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Groundwater potential and its management in the hard rock terrain: a case study from the Varada River, India

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ABSTRACT

The study area occupies over 2,900 km² in the Varada River Basin of the Haveri District, the Karnataka State, India. Residual hills, pediments, pediplains, and ridges are the major landforms. Hard rocks, viz., greywacke, biotite schist, and associated rocks of Archean age (Ranebennur-Sirsi series) constitute the country rock. The region is also criss-crossed by a number of lineaments. In this area, there are no large-scale irrigation schemes and industries. Depth to water table and quality of groundwater varies from place to place. Though most part of the region has moderate rainfall and groundwater potential, lowering in water table depth has been observed due to overdraft by excessive pumping. The zones of fresh groundwater and brackish water are demarcated based on integrated geological and hydrogeological investigations. In the paper, total groundwater demand at present and for the future few years, available reserves, and scope for further development and management are discussed.

INTRODUCTION

The Varada River Lower Basin (VRLB) covers about 2,900 km² in the Haveri District of the Karnataka State, India (latitudes: 14° 31' and 15° 07' N and longitudes: 75° 00' to 75° 45' E; Fig. 1). There is only one major project that operates in the rainy season and irrigates about 5,000 hectares of land. There are also a few minor lift irrigation schemes along the river course. Most of the existing tanks are silted and dry. Monsoon also is erratic. These conditions have compelled many farmers to depend on subsurface water for irrigation resulting in a high demand for groundwater. This urge for groundwater has given rise to unscientific exploration and overexploitation resulting in lowering of water table, failure of wells, and deterioration in groundwater quality. Considering these problems, the area was investigated in different phases for the purpose of demarcating groundwater potential zones, estimating their reserves, and assessing the scope for future development and management.

PHYSIOGRAPHY AND GEOLOGY

The VRLB forms an elliptical physiographic basin and has an undulating topography. While the upper region is thickly forested and receives heavy (>950 mm) rainfall, the lower part is sparsely vegetated and receives less (700 mm) rainfall. Hence, the latter can be categorised under 'drought-prone' area (Marihal 1991). Most of the area is characterised by gently undulating pediplains with a few residual hills, pediments, and ridges. The dendritic to sub-dendritic drainage pattern is structurally controlled and follows four prominent sets of lineament running N-S, NW-SE, E-W, and NE-SW (Fig. 2).

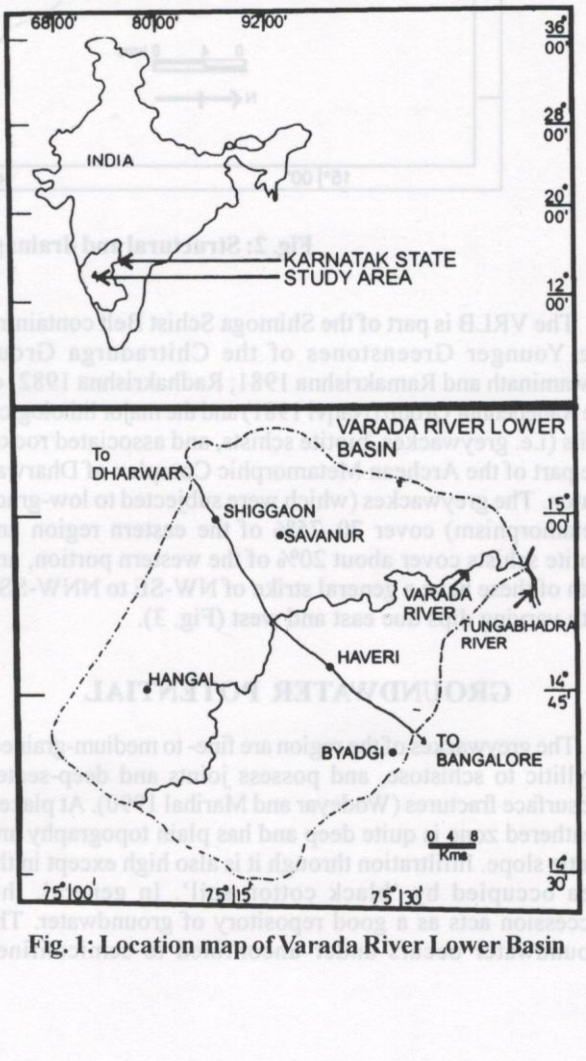

Fig. 1: Location map of Varada River Lower Basin

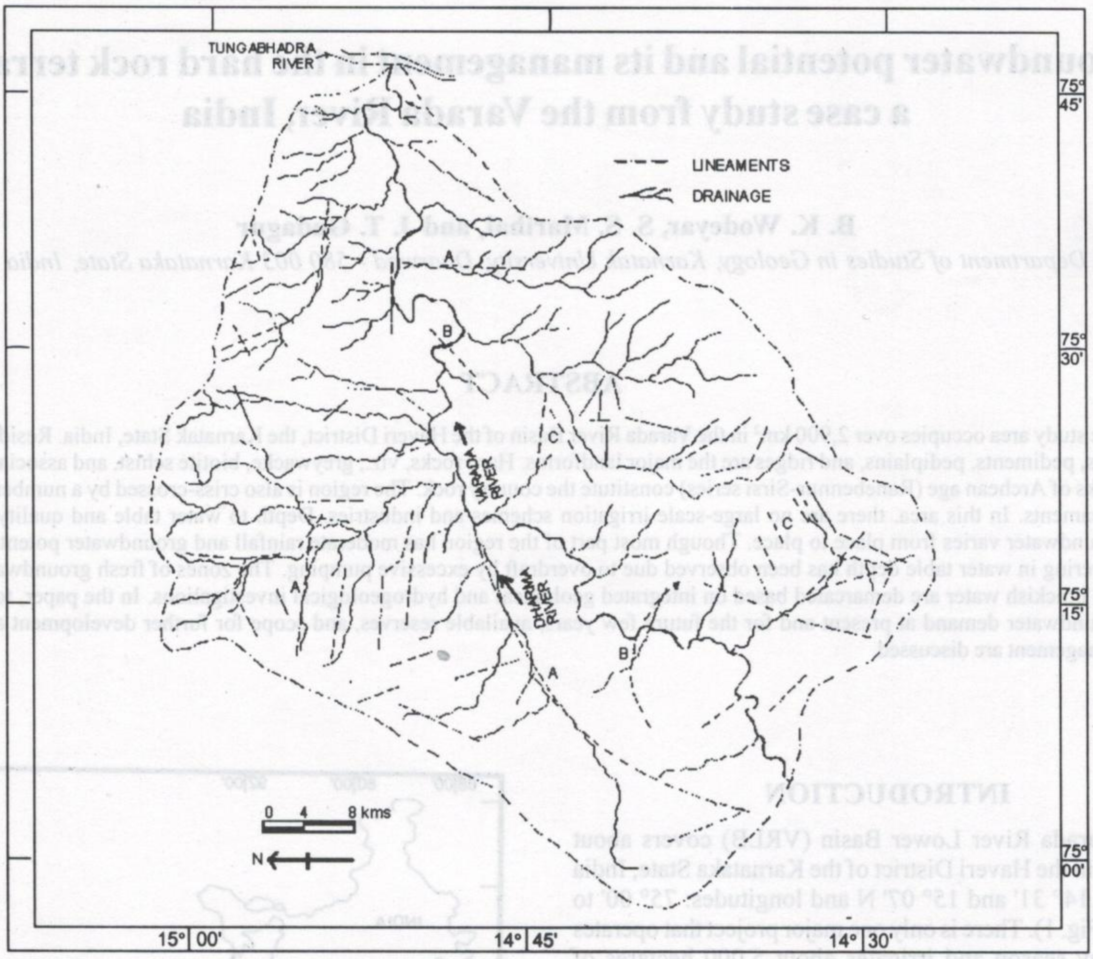

Fig. 2: Structural and drainage map of Varada River Lower Basin

The VRLB is part of the Shimoga Schist Belt containing the Younger Greenstones of the Chitradurga Group (Swaminath and Ramakrishna 1981; Radhakrishna 1982) or the Ranebennur Group (Naqvi 1981) and the major lithological units (i.e. greywackes, biotite schists, and associated rocks) are part of the Archean Metamorphic Complex of Dharwad craton. The greywackes (which were subjected to low-grade metamorphism) cover 70–75% of the eastern region and biotite schists cover about 20% of the western portion, and both of these have a general strike of NW-SE to NNW-SSE with varying dips due east and west (Fig. 3).

GROUNDWATER POTENTIAL

The greywackes of the region are fine- to medium-grained, phyllitic to schistose, and possess joints and deep-seated subsurface fractures (Wodeyar and Marihal 1990). At places, weathered zone is quite deep and has plain topography and gentle slope. Infiltration through it is also high except in the area occupied by 'black cotton soil'. In general, this succession acts as a good repository of groundwater. The groundwater occurs under unconfined to semiconfined conditions. Phreatic condition is limited to the weathered zone, whereas the biotite schists are fine-grained, possess fewer joints and fractures, and have varying depth of weathering. Added to this, the biotite schists have a cover (up to 20 m deep) of argillaceous matter developed due to weathering and heavy rainfall. Though this region receives heavy rainfall, recharge to groundwater is low. Zones with high groundwater potential are confined to the areas crisscrossed by lineaments and minor intrusives (Fig. 4).

GROUNDWATER RESERVES

The estimated groundwater recharge from rainwater (based on the hydrodynamic method) in the study area is 272.59 million cubic metre (Mm^3)/year (Adyalkar and Srihari Rao 1979). The total groundwater recharge of the region is estimated at 292.09 Mm^3/year (including 10% return from irrigation and 2% from drainage system). At present, about 15,000 pumps have been electrified. Assuming that the irrigation requirement for a year is about 200 days, with an average rate of pumping of 12 hours/day and with an average discharge rate of 1,500 gph, the discharge would be

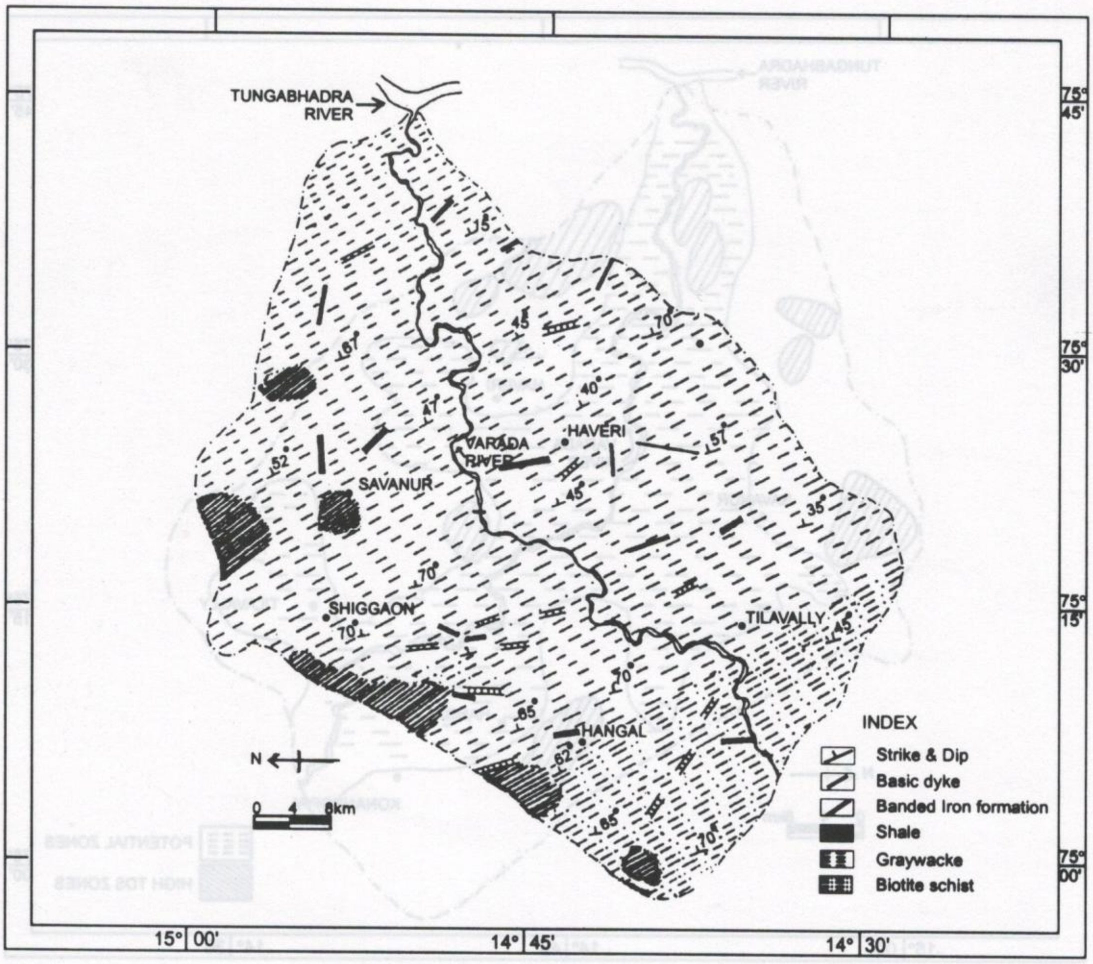

Fig. 3: Geological map of Varada River Lower Basin

204.39 Mm^3/year. The total domestic consumption of the entire region is about 24.59 Mm^3/year (70l pd/person and for the population of about 10,00,000; Statistical data on Haveri District 1998). The total demand for subsurface water including the domestic consumption amounts to 228.98 Mm^3/year. Hence, the present total groundwater balance of the VRLB is estimated at 63.11 Mm^3/year.

In the past 10 years, about 6,000 wells were electrified. This fact implies that the rate of new installations is about 600 wells/year. Considering the same trend of increase in number of wells, this region will have about 21,000 drill holes by 2010. Hence, the total groundwater demand including the domestic consumption (for a population of about 11,55,000 by 2010), would be 315.64 Mm^3/year as against the total recharge of 292.09 Mm^3/year.

DISCUSSIONS AND CONCLUSIONS

An exact appraisal of groundwater resources, adoption of scientific exploitation techniques, and proper management to meet the water demand are the immediate needs of the region. It is required to carry out the quality assessment of the groundwater in the area of about 500 km^2, which is characterised by brackish quality groundwater (Fig. 4). This groundwater often contains the total dissolved solids (TDS) more than their permissible limits (Table 1) and occupies mostly the peripheral region. At many locations, the bored wells that yielded sweet water a few years ago have now become either brackish or contain hard water, which may be due to the low recharge and excessive pumping. In future, these brackish patches may increase their dimensions.

The rate of total utilisation of groundwater between 1989 and 1999 has increased immensely. In 1989 it was 103.01 Mm^3 (Marihal 1991). This estimate was based on the working time of 8 hrs/day for 200 days in a year for 8879 wells. Now it has been observed that most of the pumps operate for 10–15 hrs/day. Considering that, each pump is used on an average for 12 hrs/day (because of increase in extensive land irrigation), the total groundwater utilisation at present is estimated at 228.98 Mm^3/year. The total groundwater balance was 182 Mm^3/year in 1989 (Marihal 1991), and 63.11 Mm^3/year in 1999, and the region will have a deficit of 23.55

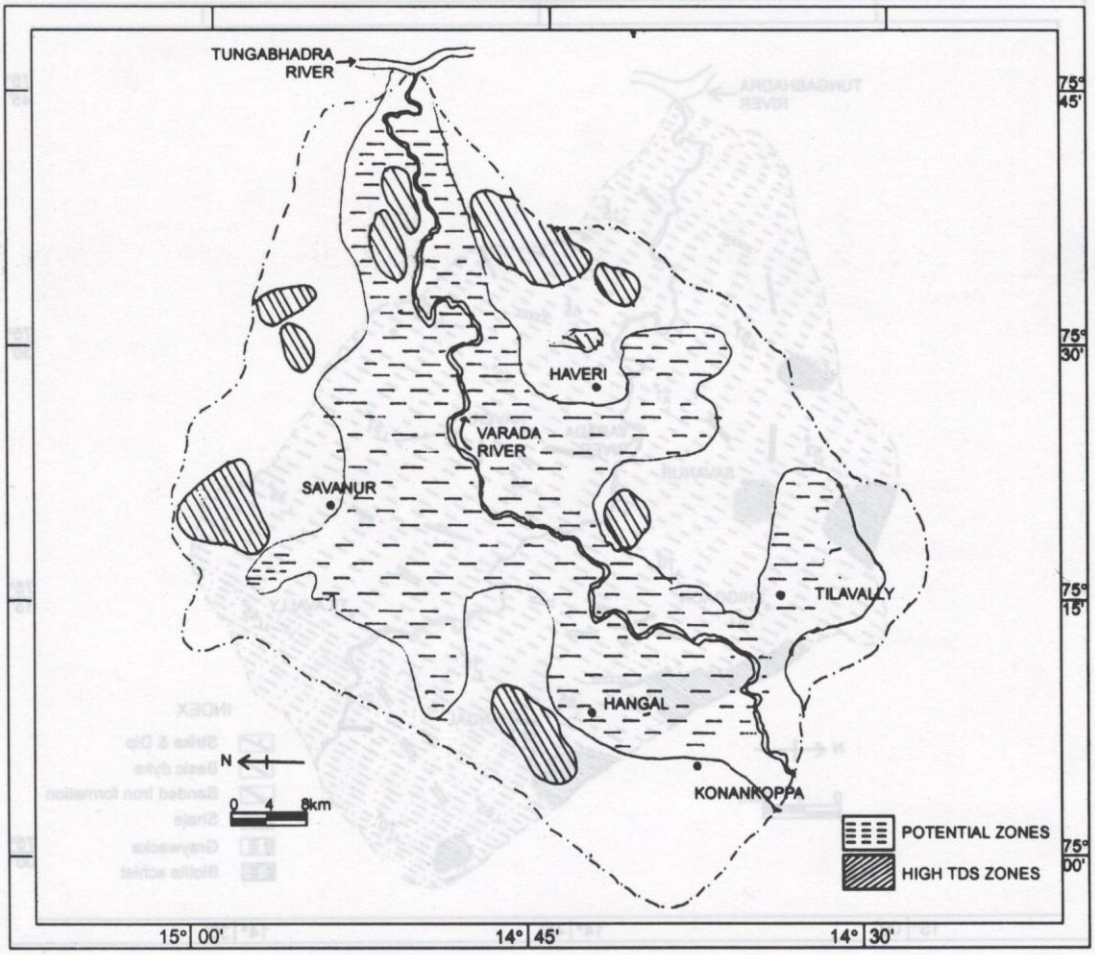

Fig. 4: Potential and high TDS groundwater zones of Varada River Lower Basin

Mm^3/year by 2010 AD. This clearly indicates an acute scarcity of groundwater in the future. Considering all these aspects, following recommendations are made.

It is advisable to develop groundwater through dug wells or dug cum bored wells in the biotite schist region. In the area covered by greywackes, groundwater should be developed only through bored wells and the aquifers can be recharged by a) injection wells drawing water from the Varada River during rainy season and b) by constructing a number of check dams and bunds across the river and major streams.

Western and central parts of the region have a large number of silted irrigation tanks. They should be cleaned and interconnected with each other by surface channels, so that the runoff that gets wasted during the rainy season could be stored, and this will also recharge the aquifers.

In the vicinity of brackish water patches, either artificial recharge through injection wells should be undertaken (which will not only recharge the aquifers but will also dilute the brackish quality groundwater) or the use of groundwater should be minimised.

At present, many farmers depend on water diviners for selecting sites for drilling a well. This has resulted in failure of many wells. As they do not maintain a minimum distance between two bored wells, there are many incidences of well failure or low yield. Hence, there is a need to educate the farmers to depend on scientific methods for selecting a well site.

To meet the water demand for irrigation and drinking purposes, the government of India and state governments have many plans but most of them are proceeding in a slow pace (Choudhary 1999). Even though there is scope for further development in this region, the availability of groundwater at any location cannot be guaranteed. This situation demands for adoption of proper prospecting methodologies in siting and developing wells. On the other hand, proper maintenance of wells is also lacking. Under these circumstances, it is necessary to have strict legislative regulations.

This investigation is a case study in a semi-arid and hard rock terrain where overexploitation of groundwater has led to changes in its quality and decline in yield. This case study

Table 1: Partial chemical analysis of groundwater samples of VRLB region (values in ppm)

S. N.	Village	TDS	Na+K	Cl
1	Kerikoppa	960	5051	4.56
2	Balehosur	1184	10.10	8.87
3	Kurabgeri	640	6.98	4.78
4	Kurabgeri	1184	9.37	5.23
5	Gudusalkoppa	1056	2.19	5.07
6	Gudusalkoppa	1472	15.62	13.77
7	Marol	1600	13.56	13.91
8	Negalur	676	4.97	4.45
9	Yellapur	640	6.08	3.50
10	Yellapur	768	7.98	9.00
11	Siddapur	1300	10.04	11.01
12	Siddapur	1076	8.71	7.85
13	Ichangi	1600	15.99	13.12
14	Ichangi	1024	5.49	0.33
15	Bailmadapur	896	5.14	5.77
16	Kittur	1536	2.73	2.19
17	Kittur	1472	14.46	7.85
18	Basapur	1696	5.18	4.84
19	Basapur	928	8.00	5.21
20	Haleritty	512	4.70	2.98
21	Haleritty	2112	16.49	13.07
22	Bommanakatty	1568	7.52	3.88
23	Bommanakatty	896	7.32	6.46
24	Hosaritty	896	6.73	5.21
25	Hisaritty	960	7.40	4.84
26	Hosaritty	1088	9.86	11.26
27	Maradur	1088	9.80	5.35
28	Maradur	576	3.91	3.74
29	Teggihally	640	4.71	5.42
30	Yelvgi	448	3.17	4.84
31	Teggihally	640	5.29	4.22
32	Handginur	896	8.37	5.94
33	Mannur	960	4.37	3.07
34	Kanavally	323	4.45	1.94
35	Kanavally	672	5.90	3.43
36	Kalkote	736	6.09	5.14
37	Gundenahally	1120	12.63	9.50
38	Shankarikoppa	896	7.21	6.35
39	Hormarde	640	5.93	3.50
40	Neluvgal	704	4.14	4.30
41	Hirekoppa	384	2.30	2.33
42	Kalihally	608	5.20	2.50
43	Yettinahally	1504	1051	13.49
44	Katenahally	768	5067	3.38
45	Karjgi	320	3.09	0.85
46	Aladakatty	608	4.23	3.88
47	Kaginele	736	5.30	3.02
48	Hattimuttur	640	9.95	6.42
49	Sirabadgi	512	4.26	2.92
50	Kalalakonda	576	3.11	3.30
51	Hosahally	448	4.25	2.82
52	Mallur	640	6.02	2.95
53	Hulagur	864	8.95	7.35
54	Madapur	704	6.79	4.56
55	Hulagur	384	2.00	2.78
56	Karadgi	1216	13.60	11.35
57	Savanur	832	8.27	3.66
58	Savanur	288	2.39	1.15
59	Savanur	1088	9.07	6.53
60	Geggihally	640	4.88	2.45
61	Mannur	704	3.40	4.84
62	G. Chennapour	768	6.74	5.07
63	Kunimellyhally	352	2.59	1.40
64	Kundur	480	3.14	3.15
65	Kundur	448	4.10	2.45
66	Bankapur	408	2.66	1.99
67	Bankapur	448	3.67	3.69
68	Mannur	640	3.63	3.49
69	Nandihally	1184	9.53	5.50
70	Bannikoppa	640	2.85	3.60
71	Ganjigatti	576	3.04	3.09
72	Nidagundi	416	1.72	2.53
73	Sidlapur	704	4.25	4.90
74	Torur	832	5.09	6.71
75	Torur	448	3.15	3.15
76	Lakkikoppa	544	4.35	2.76
77	Nellikoppa	320	2.35	1.77
78	Badamgatta	608	3.04	3.23
79	Hospet	352	2.18	3.18
80	Hospet	896	6.98	7.38
81	Hotanahally	512	3.70	3.57
82	Gundur	448	4.20	2.87
83	Yallur	480	6.13	7.40
84	Yelavatty	448	6.67	2.20
85	Nidasangi	640	3.94	4.64
86	Bailavatty	352	1.26	1.77
87	Hullatti	576	5.19	5.24
88	Chiranahally	864	6.75	5.53
89	Hulaginkoppa	544	6.68	4.19
90S	Hangal	768	6.44	3.66
91	Sangur	384	3.18	2.40
92S	Gunddanahally	640	5.45	4.19
93S	Hirebasur	576	5.59	3.46
94	Somasagar	612	3.88	3.38
95S	Hirebasur	896	3.11	2.64
96S	Chikabasur	832	4.67	6.12
97S	Ghalapuji	448	1.97	1.77
98	Gejjihally	576	2.26	1.69
99	Kanchineglur	480	4.77	3.60
100	Chennapur	288	2.33	0.98
101	Hotanahally	480	1.33	1.29
102	Havargi	608	1.73	1.00
103S	Mulgund	576	1.42	2.65
104S	Yattinahally	1472	1.38	1.45
105S	Shyadaguppa	448	2.43	1.70
106S	Makravally	384	4.06	3.35
107S	Tattiahally	256	1.52	1.34
108S	Kodihally	224	2.13	1.40
109S	Balehally	288	1.97	1.49
110S	Kyasanur	160	0.47	0.59
111S	Alur	224	1.84	1.18

Note: Suffix 'S' denotes samples from schistose region and the remaining from greywacke region. *Analyst Dr. S.S. Marihal clearly indicates an alarming situation existing in semi-arid zones of many developing countries.

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