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Hydrochemical Assessment of the Pollutants in Groundwaters of Vrishabhavathi Valley Basin in Bangalore (India)

B.S. SHANKAR*, N. BALASUBRAMANYA** AND M.T. MARUTHESHA REDDY***

The present study aims at the assessment of groundwater quality in and around the Vrishabhavathi Valley, the erstwhile fresh water stream, today carrying huge quantities of industrial, agricultural and domestic effluents from the western part of Bangalore metropolis. Groundwater samples were collected from both bore wells and open wells along the Vrishabhavathi watershed and subjected to a comprehensive physico- chemical and bacteriological analysis. The study revealed that 57% of the samples were non-potable due to their values when compared to the BIS standards. The concentrations of nitrate and total hardness were found higher than the standards in 43.33% and 40% of the samples respectively. 50% of the samples examined, indicated bacterial contamination in the groundwater.

Key words : *Groundwater, pollution, quality, contamination*

Introduction

Nearly 90% of the rural population in India is primarily dependent on groundwater and about 25% of the people's need in urban areas is met by groundwater. Due to unavailability of surface water at many places, groundwater is the only alternate source of good quality water. The groundwater exploration and development have gained momentum not only in India, but also the world over, to cope up with the increase in demand of the quality and quantity of freshwater, due to population explosion, industrial expansion and rapid agricultural development.

Bangalore city has meager water resource in its neighbourhood, being a part of semi-arid peninsular India. The undulating topography of the city has been meticulously managed in the past, to build a chain of water storage lakes in the Valley areas. But, the city has been heading towards freshwater crisis, mainly due to improper management of water resources and environmental degradation, which has led to lack of access of safe water supply.

The Department of Mines and Geology carried out investigations to evaluate the groundwater quality in Bangalore Metropolis and based on the analysis, it was reported that 51 percent of the samples were non-potable due to the presence of excess concentrations for one or more water quality parameters[1] and nitrate was found to be the major cause, accounting for 45 percent of non-potability. Recently, the Central Groundwater Board carried out studies on industrial pollution in Bangalore city covering major industrial belts of an area of 80 square km and reported that the groundwater was slightly alkaline in nature and dominated by calcium and magnesium as cations and chloride and nitrate as anions. The groundwater occurring in these belts showed excessive concentrations of nitrates, resulting in non-potability ranging from 12.5 percent to 50 percent[1].

Status (scenario) of Bangalore water supply

In the recent past, Bangalore has witnessed phenomenal growth, which has taken heavy toll of the groundwater resources in the city. The water requirement of the city is partly met by the supplies from Cauvery, Thippagondanahalli and Hesaraghatta[2]. The requirement has however outstripped these supplies. To quench the insatiable thirst of the city, groundwater has been tapped as a complimentary and wholesome resource. Therefore, there has been an increasing spurt in the activity of drilling of borewells. Several government agencies have been responsible for over 8000 such borewells. Besides, there are more than a lakh private borewells in the city. A huge quantity of groundwater is also being extracted for industrial requirements and construction activities. Large numbers of borewells are being drilled by private people for supplying water through tankers in the city and its outskirts. This rapid urbanization and industrialization

* Assistant Professor, Civil Engineering Department, EPCET, Bangalore
** Professor in Civil Engineering, MSRIT, Bangalore
*** Assistant Professor, Civil Engineering Department, MVJCE, Bangalore

has also resulted in drying up of various fresh water tanks which were earlier, sound groundwater recharge zones. Whatever few tanks remaining now have become dumping grounds for solid and liquid waste giving rise to serious concern for pollution. Groundwater resource is thus threatened with contamination with the demographic change such as spread of human settlement and industrial activity. The monitoring of groundwater quality therefore has become the need of the hour.

The problem

The Vrishabhavathi river, once used as a major source of water, is now entirely contaminated due to household, agricultural and industrial wastes. While the original river has dried up, at present, it is carrying sewage and industrial effluents from more than 100 industries of various kinds. The wastewaters up to 300 MLD flow into the Vrishabhavathi Valley. It receives improperly treated and /or untreated effluents and domestic wastewater from the Bangalore water supply and sewerage board (BWSSB) treatment plant, containing various organic materials, toxic elements and pathogens[3]. In the study area, the sewage laden surface water, that is, the surface water of Vrishabhavathi river is applied extensively for irrigation. The sewage after lift is conveyed by the field channels and spread to irrigate some food and horticultural crops. A majority of the farmers own both dug wells and bore wells for irrigating various crops. Thus, the groundwater, which is the most utilized source, especially the open dug wells which are situated in this environment are vulnerable to ambient pollution. In the recent years, pollution of groundwater in the Vrishabhavathi locality has emerged as a severe environmental issue, constraining its use drastically. In this context, the present study assumes great importance.

The study area

Vrishabhavathi is one of the tributaries of the river Cauvery. It drains a major part of Bangalore metropolis in the west and is the outlet channel for domestic and industrial effluents in the area[4]. This erstwhile freshwater stream, has now become the carrier of heavy pollutants. The Vrishabhavathi, a tertiary tributary of the river Cauvery, drains an aerial extent of 545 sq km before it joins the Suvarnamukhi river at Bhadragundadoddi of Kanakapura taluk, Bangalore district. It is encompassed by North Latitudes $12^{0}45^{1}$ to $13^{0}\ 03^{1}$ and East Longitudes $77^{0}\ 23^{1}$ to $77^{0}\ 35^{1}$. The topographic coverage of the area is available on the topo sheets 57H/5 and 57H/9 published on scale 1: 50,000.

Materials and methods

30 water samples were collected from the bore wells and open wells in the study area **(Fig. 1)** during April 2006 in two litre PVC containers. The samples were sealed and analyzed

Fig. 1 : Location map of Vrishabhavathi Valley with sampling locations

for the major physico-chemical parameters in the laboratory. 10 samples were analyzed for bacterial contamination in the wake of the reported bacterial infection of groundwater causing water borne diseases such as cholera, typhoid etc.

The physical parameters such as pH and electrical conductivity were determined in the field at the time of sample collection[5]. The chemical analysis including metals and bacteriological analysis were carried out as per the standard methods for examination of water and wastewater[6] The results obtained were evaluated in accordance with the standards prescribed under 'Indian Standard Drinking Water Specification IS 10500: 1991 of Bureau of Indian Standards[7].

Results and discussion

30 groundwater samples were collected from the open wells and bore wells which included hand pumps, piped water supplies and mini water supply schemes. The samples were analyzed for 20 physico-chemical parameters including trace metals. 10 groundwater samples were collected for the bacteriological analysis. The results of the physico-chemical analysis are presented in **Table 1** and the diagrammatic interpretations of the results are presented in **Fig. 1** to **Fig. 5.** Out of 30 samples analyzed for physico-chemical parameters, 17 samples (56.67%) were found to be non-potable as per the Bureau of Indian Standards. At least one or more parameters

Table 1: Result of physico-chemical analysis of groundwater samples

Sample no	p^H	Turbidty NTU	Total Hardness mg/L as $CaCO_3$	Ca, mg/L	Mg, mg/L	Na, mg/L	K, mg/L	Fe, mg/L	HCO_3 mg/L	CO_3, mg/L	Cl, mg/L	NO_3, mg/L	SO_4, mg/L	PO_4, mg/L	TDS, mg/L	EC umhos/	F, mg/L	Cu, mg/L	Pb, mg/L	Cr, mg/L
	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20
1	7.42	0.1	190	52	14	26	02	0.16	204	nil	100	18	10	0.3	328	520	1.3	nil	nil	nil
2	7.60	nil	210	56	18	30	1.4	0.04	275	nil	90	32	40	0.8	390	620	1.2	nil	nil	nil
3	7.5	5.1	210	50	16	32	0.6	1.24	200	nil	82	54	16	1.9	340	540	1.0	0.1	nil	nil
4	7.84	nil	688	130	69	55	1.1	0.20	544	08	210	52	42	0.1	840	976	1.3	nil	nil	nil
5	7.15	0.4	492	128	41	76	03	0.1	309	nil	137	157	84	0.8	806	1210	0.8	nil	nil	nil
6	7.26	nil	416	102	38	56	02	nil	270	nil	120	109	56	2.8	646	1050	0.9	nil	nil	nil
7	7.62	0.7	584	108	76	54	1.3	0.12	458	06	220	10	44	06	628	1010	1.3	nil	nil	nil
8	7.48	0.7	480	64	72	48	1.2	nil	471	nil	205	34	45	0.5	744	1174	1.0	nil	nil	nil
9	7.42	0.1	430	108	40	54	1.0	0.2	427	nil	235	10	56	1.1	714	1100	0.9	nil	nil	nil
10	7.22	nil	380	88	39	44	1.4	0.1	280	nil	160	36	29	1.0	530	850	0.7	nil	nil	nil
11	7.60	0.2	360	56	54	48	2.2	nil	442	nil	130	09	31	0.4	550	830	1.4	nil	nil	nil
12	7.6	0.5	392	94	38	35	2.6	nil	300	10	130	12	25	0.8	490	780	1.9	nil	nil	nil
13	8.21	nil	280	55	35	48	3.0	nil	402	12	164	12	14	0.6	510	810	0.4	nil	nil	nil
14	7.80	nil	626	202	30	52	3.4	0.1	549	nil	265	70	30	1.0	930	1350	nil	nil	nil	0.1
15	7.55	nil	560	118	65	46	3.2	1.08	442	nil	350	11	31	0.4	840	1330	nil	nil	nil	nil
16	6.92	nil	388	106	31	203	20	0.1	630	nil	212	20	56	2.0	990	1520	0.5	nil	nil	nil
17	6.55	0.4	432	110	40	200	14	nil	580	nil	150	05	80	2.6	1000	1520	nil	nil	nil	nil
18	7.20	nil	612	150	58	40	1.0	0.08	225	nil	300	54	28	1.0	730	1120	1.4	nil	nil	nil
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20	7.82	nil	672	202	40	40	1.4	0.12	321	nil	275	20	34	1.0	764	1240	nil	nil	nil	nil
21	8.42	0.5	618	204	26	72	2.0	nil	336	nil	285	60	51	1.2	880	1450	0.1	nil	nil	nil
22	6.79	1.4	1960	386	249	202	10	0.8	286	nil	1338	84	216	6.2	2850	4270	0.8	nil	nil	nil
23	6.76	0.8	604	155	36	140	5.2	0.4	494	nil	232	153	51	4.0	1045	1712	0.6	nil	nil	Nil
24	7.70	nil	620	142	64	220	30	0.09	540	nil	400	10	150	06	1310	2010	0.6	nil	nil	nil
25	6.60	Nil	70	15	08	14	0.4	0.12	140	nil	60	38	18	nil	200	310	nil	nil	nil	nil
26	6.80	0.8	570	108	73	36	1.1	nil	407	nil	305	20	18	1.8	746	1220	0.6	nil	nil	nil
27	7.12	Nil	416	100	40	48	2.2	0.05	332	nil	320	24	40	1.2	742	1260	0.7	nil	nil	nil
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29	7.62	26	1062	330	58	78	3.6	1.02	570	nil	1044	84	90	2.0	2008	3270	2.3	nil	nil	nil
30	7.80	14	1095	270	101	106	4.0	0.28	700	80	780	98	90	4.3	2200	4010	2.5	nil	nil	0.2

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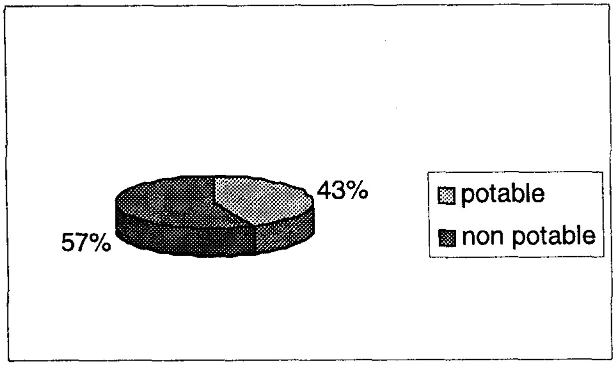

Fig. 2: Potability of samples

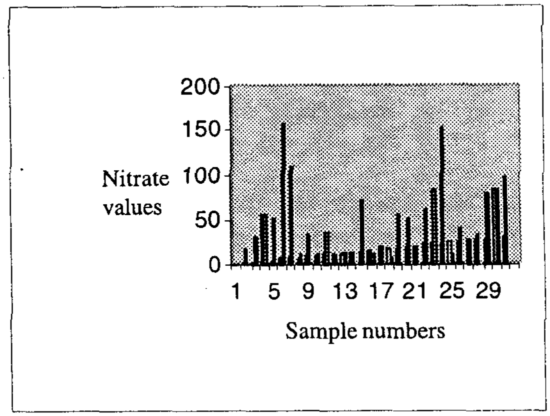

Fig. 3: Nitrate variations in borewells

such as nitrates, total hardness, calcium, magnesium, fluoride, total dissolved solids, iron and chloride indicated non-potability in more than half the number of samples examined. The main constituents for the non-potability were found nitrates and total hardness, which were present in excess concentrations in 43.33% and 40% of the samples respectively. The concentrations of calcium were found at higher side in 23.33% of the samples. Total dissolved solids, fluorides and iron were present in excess conuntations in 13.33% of the samples, resulting in non-potability of water. High concentrations of chlorides and iron were responsible for making 10% of the samples non- potable.

The study area indicated excess concentrations of nitrates which contributed to 43.33% of the samples being non-potable. The maximum, minimum and average concentrations of nitrates were found to be 157 mg/L, 5 mg/L and 47.60 mg/L respectively (**Table 2**),. Nitrates in several samples were found alarmingly high, when compared to the BIS permissible limit of 50 mg/L. In the study area, organic origin is probably the cause for most of such occurrences which can be assigned fairly definitely to drainage of water through soil containing domestic and industrial wastes, vegetable and animal matter. Septic tanks and garbage dump disposal may also be responsible for the high nitrate content in the study area. Beyond 50 mg/L, this may cause Methaemoglobinemia or blue baby disease in infants. It may also be carcinogenic in adults.

Total hardness attributing to 40% of non potability of samples has shown maximum, minimum and average concentrations of 1960 mg/L, 70 mg/L and 563.67 mg/L as $CaCO_3$ respectively. The maximum permissible limit as per BIS is 600 mg/L. The high degree of hardness in the study area is definitely attributed to the disposal of untreated / improperly treated sewage and industrial wastes, that is, anthropogenic activities

Table 2: Maximum, minimum and average concentrations of critical parameters and BIS permissible limits

No.	Parameter	Maximum	Minimum	Average	BIS limits
1	p^H	8.42	6.55	7.40	6.5to 8 .5
2	Chlorides	1338	60	320.63	1000
3	TDS	2850	200	921.77	2000
4	Total Hardness	1960	70	563.67	600
5	Calcium	386	15	137.83	200
6	Magnesium	249	08	52.63	100
7	Nitrate	157	05	47.6	50
8	Sulphate	216	10	54.17	400
9	Fluoride	2.5	nil	0.87	1.50
10	Iron	1.24	Nil	0.225	1.0

contributing to sewage and the disposal of untreated industrial effluents[8]. The other problem may be only 40% of the industries in the study area have installed effluent treatment units and even the Vrishabhavathi valley sewage treatment plant found to treat only about 55 % of the influent sewage. Relative proportion diagrams for (Ca + Mg) and (Na + K), and (CO_3 + HCO_3) and (Cl + SO_4) are indicated in **Fig. 4** and **Fig. 5**. It is clear from these diagrams that Ca and Mg are predominant cations and CO_3 and HCO_3 are the predominant anions. Hence, it can be concluded that most of the hardness is of temporary type. Therefore, in such sources, where other causative factors are not significant, the water could be retrieved for domestic use by mere boiling.

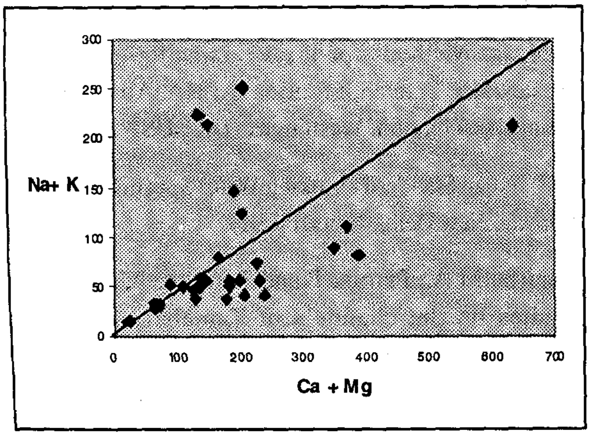

Fig. 4: Relative proportion diagram for cations

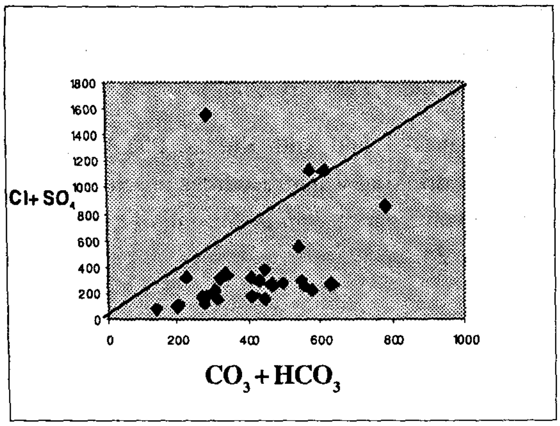

Fig. 5: Relative proportion diagram for anions

The fluoride value ranged from 2.5 mg/L to nil. The high levels of fluoride were found in 13.33% of the samples making the water non-potable. Apart from the natural processes which cannot be controlled, considerable amount of fluorides found to contribute from other reasons, such as the use of fluoride salts in the large number of industries in the study area, which are using it in steel, aluminum, brick and tile industries. Fluorides in excess of 1.5 mg/L may lead to a crippling and painful disease called fluorosis, which may be in the form of dental fluorosis, skeletal fluorosis and non skeletal fluorosis[9].

The total dissolved solids concentrations varied from 200 mg/L to 2850 mg/L and accounted for 13.33% of the non-potability. Waters with high total dissolved solids (>2000mg/L) are of inferior palatability and may induce an unfavourable physiological reaction in the transient consumer and gastro intestinal irritation[10].

Iron concentrations showed a high of 1.24 mg/L and four samples were found to have iron in excess compared to the maximum permissible limit of 1 mg/L. The higher value may be due to rusting of casing pipes, non usage of borewells for long periods and disposal of scrap iron in open areas due to industrial activity.

Chlorides, resulting in 10% of the non-potability, indicated maximum value of 1338 mg/L, as compared to the BIS limit of 1000mg/L. The high value can definitely be attributed to the discharge of industrial effluents in the area.

Only two samples were found to affect by excess chromium and one sample by copper. The area did not show the presence of lead in the groundwater.

Out of ten samples analyzed for bacteria, five samples (50%) were found to be contaminated, mainly in sewage contaminated and slum areas, with an alarmingly high MPN value of 350 in an open well as compared to the maximum limit of 10/100mL. (**Table 3**). Coliforms in excess number may be responsible for the out-break of a number of water-borne diseases as mentioned earlier.

Table 3: Results of bacteriological analysis (MPN)

Sample. No	Coliform organisms/ 100 mL of water
3	NIL
11	01
15	NIL
16	23
18	04
19	350
22	23
23	120
25	NIL
29	35

Conclusions

The analysis of groundwater samples reveals that nearly 57% of the samples are non-potable. There is the need for replacement of damaged pipelines and lining of sewer drains in the study area. Augmenting the ground water resources by recharging the ground water aquifier through rain water harvesting and thus reducing the high concentration of chemical parameters is a very important measure. Use of bio fertilizers by farmers instead of chemical fertilizers in agricultural activities is another very important control measure. The public should be instructed to use boiled water for drinking, as the study area has shown considerable hardness, mostly of temporary type. Public awareness programmes should be initiated to create a sense of awareness in them to safeguard against the perils of water-borne diseases.

Acknowledgement

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