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# Water Management in oases

**Abdalla KAMAL EL-DIN**

Department of Horticulture, Faculty of Agriculture
Zagazig University, Zagazig (Egypt)

## I. - Introduction

All life depends on water. The role of water in metabolism, in regulating body temperature, and in nourishing the tissues, explains why we could not long survive without adequate amounts of water. A man in good health might be able to survive without water for a few days in a desert if he is only slightly active. If he tried to be more active he might not last a single day because the consequent losses of water from the body would greatly exceed the losses incurred under slight activity.

Water serves in many other ways to maintain life, health, vigour, and social stability. The nutritive value of food crops may be affected by the amount of moisture available to them when they are in active growth. The occurrence of water in a locality confers advantages on the people who own use the lands.

Today, water is as necessary for our life and health as it was for our prehistoric ancestors. However, modern civilization imposes heavy demands on water. Merely to sustain life takes relatively little water. But even in pastoral or other simple societies, additional amounts are needed in preparing food and washing bodies and clothes. The total daily requirement for all purposes, including drinking, in ancient villages may have averaged 3 to 5 gallons a person. Now a person uses 60 gallons or more each day for household and lawn-watering purposes in the average electrified farm or urban home. The figures are for homes with running water ; the corresponding average for homes without convenience is only 10 gallons a person a day. However, irrigation of arid farmlands was stated to consume about 15 times the human needs at the comfort level – 5 gallons a person a day – for 37 million people within the same area.

The impact of new inventions and new developments and growth in population and industry has not commonly been given the attention it has merited. Furthermore, the application of more intensive farming practices, and the development of new products all impose additional demands for water.

The task of finding, developing, and maintaining suitable water supplies has not been limited to modern times. It has had to be faced wherever large numbers of people have crowded together in small spaces like oases in arid and semi-arid regions. Such oases are completely dependent on the underground sources of water as precipitation is either insufficient or non existent.

## II. - Aspects of water status in oases

An oasis is usually defined as an isolated fertile tract within a land depression in a desert or waste. Oases vary in size from a few acres around small springs to vast areas of naturally watered or irrigated land. However, the largest oases occur along rivers traversing deserts from headwaters in distant rainy regions. In Egypt, for example, most of the population is concentrated within the nearly 3 600 sq.km. of the intensively cultivated, irrigated land along the Nile River.

Underground water sources account for large numbers of oases, where springs and wells, many of them artesian, are supplied from sandstone and limestone aquifers. In this respect, it should be noted that water beneath the land surface is not all ground water. Ground water is only the part of subterranean water that occurs where all pores in the containing rock materials are saturated. The "zone of saturation" may extend up to the land surface, notably in seep areas and in some stream channels, lakes, and marshes. At all other places, above the ground-water zone, "a zone of aeration" exists and may range in thickness from a few centimeters to hundreds of metres. Some water is in the zone of aeration at all times, held there by molecular attraction, in particular, soils may hold significant volumes of water against the downward pull of gravity. Wells cannot extract any of this water ; wells must be drilled through the zone of aeration and obtain their supplies from ground water. The capillary rise usually results in saturation of a zone above the water table and must be considered in determining the drilling depth for reaching the true water table.

The use of ground water expanded rapidly at the beginning of this century as a result of both the increasing demand for water and the improvements in construction of wells and pumps in addition to the significant reduction in cost of power from electricity, gas and oil.

Nowadays, ground water furnishes a substantial part of the water supply for domestic, livestock, industrial and irrigation uses not only in oases of the arid and semi-arid regions but also in other parts of Western Europe, North America, the Near East, the Mediterranean basin and Australia.

In much of the arid and semi-arid regions of Africa, a supply of adequate and suitable ground water usually is harder to find than land that is suitable for farming. In most of the African nations, water exists beneath the surface of the ground but conditions often are not favourable for using it to irrigate crops. Sometimes the water is so far down that the cost of pumping is too great ; or the formation in which the water occurs is so tight that it does not yield water readily or is so limited in extent that the supply would soon be exhausted; or the rate of recharge of the ground water reservoir is too small to justify extensive development of the area ; or the supply may contain too much salt.

Ground water for irrigation need not be potable, but it must not contain high concentrations of salts injurious to plants or soil. Water of doubtful quality should be tested to determine which alkalies are present and the percentage of each. As a rule, four major characteristics determine quality of water for irrigation : *(i)* The total concentration of soluble salts ; *(ii)* The concentration of sodium and the proportion of sodium to calcium plus magnesium ; *(iii)* The concentration of bicarbonate ; *(iv)* The occurrence of minor elements such as boron, in amounts that are toxic.

The suitability of irrigation water (SIW) can be expressed as :

**SIW : f (QSPCD)**

in which :

*Q : quality of irrigation water*
*S : soil type*
*P : salt tolerance characteristics of the plant*
*C : climate*
*D : drainage characteristics of the soil.*

Some other factors, like the depth of water table, presence of a hard pan of lime or clay, calcium carbonate content in the soil and potassium and nitrate ions in irrigation water, also indirectly affect the suitability of irrigation water. This is probably the main reason for the several classifications, varying in limits of salinity and other chemical indices. The soil type, major crops of the area, climate and drainage characteristics profoundly influence the suitability of a particular water for irrigation. A highly saline water may be suitable in a well drained, light textured, fertile soil while a much less saline water may be more harmful for the same crop grown on a heavy textured soil with impeded drainage. It is the actual salt concentration near the root zone that determines the suitability of an irrigation water rather than the chemical properties of irrigation water alone.

The quality of an irrigation water is generally judged by its total salt concentration, relative proportion of cations or sodium adsorption ratio and the contents of bicarbonate and boron.

## 1. - Salinity

Irrespective of ionic composition, the harmful effects of an irrigation water increase with its total salt concentration as it increases the soil salinity significantly. Waters of low salinity (EC 3 mmhos/cm or of less than 1920 ppm) are generally composed of higher proportions of calcium, magnesium and bicarbonate ions. Highly saline waters (EC 10 mmhos/cm or of more than 6400 ppm) consist mostly of sodium and chloride ions. Moderately saline waters (EC 3 to 9 mmhoscm or from 1920 to 5 760 ppm) have varying ionic composition. Waters containing high concentrations of sodium, bicarbonate and carbonate ions have high pH.

## 2. - Sodium adsorption ration (SAR)

Any increase in the SAR of irrigation water increases the SAR of the soil solution. This ultimately increases the exchangeable sodium of the soil. Generally, there is a linear relationship between SAR and exchangeable sodium percentage (ESP) of the soil up to moderate ESP levels, and at high ESP levels, the relationship tends to be curvilinear.

In judging the suitability of irrigation water, both salinity and SR should be kept in view along with the salinity and sodicity developed during the cropping period. Salinity increases the osmotic stress while adsorption of sodium is increased both by salinity and SAR.

## 3. - Magnesium calcium ratio

At the same level of salinity and SAR, but with varying proportions of calcium and magnesium, adsorption of sodium by soils and clay minerals increases at higher Mg : Ca ratios. This is because the bonding energy of magnesium is generally less than that of calcium, allowing more sodium adsorption. It suggests that soil sodicity would increase more at the same SAR if the water contains a higher proportion of magnesium to calcium. Thus, it is desirable to analyse both calcium and magnesium in irrigation water separately in order to predict soil sodicity hazard more accurately. It is more important if the Mg:Ca ratio in irrigation water happens to be more than 4.

## 4. - Bicarbonate

Irrigation waters rich in bicarbonate content tend to precipitate insoluble calcium and magnesium in the soil as their carbonates :

$$2HCO_3 + Ca^{++} \downarrow \rightleftharpoons C_aCO_3 + H_2O + CO_2 \uparrow$$

This leaves a higher proportion of sodium to divalent cations in the soil solution and increases the SAR. This bicarbonate induced increase in the SAR of the soil solution ultimately results in higher adsorption of sodium on the soil exchange complex.

## 5. - Boron

Though boron is an essential nutrient for plant growth, it becomes toxic beyond 2 ppm in irrigation water for most of the field crops. It does not affect the physical and chemical properties of the soil, but at high concentrations it affects the metabolic activities of the plant.

### 6. - Potassium and nitrate

Potassium and nitrate ions are often present in significant amounts in irrigation waters. Being essential nutrients, they act favourably in reducing the harmful effect of saline water on crop growth by way of providing these nutrients regularly, rather than by reducting soil salinity. Among these, the effect of nitrate ion has been found more spectacular than potassium because irrigated soils are themselves deficient in nitrogen status and are generally well supplied with potassium. Regular supply of the nitrate form helps in decreasing the salt induced nitrogen deficiency and in increasing crop productivity.

## III. - CLassification of irrigation waters

Several classifications of irrigation water have been proposed in different nations on the basis of their chemical characteristics and their effect on crop growth. We shall consider an Indian proposal for water quality rating based on the classification introduced by the United States Soil Salinity Laboratory (USSSL), and giving emphasis on salinity and soil texture along with some specific situations.

**Water quality ratings**

| Nature of soil | Crop grown | Safe max. Limit of EC of irrigation water micromhos/cm |
|---|---|---|
| Deep black soils and alluvial soil having a clay content more than 30% : soils that are fairly tó moderately well drained. | Semi-tolerant<br>Tolerant | 1500<br>2000 |
| Heavy textured soils having a clay content of 20-30% ·: soils that are well drained internally and have a good surface drainage system. | Semi-tolerant<br>Tolerant | 2000<br>4000 |
| Medium textured soils having a clay content of 10-20% : soils that are well drained internally and have a good surface drainage system. | Semi-tolerant<br>Tolerant | 4000<br>6000 |
| Light textured soils having a clay content less than 10% : soils that have excellent internal and surface drainage. | Semi-tolerant<br>Tolerant | 6000<br>8000 |

The world wide applicability of such water quality indices shows that none of them is fully applicable under all conditions due to several soil factors and their interactions. However, they act as guidelines in a broad sense.

Under certain conditions, the use of saline irrigation water is inevitable. It can be better used for irrigation after obtaining the following informations and adopting proper management practices :

*i) Knowledge of the total salt concentration and ionic composition ;*
*ii) Salt tolerance behaviour of the crop variety to be grown ;*
*iii) Climatic data ;*
*iv) Consumptive use of water by the crop ;*
*v) Soil factors, such as initial soil salinity, fertility and calcium carbonate content ;*
*vi) Drainage characteristics and leaching requirement of the soil.*

## IV. - Factors affecting quality of ground water

Quality of the well water is highly variable due to climatological and hydro-geological conditions. The quality of ground water resources was classified into three main groups :

*i) Water quality of arid and semi-arid regions having rain fall below 45 cm per year ;*
*ii) Water quality as influenced by hydrological conditions such as high water table ;*
*iii) Water quality of wells in some areas of the coastal regions as affected by salt water intrusion.*

Of all the factors, aridity is the most important single factor responsible for a very high degree of salinity of well waters.

In addition to the total salt concentration, individual cation and anion compositions, and pH of irrigation water are important characteristics. Statistical analysis shows that all saline waters are alkaline in reaction and their pH values are confined mostly within the range of 7,5 to 8,3. Regarding individual ionic composition, highly saline water is dominated by sodium and chloride ions. Calcium is confined mostly to the narrow range of traces to 20% of the total salt concentration. This indicates the predominance of sodium and insufficiency of calcium. Another interesting feature of these waters is the predominance of magnesium over calcium. In those waters, carbonate is either absent or present in very little quantities and the concentration of bicarbonate ion is mostly confined to the range of 5 to 30%. Sulphate is uniformly distributed in all ranges. However, the continuous use of poor quality irrigation waters may not only cause calcium deficiency but also create poor soil physical conditions.

The problem of boron hazard may appear in some arid areas where its concentration in the irrigation water ranges from 2 to 5 ppm. The toxic effect of boron in irrigation water is dependent on its concentration, soil texture, calcium carbonate content, pH, organic matter, amount of clay in the soil, depth to water table and the drainage condition of the soil in addition to the boron tolerance limit of crops.

Salinity of the ground water shows significant seasonal differences as it increases during the summer and is reduced wherever effective rainfall occurs especially in the low lying areas. Quality of the ground water also varies according to the well depth and between different places even within the same area at a distance of a few metres.

## V. - Aspects of irrigation management in oases

Oases are mainly dependent on the ground water source under arid or semi-arid environmental conditions. In such areas, there may be no alternate source of good quality irrigation water and it is inevitable to use the available water of poor quality. However, the yield potential of such oases can be increased by adopting proper management practices such as :

*i) Improvement of sodium and bicarbonate rich water by gypsum application.*
*ii) Choice of salt tolerant crop varieties.*
*iii) Optimum fertilization.*
*iv) Proper irrigation management.*
*v) Breaking of any impervious layer by deep ploughing.*
*vi) Adopting other management practices suitable for the area.*

### 1. - Improvement of water quality

The harmful effect of irrigation water can be minimized to some extent by modifying its ionic composition by adding chemicals which tend to precipitate the harmful constituents such as bicarbonate and carbonate in the form of less soluble salts or tend to create a favourable cation (Ca:Mg:Na) ratio. There appears to be no technique to reduce the total salt concentration of irrigation water for large irrigation projects except by diluting it or mixing with good quality water, if available nearby. Improvement in Ca:Na ratio or SAR takes place by increasing the calcium ion concentration, decreasing Mg:Ca ratio and precipitating excessive carbonate ions by adding gypsum (hydrated calcium sulphate) :

$$2NaHCO_3 + Ca\ SO_4 \rightleftharpoons Ca(HCO_3)_2 + Na_2SO_4$$

$$Ca(HCO_3)_2 \rightleftharpoons CaCO_3 + H_2O + CO_2$$

Gypsus can be applied as a saturated solution by a mechanical device in flowing water at a constant rate. Since gypsum application improves both poor quality water and alkali soil, it is desirable to apply gypsum, both in the soil and in water, rather than treating water alone. But if the soil is good and only the water is bad, gypsum should be applied only in water.

## 2. - Choice of salt tolerant crops

Salt tolerance means the ability of a plant to tolerate salt concentrations in the root zone. A knowledge of the salt tolerance characteristics of a crop is important in selecting a particular crop or its variety to suit the soil conditions and for determining the leaching requirement.

The effect of soil salinity on crop growth is negligible when the electrical conductivity of the saturation extract (ECe) is less than 2 mmhos/cm. Yields of very sensitive crops are reduced when the ECe value about 4 mm hos/cm. Many of the common field crops are affected when the ECe value is in the range of 4 to 8 mmhos/cm. Crops with high salt tolerance can grow satifactorily when the ECe values are between 8 and 16 mmhos/cm. Only a few crops survive at ECe values beyond 16 mmhos/cm.

## 3. - Optimum fertilization

Saline and alkali soils or soils irrigated with poor quality water are low in their fertility status, especially with reference to nitrogen or sometimes to phosphorus. Better crops can be grown by raising their fertility status. Nitrogen response to crops is better when it is applied to soil along with manures. It has been observed that for different field crops, the usual doses of fertilizers, as applied on normal soils, can be applied up to an EC value of 6,5 millimhos/cm. and an exchangeable sodium percent of about 30. Generally, the efficiency of fertilizers on soils irrigated with saline water or salt affected soils depends largely on the interactive effects of salts, exchangeable sodium and fertilizers ; in such cases, the efficiency of fertilizers has to be evaluated keeping in view the quality of irrigation water, level of soil salinity and sodicity and their interactive effects.

## 4. - Irrigation management

In order to adopt irrigation under the arid or semi-arid conditions of oases, it is of major importance to have information about soil physical and chemical properties through representative soil profiles ; depth of the water table ; and climatic parameters such as amount of rainfall, its intensity, distribution, evaporation in addition to the thermal properties ; wind directions and velocity.

Success of irrigation, under oases conditions lies in the degree of accuracy in the predicted values of soil salinity and sodicity expected to be developed during the cropping period. Saline waters can more safely be used in coarse than in fine textured soils. However, it is essential to adopt irrigation practices such that the salinity at the root zone is kept to the minimum. For this purpose, the quantity of water and the frequency of irrigation are so kept that they could meet the leaching requirement of the soil and the consumptive use of the crop grown.

Salts often accumulate in the top few centimetres of the soil during non-crop periods. Where high water tables complicate salinity control, fallow and idle lands may rapidly accumulate surface salts particularly in hot arid climates. Under such conditions, both crop germination and yield can be seriously reduced. A heavy pre-sowing irrigation to leach these surface salts will improve germination and early growth and is sometimes an essential practice. It is made far enough in advance of the desired planting date to allow for cultivation to remove weeds and prepare the seed-bed.

Wherever salinity is a problem, planting seeds in the centre of a single-row-raised-bed will place the seed exactly in the area where salts concentrate. A double-row raised planting bed by comparison offers an advantage. The two rows are placed so that each is near a shoulder of the raised bed, thus, placing the seed away from the area of greatest salt accumulation. By this method, higher soil and water salinities can be tolerated than with the single-row plantings because the water moves the salts through the seed area to the centre of the ridge. Alternate furrow irrigation is often advantageous. If the beds are wetted from both sides, the salts accumulate in the top and the centre of the bed, but if alternate furrows are irrigated, the salt can be moved beyond the single seed row, thus reducing the extent of salt accumulation. Off-centre, single-row planting on the shoulder of the bed closest to the watered furrow aids germination under salty soil conditions.

With either single or double row planting, if salts are expected to be a problem, increasing the depth of water in the furrow can also be an aid to improve germination. Better salinity control can be achieved by using sloping beds with seeds planted on the sloping side and the seed row placed just above the water line.

The larger seeded crops, such as maize, have been planted in the water furrow as an aid to salt control during germination. Grapes, too, have sometimes been grown with problem waters, by placing the vine row at the bottom of wide flat furrows or at the bottom of wide flat furrows or at the bottom of wide gently sloping V-shaped furrows. Salinity problems have been aggravated when permanent crops such as tree crops and citrus are planted on raised beds and surface irrigated with poor quality water. Salts gradually accumulate in the raised beds to the extent that in a few years crop tolerance is exceeded.

Selection of the proper water distribution system can save expensive labour and ensure better crop yields as well as saving water.

The method of water application is important, especially if the cost of water is high. Some factors that determine the method and type of system used are : *(i)* Climate, *(ii)* Type of crops, *(iii)* Cost of water, *(iv)* Slope of field, *(v)* Physical properties of soil, *(vi)* Water quality, *(vii)* Water availability, *(viii)* Drainage capability, and *(ix)* Salinity or other problems.

**The common methods of irrigation**

**1. - Methods of surface irrigation**

–▶ *(a) Boarder irrigation*

I - Straight boarder irrigation

II - Contour boarder irrigation

–▶ *(b) Check-basin irrigation*

I - Rectangular check-basin irrigation

II - Contour check-basin irrigation

III - Ring check-basin irrigation

–▶ *(c) Furrow irrigation*

I - Deep furrow irrigation

i) Straight deep furrow irrigation

x) Level straight deep furrow irrigation

xx) Graded straight deep furrow irrigation

ii) Contour deep furrow irrigation

II - Corrugation furrow irrigation

i) Straight corrugation furrow irrigation

ii) Contour corrugation furrow irrigation

**2. - Method of sub-surface irrigation**

**3. - Method of sprinkler irrigation**

–▶ *(a) Rotating head sprinkler irrigation*

–▶ *(b) Perforated pipe sprinkler irrigation*

**4. - Method of drip irrigation**

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