IRRIGATION WATER

Plant life, like the animal life, is dependent primarily on three components, viz. air, water and nutrition (food). Water application to soil is done for the purpose of supplying moisture essential for plant growth. Water, after entering the soil, dissolves the soluble plant food nutrients. During the process of water uptake by the plants, the dissolved nutrients are mainly taken up by the plants. Further, application of water to the soil helps to make the soil relatively cool, overcome drought, dilute the salts in the soil, leach out some toxic su[illegible] the root zone, and soften the plough pan, if present.

The sources of water for crops include rainfall, atmospheric water other than rain fall (dew, fog, humidity), flood water, river/canal water, and ground water.

Water Quality

Crop production in arid and semi-arid regions is dependent on artificial irrigation. The hot and dry climates of these regions require that the irrigation water does not contain soluble salts in amounts that are harmful to the plants or have an adverse effect on soil properties. Water quality concerns were somewhat neglected in the past because good quality water supplies were plentiful and readily available. This situation is now changing fast. Many parts of the world are falling short of good quality irrigation water because of increased cropping intensity as well as increased cropped area to fulfill the demands of ever-increasing human population. Under these circumstances, the farmers are using the water that is generally not recommended for irrigation. Indiscriminate use of such low-quality waters can often lead to reduce crop yields or under certain conditions there may be a complete crop failure. Moreover, the soils under irrigation of these type of waters can develop salinity and/or sodicity problems which, in turn, require expensive treatment to make them productive again. On the other hand, when poor quality water is skilfully used, it can contribute to the successful production of a variety of crops. Therefore, to avoid problems when using poor quality waters, there must be sound planning to ensure that the quality of water available is put to the best use, i.e. unproductive loss of water must be decreased.

Water quality refers to the characteristics of a water that influence its suitability for a specific use, i.e. how well the water quality meets the needs of a user. Specific uses have different quality needs because one water supply can be considered more acceptable if it produces better results or causes fewer problems than an alternate water supply. For instance, good quality river water which can be used successfully for flood irrigation. However, because of its sediment load, it is unacceptable for municipal use without treatment to remove the sediment.

The ideal situation is to have several water supplies from which one can make a selection, but normally only one supply is available. In this case, the quality of the available supply must be evaluated to see how does it fit in the intended use plans.

Water used for irrigation can vary greatly in quality depending on the type and quantity of dissolved salts. Therefore, the suitability of a water for irrigation is determined not only by the total amount of salts present but also by the kind of salts. Water quality or suitability for irrigation purpose is judged on the potential severity of the problems that can be expected to develop during long-term use. The problems that result vary both in kind and degree/magnitude, and are modified by soil, climate and water user. As a result, there is no set limit on crop, as well as by the skill and knowledge of the water user. As a result, there is no set limit on quality. There have been a number of different water quality guidelines related to irrigated agriculture. Each has been useful but none has been entirely satisfactory for the situations because of the wide variability in field conditions.

Hazards associated with water quality

There are three principal problems that can arise from the quality of irrigation water delivered to the agricultural fields. These are salinity, sodicity and toxicity problems/hazards.

Salinity hazard

This is directly related to the quantity of salts dissolved in irrigation water. All the irrigation waters contain salts and mostly all the dissolved salts are left in the soil after the applied water is lost by evaporation from the soil surface or through transpiration by the plants. Unless the salts are leached from the root zone, sooner or later they will accumulate in quantities harmful for the growth of most crop plants.

The salinity hazard is expressed in terms of electrical conductivity (EC) of the water or total soluble salts (TSS) or total dissolved salts (TDS) present in the water. Electrical conductivity is expressed as dS m^{-1} while TSS/TDS are expressed as $mmol_c\ L^{-1}$.

Sodicity hazard

The effects of sodicity hazard can be divided into three categories, viz. sodium adsorption ratio (SAR), residual sodium carbonate (RSC), and permeability problem or permeability index (PI).

Sodium adsorption ratio (SAR)

This problem develops when irrigation water contains relatively more Na^+ ions than divalent Ca^{2+} and Mg^{2+} ions. Prolong use of this type of irrigation water results in the accumulation of Na^+ ions onto the soil exchange complex. This accumulation, in turn, results in a breakdown of soil aggregates (soil dispersion). Better aggregation is responsible for good soil structure which is needed for better movement of water and air through soils.

Sodium adsorption ratio (SAR) of water is expressed as:

$$SAR = Na^+/[(Ca^{2+} + Mg^{2+})/2)]^{1/2}$$

The concentrations of Na^+, Ca^{2+}, and Mg^{2+} are expressed in $mmol_c\ L^{-1}$. Sodium adsorption ratio can also be expressed as:

$$SAR = Na^+/ \ldots$$

In this case the concentrations of Na^+, Ca^{2+}, and Mg^{2+} are expressed in mmol L^{-1}. Sodium adsorption ratio in both the cases is expressed in units of $(mmol\ L^{-1})^{1/2}$.

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Carbonate/bicarbonate problem

This problem occurs when irrigation water contains higher concentrations of CO_3^{2-} and HCO_3^- ions than that of Ca^{2+} and Mg^{2+} ions. Use of this water expedites the sodication process by inactivating the Ca^{2+} and Mg^{2+} ions of water through the precipitation of these ions in the form of $CaCO_3$ and $MgCO_3$. This process indirectly yields an increase in Na^+ ions and a corresponding decrease in Ca^{2+} and Mg^{2+} ions.

There are three terms which are in use for this problem, i.e. soluble sodium percentage "found", soluble sodium percentage "possible", and residual sodium carbonate.

Soluble sodium percentage "found" = $(Na^+ \times 100)/(Ca^{2+} + Mg^{2+} + Na^+)$

Soluble sodium percentage "possible" = $(Na^+ \times 100)/[(Ca^{2+} + Mg^{2+} + Na^+) - (CO_3^{2-} + HCO_3^-)]$

Residual sodium carbonate = $(CO_3^{2-} + HCO_3^-) - (Ca^{2+} + Mg^{2+})$

Here the concentrations of CO_3^{2-}, HCO_3^-, Ca^{2+} and Mg^{2+} are expressed in mmol$_c$ L^{-1}.
It has been an established fact that waters having high SAR and $CO_3^{2-} + HCO_3^-$ generally cause more problems than those having either high SAR or $CO_3^{2-} + HCO_3^-$ alone. For instance, a water having high SAR and RSC (e.g. SAR = 8, RSC = 6 mmol$_c$ L^{-1}) is more detrimental to soils than a water having high SAR and low RSC (e.g. SAR = 8, RSC = 1 mmol$_c$ L^{-1}).

Permeability problem

An infiltration problem related to water quality occurs when the soil permeability to the applied irrigation water is appreciably reduced. Water remains on the soil surface too long or infiltrates very slowly to supply the crop with sufficient water to maintain acceptable yields. Although soil permeability varies widely and can be greatly influenced by the quality of irrigation water but soil factors such as structure, degree of compaction, organic matter content and chemical and mineralogical make-up can also greatly influence the water intake rate.

The two most common water quality factors which influence soil permeability are the salinity of water (total quantity of salts in the water) and its Na^+ content relative to the Ca^{2+} and Mg^{2+} contents. A high salinity water generally increases infiltration while a low salinity water or a water with a high Na^+ to $Ca^{2+} + Mg^{2+}$ ratio generally decreases infiltration. Both factors may operate at the same time. Generally, an infiltration problem related to water quality occurs in the surface few centimetres of soil. When a soil is irrigated with a high Na^+ water, a high Na^+ surface soil develops which weakens soil structure. The surface soil aggregates then disperse to much smaller particles which clog soil pores. In the case of the low salinity water, water dissolves and leaches most of the soluble minerals, including Ca^{2+}, from the soil surface.

Long term irrigation influences soil permeability through Na^+, HCO_3^-, Ca^{2+} and Mg^{2+} concentrations of applied water according to the following relationship:

(90)

Permeability Index (PI) = $[Na^+ + (HCO_3^-)^{1/2}]100/(Ca^{2+} + Mg^{2+} + Na^+)$

Where the concentrations of all the ions in irrigation water are expressed in $mmol_c\ L^{-1}$. This index was empirically developed from a series of experiments conducted in the laboratory and a series of experiments conducted in lysimeters using a large number of waters varying in ionic relationships and concentrations. The index has also been tested under field conditions.

Water is classified by the permeability index by keeping in view texture/permeability of the soils under irrigation. With high permeability soils and water of high permeability index values, it may be advantage to lower the infiltration rate and increase the irrigation efficiency by reducing the amount of water percolating below the root zone. This practice will decrease the possibilities of raising the ground water table. Apart from the routine analysis for other water quality parameters, no additional analytical determination is required for the evaluation of permeability index.

Toxicity hazard Constituents (ions) in irrigation water taken up by plants.

Toxicity problem occurs when certain constituents (ions) in irrigation water are taken up by the plants and accumulate in concentrations high enough to cause crop damage or reduced yields. The degree of damage depends upon the uptake of a particular ion and the crop sensitivity to that ion. Damage results when the potentially toxic ions are absorbed in significant amounts with the water taken up by the plant roots. The absorbed ions are transported to the leaves where they accumulate during transpiration. The ions accumulate to the greatest extent in the areas where the water loss is greatest, usually the leaf tips and the leaf edges.

The ions of primary concern are chloride, sodium, and boron. These ions can have a toxic effect to specific crops if present in excessive quantities.

Calcium to magnesium ratio in irrigation water is also crucial. Prolong irrigations with a water having Mg^{2+} concentration equal to or greater than the Ca^{2+} concentration can affect the soil properties in a way similar to that of a water having high Na^+ concentration. The potential effects of Na^+ are increased when irrigation water contains $Ca^{2+} : Mg^{2+}$ ratio ≤ 1. In other words, the lower the $Ca^{2+} : Mg^{2+}$ ratio, more damaging will be the irrigation water. In areas receiving irrigation water having safe levels of Na^+ and a low $Ca^{2+} : Mg^{2+}$ ratio, the yields of some crops were reduced because of Mg^{2+} induced Ca^{2+} deficiency.

Ca : Mg ratio

Permeability Index (PI) = $$\frac{100 \cdot [Na^+ + (HCO_3^-)^{1/2}]}{Ca^{2+} + Mg^{2+} + Na^+}$$

All ions in $mmol_c\ L^{-1}$