CHAPTER 2

SALINITY IN THE SOIL ENVIRONMENT

KENNETH K. TANJI
Department of Land, Air and Water Resources
University of California
One Shields Avenue
Davis, CA 95616 U.S.A.

Abstract

The purpose of this chapter is to provide plant scientists with a background on the nature of soil salinity with a particular emphasis on irrigated agriculture. Since the chemistry of soil solutions plays a major role in soil salinity, considerable details on this topic are offered. Chemical speciation in the soil solution should be of importance to plant scientists. The dynamic nature of soil salinity in the rootzone affects performance of plants. Profile distribution of salts is affected by leaching fraction and changes with changing water content from irrigation and rootwater extraction. Soluble salts in soils are highly mobile and transported by water through mass flow and dispersion. Irrigation water management is one of the keys in maintaining salt balance in the rootzone. Growing regulations on the disposal and management of poor quality drainage waters is now exacerbating the maintenance of salt balance in the rootzone in irrigated lands.

2.1 Introduction

The world’s surface area occupies about 13.2 billion ha, but no more than 7 billion ha are arable and 1.5 billion ha are cultivated (Massoud, 1981). Of the cultivated lands, about 0.34 billion ha (23%) are saline (salt-affected) and another 0.56 billion ha (37%) are sodic (sodium-affected). Thus, saline and sodic soils cover about 10% of the total arable lands and exist in over 100 countries. Another set of database (FAO, 1989) indicates that the world has about 227 million ha of irrigated lands of which 20% are salt-affected. Since irrigated agriculture provides about one third of the world food supply, secondary salinization of irrigated lands is of major concern. And of the remaining 1,247 million ha of non-irrigated lands, 31.2 million ha are salinized. Ghassemi et al. (1995) point out that land degradation, including soil salinization, is a
principal constraint in meeting the needs of world food production. The reader is directed to Chapter 1 for more details.

2.2 Nature of Soil Salinity

2.2.1 SALINITY CONSTITUENTS AND SALINITY PARAMETERS

Salinity as defined herein is the concentration of dissolved mineral salts present in soils (soil solution) and waters. The dissolved mineral salts constitute a mixed electrolyte of cations and anions. The major cations in saline soil solutions consist of \( \text{Na}^+ \), \( \text{Ca}^{2+} \), \( \text{Mg}^{2+} \) and \( \text{K}^+ \) and the major anions, \( \text{Cl}^- \), \( \text{SO}_4^{2-} \), \( \text{HCO}_3^- \), \( \text{CO}_3^{2-} \) and \( \text{NO}_3^- \). Other constituents contributing toward salinity in hypersaline soils and waters include \( \text{B} \), \( \text{Sr}^{2+} \), \( \text{SiO}_2 \), \( \text{Mo} \), \( \text{Ba}^{2+} \) and \( \text{Al}^{3+} \). These salinity constituents are reported in units of mmol/L or mmol charge/L (meq/L) or mg/L (ppm) for major solutes and or charge/L or for trace elements. Smaller but important activities of \( \text{H}^+ \) and \( \text{OH}^- \) are also present and they are respectively reported in terms of pH and pOH.

Salinity in soils and waters is often reported as a lumped parameter, i.e., Electrical Conductivity (EC) or Total Dissolved Solids (TDS), and sometimes, Total Soluble Cations (TSC) and Total Soluble Anions (TSA). EC is an intensive (electrical) parameter and reported as milliSiemens/cm (mS/cm, equivalent to \( \mu \text{mhos/cm} \)) for lower salinities and deciSiemens/m (dS/m, equivalent to mmhos/cm) for higher salinities. A saline solution offers smaller resistance to the passage of an electric current and hence has higher conductance while a dilute solution offers greater resistance and hence has lower conductivity. TDS is an extensive (capacity or gravimetric) parameter and is reported as mg/L or g/L for hypersaline waters and soils. TDS is obtained by evaporating a sample of water or soil solution down to dryness in which a portion of the carbonates is lost as CO\(_2\) gas during desiccation. TSC and TSA are reported as mmol charge/L or meq/L and are obtained from detailed chemical analyses of cations and anions. TSC and TSA are frequently compared to check on the accuracy of chemical analyses, i.e., salinity is a heterogeneous mix of electrolytes in which the charges (cations and anions) should be balanced assuming that all of the major ions have been analyzed.

No exact relationship exists between intensive and extensive lumped salinity parameters, however, approximate conversion factors are used (Tanji, 1990 a). TDS may be approximated by taking the product of EC in dS/m and 640 for solutions up to about EC 5 dS/m or for more saline waters and soil solutions, EC in dS/m and 800. Taking the product of EC in dS/m and 10 approximates TSC or TSA in meq/L. Taking the product of EC in dS/m and 0.00364 approximates solute potential (osmotic pressure) in MPa. Taking the product of EC in dS/m and 0.0127 approximates ionic strength in M/L.

2.2.2 DYNAMIC NATURE OF SOIL SALINITY

The measurement of salinity in waters for EC, TDS, TSC and TSA is straightforward. In contrast, the measurement of soil salinity is challenging because of the strong influence