## REFERENCES

Anon. 1967. *Report of the Activities of the USAID* / Univ. of Tennessee APP Team, Coimbatore – April to September, 1967.

——— 1967. *Semi-Annual Report USAID*/Univ. of Tennessee, APP – Madras State – July to December 1967.

——— 1968. *Semi-Annual Report* – *USAID*/Univ. of Tennessee APF Madras State, October 1967 to March 1968.

——— 1968. *Quarterly Report* – *USAID*/Univ. of Tennessee App – Madras State – April to June 1958.

Kelsey D. Lincoln and Hearne C. Cannon. *Cooperative Extension Work*. Cornell University Press (N.Y.)

Leagans, J. Paul. 1960. Abilities related to Programme Development needed by Extension Workers Course R.E. 224, Fall Term.


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# Ionic Composition as a Basis for Assessing the Suitability of Ground Waters for Irrigation


by

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**Introduction:** When successful sea-water farming is being reported, the old concept of rating the irrigation waters on the basis of total salt concentrations and pH values needs a revision. Salinisation and alkalisation problems are mainly concerned with the total salt concentration and the sodium ion concentration. The alkali hazard and salinity hazard of irrigation water indicated by S. A. R. limits and E. C. limits prescribed by U. S. D. A. (1954) have been criticised by Hiemann (1958) and Kanwar (1961). Venkatachalam (1958) pointed out that the irrigation waters have to be studied in conjunction with the soil irrigated. It is observed that rather than the mere concentration of individual ions, the balanced ionic environment plays a vital role in soil-plant relationship. Hence, it is essential to revise the code of classifying irrigation waters, so as to have an efficient utilisation.

In the present study, the ionic composition of water along with the irrigated soil is considered for the irrigation waters used in the farms of the Agricultural College, Coimbatore in order to find the suitability of old classifications and also the nature and effect of these waters used in the farms.

**Experimental:** Thirteen water samples from open wells and borewells of the farms of the Agricultural College, Coimbatore and one sample of Siruvani water were collected and analysed for the following:

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| | | |
|---|---|---|
| Sodium and potassium | ... | Flame photometry method |
| Calcium and magnesium | ... | Versenate method |
| Carbonate, bicarbonate and chloride | ... | Titrimetry method |
| Sulphate | ... | Turbidimetry method (Chesmin and Yien, 1951) |
| Boron | ... | Method by Jackson (1962). |
| Electrical conductivity | ... | Using Elico conductivity meter |
| pH | ... | Using glass electrodes |

The analytical values are tabulated in Table 1. The soil samples were collected from the fields where the irrigation waters have been used. The soils were analysed for E. C, pH, exchangeable cations and exchangeable sodium percentage by usual methods. The classifications based upon Wilcox (1948), U. S. D. A. (1954) and Eaton (1950) along with the analysis of the soil and the general performance of the crops in these fields are tabulated in Table 2.

**Results and Discussion:** Activities of the ions are preferred in the places of molar and equivalent concentrations in an atmosphere of polyvalent ions. Hence the activity terms were used to have a realistic picture of the chemical potential. The activities are given by the product of the concentrations of the ions in millimoles/litre and their activity coefficients. The activity coefficients were calculated using the Debye-Huckel equation,

$$\log f_i = \frac{-AZ_i^2\sqrt{\mu}}{1+a^B\sqrt{\mu}}$$

where $f_i$ = activity coefficient of the ion "i", Zi = valency of the ion, $\mu$ = ionic strength, A and B are constants depending upon the solvent and temperature and a, the mean ionic diameter. The ionic strength is given by the equation by Lewis and Randall.

$$\mu = \tfrac{1}{2}\Sigma C_i\ Z_i^2$$

where $C_i$ = concentration of ion in moles/litre and $Z_i$ = valency of the ion.

*Electrical conductivity:* It has been recognised that the total salt concentration in a solution is directly related to the conductance (Krishnamoorthy, 1965 and Sree Ramulu, 1962). Though the relationship between total salt concentration either in ppm or in milliequivalents and the electrical conductivity has been established, the ratio between these two terms varies depending upon the nature of the ions present. It is because the number of ions available for carrying the current is less than would be expected from the stoichiometric concentration. The variation of conductance with the type of ions is due to the asymmetry effect of the ionic atmosphere and the electrophoretic effect. The thickness of the ion-atmosphere is given by the equation

Table 1. *Chemical composition of irrigation waters*

| Particulars | E.C. milli-mhos/cm | pH | Cations (meq./litre) $K^+$ | $Na^+$ | $Ca^{++}$ | $Mg^{++}$ | Total | Anions (meq./litre) $CO_3^{--}$ | $HCO_3^-$ | $Cl^-$ | $SO_4^{--}$ | Total | Boron ppm | Ionic strength moles/litre | S.S.P. | Concentration SAR | Activity SAR |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Eastern Block Borewell Field No. 75 | 3.57 | 7.2 | 0.87 | 12.61 | 16.00 | 13.42 | 42.90 | Nil | 6.0 | 23.0 | 17.71 | 46.71 | 0.170 | 0.068 | 29.39 | 3.28 | 4.18 |
| Eastern Block Borewell Field No. 5 | 4.69 | 7.4 | 1.13 | 27.83 | 12.80 | 12.24 | 54.00 | Nil | 8.0 | 22.0 | 31.77 | 59.77 | 0.180 | 0.086 | 51.53 | 7.87 | 10.27 |
| Old Hostel Field No. 68 | 3.19 | 7.4 | 0.80 | 17.40 | 8.00 | 11.84 | 38.04 | Nil | 6.0 | 20.0 | 13.29 | 39.29 | 0.129 | 0.055 | 45.73 | 5.53 | 6.91 |
| Siruvani water | 0.17 | 6.9 | Nil | 0.22 | Nil | 2.17 | 2.39 | Nii | 1.0 | 1.0 | Nil | 2.00 | 0.012 | 0.003 | 9.20 | 0.21 | 0.22 |
| Wetland J-Block | 0.80 | 8.2 | 0.30 | 6.24 | 1.60 | 2.17 | 10.31 | 1.0 | 5.0 | 3.0 | Nil | 9.00 | 0.025 | 0.012 | 60.53 | 4.60 | 5.17 |
| Virology Laboratory Bore-well Field No. 54 | 3.80 | 7.5 | 1.03 | 28.26 | 9.60 | 6.71 | 45.60 | Nil | 9.0 | 27.0 | 14.33 | 50.33 | 0.170 | 0.063 | 61.94 | 9.89 | 12.51 |
| Well Field No. 50 | 3.50 | 7.5 | 1.04 | 31.74 | 7.20 | 8.69 | 48.67 | Nil | 6.0 | 27.0 | 7.56 | 40.56 | 0.112 | 0.056 | 65.24 | 11.27 | 14.11 |
| Near Tractor Workshop Field No. 39 | 3.19 | 8.0 | 0.98 | 22.61 | 4.00 | 9.08 | 36.67 | 1.0 | 5.0 | 19.0 | 5.52 | 30.52 | 0.170 | 0.043 | 61.66 | 8.84 | 10.82 |
| Cotton Breeding Station F.C. 1 | 2.10 | 7.6 | 0.72 | 12.17 | 4.00 | 7.90 | 24.79 | Nil | 7.0 | 13.0 | 1.31 | 21.31 | 0.069 | 0.024 | 49.08 | 4.49 | 5.84 |
| Botanic Garden (Front side Bore-Well) | 2.40 | 7.2 | 0.80 | 13.04 | 7.60 | 8.69 | 30.13 | Nil | 7.0 | 17.0 | 4.69 | 28.69 | 0.080 | 0.040 | 43.28 | 4.57 | 5.56 |
| Near G. C. T. Field No. 37 | 1.86 | 7.2 | 0.72 | 10.86 | 6.80 | 7.90 | 26.28 | Nil | 6.0 | 16.0 | 3.92 | 25.92 | 0.082 | 0.035 | 41.33 | 4.01 | 4.82 |
| Millet Breeding Station Field No. 7 | 1.86 | 7.1 | 0.55 | 10.00 | 6.80 | 8.13 | 22.48 | Nil | 7.0 | 12.0 | 2.04 | 21.04 | 0.071 | 0.032 | 44.49 | 4.10 | 4.90 |
| Paddy Breeding Station A-Block – 4A | 0.87 | 8.1 | 0.30 | 5.65 | 3.60 | 1.18 | 10.73 | 1.0 | 7.0 | 2.0 | Nil | 10.00 | 0.025 | 0.013 | 52.65 | 3.66 | 4.13 |
| Paddy Breeding Station B-Block Bore-well | 0.87 | 7.9 | 0.30 | 2.87 | 2.80 | 2.37 | 8.34 | 1.0 | 7.0 | 3.0 | Nil | 11.00 | 0.029 | 0.013 | 34.34 | 1.79 | 2.48 |

TABLE 2. *Comparison of classifications*

| Wilcox | USDA classification | Eaton's classification Residual carbonate meq./litre | Analysis of the irrigated soil | | | | Crops grown | Performance of crops |
|---|---|---|---|---|---|---|---|---|
| | | | E.C. m.mhos/cm | pH | Exchangeable Na meq./100 gm | E.S.P. | | |
| Unsuitable | $C_1$ $S_1$ | − 23.4 | 0.8 | 8.0 | 0.98 | 3.08 | Ragi, Maize, Cotton and Lucerne | Good |
| -do- | $C_5$ $S_2$ | − 17.0 | 1.0 | 8.3 | 3.00 | 9.59 | Maize, Ragi and Castor | -do- |
| -do- | $C_3$ $S_1$ | − 13.8 | 0.9 | 7.8 | 1.24 | 1.96 | Cumbu, Cholam and Vegetables | -do- |
| Excellent | $C_1$ $S_1$ | − 1.2 | 0.3 | 7.9 | 1.86 | 2.12 | Vegetables | -do- |
| Good | $C_3$ $S_1$ | + 2.2 | 0.3 | 8.5 | 1.96 | 4.79 | Paddy | -do- |
| Unsuitable | $C_5$ $S_3$ | − 7.3 | 2.4 | 8.0 | 1.96 | 7.33 | Cholam and grapes | -do- |
| -do- | $C_5$ $S_3$ | − 9.9 | 1.1 | 8.4 | 2.02 | 8.70 | Maize and Ragi | -do- |
| -do- | $C_4$ $S_2$ | − 7.1 | 1.3 | 8.2 | 2.02 | 7.03 | Oilseeds | -do- |
| Doubtful | $C_1$ $S_2$ | − 4.9 | 0.6 | 8.2 | 0.83 | 2.20 | Cotton | -do- |
| -do- | $C_3$ $S_2$ | − 9.3 | <0.2 | 8.5 | 0.65 | 2.51 | Ornamental flowers | -do- |
| Permissible | $C_1$ $S_1$ | − 8.7 | 0.3 | 8.3 | 1.02 | 2.93 | Cotton, Onion and Cumin | -do- |
| -do- | $C_4$ $S_1$ | − 4.9 | <0.2 | 8.3 | 0.35 | 2.57 | Millets and vegetables | -do- |
| Good | $C_3$ $S_1$ | + 3.2 | 0.3 | 8.0 | 0.78 | 2.26 | Paddy | -do- |
| Good | $C_3$ $S_1$ | + 2.8 | 0.3 | 8.0 | 0.78 | 2.19 | Paddy | -do- |

$$1/k=\left(\frac{DT}{\Sigma C_i\ Z_i^2}\cdot\frac{1000\ K}{4\pi\Sigma^2 N}\right)^{\frac{1}{2}}$$

where $1/k$ is a measure of the thickness of ion atmosphere, D, K, $\Sigma$, N are constants, T temperature in absolute units and $C_i$ and $Z_i$ are as given above. It can be seen that the thickness of ion atmosphere is dependent upon the product term of concentration and the square of the valence in a particular solvent and temperature. So, the conductance of an irrigation water may be related to the ionic strength at lower concentrations. At higher concentrations, modified form of Onsager conductance equation is not strictly obeyed. Hence, even at lower concentrations, the conductance value may not give the "ionic effect" due to a particular ionic composition, but only can reflect the ionic strength. The correlation is worked out between the conductance values (in millimhos/cm) and the ionic strength (moles/litre). It is highly significant at 1% level and the correlation coefficient is 0.98. The regression equation is

$Y = 53.86\ X + 0.26$

($Y$ = Conductance, $X$ = ionic strength)

The relation between conductance and total activities of the ions is not significant, showing that the conductance values cannot be relied upon for understanding the chemical potential. It is inferred that the electrical conductivity is only a measure of intensity of the electrical field due to the ions in solution.

In the present study, according to Wilcox method of classification based upon the E. C. values, six waters are unsuitable and two waters are doubtful. According to U.S.D.A. classification on salinity hazard standards, nine waters are injurious and four waters are to be used with special management practices. Siruvani water alone escapes the limit of danger. But all waters have been successfully used in the College Farms and the performances of the different crops are uniformly good. The salinity conditions of the soils irrigated are low. It may be safely concluded that the limits of the indices for salinity needs a thorough revision. Kelly (1963) concluded that the expression total salinity of an irrigation water did not afford a significant criterian. It may also be pointed out that the "balanced ionic environment" suggested by Hiemann (1958) should be given more thought of.

*Carbonates:* High concentration of carbonates and bicarbonates are thought to be harmful and Eaton classified the irrigation waters on the basis of Residual Sodium Carbonate given by $(CO_3^{--} + HCO_3^{-}) - (Mg^{++} + Ca^{++})$ all represented in m.eq/litre. The negative values are good and the positive values above 2.0 is deemed to be unfit. As per this classification three waters are unfit with reference to carbonates. But that these waters have produced good crops, show that this method also cannot be relied upon solely.

*Activity sodium adsorption ratio:* The activity sodium adsorption ratio is calculated using the formula

$$^{a}SAR = \frac{[Na]}{\sqrt{[Ca]+[Mg]}}$$

where [Na] [Ca] and [Mg] represent the activities of the respective ions in moles/litre. The concentration SAR values. generally used, are also calculated and according to U.S.D.A. classification based on alkali hazard, four waters are of medium hazard and others of no hazard. Sodium Adsorption Ratio gives an idea of the amount of sodium adsorbable by soil. This was developed on the basis of the relation between Exchangeable Sodium Percentage of soil (E.S.P.) equilibration with the irrigation water and the sodium adsorption ratio of the latter. Eventhough the relationship is universal, the regression equation obtained are different for different clay minerals (Pratt *et al.* 1964). In the present investigation the correlation of this relationship is 0.88 (significant at 1% level) and the regression equation is $Y=0.66\,x-0.16$ (where Y=E.S.P. of soil irrigated; $x={}^{a}SAR$ of water) and this is different from that of

$$Y=0.015-0.013$$

obtained by United States Salinity Laboratory Staff (1954). This clearly indicates that the Sodium Adsorption Ratio limits have to be revised on the basis of the soil type. Venkatachalam (1958) and Ranganathan (1968) have found that a constant factor for each soil determines the maximum sorbable sodium by a soil. Hence Sodium Adsorption Ratio values of waters have to be critically viewed in conjunction with the soil irrigated with.

*Boron concentration:* From the limits prescribed by Scofield (1936) it may be seen that all the waters studied have very low concentration of boron, being far from danger.

*Concentration of other ions:* The concentration of ions in most of the waters studied is normally high. But from the fact that the crops are grown well by utilising these waters, it may be inferred that balanced ionic concentration plays a vital role in the osmotic relationships of soil and plant.

*Irrigated soil:* Though we cannot expect a complete equilibrium attained by the soils irrigated with these waters, the analysis of these soils indicate less salinisation effect than predicted by the conventional classification methods. All the soils have low E.C. values. The agronomic and management practices adopted in the farms are normal. High values of exchangeable Ca+Mg of the soils enable them to adsorb less sodium.

**Summary and Conclusion:** Thirteen irrigation waters used in the Agricultural College farms and one sample of Siruvani water were completely analysed for all the common ions, E.C. and pH. The classifications based

upon Wilcox, U.S.D.A. and Eaton were worked out to see their effectiveness in adjudicating the irrigability of ground waters. By comparing with the crop performance and the effect upon the irrigated soils, these methods have been observed to be far from satisfactory. It is also discussed that the conductance values cannot be relied upon for understanding the ionic composition and the limits of Sodium Adsorption Ratio values have to be revised on the basis of the soil type. A satisfactory method of classification can be evolved only after a thorough probe into the concept of balanced ionic environment, alkalisation co-efficient of soil and toxic concentration of ions. Further it may be concluded, that the ionic composition of water alone cannot form a basis for evaluating its quality. The soil also is to be considered along with.

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## REFERENCES

Chesmin and Yien. 1951. Turbidimetric determination of available sulphhate. *Proc. Soil Sci. Soc. Am.*, **15** : 149.

Eaton, F. M. 1950. Significance of carbonates in irrigation waters. *Soil Sci.*, **69** : 123-34.

Heimann, H. 1958. Irrigation with saline water and the ionic environment. Potassium Symposium 173-211. Berne, 1958.

Jackson, M. L. 1962. *Soil Chemical Analysis*. Constable & Co. Ltd., London.

Kanwar, J. S. 1961. Quality of irrigation water as an index of its suitability for irrigation purposes. Potash Review: Spt. 1-13.

Kelley, W. P. 1963. Use of saline irrigation water. *Soil Sci*, **95** : 385-91.

Krishnamoorthy, R. 1965. A study on the utility of Electrical Conductivity as an index of quality of irrigation water. *Madras agric. J.*, **52** : 449-505.

Pratt, P. F. and B. L. Gravel. 1964. Monovalent-Divalent exchange equilibria in soils in relation to organic matter and type of clay. *Soil Sci. Soc. Am. Proc.*, **28** : 32-5.

Ranganathan, V. 1968. Cationic equilibrium with reference to alkalisation of soils. *Jour. Inst. of Chem* (India), **40** : 60-4.

Schofield, C. S. 1936. The salinity of irrigation water. *Smithsn. Inst. Ann. Rpt.* 1935. p. 275-87.

Sreeramulu, U. S. 1962. Influence of cations and anions of the electrical conductivity measurement of ground waters. *Madras agric. J.*, **49** : 101-9.

United States Salinity Laboratory Staff. 1954. Diagnosis and improvement of saline and alkali soils. U. S. Dept. Agric. Handbook 60.

Venkatachalam, S. 1958. Studies on some soil factors in evaluating the quality of irrigation waters as regards their alkali hazards' Assoc. I.A.R.I. Thesis 1958.

Wilcox, L. V. 1948. The quality of water for irrigation use. U. S. Dept. Agric. Tech. Bull. 962.