EVALUATION OF SUITABILITY OF GROUND WATER FOR DRINKING AND ITS SUSTAINABLE MANAGEMENT - A CASE STUDY FROM CHIKBALLAPUR DISTRICT, KARNATAKA, INDIA

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Abstract

Ground water is an important resource for meeting domestic, agricultural and industrial needs. Its quality is a vital parameter for assessing the overall socio-economic development of mankind. This paper deals with the quality of 149 groundwater samples collected under Aquifer Mapping Studies in Chikballapur district of Karnataka. Due to drying up of shallow aquifers, samples were mainly collected from borewell representing deeper aquifer to evaluate its suitability for drinking purpose as per Bureau of Indian Standard (BIS), 10500:2012. Parameters like pH, Electrical Conductivity (EC), Total Hardness (TH), Calcium (Ca^{++}), Magnesium (Mg^{++}), Sodium (Na^{+}), Potassium (K^{+}), Carbonate (CO_3^{--}), Bicarbonate (HCO_3^{-}), Chloride (Cl^{-}), Sulphate (SO_4^{--}), Nitrate ($N0_3^{-}$), Fluoride (F^{-}) and Boron (B) were analyzed. The chemical analysis results reveals that Fluoride and Nitrate in the groundwater samples are found beyond the permissible limit, probably influenced by both geogenic and anthropogenic factors respectively. Fluoride contamination is more widespread than nitrate. Hence, mitigative measures are immediately required to provide safe drinking water through appropriate management plans to achieve sustainability of the ground water resources in the area.

Keywords: *Ground Water, Quality, Sustainable, Management.*

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1. INTRODUCTION

The quality of ground water is a vital parameter for mankind because it supports life. Emphasis is on providing safe drinking water as it is an essential requirement to human beings and its availability is important for the overall socio economic development of a nation (Llamas Ramon, 1993). The major challenge faced by the supplier and users in the realm of drinking water sector is the availability of safe drinking water from its source to the consumers (Sangita.P. Bhattacharjee,et.al; 2014). In this era of accelerated agricultural and industrialization development coupled with rapid urbanization, stress has been created on the groundwater sector leading to myriad of ground water quantity and quality problems.

The quality of groundwater is controlled by several factors, including climate, soil characteristics, manner of circulation of groundwater through the rock types, topography of the area, saline water intrusion in coastal areas and human activities on the ground. (Rajesh et al., 2002; Lakshmanan et al., 2003; Srivastava, 2005; Das Brijraj and Kaur, 2007; Cloutier et al., 2008). It is the resultant of all the processes and reactions that have acted on the water from the moment it condensed in the atmosphere to the time it passes through soils and subsurface geological formations ultimately discharging through well giving rise to geogenic elements like Fluoride (F), heavy metals etc. Man made or anthropogenic factors may also contribute to the presence of element like nitrate in groundwater. Presence of such elements causes pollution of drinking water resulting in water born disease, epidemics and is still looming large of the horizon in many states of India (T.J Patil and N.J. Biajaris, 2012).

2. STUDY AREA

Chikballapur district of Karnataka, covering an area of 4244 sq.km is located in the south eastern part of Karnataka. The district is located between north latitude 13˚ 13’ 04” to 13˚ 58’29” & east longitude 77˚ 21’ 52” to 78˚ 12’ 31” consisting of 6 taluks namely Chikballapur, Sidlaghatta, Bagepelli, Gauribidanur, Gundibanda and Chintamani (Fig.1). Ground water sampling was carried out in the study area under National Aquifer Mapping (NAQUIM) studies which is a flagship programme of Central Ground Water Board (CGWB) to evaluate its quality for drinking purpose.

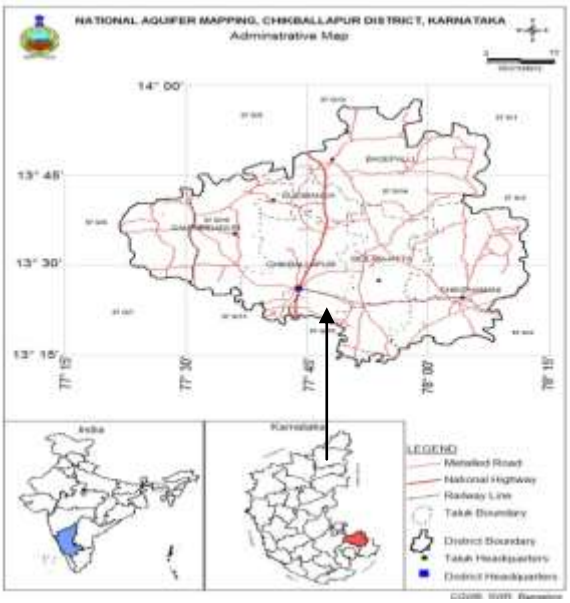

Fig 1: Location map of the Study Area.

The study area is occupied mainly by Banded Gneissic Complex (BGC) and the major water bearing formations are granites, granitic-gneiss, laterites and schists. The ground water occurs under water table conditions in the weathered zone and under confined to semi confined conditions in the fractured hard rock formations. The ground water which occurs in the weathered zone is considered as 1st Aquifer and beyond that is referred as 2nd Aquifer in this paper.

3. METHODOLOGY

To assess the quality of groundwater for drinking, a total of 149 samples were collected and analyzed at Regional Chemical Laboratory of CGWB, SWR, Bangalore. Majority of the samples collected were from Borewells/ Handpumps representing the 2nd Aquifer (133 samples) and only 16 samples were from 1st Aquifer (Table 1)

Table 1: Distribution of Groundwater sampling in Chikballapur district

Taluk	Samples of 1st Aquifer	Samples of 2nd Aquifer	Total
Chikballapur	1	18	19
Sidlaghatta	---	23	23
Bagepelli	4	36	40
Gauribidanur	1	17	18
Gundibanda	---	10	10
Chintamani	10	29	39
Total	16	133	149

4. RESULTS AND DISCUSSIONS

The procedures of the analysis were based on standard procedures recommended by APHA (American Public Health Association) 22nd Edition and analytical grade reagents were used for all analysis. Parameters like Conductivity (EC), Total Hardness (TH), Calcium (Ca^{++}), Magnesium (Mg^{++}), Sodium (Na^{+}), Potassium (K^{+}), Carbonate (CO_3^{--}), Bicarbonate (HCO_3^{-}), Chloride (Cl^{-}), Sulphate (SO_4^{--}), Nitrate ($N0_3^{-}$), Fluoride (F^{-}) and Boron (B) were analyzed to assess its suitability for drinking as per IS, 10500:2012.

4.1 pH

The BIS recommended ranges are 6.5 to 8.5 (Acceptable limit) and there is no further relaxation. In the district, only two locations namely Somenahalli (13.6522, 77.8358) and Hampasandra (13.7409, 77.7517) in Gudibanda taluk are showing values of 8.5 and 8.9 respectively. Both the samples are from 2nd Aquifer**.**

4.2 Electrical Conductivity (EC)

All the 149 samples analyzed for Chikballapur district are within the acceptable range.

4.3Total Hardness (TH)

The BIS recommended ranges are 200 mg/l (acceptable limit) and 600 mg/l (permissible limit). In the area of 1st Aquifer, one location - Chilakalnerupu (13.6565, 78.0743) of Chintamani taluk is showing a value of 620 mg/l and from 2nd Aquifer two locations viz. Kambalapalli (13.7335, 77.8391) in Bagepali taluk and Kalahalli (13.2739, 77.9467) in Chintamani taluk is showing value of 600 mg/l and 740 mg/l respectively.

4.4Calcium (Ca^{++})

The BIS, 10500:2012 recommended ranges are 75 mg/l (acceptable limit) and 200 mg/l(Permissible limit) and all the samples of 1st Aquifer and 2nd Aquifer are within the permissible limit.

4.5 Magnesium (Mg^{++})

The BIS acceptable and permissible ranges are 30 mg/l 100 mg/l respectively. In the district, only one sample of 2nd Aquifer, i.e., Kambalapalli in Bagepali taluk is having a value of 123 mg/l.

4.6 Sodium (Na)

It ranges from 82 mg/l to 357 mg/l in 1st Aquifer and from 19 mg/l to 320 mg/l in the 2nd Aquifer of the district.

4.7 Potassium (K)

K value from 0.90 mg/l to 107 mg/l in 1st Aquifer and from 0.20 mg/l to 79.40 mg/l in 2nd Aquifer of Chikballapur district.

4.8 Carbonate (CO_3^{--})

Carbonate is not detected in 1st Aquifer of the district and in 2nd Aquifer it ranges from nil to 30 mg/l.

4.9 Bicarbonate (HCO_3^{-})

It ranges from 73 mg/l to 525 mg/l in 1st Aquifer and from 24 mg/l to 576 mg/l in 2nd Aquifer in the district.

4.10 Chloride (Cl^-)

The BIS recommended ranges are 250 mg/l (acceptable limit) and 1000 mg/l (permissible limit). In the area it ranges from 43 mg/l to 795 mg/l in 1st Aquifer and from 21 mg/l to 483 mg/l in 2nd Aquifer. All the 149 samples are within the permissible limits.

4.11 Sulphate (SO_4^-)

The BIS 10500:2012 recommended ranges are 200 mg/l (acceptable limitand 400 mg/l (permissible limit). In the area it ranges from 28 mg/l to 164 mg/l in 1st Aquifer and from 8 mg/l to 211 mg/l in 2nd Aquifer.

4.12 Nitrate ($N0_3$)

The BIS, 10500:2012 recommended ranges is 45 mg/l (Acceptable limit) and there is no further relaxation. In Chikballapur district, it ranges from 9 mg/l to 120 mg/l in 1st Aquifer (Fig 3) and from 6 mg/l to 106 mg/l in 2nd Aquifer (Fig 4). Totally **38** samples (7 samples of 1st Aquifer and 31 samples of 2nd Aquifer) is above the acceptable limit of 45 mg/l.

4.13Fluoride (F^-)

As per BIS, 10500:2012, the acceptable limit of Fluoride is 1.0 mg/l and permissible limit is 1.5 mg/l. In 1st Aquifer, it ranges from 0.49 mg/l to 1.90 mg/l (Fig 5) and from 0.16 mg/l to 3.27 mg/l in 2nd Aquifer (Fig 6). Totally **69** samples (5 samples from 1st Aquifer and 64 samples from 2nd Aquifer) are above the permissible limit of 1.5 mg/l.

4.14 Boron (B)

The acceptable limit of B is 0.5 mg/l and permissible limit is 1.0 mg/l. It is generally not considered as hazard in drinking water whereas it is an essential component for plant growth. In all the taluks, the boron content is within permissible limit except Bagepalli which may be due to tourmaline minerals present commonly in igneous and metamorphic rocks.

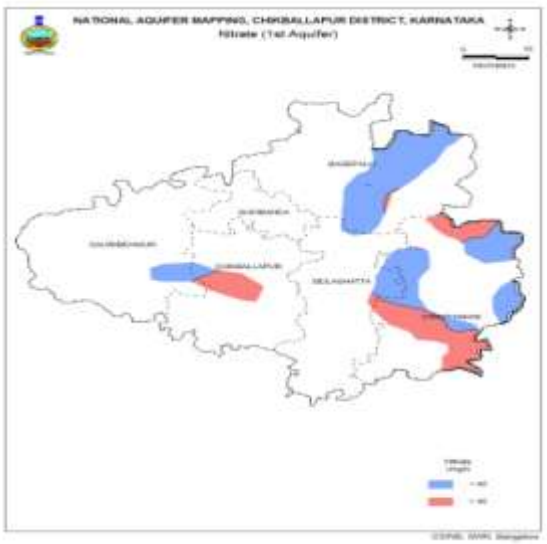

Fig 3: Nitrate in Aq-I of Chikballapur district

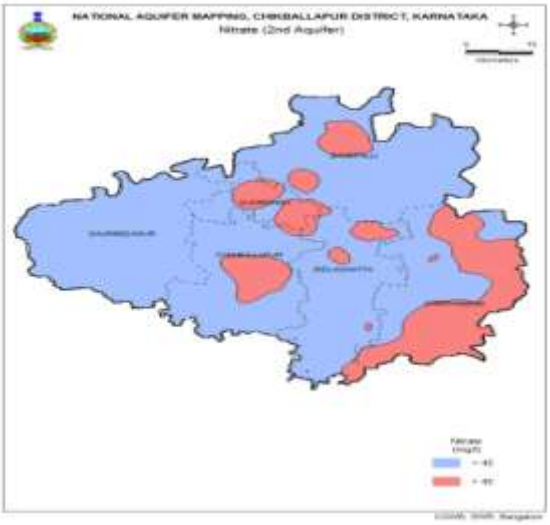

Fig 4: Nitrate in Aq-II of Chikballapur district

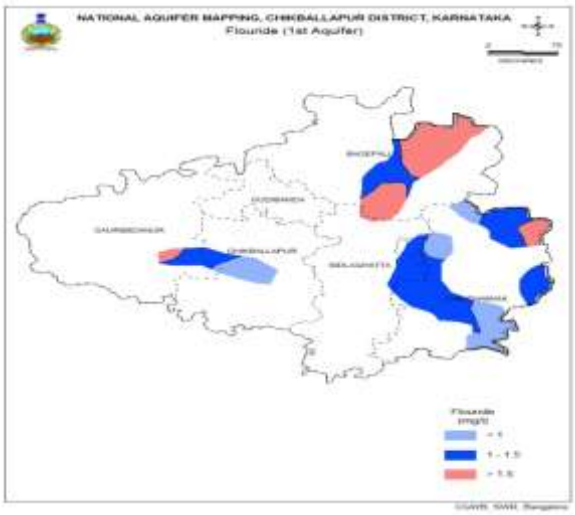

Fig 5: Fluoride in Aq-I of Chikballapur district

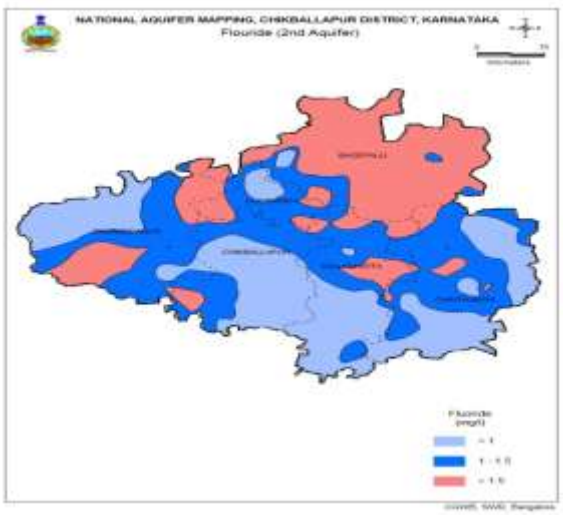

Fig 6: Fluoride in Aq-II of Chikballapur district

4.2 Observations

From the ongoing discussion, the following observations are made:

Main quality issues in the district are sporadic occurrence of high fluoride and nitrate in ground water in both the Aquifers. This is a complex situation as 1st Aquifer is almost dried-up and 2nd Aquifer is facing quality problem warranting urgent remediation methods.

Contamination of ground water by fluoride is more common in Chikballapur in comparison to nitrate contamination (Table 2). 46.30% of the samples are affected by it. The highest value of Fluoride (3.27 mg/l) is recorded from 2nd Aquifer at Bagepali taluk (Table 3). The fluorine bearing minerals like Amphibole (hornblende), mica, fluorite and apatite which are commonly associated with BGC rocks may give rise to fluoride, indicating a geogenic origin.

Though igneous rocks contain small amount of nitrate, mostly presence of nitrate in ground water suggest its origin to anthropogenic factors like animal excrements, industrial effluents, municipal waste and nitrate fertilizers. The highest value of nitrate (120 mg/l) is reported from 1st Aquifer in Chintamani taluk.

Table 2: Parameters found in higher value than 'Permissible limit' of BIS, 10500:2012 in Chikballapur district

Parameters	No of samples					
	With higher values than BIS 'Permissible limit'10500:2012			In %		
	Total	1st Aquifer	2nd Aquifer	Total	1st Aquifer	2nd Aquifer
pH	2	---	2	1.34	---	100
Total Hardness (TH) as $CaCo_3$	3	1	2	2.01	33.33	66.67
Magnesium (Mg^{++})	1	---	1	0.67	---	100
Nitrate (NO_3)	38	7	31	25.50	18.42	81.58
Fluoride (F^-)	69	5	64	46.30	7.25	92.75

Table 3: Taluk wise range of chemical parameters in Chikballapur district

Taluk	pH		EC µS/cm at 25°C		CO_3		HCO_3		Cl		NO_3		SO_4	
					Ranges of chemical constituents in mg/l									
	Aq-I	Aq-II	Aq-I	Aq-II	Aq-I	Aq-II	Aq-I	Aq-II	Aq-I	Aq-II	Aq-I	Aq-II	Aq-I	Aq-II
Chikballapur	7.7	7.2-8.3	1600	260-1360	0	0-12	281	49-262	305	21-263	102	15-65	44	10-90
Sidlaghatta	---	7.5-8.3	---	220-1830	---	0-9	---	43-288	---	28-355	---	8-75	---	8-120
Bagepelli	7.2-7.6	6.8-8.0	880-1150	140-2270	0	0	287-354	24-576	64-149	21-476	9-45	7-95	48-68	10-186
Gauribidanur	7.9	7.3-8.4	1810	450-1560	0	0-12	427	134-360	305	36-248	20	6-50	84	22-110
Gundibanda	---	6.7-8.9	---	310-1990	---	0-30	---	73-384	---	28-362	---	8-106	---	12-211
Chintamani	7.5-8.2	7.0-8.4	650-2860	190-2410	0	0-15	73-525	30-488	43-795	21-483	22-120	0-15	28-164	8-158

Contd...

Taluk	**Ranges of chemical constituents in mg/l**													
	F		**Ca**		**Mg**		**TH**		**Na**		**K**		**B**	
	Aq-I	Aq-II	Aq-I	Aq-II	Aq-I	Aq-II	Aq-I	Aq-II	Aq-I	Aq-II	Aq-I	Aq-II	Aq-I	Aq-II
Chikballapur	0.49	0.3-1.6	176	8-64	29	7-68	560	60-380	102	26-129	12.1	1.7-79.4	0.25	0.001-0.25
Sidlaghatta	---	0.21-1.63	---	20-80	---	2.4-73	---	60-500	---	19-174	---	1.6-25	---	0.001-0.57
Bagepelli	1.16-1.90	0.16-3.27	12-56	4-44	39-51	2.4-123	190-300	20-600	82-167	22-320	0.9-4.9	0.2-68.6	1.0-1.7	0.6-3.0
Gauribidanur	1.5	0.4-	100	20-	46	7-89	440	140-	209	27-	4.8	1.8-	0.02	0.001-

		1.7		68				480		125		23.8		0.08
Gundibanda	---	0.69-1.8	---	20-140	---	7-70	---	80-580	---	32-257	---	0.9-40.8	---	0.001-0.03
Chintamani	0.64-1.61	0.32-1.80	16-168	8-168	12-77	7-77	100-620	50-740	100-357	19-212	1.8-107	0.8-50	0.001-0.12	0.001-0.065

1st Aquifer: Aq-I, 2nd Aquifer: Aq-II

5. CONCLUSION

Attention on groundwater contamination and its management has become a need of the hour gaining significance because of it's far reaching impact on human health. (Singh K.P. et.al; 2005, Palanisami P. N. et.al;2007).

Though commendable efforts has been made by various Government departments, NGOs for mitigation of ground water quality problem in the district (Table 4), efforts on management issues are recommended to provide safe drinking water.

Table 4: Steps adopted for groundwater quality mitigation and recommendations in Chikballapur district

Department /Agency	**Issues**	**Steps taken**	**Recommendations**
Rural Water Supply and Sanitation Department (RWS&SD)	Laboratories for water testing	Totally 6 laboratories are established in the district of which one is District laboratory, 2 are Block laboratories and 3 are Sub-divisional laboratories. (Source: RWS&SD, Govt. of Karnataka)	Number of laboratories can be increased.
		At Sub- divisional/taluk or district water testing laboratory where the samples received from Grama Panchayat level are tested and test report are entered in Integrated Management Information System (IMIS) and shared with concerned Zilla Panchayats for further action like marking the contaminated water sources in the habitations and prohibiting its usage.	
		Based on IMIS data, Executive Engineers at district level take necessary action by providing alternate source for drinking water by directing the Sub divisional offices at Divisional office at district level.	
	Field test kit	Drinking water sources are tested using Field test kit and the quality affected water samples are send to taluk and district level laboratories for confirmation. For the district, there are 8 field testing Kits and during 2015-16, out of totally 26662 sources in the six blocks, 3917 sources were tested and 4482 nos. were analyzed.	Advanced pocket type field test kit can be used for instant results saving time in transportation and analysis. More kits may be procured and personnel may be trained at village, taluk and district level.

Department /Agency	**Issues**	**Steps taken**	**Recommendations**
Rural Water Supply and Sanitation Department	Safe drinking water	As short term measures separate safe sources are provided from neighbouring habitations.	Tested sources may be used.

(RWS&SD)		As long term measures, multi Village Water supply scheme tapping purified river/perennial sources are used. In the absence of perennial source, water treatment plants like de-fluoridation plants or Reverse Osmosis are installed. Treated drinking water is provided in quality affected areas through "Jalnirmal Project".	The treated water may be regularly tested and awareness and training is suggested in quality affected areas.
	Artificial Recharge structures	Artificial recharge structures like Check dams, pits, percolation tanks, roof top rain water harvesting structures etc are implemented in the district.	Feasibility and impact assessment studies of the structures are to be taken up.
Directorate of Health and Family Welfare (DH&FW)	National Programme for prevention and control of fluorosis since 2009-10	Implemented in the district where each district has one district fluorosis consultant, one fully established district fluorosis laboratory with one laboratory technician to handle the health related issues with fluoride. Based on the laboratory finding of fluoride in blood, urine and water, confirmed cases are given reconstructive surgery, supplement of Ca and Vitamin C. (Source: DH&FW, Govt. of Karnataka)	Medical screening in quality affected areas may be increased. Awareness and training programme may be organized involving local people, NGOs, Self Help group, Shree Shakti etc. The data may be disseminated with allied department involved in water sector.
BIRD-K (NGO)	To provide safe drinking water and to enrich ground water table on pilot basis.	Construction of artificial recharge structures in Bagepalli taluk of Chikballapur district: Rain Water Harvesting Structure (RWHS):1344 BW recharge: 7,Direct Aquifer:4 Farm pond:594 (Source: BIRD-K)	To assess the quality of water for various uses, it is recommended for analysis of basic water quality parameters in RWHS. Impact assessment study may be carried out.
CGWB	Monitoring of Ground water quality and quantity	Established Hydrograph Network station under Ground water regime monitoring for water level and quality assessment.	Frequency and Number of stations may be increased .For sustainable development management plan is being worked out.

5.1 Management Plan

For sustainable management of the quality affected ground water of Chikballapur district of Karnataka, the following management plans are proposed:

- Treated and safe water source is strongly recommended for drinking purpose.
- For removal of fluoride, which is of geogenic origin, adoption of site specific standard filtration/ removal technique like activated alumina de-fluoridation filter and distillation filtration is strongly recommended. Other methods like Nalgonda techniques, Ion exchange process, adsorption methods like activated carbon, Tri calcium phosphate and activated alumina may be used. The blue print for cost effectiveness and economically feasible techniques with zero environmental impact and inbuilt arrangement for proper sanitary disposal of sludge needs to be prepared.
- In localities affected by nitrate arising because of anthropogenic activities, awareness programme, health campaign and training may be imparted on solid waste disposal, contaminants and health hazards issues and ground water management by involving the local people, NGOs, Shree-Shakti, Self Help Groups etc.
- Construction of artificial recharge structures and in-situ rainwater harvesting structures may be taken up in the areas feasible for artificial recharge.
- Formulation of common platform for data sharing and dissemination among the various allied State and Central Government departments in the state.

- Roof top rainwater harvesting experience of BIRD-K in Bagepalli taluk can be taken up on large in the district affected by fluoride contamination.
- Comprehensive quality mitigative plan for the district may be formulated by incorporating:
- Research plan to determine the geological, hydro geological and geochemical factors controlling the chemical reactions generating and releasing pollutants to groundwater.
- Forming research group with geologists, hydrologists, geochemist, environmental engineers and public health experts to conduct in-depth investigation on the sources and causes of pollution in groundwater.
- Separate cell / committee may be constituted exclusively for the management, execution and monitoring of quality assurance measures for sustainability of ground water in the coming years.

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