*Journal of Nepal Geological Society, 2000, Vol. 21, pp. 87-92*

# Prospects of groundwater quality for irrigation in central tracts of Lalitpur region, Uttar Pradesh, India

**A. L. Haldar[1] and P. Dev[2]**
[1]*Remote Sensing Applications Centre, Lucknow – 226021, U. P., India*
[2]*School of studies in Geology, Vikram University, Ujjain–456010, India*

## ABSTRACT

The quality of selected bored well and dug well waters from the central tracts of the Lalitpur region in the state of Uttar Pradesh, India, was investigated for irrigation purposes. The study area is situated within the latitudes 24° 35' N and 24° 43' N, and the longitudes 78° 20' 41" E and 78° 30' E in the basin of the Shahzad River, which is a tributary of the Betwa River. Granites and gneisses of Archaean age are exposed in various parts of the area.

The selected groundwater samples were analysed for major cations, anions, trace elements, *pH*, electrical conductivity *(EC)*, sodium absorption ratio *(SAR)*, residual sodium carbonate *(RSC)*, permeability index *(PI)*, and sodium per cent *(SP)*. The analysed data were plotted on Wilcox and U.S. salinity diagrams to evaluate chemical quality of groundwater for irrigation. The *SAR* values (ranging from 0.47 to 79) are within the permissible limits. A majority of samples (i.e., 57.5%) belong to $C_3$-$S_1$ class whereas remaining samples (42.5%) fall in $C_2$-$S_1$ class. Plots of *SP* against *EC* indicate that a large number of samples (67.5%) fall within Excellent to Good type of water whereas remaining samples lie within Good to Permissible type. Hence the water can be used for all types of crop on soils of medium to high permeability.

## INTRODUCTION

In recent years, various irrigation schemes are getting increasing emphasis to yield maximum productivity of agriculture. Many countries in the world are now conducting irrigation development programmes based on groundwater resources. Groundwater quality is one of the important parameters of concern for implementation of such programmes. In this perspective, the paper presents a study on suitability of the groundwater quality in the central tracts of the Lalitpur District, Uttar Pradesh, India.

The study area (Fig. 1) lies within the latitudes 24° 35' N and 24° 43' N, and the longitudes 78° 20' 41" E and 78° 30' E. It falls in the basin of the Shahzad River, a tributary of the Betwa River. The area receives mean rainfall of about 890 mm spreading over 30 to 35 rainy days. December is the coolest month and mean minimum temperature is 6.3° C, whereas May is the hottest month with mean maximum temperature of 43° C.

Granites and gneisses of Archaean age constitute the bedrock. Grey to reddish brown or pink granites are dominantly coarse grained with phenocrysts of feldspar.

The area exhibits pediplains (PP), valley fills (VF), and buried pediplains (BPP). Some lineaments are also observed in NE-SW and NW-SE directions (Fig. 1). The thickness of overburden up to the basement varies from 0 to 35 m (Haldar et al. 1994). The depth of groundwater level varies from 4.15 to 12.9 m during the pre-monsoon time and from 1.75 to 6.8 m during the post monsoon time.

## WATER QUALITY

It is interesting to study the quality of groundwater in this draught-prone area with wide variations in rock and overburden types. The water samples were collected mostly from the bored wells except one, which was from a dug well. They were analysed for major cations, anions, trace elements, *pH*, *EC*, *SAR*, *RSC*, *PI*, and *SP* for a comparative study of its agricultural utility.

The suitability of groundwater for irrigation depends on many factors such as texture and composition of soil type, climate, and irrigational practices. It also depends on chemical quality of groundwater, where important parameters are total salinity of water, *SAR*, *RSC*, *PI*, and *SP*.

Wilcox (1948, 1955) and Richards (1954) studied the water quality for irrigation purposes. On the basis of *SP* values, Wilcox (1948) classified the irrigation water quality into the following classes:

| Water Quality | *SP* Value, % |
|---|---|
| Excellent | < 20 |
| Good | 20 - 40 |
| Permissible | 40 - 60 |
| Doubtful | 60 - 80 |
| Unsuitable | > 80 |

In the study area, the *SP* values range from 8.75 to 52.43%. Hence, the water is under the permissible category.

The U. S. salinity diagram ( Fig. 2) takes into account the electrical conductivity as an index of salinity hazard and

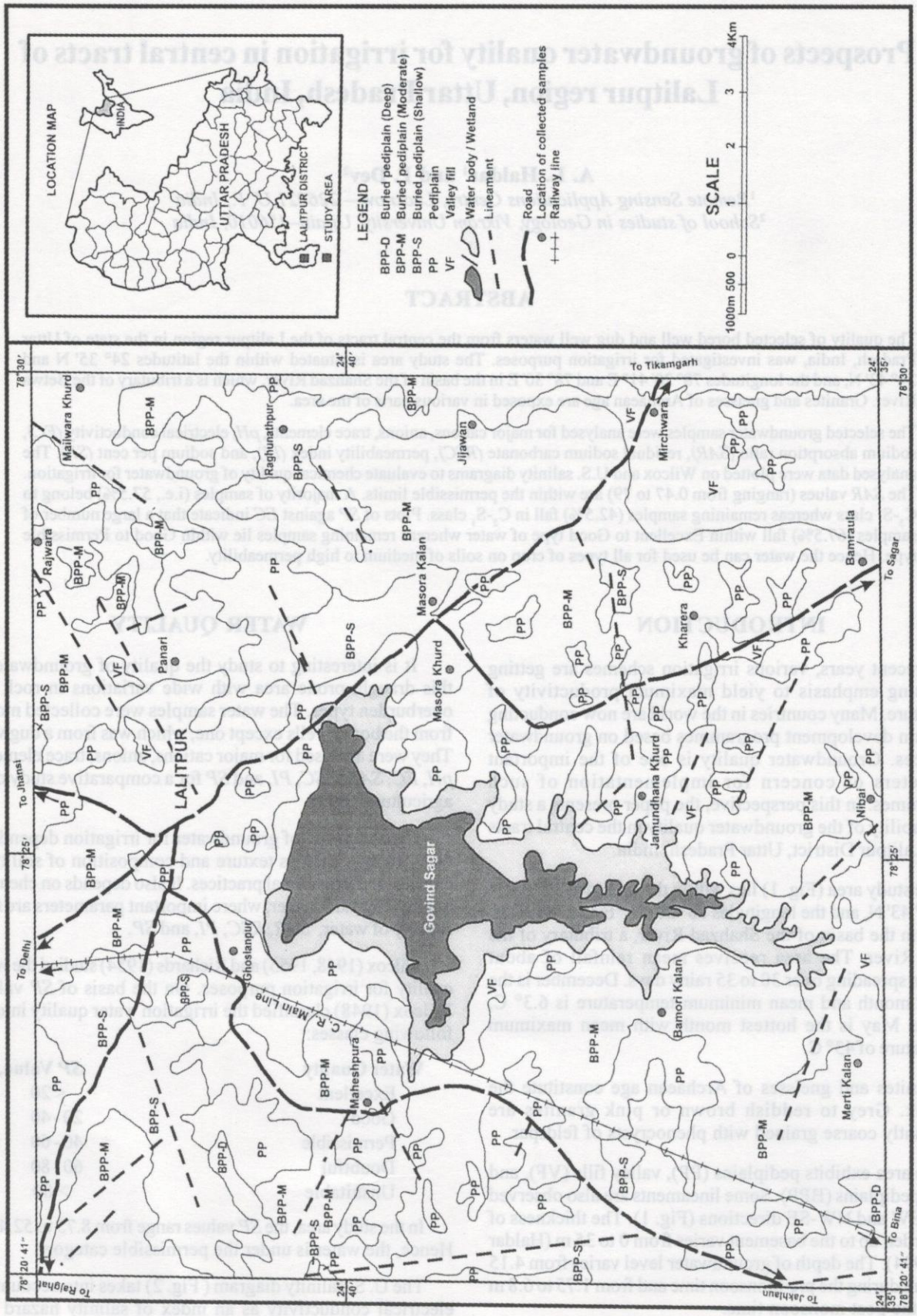


**Fig. 1: Geomorphological map of the Lalitpur area, Uttar Pradesh, India**

sodium absorption ratio as an index of alkali hazard. *SAR* is defined as:

$$SAR = \frac{Na}{\sqrt{\frac{Ca + Mg}{2}}}$$

where, the concentration of cations is expressed in equivalent per million parts of solution (epm).

*SAR* has a direct relationship with the sodium adsorption by soil. The obtained values of *SAR* range from 0.47 to 3.79 (i.e., they are within the permissible limits) and hence, it is low sodium water. The water can be used for irrigation in almost all soils and all types of crop, except those that are highly sensitive to sodium (such as stone fruit tree and avocado). The *SAR* values (Table 1) are plotted on an arithmetical scale against *EC* on a log scale and different classes of water were marked in the salinity diagram. The perusal of diagram (Fig. 2) indicates that 42.5 % of water samples fall in $C_2$-$S_1$ class and remaining 57.5 % of them lie in $C_3$-$S_1$ class.

Hem (1959) suggested that chlorides below 250 mg/l are harmless for agriculture. The mean values beyond the said limits are hazardous. According to Singh and Chawla (1966), Total Dissolved Solids (*TDS*) in the water for irrigation should be less than 1000 ppm. In view of above, there is only one village (i.e., Bomhari Kalan), where the groundwater is not suitable for irrigation (since the values of *TDS* is 1298 ppm). Rest of the villages are having *TDS* within the permissible limits and the water in those villages is suitable for agricultural development. Also, the water with the values of less than 1000 mg/l can be utilised to grow such semi-tolerant crops as vegetables, wheat, and orchards of mango, guava, orange, and lemon.

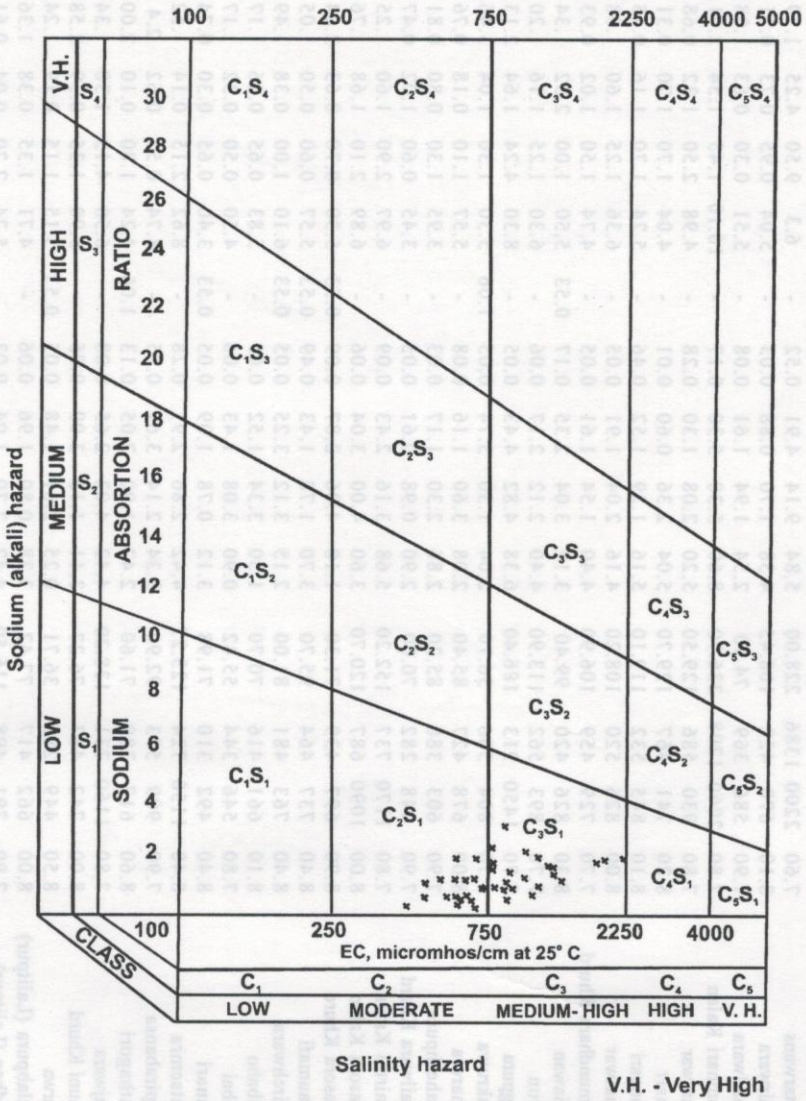


**Fig. 2: Data plotted in the U.S. salinity diagram (Richards 1954) for classification of irrigation waters**

**Table 1: Chemical analysis of groundwater samples from the Lalitpur district, Uttar Pradesh, India**

| S.N. | Village Name | pH | EC µS/cm | TDS ppm | T Hardness ppm | $Ca^{++}$ meq/l | $Mg^{++}$ meq/l | $Na^{+}$ meq/l | $K^{+}$ meq/l | $CO_3^{--}$ meq/l | $HCO_3^{-}$ meq/l | $Cl^{-}$ meq/l | $SO_4^{--}$ meq/l | SAR | Na % | RSC meq/l | P I | $NO_3^{-}$ mg/l | $PO_4^{---}$ mg/l | $F^{-}$ mg/l | $Zn^{++}$ mg/l | $B^{+}$ mg/l | $Fe^{+++}$ mg/l |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 1 | 2 | 3 | 4 | 5 | 6 | 7 | 8 | 9 | 10 | 11 | 12 | 13 | 14 | 15 | 16 | 17 | 18 | 19 | 20 | 21 | 22 | 23 | 24 |
| 1 | Bhainsai | 8.40 | 1060 | 668 | 100.76 | 1.56 | 5.72 | 3.74 | 0.20 | 0.53 | 7.95 | 1.10 | 0.70 | 1.96 | 35.17 | 1.77 | 50.79 | 0.36 | 0.47 | 0.479 | 0.658 | 0.271 | NIL |
| 2 | Bamrola | 7.70 | 999 | 629 | 118.81 | 2.68 | 5.36 | 2.52 | 0.05 | - | 5.50 | 1.70 | 0.88 | 1.26 | 24.22 | -0.62 | 49.64 | 0.12 | 0.18 | 0.216 | 0.664 | 0.239 | NIL |
| 3 | Satarwans | 7.60 | 2200 | 1386 | 228.00 | 5.84 | 9.14 | 4.91 | 0.52 | - | 6.3 | 9.50 | 4.25 | 1.79 | 26.6 | -7.71 | 64.98 | 0.91 | 0.18 | 0.333 | 0.137 | 0.289 | NIL |
| 4 | Bairwara | 8.10 | 670 | 422 | 108.45 | 4.38 | 1.70 | 0.88 | 0.03 | - | 5.04 | 0.95 | 0.73 | 0.51 | 13.16 | -1.04 | 44.89 | 0.17 | 0.16 | 0.382 | 0.039 | 0.249 | NIL |
| 5 | Bhailwara | 7.90 | 586 | 369 | 74.50 | 2.54 | 1.94 | 1.61 | 0.08 | - | 5.51 | 0.30 | 0.63 | 1.08 | 27.39 | 0.33 | 62.45 | 0.33 | 0.02 | 0.571 | 0.041 | 0.271 | NIL |
| 6 | Bamhari Kalan | 7.80 | 2060 | 1298 | 236.70 | 8.60 | 5.30 | 5.30 | 0.17 | - | 16.10 | 1.45 | 1.54 | 2.01 | 30.39 | 2.30 | 48.50 | 0.33 | 0.50 | 0.369 | 0.044 | 0.308 | NIL |
| 7 | Burdwar | 7.80 | 930 | 586 | 129.50 | 5.20 | 2.08 | 1.30 | 0.28 | - | 4.98 | 2.50 | 1.32 | 0.68 | 17.83 | -2.30 | 41.16 | 0.36 | ND | 0.277 | 0.054 | 0.328 | NIL |
| 8 | Charr | 8.20 | 741 | 467 | 129.70 | 5.04 | 2.36 | 0.60 | 0.01 | - | 4.04 | 1.70 | 1.70 | 0.31 | 8.75 | -3.36 | 32.62 | 0.34 | ND | ND | 0.045 | 0.280 | NIL |
| 9 | Gangari | 8.10 | 845 | 532 | 119.10 | 5.16 | 1.29 | 1.52 | 0.46 | - | 5.24 | 1.70 | 1.16 | 0.85 | 23.49 | -1.21 | 47.79 | 0.39 | ND | 0.199 | 0.053 | 0.371 | NIL |
| 10 | Ghatwar | 8.00 | 826 | 520 | 108.20 | 4.16 | 2.04 | 1.91 | 0.05 | - | 6.36 | 1.25 | 1.60 | 1.08 | 24.02 | 0.16 | 55.02 | 0.36 | ND | 0.228 | 0.044 | 0.321 | NIL |
| 11 | Jamundhara Khurd | 7.70 | 729 | 459 | 106.90 | 4.40 | 1.54 | 1.61 | 0.05 | - | 4.74 | 1.50 | 1.02 | 0.93 | 21.84 | -1.20 | 50.16 | 0.37 | ND | 0.126 | 0.054 | 0.261 | NIL |
| 12 | Jijiawan | 8.30 | 826 | 420 | 99.40 | 3.12 | 3.04 | 2.35 | 0.17 | 0.53 | 5.50 | 1.00 | 2.32 | 1.34 | 29.03 | -0.13 | 55.17 | 0.16 | ND | 0.380 | 0.103 | 0.337 | NIL |
| 13 | Jiron | 7.70 | 893 | 562 | 113.90 | 4.40 | 2.12 | 2.17 | 0.06 | - | 6.30 | 1.25 | 1.16 | 1.20 | 25.49 | -0.22 | 53.85 | 0.15 | 0.15 | 0.609 | 0.664 | 0.251 | NIL |
| 14 | Jugpura | 7.70 | 1450 | 913 | 186.40 | 6.38 | 4.82 | 4.43 | 0.05 | - | 8.30 | 4.24 | 1.64 | 2.13 | 28.57 | -2.90 | 46.78 | 0.36 | ND | 1.228 | 0.035 | 0.314 | NIL |
| 15 | Kakruwa | 8.70 | 804 | 506 | 56.70 | 2.04 | 1.30 | 3.74 | 0.05 | 1.06 | 5.30 | 1.30 | 1.04 | 3.46 | 52.43 | -0.80 | 84.15 | 0.37 | ND | 0.428 | 0.054 | 0.323 | NIL |
| 16 | Kharera | 8.00 | 678 | 427 | 85.40 | 2.08 | 3.60 | 1.16 | 0.08 | - | 5.57 | 1.10 | 0.18 | 0.76 | 17.92 | -0.11 | 51.46 | 0.37 | ND | 0.601 | 0.053 | 0.272 | NIL |
| 17 | Maheshpura | 7.90 | 603 | 380 | 85.20 | 2.86 | 2.30 | 1.17 | 0.03 | - | 3.95 | 1.30 | 0.80 | 0.81 | 18.87 | -1.21 | 49.88 | 0.37 | ND | 0.24 | 0.059 | 0.341 | NIL |
| 18 | Mailwara Khurd | 7.90 | 448 | 282 | 70.00 | 2.90 | 0.98 | 0.61 | 0.05 | - | 3.45 | 0.60 | 1.02 | 0.47 | 14.54 | 0.07 | 61.84 | 0.23 | ND | 0.289 | 0.040 | 0.215 | NIL |
| 19 | Mairthi Kalan | 7.80 | 1170 | 737 | 152.20 | 5.68 | 3.16 | 2.43 | 0.09 | - | 6.97 | 2.90 | 1.60 | 1.25 | 22.18 | -1.83 | 44.87 | 0.12 | ND | 1.051 | 0.045 | 0.307 | NIL |
| 20 | Masora Kalan | 8.00 | 1090 | 687 | 120.70 | 3.60 | 4.00 | 3.04 | 0.06 | - | 6.89 | 2.10 | 1.68 | 1.76 | 28.97 | -0.71 | 53.24 | 0.79 | 0.01 | 1.153 | 0.080 | 0.352 | NIL |
| 21 | Masora Khurd | 8.90 | 697 | 439 | 71.30 | 1.10 | 4.06 | 2.87 | 0.09 | 0.53 | 5.30 | 0.70 | 0.63 | 2.04 | 36.45 | 0.67 | 64.41 | 0.29 | ND | 0.312 | 0.044 | 0.307 | NIL |
| 22 | Maumafi | 8.40 | 737 | 464 | 95.70 | 3.70 | 1.78 | 1.43 | 0.49 | 0.53 | 5.57 | 0.60 | 0.50 | 1.05 | 25.95 | 0.62 | 54.85 | 0.41 | ND | 0.614 | 0.039 | 0.285 | NIL |
| 23 | Mirchwara | 8.40 | 763 | 481 | 81.00 | 2.15 | 3.12 | 3.25 | 0.05 | 0.53 | 6.10 | 1.00 | 0.38 | 1.49 | 30.88 | 1.36 | 63.25 | 0.36 | 0.07 | 0.661 | 0.034 | 0.297 | NIL |
| 24 | Nibaho | 8.10 | 661 | 416 | 70.70 | 1.50 | 3.34 | 1.52 | 0.05 | - | 5.83 | 0.65 | 0.26 | 1.17 | 24.49 | 0.99 | 61.86 | 0.18 | 0.07 | 0.469 | 0.036 | 0.279 | NIL |
| 25 | Nibai | 7.80 | 546 | 344 | 55.42 | 0.90 | 3.08 | 1.43 | 0.06 | - | 4.50 | 0.50 | 0.32 | 1.17 | 27.24 | 1.52 | 80.53 | 0.11 | ND | 0.046 | 0.035 | 0.277 | NIL |
| 26 | Panari | 8.40 | 492 | 310 | 71.98 | 3.12 | 0.78 | 1.09 | 0.05 | 0.53 | 3.40 | 0.65 | 0.30 | 0.74 | 22.62 | 0.03 | 58.79 | 0.22 | ND | 0.452 | 0.045 | 0.359 | NIL |
| 27 | Patsemra | 8.40 | 1150 | 724 | 123.27 | 4.42 | 2.86 | 2.91 | 0.28 | - | 8.62 | 2.15 | 0.14 | 1.52 | 30.47 | 1.34 | 57.37 | 0.36 | ND | 1.117 | 0.047 | 0.254 | NIL |
| 28 | Pipirabansa | 7.90 | 909 | 573 | 92.90 | 3.34 | 2.14 | 3.61 | 0.05 | - | 8.74 | 0.55 | 0.62 | 2.4 | 40.04 | 4.36 | 82.18 | 0.28 | 0.05 | 0.814 | 0.033 | 0.289 | NIL |
| 29 | Pathagori | 8.60 | 617 | 389 | 71.60 | 2.42 | 1.90 | 2.05 | 0.13 | 1.06 | 4.24 | 1.80 | 0.10 | 2.00 | 33.54 | 0.98 | 64.51 | 0.18 | 0.42 | 0.691 | 0.028 | 0.372 | NIL |
| 30 | Rajwara | 7.80 | 1160 | 731 | 138.20 | 4.42 | 4.02 | 2.65 | 0.08 | - | 6.50 | 4.15 | 1.38 | 1.34 | 24.38 | -2.00 | 46.63 | 0.24 | 0.01 | 1.087 | 0.033 | 0.283 | NIL |
| 31 | Sauni Khurd | 8.00 | 742 | 467 | 76.27 | 3.11 | 1.15 | 3.09 | 0.05 | - | 5.90 | 1.35 | 0.39 | 2.58 | 42.43 | 1.64 | 75.09 | 0.36 | ND | 0.520 | 0.025 | 0.334 | NIL |
| 32 | Surwa | 8.50 | 449 | 283 | 36.71 | 0.25 | 2.61 | 1.48 | 0.05 | 0.53 | 3.15 | 1.15 | 0.19 | 1.24 | 34.85 | 0.82 | 74.99 | 0.36 | 0.03 | ND | 0.028 | 0.203 | NIL |
| 33 | Talabpura (Lalitpur) | 8.00 | 662 | 417 | 77.42 | 3.38 | 0.80 | 1.96 | 0.06 | - | 4.71 | 1.35 | 0.38 | 1.36 | 32.58 | 0.53 | 65.18 | 0.22 | ND | 0.497 | 0.053 | 0.387 | NIL |
| 34 | Sidhan (Lalitpur) | 7.90 | 791 | 498 | 116.50 | 4.42 | 2.30 | 1.04 | 0.03 | - | 5.24 | 2.20 | 0.04 | 0.61 | 13.74 | -1.48 | 42.90 | 0.38 | 0.05 | 0.113 | 0.062 | 0.282 | NIL |
| 35 | Ramnagar (Lalitpur) | 7.80 | 647 | 408 | 92.50 | 3.38 | 2.04 | 1.22 | 0.08 | - | 4.24 | 2.00 | 0.71 | 0.82 | 19.49 | -1.18 | 49.38 | 0.76 | 0.05 | 0.221 | 0.024 | 0.267 | NIL |
| 36 | Azadpura (Lalitpur) | 8.40 | 1510 | 951 | 208.70 | 8.50 | 3.16 | 3.96 | 0.05 | 0.53 | 7.96 | 5.00 | 1.79 | 1.97 | 25.59 | -3.70 | 45.41 | 0.35 | 0.56 | 0.273 | 0.105 | 0.189 | NIL |
| 37 | Mabesi Bazar(Lalitpur) | 7.90 | 792 | 499 | 119.70 | 5.16 | 1.34 | 1.39 | 0.05 | - | 4.82 | 3.15 | 0.42 | 0.84 | 18.14 | -1.68 | 45.44 | 0.43 | ND | 0.357 | 0.026 | 0.363 | NIL |
| 38 | Kailguan Road(Lalitpur) | 8.00 | 568 | 358 | 66.05 | 0.80 | 4.12 | 1.17 | 0.03 | - | 4.50 | 0.75 | 0.74 | 0.83 | 19.61 | -0.42 | 54.04 | 0.36 | ND | 0.311 | 0.025 | 0.315 | NIL |
| 39 | Pisnari (Lalitpur) | 7.70 | 610 | 384 | 75.25 | 1.25 | 4.13 | 1.04 | 0.03 | - | 5.56 | 0.55 | 0.76 | 0.68 | 16.59 | 0.18 | 52.93 | 0.34 | ND | 1.350 | 0.034 | 0.267 | NIL |
| 40 | Raghunathpur | 9.00 | 790 | 497 | 130.50 | 4.28 | 3.68 | 0.92 | 0.06 | 0.73 | 4.62 | 0.50 | 1.96 | 0.92 | 10.96 | -3.34 | 34.57 | 0.31 | 0.04 | 0.310 | 0.036 | 0.224 | NIL |

Wilcox (1955) proposed another classification scheme for rating the irrigation water on the basis of *EC, SP* and boron concentration. *SP* is calculated by the formula:

$$SP = \frac{Na + K}{Ca + Mg + Na + K} \text{x} 100\%$$

The *SP* values were plotted against *EC* values (Table 1) in Fig. 3. The diagram reveals that the water quality of study area belongs to Excellent to Good and Good to Permissible classes.

When carbonate concentration in irrigation water is higher than the alkaline earth metals, the remaining part of $HCO^-_3$, which is left after precipitation of alkaline earth carbonates, combines with sodium to form a highly soluble carbonate known as residual sodium carbonate (*RSC*) and is defined as:

$$RSC = (HCO_3 + CO_3) - (Ca + Mg)$$

where, concentrations are expressed in epm.

This is also called Eaton's Index (1950). The water with *RSC* content below 1.25 meq/l is safe, between 1.25 and 2.5 meq/l is marginal, and above 2.5 meq/l is not suitable for irrigation purposes. The excessive *RSC* content causes the soil structure to deteriorate as water and air movement through soil will be restricted. With exception of one village (i.e., Pipriabansa), rest of the villages have the *RSC* content within the permissible limits. Some of the samples in the present study have shown even negative values (Table 1), indicating that the water is quite safe for irrigation.

The soil permeability is affected by long-term use of irrigation water. Sodium, calcium, magnesium, and $HCO^-_3$ components of soil also influence it. Doneen (1962) has

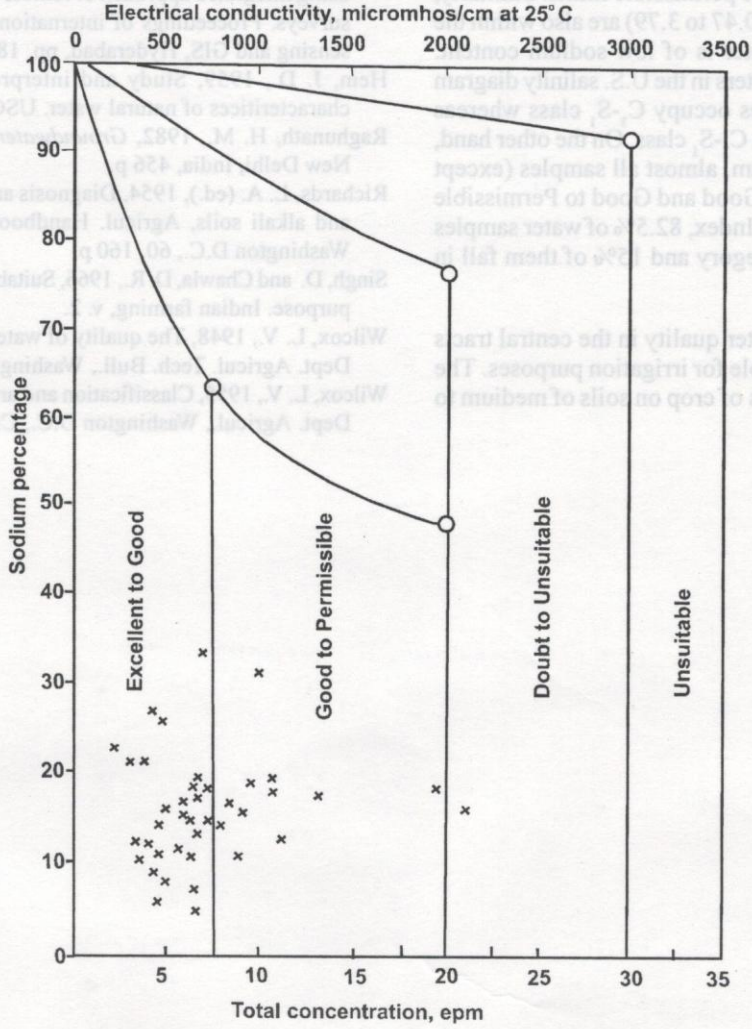


**Fig. 3: Data plotted on the diagram (Wilcox 1955) of sodium per cent against *EC* values**

evolved a criterion for assessing the suitability of water for irrigation based on permeability index (*PI*):

$$PI = \frac{(Na + \sqrt{HCO_3})}{(Ca + Mg + Na)} \text{x}100$$

According to *PI* values, the groundwater in the entire study area can be designated as Class II (25 to 75%) except at Kakruwa, Nibai, Pipriabansa, and Seuni Khurd. The groundwater of the above four places belongs to Class I (>75%).

As suggested by Raghunath (1982) as well as based on the U.S. salinity diagram and Danees' chart, the groundwater in the study area in general is suitable for irrigation purposes.

## CONCLUSIONS

The *SP* values of the irrigation water range from 8.75 to 52.43% and they are within the permissible limits. Similarly, the *SAR* values (ranging from 0.47 to 3.79) are also within the acceptable limits and the water is of low sodium content. The plots of computed parameters in the U.S. salinity diagram exhibit that 57.5% of samples occupy $C_3$-$S_1$ class whereas 42.5% of water samples fall in $C_2$-$S_1$ class. On the other hand, in the sodium per cent diagram, almost all samples (except one) fall within Excellent to Good and Good to Permissible classes. According to Eaton's Index, 82.5% of water samples belong to absolutely safe category and 15% of them fall in marginally safe category.

In general, the groundwater quality in the central tracts of the Lalitpur region is suitable for irrigation purposes. The water can be used for all types of crop on soils of medium to high permeability.

## ACKNOWLEDGEMENTS

We are thankful to the Director, RSAC, UP, for giving the permission to publish the paper. We wish to extend our deep sense of gratitude to Sri Rajiva Mohan, Head WRD-I of Remote Sensing Applications Centre, Lucknow, who helped in many ways during the preparation of this paper.

## REFERENCES

Doneen, L. D., 1962, Notes on water quality in agriculture. Pushished as water sciences and engineering paper 4001, Dept. of water, Science and Engineering, University of California, Davis.

Eaton, F. M., 1950, Boron in soils and irrigation water and its effect on plants, with particular reference to the San Joaquin Valley of California. U. S. Dept. Agricul. Tech. Bull., Washington D.C., v. 448(131), 935 p.

Haldar, A. L. and Rao, M. B. S., 1994, Groundwater exploration in southern part of Lalitpur district, Uttar Pradesh, India, using integrated approach of remote sensing and geoelectrical surveys. Proceedings of international conference on remote sensing and GIS, Hyderabad, pp. 189-195.

Hem, J. D., 1959, Study and interpretation of the chemical characteritices of natural water. USGS paper, 1473, 364 p.

Raghunath, H. M., 1982, *Groundwater*. Wiley Eastern limited, New Delhi, India, 456 p.

Richards, L. A. (ed.), 1954, Diagnosis and improvement of saline and alkali soils, Agricul. Handbook. U. S. Dept. Agricul., Washington D.C., 60, 160 p.

Singh, D. and Chawla, D. R., 1966, Suitability of water for irrigation purpose. Indian farming, v. 2.

Wilcox, L. V., 1948, The quality of water for irrigation use. U. S. Dept. Agricul. Tech. Bull., Washington D.C., 40 p.

Wilcox, L. V., 1955, Classification and are of irrigation water. U. S. Dept. Agricul., Washington D.C., Cir. 969, 19 p.