Originated by: Agriculture Department

Title: The use of saline waters for crop production...

More details

Chapter 2 - Saline waters as resources

Quality characteristics of saline waters

Chemical and physical characteristics of irrigation waters are discussed in detail by Ayers and Westcot (FAO 1985). Hence, only brief descriptions of terminology, units and key parameters are given in this publication. The parameters of relevance, in this case, are restricted to those which predominantly affect crop production either directly or indirectly. The limiting values of the quality parameters vary considerably depending upon circumstances of use. Sewage and industrial effluents are not considered as the focus of these guidelines is on irrigation with drainage waters and moderately saline natural waters of various kinds. An abbreviated classification of waters in terms of salinity is given to facilitate the identification of the kinds of saline waters included in the scope of these guidelines.

Definitions and Indices of Salinity Related Parameters

The term salinity used herein refers to the total dissolved concentration of major inorganic ions (i.e. Na,
Ca, Mg, K, HCO_3, SO_4 and Cl) in irrigation, drainage and groundwaters. Individual concentrations of these cations and anions in a unit volume of the water can be expressed either on a chemical equivalent basis, $mmol_c/l$, or on a mass basis, mg/l. Total salt concentration (i.e. salinity) is then expressed either in terms of the sum of either the cations or anions, in $mmol_c/l$, or the sum of cations plus anions, in mg/l. For reasons of analytical convenience, a practical index of salinity is electrical conductivity (EC), expressed in units of deciSiemen per metre (dS/m). An approximate relation (because it also depends upon specific ionic composition) between EC and total salt concentration is 1 dS/m = 10 $mmol_c/l$ = 700 mg/l. Electrical conductivity values are always expressed at a standard temperature of 25 °C to enable comparison of readings taken under varying climatic conditions. With all its obvious shortcomings, this custom of using EC as an index of salinity emphasizes the concept that, as a good first approximation, plants respond primarily to total concentration of salts rather than to the concentrations or proportions of individual salt constituents.

A similar usage of EC for expressing soil salinity has evolved, where the parameter of primary interest is the total salt concentration, or EC, of the soil solution. However, the content of water in the soil is not constant over time nor is the composition of the soil solution. For this reason, soil salinity is not an easily defined, single-valued parameter. In an attempt to standardize measurements and to establish a reasonable reference for comparison purposes, "soil salinity", is commonly expressed in terms of the electrical conductivity of an extract of a saturated paste (EC_e; in dS/m) made using a sample of the soil.

In addition to total salt concentration, sodium and pH can adversely affect soil properties for irrigation and cropping. At high levels of sodium relative to divalent cations in the soil solution, clay minerals in soils tend to swell and disperse and aggregates tend to slake, especially under conditions of low total salt concentration and high pH. Whether from slaking, swelling or from clay dispersion, the permeability of the soil is reduced and the surface becomes more crusted and compacted under such conditions. Thus the ability of the soil to transmit water can be severely reduced by excessive sodicity (the term used herein to refer to the combined deleterious effects of high sodium and pH, and low electrolyte concentration on soil physical properties). Since high total salt concentration tends to increase a soil's stability with respect to aggregation and permeability, distinction is made between saline soils and sodic soils. With respect to sodicity, it is the proportion of adsorbed exchangeable sodium relative to the cation exchange capacity (often expressed as the exchangeable sodium percentage, ESP), rather than the absolute amount of exchangeable sodium, that is relevant along with the total salt concentration of the infiltrating and percolating water and the soil pH. Because ESP and the sodium adsorption ratio of the saturation extract $(SAR = NA/\sqrt{(Ca+Mg)/2}$, where solute concentrations are in $mmol_c/l$) are so closely related, SAR is commonly used as a substitute for ESP and as an index of the sodium hazard of soils and waters.

Certain ions in saline waters can be specifically toxic to plants, if present in excessive concentrations or proportions. Of particular concern are sodium (Na), chloride (Cl), and boron (B). While not often toxic to plants, a few solutes sometimes (though not frequently) found in natural saline waters may accumulate in plant parts at levels that can be toxic to consumers, if their diet is largely restricted to this food. Such elements include selenium (Se), arsenic (As), and molybdenum (Mo). Standards for such specific toxicants in waters are usually given in terms of their individual concentrations (FAO 1985).

Classification of Saline Waters

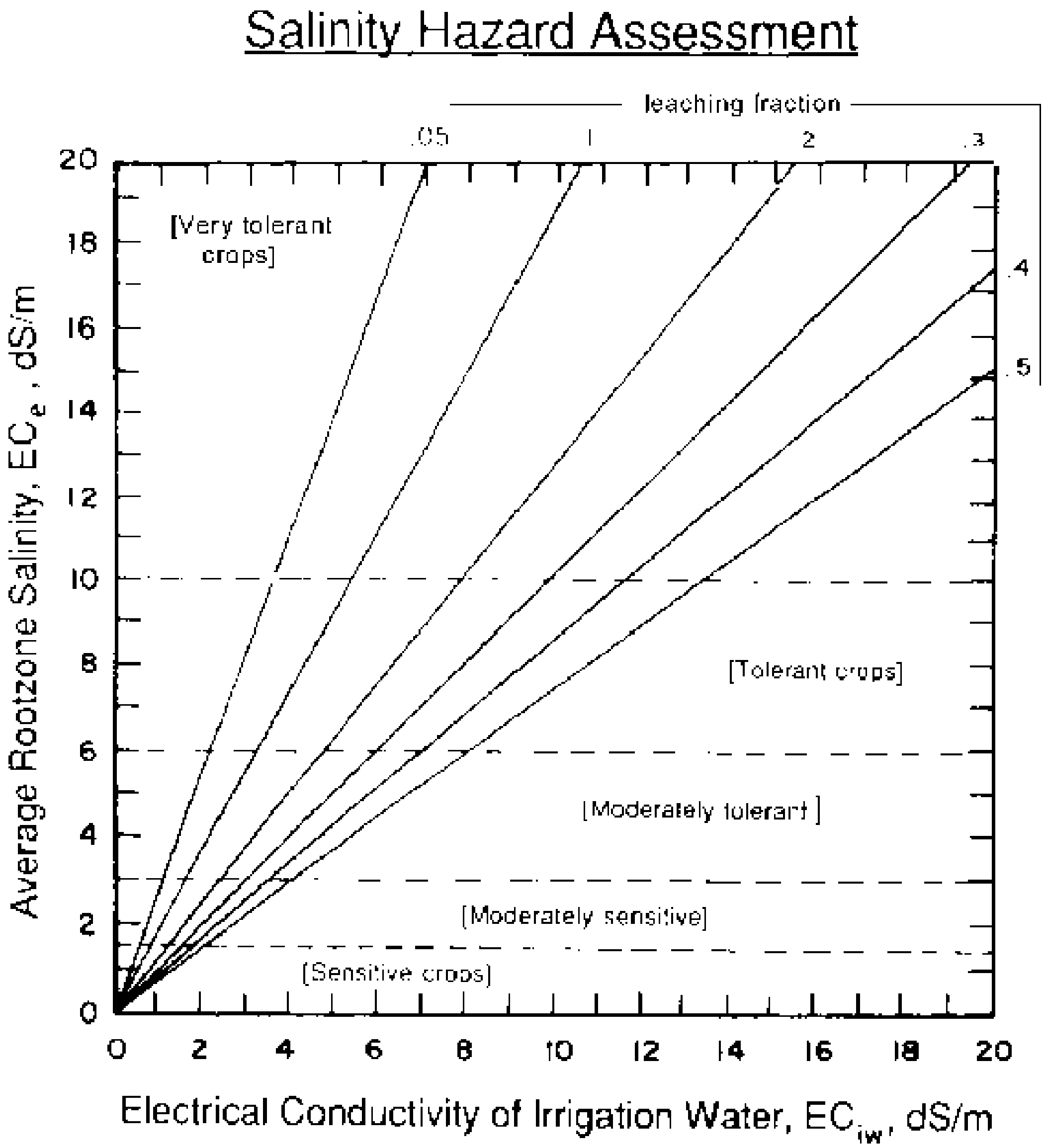
Because the suitability of a saline water for irrigation is so dependent upon the conditions of use, including crop, climate, soil, irrigation method and management practices, water quality classifications are not advised for assessing water suitability for irrigation. However, for the purpose of identifying the levels of water salinities for which these guidelines are intended, it is useful to give a classification scheme.

Such a classification is given in Table 1 in terms of total salt concentration, which is the major quality factor generally limiting the use of saline waters for crop production. As seen in Figure 1, only very tolerant crops (hardly any conventional crops) can be successfully produced with waters that exceed about 10 dS/m in EC. Few generally-used irrigation waters exceed about 2 dS/m in EC. Many drainage waters, including shallow groundwaters underlying irrigated lands, fall in the range of 2-10 dS/m in EC. Such waters are in ample supply in many developed irrigated lands and have good potential for selected crop production, though they are often not used in this regard and are more typically discharged to better quality surface waters or to waste outlets. It is the use of such saline waters that is the major focus of these guidelines. Reuse of second-generation drainage waters for irrigation is also sometimes possible and useful, especially for purposes of reducing drainage volume in preparation for ultimate disposal or treatment. Such waters will generally have ECs in the range 10-25 dS/m. Thus, they too are considered in these guidelines, though to a much lesser degree because the "crops" that can be grown with them are atypical and much less experience exists upon which to base management recommendations and to develop guidelines. Very highly saline waters (25 - 45 dS/m in EC) and brine (> 45 dS/m in EC) are beyond the scope of these guidelines and their uses for crop production are therefore not discussed herein.

TABLE 1 Classification of saline waters

Water class	Electrical conductivity dS/m	Salt concentration mg/l	Type of water
Non-saline	<0.7	<500	Drinking and irrigation water
Slightly saline	0.7 - 2	500-1500	Irrigation water
Moderately saline	2 - 10	1500-7000	Primary drainage water and groundwater
Highly saline	10-25	7000-15 000	Secondary drainage water and groundwater
Very highly saline	25 - 45	1 5 000-35 000	Very saline groundwater
Brine	>45	>45 000	Seawater

Figure 1: Relationships between EC_e (saturation extract basis), EC_{iw} and leaching fraction under conventional irrigation management (after Rhoades 1982)



Sources and availability of saline waters

In practical agricultural use, a common source of saline water is groundwater. Salinity of groundwater can be man-induced or natural.

In many areas, saline and fresh subsurface waters exist in close proximity. When fresh groundwater is pumped from aquifers that are in hydraulic connection with seawater, the change in gradients as a result of pumping may result in a flow of salt water from the sea towards the well. This is called seawater intrusion.

Upconing is another mechanism by which groundwater could become brackish. Upconing refers to a situation where a well, located close enough to saline water underlying freshwater, is pumped at a rate sufficient to cause the salt water to be drawn into the well in an upward shaped cone or mound. It has been estimated that in the USA over two-thirds of the continental area are underlain by saline groundwater that could intrude on freshwater supplies as a result of upconing.

There are also natural causes of salinity. Numerous investigators have noted that water within sedimentary strata becomes increasingly saline with an increase in depth. In general, the sequence noted is sulphate-rich water near the surface, saline bicarbonate water at an intermediary level and more concentrated chloride water at greater depths (Craig 1980). There are several mechanisms by which water trapped in sedimentary rocks can be altered into saline water. One of these is the solution of sediments and rocks.

In coastal regions, surface water sources can become saline due to the tidal influence of the sea. As the high tide moves into the coastal area, seawater moves into streams and drainage canals and travels inland. This upstream migration of seawater alters the quality of water in affected streams and drainage canals significantly. This phenomenon is also observed during times of drought.

Another important source of saline water is drainage effluent (including perched groundwater) from irrigated areas. Drainage water, once thought of as wastewater, is now used in many countries for irrigation. The salinity levels vary, but often the salt levels are higher than those of conventional primary irrigation water sources. Reuse of drainage effluent is important when the supply of good quality irrigation water is limited, and it is also an efficient means of reducing water pollution.

The use of saline drainage water in Egypt was reported by Abu-Zeid (1988). About 2.3 thousand million m^3 of drainage wastewater are discharged annually to the Mediterranean Sea via return to the Nile River in Upper Egypt; 12 thousand million m^3 are discharged directly into the sea and northern lakes; 2 to 3 thousand million m^3 are used for irrigating about 405 000 ha of land. About 75 percent of the drainage water discharged into the sea has a salinity of less than 3000 mg/l. The policy of the Government of Egypt is to use drainage water directly for irrigation if its salinity is less than 700 mg/l; to mix it 1: 1 with Nile water (180 to 250 mg/l) if the concentration is 700 to 1500; or 1: 2 or 1: 3 with Nile water if its concentration is 1500 to 3000 mg/l; and to avoid reuse if the salinity of the drainage water exceeds 3000 mg/l. The potential disadvantages of such blending are discussed later.

Drainage water is used for crop production on many farms in California, USA. For example, saline subsurface drainage water is blended with Delta-Mendota Canal water in the Broadview Water District of California to form blended water of a salinity equivalent to 3.2 dS/m and since 1956 is used to grow a variety of crops. Over time, the cropping pattern in this district has changed as the water quality has decreased. Crops now grown are mostly cotton, barley and alfalfa. Representative salinities and potentials for use as irrigation waters and drainage waters from the major irrigated areas of the USA are described by Rhoades (1977).

The use of brackish groundwater is reported from Tunisia, India and Israel. De-Malach *et al.* (1978) state that in the central Negev of Israel, sugarbeet is grown with saline groundwater of EC = 4.4 dS/m under sprinkler irrigation.

Gupta (1990) has treated the subject of saline water use in India comprehensively. He reported that the salinity level of the Ganges river in India is very low and average total dissolved salt concentration is less than 200 mg/l. However, there are specific stretches or locations along the river system where salinity level increases due to hydrologic as well as human-induced activities. In the deltaic region of the Ganges river in West Bengal, which comes under tidal influences, the salinity of the water can rise to greater than 10 times the average salinity of the river.

In the Punjab, Maharashtra area, canal waters are reported to be of good quality with EC values often less than 0.5 dS/m. On the other hand, drainage waters are reported to have high salinities. Prasad (1967) reported that the drainage waters of the Unnao Tehsil in Uttar Pradesh had an average EC of 2 dS/m. Gupta (1990) carried out a survey of groundwater quality in Rajasthan and estimated percentages of wells that fall into varying classes of salinity. The results are presented in Table 2.

TABLE 2 Percent distribution of groundwaters of Rajasthan in different EC classes

EC range dS/m	11 arid districts (2817)[1]	7 semi-arid districts (4000)[1]	8 humid districts (2614)[1]
<0.75	10	23	41
0.75-2.25	29	48	49
2.25-5.00	27	19	8
5.00-10.0	20	8	2
10.0-15.0	9	2	-
>15.0	5	-	-

[1] Number of samples