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# Groundwater recharge to the confined aquifer system in the Terai plain of Nawalparasi district, western Nepal: a hydrochemical approach

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## ABSTRACT

Groundwater recharge estimate is an essential part of the management of the water resources. The Terai plain of Nepal with multi-aquifer system and a number of river systems need thorough understanding on their interconnection.

Groundwater samples from the dug wells, shallow tube wells, deep tube wells, and river water were analysed for major chemical constituents. The chemistry of confined aquifer system is found to be different from the unconfined aquifers. The groundwater recharge to the confined aquifers is therefore believed to be not by vertical infiltration from the shallow aquifers but directly from the palaeo and present river beds. Estimation of groundwater recharge in parts of the Terai plain by rainfall factor warrants rethinking.

## INTRODUCTION

The Terai plain along the foothills of the Himalaya is bestowed with rich groundwater resource as it is underlain by thick pile of alluvial sediments. Though the potentiality of the aquifers varies from place to place depending on the nature of sediments which is related to their provenance (Sharma, 1974), the available resource whatever be its quantity, can be utilised economically by choosing appropriate crops and irrigation practices. Groundwater development in the Terai plain has better advantages than the surface water as the latter suffers from lack of suitable topographic settings for its impounding and its high sediment load. However, for a proper management of the groundwater resource for its sustainable development, quantification of its perennial yield is necessary. This is usually done on the basis of infiltration factor of local rainfall or on the basis of annual water level fluctuation in the wells. But since the Terai plain consists of multi layered confined aquifer system to greater depths, the varacity of adopting these conventional methods is to be judged.

The Bhabhar zone is considered to be the recharge area for the confined aquifer system in the Terai plain along the foothills of the Himalaya (Karanth, 1989; Kunwar and Karanjac, 1989). But it was shown with the fluid potential distribution in the shallow and deep confined aquifer systems in Bhairawa in the Ruapandehi district (Krishna Rao et al, 1996) and in Nawalparasi district (Krishna Rao and Dinesh Pathak, 1996) that the confined aquifer system receives the groundwater recharge from their outcrop areas located within the Terai plain itself, from the palaeo-channels and the present river beds. This study on the hydrochemistry of groundwater and surface water in the Nawalparasi district aims to find out corroborative evidence to the earlier findings.

The study area is bounded by latitude 27°21' and 27°39' N and longitude 83°35' and 83°43' E. It is a plain country gently sloping towards south between altitudes of 130 and 95 m amsl (Fig.1). The Narayani River, which descends from the Higher Himalaya, flows from the eastern boundary of the district. The other rivers like Turia, Jharai, Bhaluhi, etc. are of local nature descending from the Churia hills.

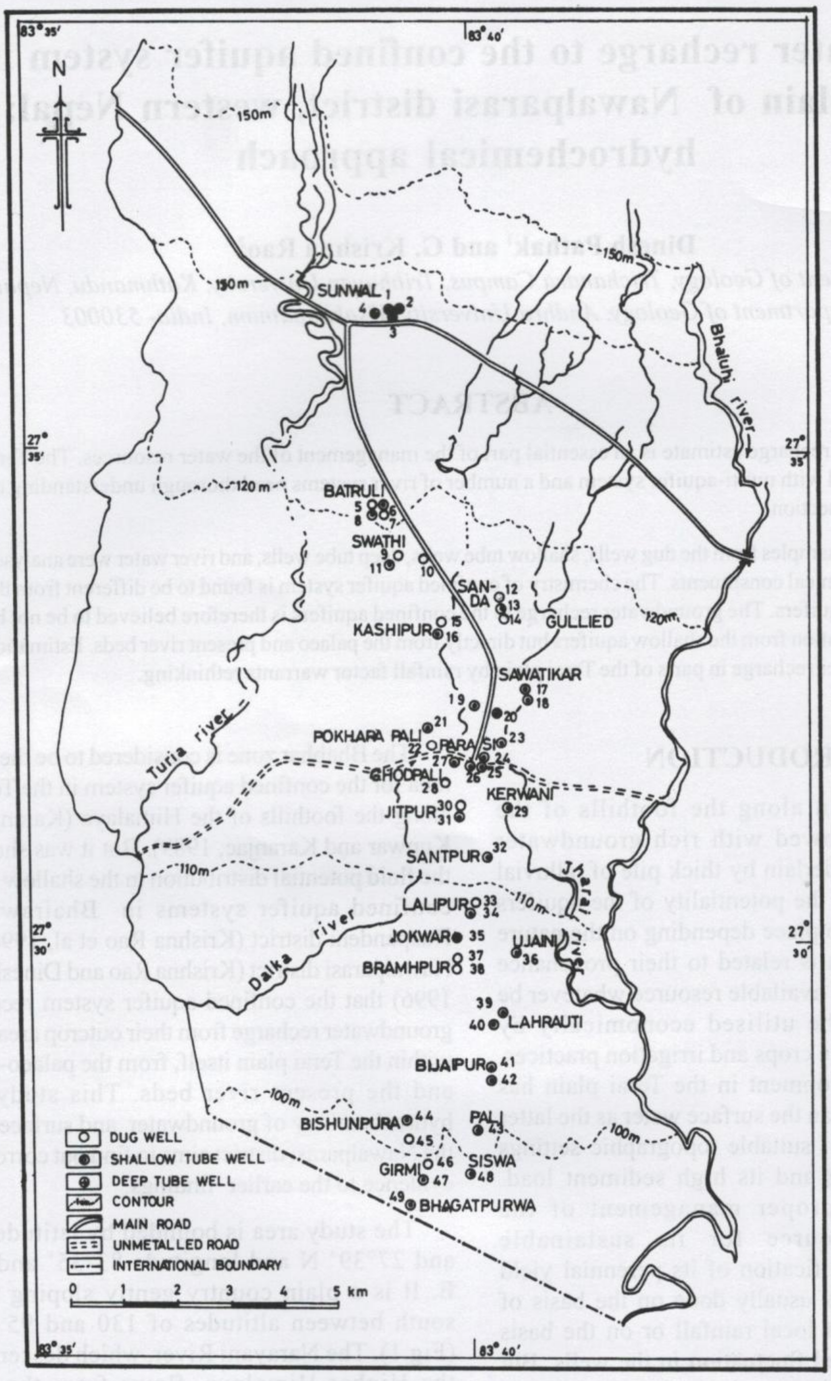


**Fig.1: Location map of wells (aquifer system) in western part of Nawalparasi district, western Nepal**

The major rivers and streams in the Terai plain are characteristic with meanderings and shifting courses (Sharma, op.cit). This explains the occurrence of fine and coarse sediments as alternate layes to greater depths.

In the study area, the Turia and Jharai rivers contain portions of blind rivers in their courses.

## HYDROGEOLOGICAL CONDITIONS

The study area is underlain by Gangetic alluvium consisting mainly of fine sediments. Coarse sediments occur at different depths. The surface sediments are sandy clay in the northern part and silty clay in the southern part. The Bhabhar boulder bed confines to the foothill of the Churia range over limited extent on the western and eastern parts of the Nawalparasi district.

Groundwater is exploited through dug wells, shallow tube wells and deep tube wells tapping unconfined and confined aquifer systems (Fig.1). Dug wells are with a depth range of 4.5 to 10.3 m. Shallow tube wells range in depth from 5 to 63m. Most of the tube wells tap confined aquifers at shallow depth while a few are ended in unconfuned aquifer composed of sandy sediments. Deep tube wells were constructed to a depth range of 95 to 302 m with multiscreens ranging in length from 3 to 15 m.

## HYDROCHEMISTRY

Groundwaters from the dug wells show high variation in quality from slightly brackish to potable. Pollution effects from domestic sources is observed in some villages. Water is turbid at a few places which may be due to clay horizon in the well section. In some wells, high iron content also imparts slight turbidity and iron smell. Groundwater from the shallow and deep tube wells are potable, except with high iron content in a few cases.

Chemistry of groundwaters from the dug wells, shallow and deep tube wells and also from the Turia River is presented in Table 1. The analytical data from the Tinau River water from the adjacent Ruapandehi district is also included in the table for comparison. pH of the groundwaters in all the wells, in general, is 8.0 to 8.6 except a few cases where these limits are exceeded. The Turia river water also shows a pH of 8.6.

Total dissolved solids (TDS) show different range for the dug well waters with 128 to 833 mg/l except in one case where it is 64 mg/l. Their average is 424 mg/l. For shallow tube wells, the TDS in most of the cases are 200 and 300 mg/l in a range of 100 to 700 mg/l. Their average is 167 mg/l. For deep tube wells, the TDS range from 128 to 256 mg/l, with an average of 169 mg/l. Surprisingly, the TDS of the Turia River and Tinau River waters are also 128 mg/l. Chlorides follow the trend of TDS. In dug wells it varies from 110 to 360 mg/l except in one case where it is low with 40 mg/l and this corresponds to the lowest TDS. For shallow tube wells, it ranges in general from 20 to 110 mg/l except at Swathi (well No.9) where the maximum is 170 mg/l and its TDS are also high. This tube well is in fact at a depth of only 4.0 m and the surface sediment layer is black silt. This, in fact, taps an unconfined aquifer. The deep tube wells contain 30 and 40 mg/l except one which has only 5 mg/l. The Turia River water contains 20 mg/l. The averages of the dug wells, shallow tube wells and deep tube wells are 205, 51 and 30 mg/l, respectively.

Sulphate values, as available for a few wells, show that it is in traces in tube well waters while it is 14 and 100 mg/l for two dug wells. Higher value relates to higher TDS among the two.

Total hardness of groundwaters shows different ranges in different wells. The ranges are 160 to 470 mg/l, 140 to 460 mg/l and 170 to 230 mg/l for dug wells, shallow tube wells and deep tube wells, respectively. The hardness of the Turia River water has 170 mg/l. Thus, while the dug wells and shallow tube wells have similar hardness, the deep tube wells have less hardness almost equal to the surface water. Hardness seems to have little relation with the TDS. It is high in the shallow aquifers.

## DISCUSSION

Chemistry of groundwaters in the study area shows different salinities for the unconfined and the confined aquifers. In any area, particularly in the confined aquifer system, the salinity of

**Table 1: Chemical analysis of groundwaters in the western part of Nawalparasi district, western Nepal**

| Sl. No. | Well No. | Location | pH | TDS | $Cl^-$ | $HCO_3^-$ | Total Hardness | Ca | Mg | Fe | $SO_4^{--}$ | Na |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | Dug Wells | | | | | | | | | | |
| 1. | 5 | Batrauli | 8.2 | 513 | 250 | 232 | 320 | 24 | 63 | - | - | - |
| 2. | 7 | Batrauli | 8.8 | 577 | 160 | 285 | 400 | 40 | 73 | - | - | - |
| 3. | 11 | Swathi | 8.4 | 577 | 330 | 255 | 260 | 29 | 46 | - | - | - |
| 4. | 12 | Sanda | 9.7 | 256 | 110 | 88 | 170 | 32 | 22 | - | - | - |
| 5. | 14 | Sanda | 8.2 | 256 | 180 | 179 | 270 | 38 | 43 | - | - | - |
| 6. | 15 | Kashipur | 8.1 | 64 | 40 | 103 | 160 | 23 | 25 | 4.8 | 13.6 | 1.02 |
| 7. | 22 | Pokhara Pali | 8.7 | 577 | 200 | 312 | 250 | 30 | 43 | - | - | - |
| 8. | 28 | Ghodpali | 8.9 | 833 | 360 | 346 | 470 | 42 | 89 | - | - | - |
| 9. | 30 | Jitpur | 8.6 | 577 | 300 | 171 | 450 | 33 | 90 | 3.4 | 99.6 | 2.40 |
| 10. | 33 | Lalitpur | 8.0 | 321 | 180 | 137 | 220 | 26 | 38 | - | - | - |
| 11. | 37 | Bramhpur | 8.7 | 128 | 210 | 182 | 270 | 25 | 51 | - | - | - |
| 12. | 45 | Bishunpura | 7.9 | 577 | 250 | 179 | 310 | 29 | 58 | - | - | - |
| 13. | 46 | Girmi | 8.2 | 256 | 90 | 175 | 260 | 29 | 46 | - | - | - |
| | | Shallow Tube Wells | | | | | | | | | | |
| 14. | 4 | Sunwal | 8.5 | 90 | 30 | 122 | 160 | 27 | 22 | - | - | - |
| 15. | 6 | Batrauli | 9.2 | 321 | 110 | 156 | 240 | 36 | 37 | - | - | - |
| 16. | 8 | Batrauli | 8.1 | 128 | 70 | 258 | 280 | 28 | 51 | 15.6 | Trac | 60 |
| 17. | 9 | Swathi | 8.3 | 385 | 170 | 114 | 240 | 38 | 35 | - | - | - |
| 18. | 10 | Swathi | 7.8 | 64 | 40 | 99 | 140 | 39 | 10 | 14.0 | Trac | 10 |
| 19. | 13 | Sanda | 8.4 | 192 | 10 | 220 | 280 | 34 | 47 | - | - | - |
| 20. | 16 | Kashipur | 8.2 | 64 | 70 | 84 | 220 | 39 | 30 | 10.6 | 13.2 | 25 |
| 21. | 17 | Sawatikar | 8.3 | 192 | 20 | 220 | 250 | 25 | 46 | - | - | - |
| 22. | 18 | Sawatikar | 8.4 | 192 | 30 | 201 | 300 | 27 | 57 | - | - | - |
| 23. | 19 | Parasai | 7.9 | 128 | 20 | 129 | 390 | 31 | 76 | - | - | - |
| 24. | 21 | Pokhara Pali | 8.6 | 38 | 20 | 198 | 260 | 34 | 43 | - | - | - |
| 25. | 23 | Parasai | 8.2 | 128 | 40 | 145 | 170 | 28 | 24 | 7.2 | Trac | 45 |
| 26. | 24 | Parasai | 8.4 | 449 | 90 | 319 | 250 | 125 | 9.1 | - | - | - |
| 27. | 25 | Parasai | 8.1 | 128 | 30 | 148 | 240 | 27 | 42 | - | - | - |
| 28. | 26 | Parasai | 7.9 | 192 | 60 | 80 | 370 | 30 | 72 | - | - | - |
| 29. | 27 | Parasai | 8.2 | 192 | 20 | 190 | 270 | 29 | 48 | - | - | - |
| 30. | 29 | Kerwani | 8.3 | 128 | 30 | 129 | 460 | 47 | 83 | - | - | - |
| 31. | 31 | Jitpur | 8.6 | 192 | 110 | 68 | 350 | 46 | 57 | - | - | - |
| 32. | 32 | Santpur | 7.9 | 256 | 100 | 129 | 330 | 43 | 54 | - | - | - |
| 33. | 34 | Lalitpur | 8.1 | 64 | 20 | 87 | 440 | 60 | 71 | - | - | - |
| 34. | 36 | Ujaini | 8.2 | 128 | 20 | 99 | 160 | 28 | 22 | - | - | - |
| 35. | 38 | Bramhpur | 8.3 | 192 | 50 | 103 | 240 | 38 | 35 | - | - | - |
| 36. | 39 | Laharauli | 8.4 | 256 | 70 | 87 | 170 | 28 | 24 | 16.6 | - | - |
| 37. | 40 | Laharauli | 8.1 | 192 | 60 | 103 | 200 | 39 | 25 | - | - | - |
| 38. | 41 | Bijayapur | 8.5 | 128 | 40 | 106 | 230 | 48 | 27 | - | - | |
| 39. | 42 | Bijayapur | 8.6 | 128 | 50 | 84 | 250 | 28 | 44 | - | - | |
| 40. | 43 | Pali | 8.3 | 64 | 40 | 72 | 180 | 27 | 27 | 5.0 | Trac | 5 |
| 41. | 44 | Bisunpura | 8.2 | 128 | 20 | 118 | 240 | 25 | 43 | | - | - |
| 42. | 47 | Girmi | 8.2 | 128 | 40 | 122 | 270 | 30 | 47 | - | - | |
| 43. | 48 | Siswa | 8.2 | 128 | 3 | 129 | 220 | 24 | 39 | 9.2 | Trac | 15 |
| 44. | 49 | Bhagatpurwa | 7.9 | 192 | 90 | 57 | 240 | 48 | 29 | | | |
| | | Deep Tube Well | | | | | | | | | | |
| 45. | 1 | Sunwal | 8.0 | 128 | 30 | 141 | 170 | 21 | 29 | 5.8 | - | - |
| 46. | 2 | Sunwal | 8.3 | 141 | 40 | 171 | 170 | 21 | 29 | 2.3 | | - |
| 47. | 3 | Sunwal | 8.0 | 128 | 40 | 152 | 210 | 29 | 33 | 2.5 | | - |
| 48. | 20 | Parasi | 8.4 | 256 | 5 | 255 | 210 | 20 | 39 | - | Trac | 85 |
| 49. | 35 | Jokwar | 8.5 | 192 | 30 | 179 | 230 | 31 | 37 | 10.8 | Trac | 30 |
| | | Rivers | | | | | | | | | | |
| 50. | 50 | Sunwal (Turia River) | 8.6 | 128 | 20 | 125 | 170 | 48 | 12 | - | - | - |
| 51. | 51 | Butwal (Tinau River) | 7.5 | 128 | 30 | 122 | 130 | 42 | 6 | - | - | - |

groundwater is expected to be increased with depth because of its less mobility and hence more residence time. On the contrary, the deeper aquifers in the study area are found to have less salinity than the upper shallow aquifers. Secondly, their salinity is almost equal to the river waters. This shows that the groundwaters in the deeper aquifers are hydraulically connected to the stream beds and are under continuous movement. This invalidates the concept of downward infiltration of shallow groundwaters to the deeper aquifers. Since most of these tube wells are located away from the river courses it may be inferred that they are located in some of their paleo-channels but having hydraulic continuity with the present river beds.

## CONCLUSIONS

The groundwaters in the confined aquifers are different from those of the unconfined aquifers. The chemistry of deep aquifer waters is nearly the same as the local river waters.

The groundwater recharge estimation to the confined aquifers in the Terai plain, therefore, should be done on the basis of induced recharge conditions with maximum stress on the aquifers and not based on the local rain fall contribution.

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## REFERENCES

Karanth, K.R., 1989, Hydrogeology. Tata Mc Graw-Hill Pub., Co.Ltd.

Krishna Rao G., Rama shrestha and Vaidya, Y.L., 1996, Hydrogeological conditions in the Terai plain of Rupandehi district, Lumbini Zone, Nepal, with special emphasis on groundwater recharge. In: Subsurface Water Hydrology (eds. V.P. Singh and B. Kumar), Kluwer Academic Publ., pp. 131- 49.

Krishna Rao, G. and Pathak, D., 1996, Hydrogeological conditioins in the Terai plain of Nawalparasi District, Lumbini zone, Nepal, with special reference to groundwater recharge. Jour. App. Hydrol., v.9, pp. 69-75.

Kunwar, M.B. and Karanjae, J., 1989, Deep tube well drilling, testing and monitoring in 1969-89. Basic Documentation and Preliminary Interpretation. Rupandehi District Technical Report No. 11, GWRDW-UNDP Project- NEW/86/025.

Sharma, C.K, 1974, Groundwater Resources of Nepal. Sangeeta Sharma, Kathmandu, Nepal