind of salt present. With poor water quality, various soil and cropping problems can be expected to develop. Special management practices may then be required to maintain full crop productivity. With good quality water, there should be infrequent problems affecting productivity.

The problems that result from using poor quality water will vary both as to the kind and degree but the most common ones are:

1. Salinity
2. Permeability
3. Specific Toxicity

SALINITY

A salinity problem related to water quality occurs if the total quantity of salt in the irrigation water is high enough that salts accumulate in the crop root zone to the extent that yields are affected. As successive quantities of soluble salts accumulate in the root zone, the crop has great difficulty in extracting enough water from the salty soil solution. This reduced water uptake by the plant can result in slow or reduced growth and may also be shown by symptoms similar in appearances to those of drought, such as early wilting. These effects of salinity may vary with the growth stage and in some cases go entirely unnoticed due to a uniform reduction in yield or growth across an entire field. The mechanism of water uptake has been studied extensively and it now appears a plant takes most of its water from, and responds more critically to salinity, in the upper part of the root zone than to the salinity level in its lower depths when using normal irrigation practices. Therefore, managing the critical upper root zone, may be as important as providing adequate leaching to prevent salt accumulation in the total root zone.

PERMEABILITY

A permeability problem related to water quality occurs when the rate of water infiltration into and through the soil is reduced by the affect of specific salts or lack of salts in the water, to such an extent that the crop is not adequately supplied with water and yield is reduced. The poor soil permeability makes it more difficult to supply the crop with water and may greatly add to the cropping difficulities through crusting of seed beds, water logging of soil surface, salinity, weeds, oxygen and nutritional problems. Permeability reduces the quantity of water placed into storage while salinity reduces the availability of the water in storage. Permeability is evaluated first from total salts in the water, since low salt water can result in poor soil permeability due to the tremendous capacity of pure water to dissolve and remove calcium and other solubles in the soil; and secondly, from a comparison of a relative content of sodium to calcium and magnesium in the water. Carbonates and bicarbonates can also affect soil permeability and must also be evaluated. The adverse influence of sodium on soil permeability has been recognized for many years but in many cases the evaluation of the sodium influence alone has proven to be in error basically because the interaction of three factors determines a water's long-term influence on soil permeability. These factors are: (1) sodium content relative to calcium and magnesium; (2) bicarbonate and carbonate content; (3) the total salt concentration of the water. A simultaneous analysis of these has been applied to soils before, but only recently has this concept been applied to estimating the permeability hazard of irrigation waters to soils.

The method most commonly used to evaluate the potential sodium problem has been the Sodium Absorption Ratio (SAR):

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

where Na=Sodium in meq/l

Ca + Mg= Calcium plus magnesium in meq/l

For SAR values greater than 6-9, the irrigation water was expected to cause a permeability problem on many soils.

However, permeability problems are also related to the carbonate (CO_3) and bicarbonate (HCO_3) content of the irrigation water, which was not considered in the SAR procedure.

The effect of carbonate and bicarbonate occurs when the soil drys between irrigations, as a part of the CO_3 and HCO_3 precipitates Ca-$MgCO_3$, thus removing Ca and Mg from the soil water and increasing the relative proportion of Na to Ca-Mg.

This effect of CO_3 and HCO_3 has been evaluated separately by the residual Sodium Carbonate Method (RSC), but until now, the SAR and RSC have never been combined.

Recent research has added refinements to the SAR and RSC procedures to create a new method called the Adjusted Sodium Absorption Ratio (Adj. SAR) Method. This procedure, outlined in Table 3, includes changes in soil water composition that are expected as a result of combinations of water salts that either dissolve lime from the soil, (adding calcium) or will result in deposition of lime from the soil water (reducing calcium). The adj. SAR is then related to the predominant soil clay mineralogy as shown in Table 1. The new adj. SAR is calculated by:

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

This new procedure will more correctly predict the potential soil permeability problem than the older SAR or RSC procedures.

TOXICITY

A toxicity problem is different from the salinity and the permeability problems, in that toxicity occurs within the crop itself as a result of the uptake and accumulation of certain constituents from the irrigation water and may occur even though salinity is low. The toxic constituents of concern are sodium, chloride or boron. Not all crops are equally sensitive but most tree crops and other woody perennial-type plants are. Toxicity problems of sodium and chloride, however, can occur with almost any crop if concentrations are high enough. Toxicity problems often accompany and are a complicating part of a salinity or permeability problem. Sprinkler irrigation may cause special toxicity problems due to sodium and chloride being absorbed through the leaves.

Sodium

Most tree crops and other woody-type perennial plants are particularly sensitive to low concentrations of sodium. Most annual crops are not so sensitive, but may be affected by higher concentrations.

Use of an irrigation water high in sodium will usually result in a soil high in sodium but it may take several irrigations to cause the change. The crop takes up sodium with the water and it is concentrated in the leaves as water is lost by transpiration. Damage (toxicity) can result if sodium accumulates to concentrations that exceed the tolerance of the crop. Leaf burn, scorch and dead tissue along the outside edges of leaves are typical symptoms.

Sodium toxicity is often modified and reduced if calcium is also present. Moderate amounts of calcium may reduce sodium damage and higher amounts may even prevent it. Since the effect of sodium is dependent on both the sodium and calcium, a reasonable evaluation of the potential toxicity is possible using the sodium adsorption ratio (SAR) for the soil water or from the adjusted sodium adsorption ratio (adj. SAR) of the irrigation water.

The symptoms of sodium toxicity occur first on the oldest leaves since a period of time (days or weeks) is normally required before accumulation reaches toxic concentrations. Symptoms usually appear as a burn or drying of tissue at the outer edges of the leaf and as severity increases, progressing inward between the veins towards the leaf center.

Sodium sensitive crops include deciduous fruits, nuts, citrus, avocado and beans. The GUIDELINES of Table 1 use the adj. SAR to evaluate the sodium hazard of the irrigation water to these sensitive crops.

Chloride

Most tree crops and other woody perennial plants are sensitive to low concentrations of chloride while most annual crops are not. However, even the less sensitive crops may be affected at higher concentrations. Chloride is not absorbed by soils but moves readily with the soil water. It is taken up by the roots and moved upward to accumulate in leaves similar to sodium. The toxicity symptom for chloride, however, is different: the leaf burn or drying of leaf tissues typically occurs first at the extreme leaf tip of older leaves rather than at the edges and progresses from the tip back along the edges as severity increases. Excessive leaf burn is often accompanied by abnormal early leaf drop and defoliation.

Boron

Boron is one of the essential elements for plant growth but is needed in relatively small amounts. If excessive, boron then becomes toxic. A boron toxicity problem is usually associated with boron in the irrigation water, but may be caused by boron occurring naturally in the soil. The sensitivity to boron appears to affect a wide variety of crops while sodium and chloride toxicities were mostly centered on the tree crops and woody perennials.

Boron is taken up by the crop and is accumulated in the leaves and other parts of the plant. Toxicity symptoms typically show first on older leaf tips and edges as either a yellowing, spotting, or drying of leaf tissues (or these in combination). The yellowing or spotting in some cases is followed by drying which progresses from near the tip along the leaf edges and toward the center between the veins (interveinal). A gummosis or exudate on limbs or trunk is also sometimes very noticeable on seriously affected trees such as almonds.

Special Toxicity Effects Due to Sprinkler Irrigation

Overhead sprinkling of certain crops can cause special toxicity problems not encountered when irrigating by surface methods. Excess quantities of sodium and chloride can be absorbed through leaves wet by the sprinkler and can cause leaf burn and, in some severe cases, defoliation. This occurs primarily during periods of high temperatures and low humidity and with rotating type of sprinkler heads. In between rotations of the sprinkler, water evaporates and salts are concentrated. The leaves absorb appreciably more salts during this alternate wetting and drying cycle than if sprayed continuously.

The leaf burn or crop damage seems to be primarily of specific toxicity due to uptake and accumulation of sodium or chloride. Toxicity occurs with sensitive crops at relatively low sodium or chloride concentrations. Toxicity has been reported to occur on citrus in several irrigated valleys of California, at concentrations as low as 3 meq/l of either sodium or chloride in the irrigation water. With furrow or flood irrigation these same concentrations cause no toxicity effects or leaf burn (Harding et al, 1958). Slight damage has been reported for more tolerant crops such as alfalfa under extremely high evaporative conditions at EC_w = 1.3 mmhos/cm containing 6 meq/l when evaporation conditions were low (Nielson, 1975). Several vegetable crops tested were fairly insensitive to foliar effect at very high concentrations in the semi-arid conditions of California (Ehli g and Bernstein, 1959).

Damage can occur from salt concentration accumulating on the external leaf surface due to salt spray. This may occur downwind from sprinklers.

Relative crop tolerances to sodium and chloride in sprinkler applied irrigation water are not well established but, in general, crops sensitive to sodium or chloride are most sensitive to foliar absorption from sprinkler applied water. Most annual crops are not expected to be sensitive.

Where foliar absorption has been a problem, several practices are being followed which greatly reduce the problem.

Sprinkler irrigation at night: Night sprinkling has been surprisingly effective in reducing or eliminating the sodium and chloride toxicity due to foliar absorption. Humidity generally rises at night and winds may decrease.

Increase speed of rotation of sprinkler heads: Frequent or continuous wetting results in less absorption than intermittent wetting. Use of sprinkler heads that rotate at 1 revolution per minute or less are recommended. Changing the speed of rotation will probably involve a change of the sprinkler head.

Sprinkling during periods of high humidity and low evaporative demand: If weather patterns for an area are known or can be forecast, and soil conditions allow for storage of sufficient quantities of water for the crop to use between irrigations, then irrigations can be timed to avoid these critical periods as much as possible.

Crop selection for quality of water: If overhead sprinklers must be used, it may not be possible to grow certain sensitive crops such as beans or grapes. Local experience may have to be relied upon as guidelines to the crops more tolerant to local conditions.

Grow crops during the cooler time of year: Autumn - winter - spring are usually periods of lower temperature and higher humidity, and crops do not need to be irrigated as often. Crops adapted to the cooler season of the year can be harvested before the periods of extreme low humidity. In some cases late-spring, early-summer maturing crops may complete their growth cycle before the sodium or chloride can accumulate to concentrations that cause damage.

Change irrigation method: A change to another irrigation method such as furrow, or basin may be necessary. Under-tree sprinklers have been used in some cases but lower leaves, if wetted, may still show symptoms due to foliar absorption. Drip irrigation could also be used.

MISCELLANEOUS PROBLEMS

From the standpoint of irrigation water, there are a few miscellaneous problems concerned with nitrogen, bicarbonate and pH.

There are others which occur less frequently but will not be considered in detail here.

Nitrate and Ammonium Nitrogen

These are the two forms of nitrogen that stimulate crop growth. If excessive quantities are present, production may be upset or maturity of the crop delayed. Concentrations occurring in water vary from zero to more than 100 milligrams per liter and are reported as either nitrate-nitrogen (NO_3-N), or as ammonium-nitrogen (NH_4-N).

Nitrogen in the irrigation water acts the same as fertilizer nitrogen and excesses will cause problems just as fertilizer excesses cause problems. Production of nitrogen sensitive crops may be affected at nitrogen concentrations above 5 mg/l from either nitrate or ammonium. Sugar beets, for example, under excessive nitrogen fertilization grow to large size but with low purity and low sugar content and the amount of sugar produced per acre may actually be reduced. Grapes, in some instances, grow too vigorously and yields are reduced, or grapes are late in maturing. Maturity of apricots, citrus and avocado may also be delayed and fruit may be poorer in quality. For many grasses and grain crops, lodging may appear due to excessive vegetative growth.

At more than 30 mg/l nitrogen, severe problems are expected with nitrogen sensitive crops. For crops not sensitive, more than 30 mg/l nitrogen may be adequate for high crop production and little or no fertilizer may be needed. However, algae and aquatic plants in streams, lakes, ponds, and canals, are often stimulated and when temperature, sunlight and other nutrients are optimum, very rapid growth or algae blooms can occur. This excessive growth may result in plugged pipelines, sprinklers, and valves, to the point that either mechanical controls, such as with screens and filters, or chemical control such as with copper sulphate may be necessary.

Bicarbonate

Bicarbonate, even at very low concentrations, has been a problem primarily when fruit crops or nursery crops are sprinkler irrigated during periods of very low humidity (RH 30%) and high evaporation. Under these conditions, white deposits are formed on fruit or leaves which are not washed off by later irrigation. The deposit reduces the marketability of fruit and nursery plants.

A toxicity is not involved but as the water on the leaves partially or completely evaporates between rotations of the sprinkler, the salts are concentrated and CO_2 is lost to the atmosphere. If the concentration effect on CO_2 loss is great enough, the less soluble constituents in the water, such as lime ($CaCO_3$), will precipitate and deposit on fruit and leaves.

pH

pH is a measure of the acidity of alkalinity of water. It is of interest as an indicator but is seldom of any real importance by itself. The main use of pH is a quick evaluation of the possibility that the water may be abnormal. If an abnormal value is found, this should be a warning and the water needs further evaluation and possible corrective measures taken. The pH scale ranges from 1 to 14, with pH=1 to 7 being acid, 7 to 14 being alkaline, and pH=7.0 being neutral. A change in pH, as from pH 7 to pH 8 represents a 10-fold decrease in acidity or a 10-fold increase in alkalinity. The normal range for irrigation water is from pH 6.5 to pH 8.4. Within this range crops have done well. Irrigation waters having pH outside this range may still be satisfactory but other problems of nutrition or toxicity become suspect.

Irrigation water quality refers to its suitability for use. A good quality water has the potential to allow maximum yield under good soil and water management practices. However, with poor quality water, soil and cropping problems can be expected to develop which will reduce yields unless special management practices are adopted to maintain and, restore maximum production capability under the given set of conditions.

Water quality problems, though often complex, generally occur in the three general categories previously discussed: salinity, permeability, and toxicity. Each may affect the crop singly or in a combination of two or more. Such a combination may be more difficult to solve and may affect crop production more severely than a single problem acting by itself.

GUIDELINES FOR INTERPRETATION OF WATER QUALITY FOR IRRIGATION

The guidelines presented in this chapter of the Irrigation Guide are limited to the various aspects of irrigation water quality that are normally encountered and which materially affect crop production. Emphasis is placed on the long-term influence of water quality on the soil-plant, soil-water system and as it affects crop production and soil and water management.

The guidelines presented here are practical and usable in general irrigated agriculture for evaluation of the more common constitutents in surface waters, underground waters, drainage waters, and sewer effluent. They are not intended, however, to evaluate the more unusual or special constiuents sometimes found in waste waters such as pesticides and trace metals.

To use the attached guidelines, certain laboratory determinations and calculations are needed, and the adjusted sodium absorbion ratio must be calculated from the laboratory determinations. The calculation procedure for the adjusted sodium absorption ratio is found in this chapter.

Analytical procedures for the laboratory determinations are discussed in USDA Handbook 60, FAO Soil Bulletin 10, and Standard Methods of the American Waterworks Association. These or other recognized procedures for analysis should be followed.

In the above discussion, the basic information needed for a field evaluation of the suitability of water for irrigation has been presented. This should show a determination that water "A" having constituents "X, Y, and Z" in concentrations shown by laboratory analysis, does or does not have the potential to limit crop production. Where limitations are indicated, the water may still be useable providing certain management steps are taken to alleviate the problem.

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