A CRITICAL APPRAISAL OF THE STANDARDS FOR JUDGING THE QUALITY OF IRRIGATION WATER.

The standard for judging the quality of irrigation water which has been put forward by U.S. Salinity Laboratory Staff (1954) is very widely used. According to this standard, the irrigation water having electrical conductivity greater than 2250 micromhos/cm., corresponding to approximately 22.5 m.e./l. of salts, is considered unfit even for salt tolerant crops on soils of good drainage. Electrical conductivity of 750 micromhos/cm. which is equivalent to approximately 7.5 m.e. of salts/l. is regarded as a safe limit for growing crops of medium salt tolerance on soil of good drainage. But in the present study 50% reduction in the yield of the first crop of maize fodder occurred only by the application of 22 inches of irrigation water containing 200 m.e./l. of salts which corresponds to an electrical conductivity of 2000 micromhos/cm. The salt concentration of 50 m.e./l. did not produce any significant reduction in yield. In case of second crop of maize which received 34 inches of irrigation water and thus exhibited the cumulative effect of 56 inches of water even 50 m.e./l. of salt concentration in water depressed the yield by 50%. It shows that the criterion of salt tolerance of crops is not an absolute guide. The irrigation water with the same salt content will behave differently to the same crop depending upon the salinity level of the soil, for instance, in case of the second crop of maize, the salinity level of soil was 6.13 mhos/cm. at the time of harvesting the crop. In case of wheat which followed the second crop of maize the electrical conductivity of the saturation

* 50% decrease in yield has been considered in comparison to the distilled water treatment. The yield of all the crops on this treatment has been given in appendix table 11.
extract of the soil rose to $8.05 \Omega \text{mhos/cm}$. The salinity level of the soil was $0.59 \Omega \text{mhos/cm}$ when the first crop of maize was sown. It rose to $6.18 \Omega \text{mhos/cm}$ by the time the second crop of maize was harvested. These results show that though the electrical conductivity of irrigation water was the same in case of both the crops of maize, but the second crop of maize was subjected to the higher level of salinity in the soil. Thus as the soil salinity rose, irrigation water with lower salinity containing $50 \text{ meq/l}$ of salts produced the same adverse effect on maize as irrigation water of $200 \text{ meq/l}$ of salt in the first crop of maize. It shows that while considering the suitability for irrigation purposes, besides the salt concentration of the water, the salinity level of the soil should also be taken into consideration. It is the accumulative effect of the salt from the soil and irrigation water which will determine the crop growth.

In this experiment after taking two crops of maize, third crop of wheat was taken which is a common crop of the arid zones. The results of the experiment show that although the yield of wheat grain was decreased significantly by irrigation water containing $50 \text{ meq/l}$ salt concentration, but the reduction in yield was not $50\%$ even at this level, though the salinity level of the soil rose to $8.05 \Omega \text{mhos/cm}$ by this treatment. This shows that wheat is more tolerant of salts than maize and the same irrigation water which is unsafe for maize, is quite safe for wheat. These results indicate that in the formulation of standards for judging the quality of water, nature of the soil and the crop to be irrigated must be taken into consideration. The triangular diagram suggested by Kanwar (1961) appears to be more useful guide than the consideration of salinity and the SAR of the irrigation water alone.

For judging the quality of irrigation water, apart from total salt concentration, the relative concentration of different ions is also taken into consideration. The alkali hazard involved by the use of irrigation
water is determined by the absolute relative concentration of cations. The U.S. Salinity Laboratory Staff (1954) after discussing the various equations used for the purpose of predicting the effect of irrigation water on soil properties proposed that SAR, which is defined as

\[
\text{SAR} = \sqrt[2]{\frac{Na^+}{Ca^{2+} + Mg^{2+}}}
\]

gives the best prediction about the alkali hazard of irrigation water. They further gave data to point out that under the conditions existing in the field the ESP value of the soil samples are generally higher than the estimated values. The deviations were explained as being due to the fact that the concentration of soil solution are somewhat higher than the concentration of irrigation water. They further pointed out the need for more data to explain the relation of ESP with water quality.

The present study indicates an agreement with U.S. Salinity Laboratory Staff (1954) that the ESP of soil is higher than those predicted from SAR of irrigation water (table 58). The differences widened as the concentration of salts in irrigation water increased. This deviation was much greater in soil of light texture than of heavy texture.

An attempt was also made to find the relationship of SAR of saturation extract of the soil and ESP of the soil. From table 58, it is evident that the ESP values predicted from SAR of saturation extract of the soil tallies reasonably well with the actual values in heavy soil. But in light soil the ESP actually found was much higher than the predicted value based on the SAR of the saturation extract of the soil. The differences further widened as the salt concentration of the irrigation water increased. These results clearly show that neither the SAR of the irrigation water nor the SAR of the saturation extract of the soil can be used as a reliable criterion for determining the sodium hazard of the irrigation water in light soil, though the SAR of saturation extract of the soil may have some prediction value in heavy soils.
### Table - 58

<table>
<thead>
<tr>
<th>Water used</th>
<th>Depth of soil sample</th>
<th>SAR of irrigation water</th>
<th>ESP predicted from SAR of saturation extract of irrigation water.</th>
<th>ESP predicted from SAR of saturation extract.</th>
</tr>
</thead>
<tbody>
<tr>
<td>Heavy soil</td>
<td>6.0</td>
<td>0.6</td>
<td>0.6</td>
<td>0.6</td>
</tr>
<tr>
<td>Light soil</td>
<td>6.0</td>
<td>0.6</td>
<td>0.6</td>
<td>0.6</td>
</tr>
<tr>
<td></td>
<td>0.5</td>
<td>0.5</td>
<td>0.5</td>
<td>0.5</td>
</tr>
</tbody>
</table>

*Note: Extracted water content of irrigation water and SAR of saturation extract in the soil. The values after the extraction of the extracted water are used for determining the ESP of the soil.*
<table>
<thead>
<tr>
<th>Depth (cm)</th>
<th>Water Slurry</th>
<th>Water Extraction</th>
<th>Soil Water</th>
<th>Soil Water Extraction</th>
<th>Note</th>
</tr>
</thead>
<tbody>
<tr>
<td>0-5</td>
<td>6.4</td>
<td>6.4</td>
<td>6.4</td>
<td>6.4</td>
<td>Actual</td>
</tr>
<tr>
<td>5-10</td>
<td>8.2</td>
<td>8.2</td>
<td>8.2</td>
<td>8.2</td>
<td>Actual</td>
</tr>
<tr>
<td>10-15</td>
<td>12.5</td>
<td>12.5</td>
<td>12.5</td>
<td>12.5</td>
<td>Actual</td>
</tr>
<tr>
<td>15-20</td>
<td>19.7</td>
<td>19.7</td>
<td>19.7</td>
<td>19.7</td>
<td>Actual</td>
</tr>
</tbody>
</table>

Table 58 continued
Fine et al. (1959) in a greenhouse study found that the ESP of the soil was higher than expected from SAR of irrigation water. Similar results have been reported by Durand (1955). Kanwar (1961) also reported that the experience in Punjab shows that the SAR is not a useful criterion in all cases since the SAR of irrigation water gives an idea of the sodium adsorbed by the soil when in equilibrium with it and this equilibrium depends on the concentration of cations and the conductivity of soil. Therefore, the results obtained by calculation are lower than those actually obtained in practice. Thus it shows that the upper safe limit of electrical conductivity of the water as proposed by U.S. Salinity Laboratory Staff (1954) is not very sound. These results corroborate the conclusions of Pantanelli and Bianchedi (1929); Bliss (1942); Thorne and Peterson (1954); Durand (1955); Bottini and Lisanti (1955) and Kanwar (1961) that irrigation waters, which are considered too saline and unsafe by U.S. Salinity Laboratory Staff (1954) can also be used depending upon the crop and soil and the upper limit of salinity in irrigation water needs to be revised.

ii. Comparative effect of carbonate or bicarbonate source of residual sodium carbonate in irrigation water on the properties of soil.

Classification of waters with respect to its quality serves a useful purpose in irrigated agriculture. One of the classifications that is widely used is that of Wilcox et al. (1954) based on the concept of residual sodium carbonate of Eaton (1950). Very few critical studies on the evaluation of this classification have been reported in the literature. Agarwal et al. (1956) reported that prolonged use of the well waters in U.P. has not been as damaging as the calculated residual alkalinity \((\text{HCO}_3^- + \text{CO}_3^{2-}) - (\text{Ca}^{++} + \text{Mg}^{++})\), Manchanda (1960) and Kanwar (1963) reporting on the quality of irrigation waters of Gurgaon district have mentioned that waters containing high amount of residual sodium carbonate are being successfully used in the field.

Eaton (1950) has assumed that effects of \(\text{CO}_3^-\) and \(\text{HCO}_3^-\) are similar as both of these ions are likely to lead to precipitation of \(\text{CaCO}_3\) and resulting increase in proportion of Na. Wilcox et al. (1954) in a study of the effect of \(\text{HCO}_3^-\) ion on suitability of water for irrigation made 86 applications of synthetic irrigation water containing various concentrations of cations and anions. He observed that out of the total \(\text{HCO}_3^-\) ions up to 54% were precipitated as \(\text{CaCO}_3\).
In the present investigations, an attempt was made to compare the
effect of $\text{CO}_3^-$ and $\text{HCO}_3^-$ ions. For this purpose, the total salinity of the water
was kept equal (12.0 mS/l.) in both the experiments and only variation was in
the carbonate or bicarbonate ions. The data in table 59 show that at the
same salt concentration and ESC in irrigation water, the electrical conductivity
soluble sodium percentage and exchangeable Na percentage were higher with waters
containing $\text{CO}_3^-$ than with water containing $\text{HCO}_3^-$ as ESC. The findings are in
accordance with those of Hilmy and Elgabaly (1954) who observed more harmful
effects of $\text{CO}_3^-$ than $\text{HCO}_3^-$ ions.

The hydraulic conductivity of the soil which is a measure of the
deterioration in soil structure is reduced more significantly by $\text{CO}_3^-$ than $\text{HCO}_3^-$
waters. These results also show that carbonate is much more harmful than
bicarbonate at the same level of total salinity of irrigation water, therefore,
the calculation of ESC assuming that $\text{CO}_3^-$ and $\text{HCO}_3^-$ are equally effective is not
sound, as the irrigation water containing same values of ESC in the form of $\text{CO}_3^-$
is more harmful than the one containing bicarbonate ions.

The results also indicate that the accumulative effect of continuous
application of even the safe amount of ESC of water is harmful. The deterioration
effect is greater in case of irrigation water having ESC in the form of $\text{CO}_3^-$ than
those of waters containing the same in the form of $\text{HCO}_3^-$. The reason is that
though a water may have safe limit of ESC, but soluble sodium percentage (SSP)
of water may be so high as to unfavourably increase ESP of the soil.

Thus it is obvious from these results that the concept of ESC as
advanced by Wilcox et al. (1954) is not a suitable index of the quality of
irrigation water. Firstly, the safe limit of ESC proposed is not safe to use
as the harmful effects have been noted even at no ESC level because of the
salinity of the water. Secondly, at the same level of salinity and ESC of
water the carbonate ions are more harmful than the bicarbonate ions.
### Composition of irrigation waters containing residual sodium carbonate in two different forms

<table>
<thead>
<tr>
<th>Source</th>
<th>Original sodium carbonate (me./l.)</th>
<th>Residual sodium carbonate (me./l.)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Source 1</td>
<td>0.00</td>
<td>1.25</td>
</tr>
<tr>
<td>Source 2</td>
<td>0.00</td>
<td>1.25</td>
</tr>
</tbody>
</table>

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<thead>
<tr>
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</tr>
<tr>
<td>Source 2</td>
<td>0.00</td>
<td>1.25</td>
</tr>
</tbody>
</table>

### Effect of irrigation water on soil

<table>
<thead>
<tr>
<th>Mean ESP of the original soils (mhos/cm.)</th>
<th>After the first crop</th>
<th>After the third crop</th>
</tr>
</thead>
<tbody>
<tr>
<td>Mean hydraulic conductivity (cm./hour)</td>
<td>0.490</td>
<td>0.359</td>
</tr>
<tr>
<td>Mean electrical conductivity of the saturation extract (mmhos/cm. at 25°c)</td>
<td>3.36</td>
<td>3.35</td>
</tr>
</tbody>
</table>

### Table - 59-145-

Composition of irrigation waters containing residual sodium carbonate in two different forms.
Therefore to determine the quality of irrigation water, due importance should be given to the total salt concentration, kind of BSC and SSP present in it instead of only considering the BSC.

iii. Effect of sulphate and chloride on the quality of irrigation water.

In the U.S. Salinity Laboratory Staff standard (1954) the quality of irrigation water is judged on the basis of electrical conductance and SAR of irrigation without attaching much importance to the specific ions such as \( \text{CO}_3^2-, \text{HCO}_3^-, \text{Cl}^- \) and \( \text{SO}_4^{2-} \) and cations i.e. \( \text{Ca}^{2+}, \text{Mg}^{2+}, \text{Na}^+ \) and \( \text{K}^+ \). But there is overwhelming evidence in the literature that the Cl are more harmful than sulphate when present in irrigation water on the basis of their chemical equivalents. However, these differences become negligible when the comparison is made on the basis of osmotic pressure of the irrigation water. (Magistad et al., 1943; Wadleigh, 1946; Shimose, 1958; and U.S. Salinity Laboratory Staff, 1954).

The results discussed on pages 77 to 80 show that chlorides proved more harmful than sulphates when the comparison was made on the basis of chemical equivalence. It was further observed that maize was more affected by Cl than wheat. It shows that specific ion effect will vary with the nature of the crop.

Thus the importance of specific ions in judging the quality of irrigation water cannot be minimised. Additional support to this view is received from the study of the effect of \( \text{CO}_3^2- \) and \( \text{HCO}_3^- \) ions in comparison with Cl and \( \text{SO}_4^{2-} \). It is observed that \( \text{CO}_3^2- \) and \( \text{HCO}_3^- \) ions had more adverse effect on soil and crop than \( \text{SO}_4^{2-} \) and Cl. Thus, there is a need for the consideration of specific ions in formulating standards for judging the quality of irrigation water.