Deterioration of irrigation water quality

Deterioration in the quality of water used for irrigation is a matter of concern in recent years. Indiscriminate use of chemical fertilizers resulting in water quality deterioration is not new. Since it is difficult to judge in exactitude as to how much nutrients are required for crop growth, under or over fertilization is an inevitable consequence resulting in groundwater pollution. The degradation of water resources can have a far-reaching effect on environmental quality[1], human health and even on global warming[2]. The concentration and composition of dissolved salts determine the quality for irrigation purpose. The major cations are Na^+, Ca^{2+}, Mg^{2+} and K^+, while anions include Cl^-, SO_4^{2-}, HCO_3^-, CO_3^{2-} and NO_3^-. These specific ions may be toxic to various plant physiological processes or may cause nutritional disorders in plants.

In the present study, the water samples received from farmers for advisory purpose for irrigation were analysed for 10 important parameters from 2000 to 2012. Eight hundred and three water samples were analysed and assessed for the possible changes in water quality parameters over a period of time. Majority of samples were from grape-growing areas of Bangalore and surrounding districts for which bore wells served as a source of irrigation. The same standard protocols were adopted for analysis of water samples throughout[3]. The water analyses information can be subjected to some simple tests for data consistency – the first being that the sum of the cations should be approximately equal to the sum of the anions expressed in meq/l. Another data consistency test is approximate validity of the relationships, i.e. total cations or anions (meq/l) $\approx 10 \times$ electrical conductivity (EC) (dSm^{-1}). The third test is provided by comparing pH and carbonate concentration values. If the pH of water is less than 9, there should be essentially no carbonate reported. In the present dataset, EC values were highly correlated with 10 times the sum of concentration of cations and anions. The sum total of cations and anions showed marginal difference because of unmeasured elements like K; however, the relation between them was highly significant ($r = 0.789$**) indicating the validity of the dataset. Since none of the water samples showed pH higher than 9, carbonates were invariably absent.

The assessment of water quality parameters during the last 13 years indicated that pH of water samples shows large variation from 6.84 to 7.27. High pH of irrigation water is a function of high carbonate and bicarbonate concentration. However, pH of irrigation water is generally given less importance in assessing water quality parameters because of poor buffering capacity of water.

EC constitutes one of the most influential water quality guidelines on crop productivity and a general increase in EC level is observed in recent years. Water with EC level of >1.0 dSm^{-1} is unsafe for irrigation purpose[4]. Only 10% of the sample had EC > 1.0 dSm^{-1} from 2000 to 2004; thereafter nearly 20–30% of the sample had EC > 1.0 dSm^{-1}, although the mean value was within the safe limit. More than 23% samples received for testing were found to be unsafe for irrigation with respect to EC during 2011 and 2012.

The threshold level of chloride (Cl) content is 3 meq/l and during 2004–07, the mean Cl content was always higher than the permissible level. During 2010–12, nearly 34% of the samples received had more than 3 meq/l chloride. The most common toxicity problem in irrigation water comes from chloride. The ion is not adsorbed or held back by soils and therefore moves readily with the soil water. Although chloride is an essential element to plants in very small amounts, it may be toxic to various physiological processes or may cause nutritional disorder[5], especially in sensitive crops like grapes at high concentrations. High chloride in leaf in association with high sodium interferes with transpiration control mechanism and burns along margins and leaf tips are common. The characteristic marginal or tip burn symptoms are seen when the leaves of woody plants accumulate more than 0.5% Cl^- on dry weight basis. However, the absolute concentration of Cl is not important as different salts affect plant growth differently.

The mean nitrate concentration during 2012 was five times higher compared to its concentration during 2000. The reference range for nitrate in water is 0–0.6 meq/l. During the last three years nearly 43% of the samples had nitrate more than 0.6 meq/l in water. Very rarely samples received before 2008 had nitrate level above this reference range. Although the nitrate content from 2.5 to 5.0 meq/l in water has been observed to cause no harmful effect[6], high nitrate levels have been observed to cause toxic effect in plants. Water with high nitrate content may result in excessive vegetative growth in some vegetable crops. Regardless of the crop and water source, nitrate is credited towards indiscriminate fertilizer application, especially in grape orchards and in vegetable crops in recent years. Nitrate being anionic has the tendency to move downward readily resulting in groundwater pollution[7].

The sulphate (SO_4) concentration in irrigation water is one parameter which showed lowest variation during the last 13 years. Sulphate is a major contributor to salinity in many irrigation waters. The relationship between EC and SO_4 was highly significant ($r = 0.523$**). Sulphate has no characteristic action on the soil other than increasing salinity, which is, however, limited in the presence of calcium that precipitates as calcium sulphate, that is much less soluble than sodium and magnesium sulphates. Plant readily takes up sulphur in the form sulphate. Toxicity is rarely a problem; however, at high concentration, it may interfere with uptake of other nutrients like phosphorus by the plant.

Carbonates were rarely present. Carbonate waters are strongly alkaline in nature, while bicarbonate waters are mildly so. If the pH of water is less than 9, essentially no carbonate is present in water. During the last 11 years, only three samples showed pH > 8.4. The standard solution of sodium bicarbonate (0.1 N) has pH of 8.4, whereas standard solution of sodium carbonate (0.1 N) has pH of 11.6. Sodium carbonates are more than three times toxic than sodium bicarbonates. Calcium ions retain some solubility in the presence of bicarbonate ions, while it reduces to zero in the presence of carbonates.

The bicarbonate level in the irrigation water has increased in the recent years. During 2000, only 4% samples had

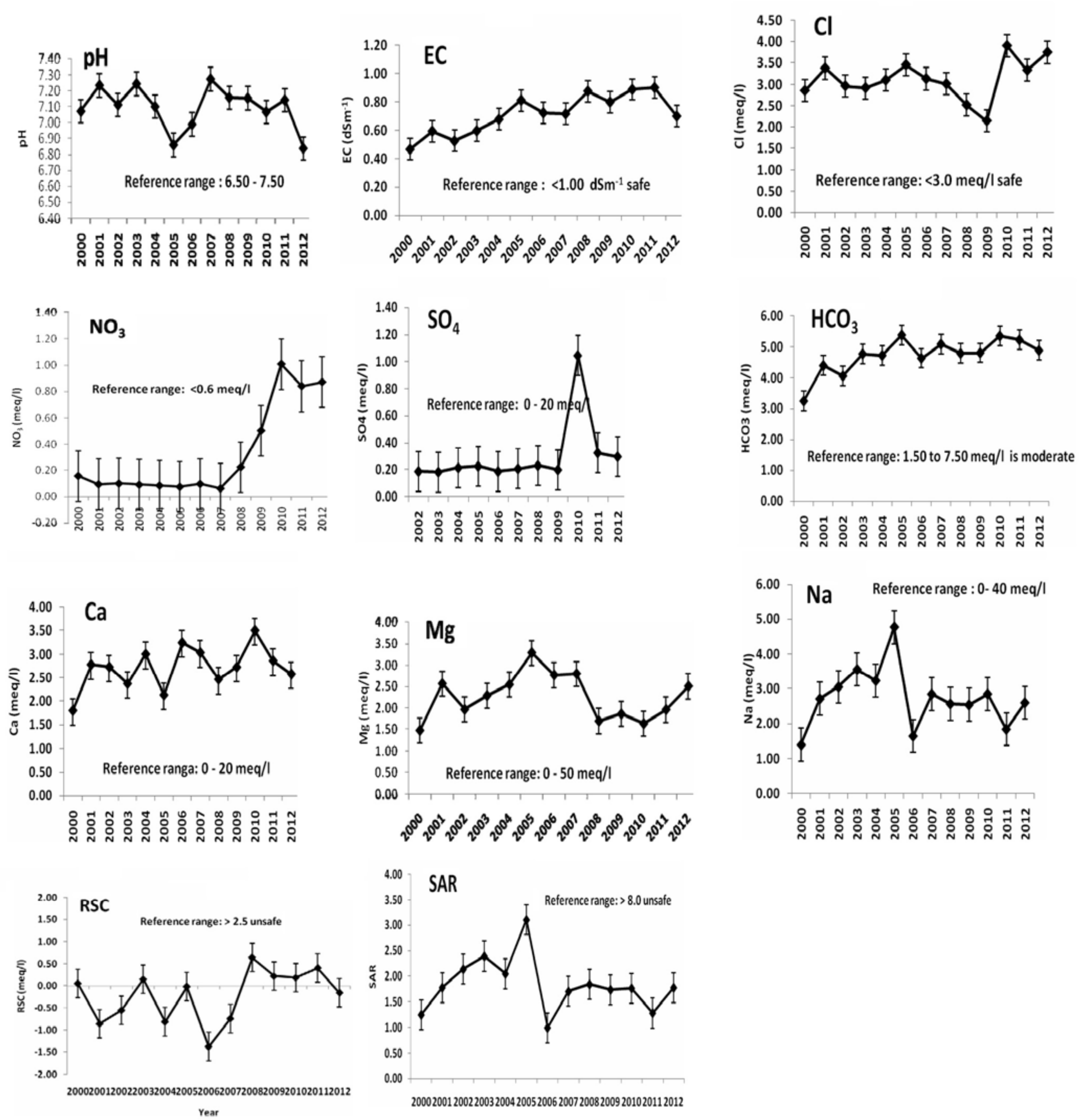

Figure 1. Temporal changes in water quality parameters during 2000–2012.

>7.50 meq/l bicarbonate and during 2010–12 nearly 15% samples had crossed this limit. Bicarbonate level ranging from 1.50 to 7.50 meq/l is considered moderately safe for most irrigation purposes. However, the deleterious effect of bicarbonate is seen in bicarbonate-sensitive crops like rose when the concentration is more than 5 meq/l. Chlorosis in many crops was induced because of high bicarbonate in irrigation water. This increases the solubility of phosphorus and results in large uptake of this element which interferes in iron metabolism in plants. Some crops are more susceptible to bicarbonate toxicity. High bicarbonate also results in micronutrient deficiency because of high pH. Bicarbonates tend to oxidize iron in plants to ferric form, which is biologically inactive causing iron deficiency in many crops.

Highly significant positive correlation ($r = 0.498^{**}$) was noticed between Ca and Mg concentration in irrigation water. The Ca/Mg ratio varied from was 0.64 in 2005 to 2.14 in 2010. Many waters and soil solutions contain 2–5 times more

Ca^{++} than Mg^{++}. The specific ion of great concern for general water quality appraisal is sodium. Certain crops are sensitive to the presence of moderate to high concentration of Na in irrigation waters. Sodium concentration alone does not reflect the sodium hazard of water, because of its relative dependence on the concentration of major divalent Ca and Mg. There was significant positive correlation between Na and EC ($r = 0.60$**). However, the mutual correlation between Ca and Cl ($r = 0.593$**) was stronger than between Na and Cl ($r = 0.508$**), indicating that the increased EC of irrigation water in the region is probably more due to $CaCl_2$ than NaCl.

The proportion of salts which may precipitate from soil solution as water is used by the plant to support normal growth processes is yet another important consideration in assessing water quality. The salt most likely to precipitate from such waters is calcium carbonate ($CaCO_3$), resulting in sodium hazard. Residual sodium carbonate (RSC) value $\{(CO_3^{2-} + HCO_3^{-}) - (Ca^{2+} + Mg^{2+})\}$ indicates the tendency of Ca and Mg to precipitate in the irrigation water. RSC showed an increasing trend during the last three years, which may be mainly due to increase in HCO_3 levels in irrigation water in recent years. Water having RSC values more than 2.5 mq/l is considered unsuitable for irrigation[8]. RSC values ranged from –1.377 to 0.638, indicating that the sum total of CO_3 plus HCO_3 varied widely in relation to Ca + Mg concentration. Both RSC and sum of Ca and Mg showed no significant correlation with pH, while HCO_3 showed a positive correlation ($r = 0.334$**) with pH, indicating that bicarbonate has an overwhelming effect on irrigation water pH in this region. RSC showed a highly negative but significant relationship with Ca ($r = -0.656$**) than Mg ($r = -0.458$**). Sodium in irrigation water affects soil physical properties and sodium hazard is defined as SAR ($Na/\sqrt{(Ca + Mg)/2}$). Owing the divalent nature of the cations, Ca^{++} and Mg^{++} is put together. SAR of the irrigation water remained steady and there was no build-up of Na, Ca or Mg.

Recharging the tube wells with rain water through enhanced infiltration by soil conservation measures is required at the community level. Fertilizer use in horticultural crops must be rationalized and monitored, as this could be one of the major sources of contamination of tube-well waters. Leaching the soil with good quality water if available, adoption of cultural practices, modification in fertilizer application practices, application of amendments to soil, treatment of waters before irrigation are some of the strategies that are suggested to deal with poor-quality water problem in agriculture.

The deterioration of water quality appears to be multifaceted. It is beyond the scope of this correspondence to ascribe a central cause for it as pollution in many places is driven by complex socio-economic, geophysical and land-use patterns requiring elaborate studies. The factors that affect groundwater quality are multiple and it is difficult to ascertain as to what extent the deterioration in water quality is due to fertilizer application. The changes in groundwater quality are apparent and if the trend continues the image of agriculture as an environmentally benign practice would suffer. This not only affects the production prospects, but also the health of the population depending on it. Any scarcity of water in future may not be caused by physical scarcity of water alone but by poor quality as well.

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Received 22 March 2013; revised accepted 18 August 2013

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