SSRG International Journal of Geo-informatics and Geological Science
ISSN: 2393 – 9206 /doi:10.14445/23939206/IJGGS-V8I3P101

Volume 8 Issue 3, 1-6, Sep-Dec, 2021

Original Article

Groundwater Quality Assessment Using GIS: A Case Study of Pavagada Taluk, Tumkur District, Karnataka, India

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Received Date: 26 July 2021
Revised Date: 01 September 2021
Accepted Date: 12 September 2021

Abstract - *An attempt has been made to analyze the water quality parameters and classify the groundwater quality by using water quality index values for Pavagada taluk. Pavagada taluk having an area of 644.8 sq-km falls under Tumkur district of Karnataka. Concentrations of few physico-chemical parameters have been estimated in 1435 groundwater sampling locations of 266 villages during pre-monsoon season (December, 2017 to April 2018). The study indicates that most of the samples have higher concentrations of Total hardness, Fluoride, Chloride, Nitrate and Iron. . In about 71. % of sampling locations, the ground water is not suitable for drinking as per IS standards. By comparing with Indian Standard Drinking Water Quality (IS 10500:1991) ,36.8 % of water samples (528 samples) exceeded the maximum permissible limits for fluoride content (1.5 ppm), 36.8% exceeded the desirable limit of total hardness (600 ppm). To represent the spatial distribution of ground water quality of Pavagada taluk various thematic maps are prepared for water quality parameters and ground Water Quality Index values using interpolation technique in ARC-GIS software. These maps help to identify the zones or locations where water is not potable and suitable remedial measures are suggested to meet drinking water standards and to lessen further stress on groundwater resources of Pavagada Taluk.*

Keywords — *Groundwater, Water quality index, physico-chemical parameters, Indian water quality standards (IS 10500:1991), spatial distribution, thematic map, remedial measures.*

I. INTRODUCTION

There is a popular saying that health is wealth. 80% of human body contains water. Hence there is necessity to consume safe drinking water to maintain good health. Due to drilling of bore wells, rapid recession of ground water table depths over 200 -2500 metres below ground level has taken place. Rural population use such water for drinking and domestic purpose. The water from such a great depth has been found unfit for human consumption. Hence it becomes necessary to provide safe drinking water to rural population. Groundwater is considered as the major source of drinking water in most parts of India. Pavagada is a taluk in Tumkuru district, Karnataka, India. The main source of drinking water is groundwater withdrawn from bore well and hand pumps. Most of the bore-wells contain high amount of fluoride including rural and urban Pavagada. According to a report in 2014, nearly 206 villages have been affected with high fluoride content in drinking water problem. This has led to the severe occurrence of dental fluorosis, osteoporosis, osteoarthritis and musculoskeletal diseases, gastro-intestinal problems, headache etc. *There is Sociological perspective of Pavagada Fluorosis.* The Pavagada taluk ground water table contains higher amount of fluoride along with considerable amount of other minerals chloride, iron, and nitrate. It has resulted in the occurrence of dental fluorosis in younger and older age group. Recently it was observed that, the parents of bride from outside the Pavagada are not happy to get associated with the grooms from the Pavagada city and vice versa.

This study was carried out by the help of Departments of Mines and Geology and rural drinking water sanitation, Government of Karnataka. Water samples have been collected from bore wells and hand pumps in 1435 locations of 266 villages of Pavagada taluk. Analysis of water samples has shown that the groundwater contains excess fluorides and other pollutants. The water samples collected from the villages have been analyzed to determine the physico-chemical parameters such as pH, Total hardness, Fluorides, Nitrate, Chlorides and Iron. Water quality index values are developed to rated the quality of water. Analysis has revealed that water samples from many villages contain excess Fluorides, Chloride, Total hardness, iron and other impurities which are harmful to the health of people who consume such

water and suitable recommendation measures area suggested to provide the good quality drinking to protect the human health in Pavagada taluk.

II. STUDY AREA

Pavagada taluk belongs to Tumkur district, Karnataka state,India. This taluk is generally Called the housing of hillocks. This taluk is located longitude $77^0$12'E & $77^0$24'E and latitudes $14^0$05'N & $14^0$11'N. Pavagada taluk has a geographical area of 644.8 sq-kms. There are 266 villages present in this taluk. Pavagada taluk experiences very hot climate with the maximum temperature is around 40.8^0 C and minimum of 29^0C. The annual rainfall is about 670 to 680 mm. The population of the taluk is 2,22,726 as per 2011 census.

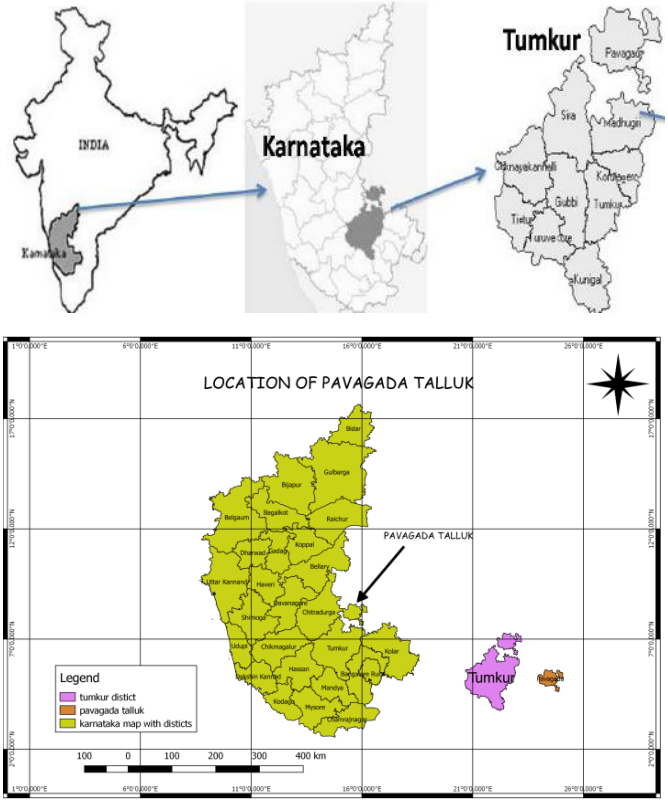

Figure 1: Location details of Pavagada Taluk.

III. Geology and Soil Details of Pavagada Taluk

65% of the area consists of rocks belonging to peninsular gneissic complex, schistose rocks of Sargur group and Dharwar supergroup. In Pavagada taluk fluorine is found in small amounts both in earth crust rocks and hillocks rocks in the form of Sodium fluoride (NaF_2), Potassium fluoride (KaF_2), Calcium fluoride (CaF_2). Through weathering of rocks fluoride mineral is released to ground water as well as soil. Leaching of fluoride containing minerals may yield of fluoride in solution, commonly at most a few mg/l. although much higher concentration may be found.

Laterites are confined to Pavagada taluk and they occur as isolated patches capping over crystalline hard rock's as flat-topped hills above the land elevation of 900m MSL. A thick mantle of Laterite covered by Laterite soils are seen in the area of Pavagada taluk and in east zone different types of soils found in this taluk and mainly two types are noticed, namely lateritic soil and Laterite gravelly soil. Laterite soils are found in parts of Pavagada taluk. They are coarse textured and well drained.

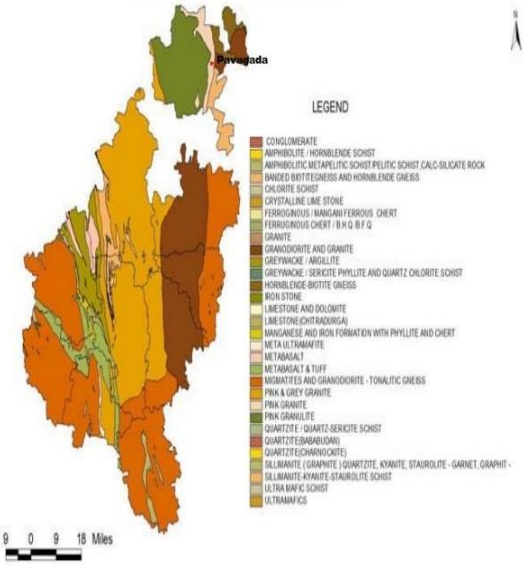

Figure 2: Geology and Soil map of Tumkur District.

IV. Methodology Used

A. Samples Collection and Analysis

In the present study, one thousand four hundred thirty five (1435) domestic drinking water sources (Bore well and PWD wells) are selected in 266 villages of Pavagada taluk in order to study the physico-chemical parameters of ground water samples in pre-monsoon season (December 2017 to April 2018). The samples were collected based on the standard procedure recommended by World Health Organization (WHO). Sampling points were identified based on the people suffering from dental fluorosis, skeletal fluorosis and non-skeletal fluorosis, other drinking water related diseases and area nearer to stone mining activity.The collected samples transported to the laboratory and analyzed as per the procedures of Standard Methods (APHA, 1995). The various physical and chemical parameters were analyzed for pH, Total Hardness, Chloride, Nitrate, Total iron. All these parameters were measured using a calibrated Ion-meter. The results obtained from the laboratory analysis were compared with Indian Standard Drinking Water Quality (IS10500:1991) values. To determine the portability of drinking water samples Water Quality Index values(WQI) are developed. Based on the WQI values, the groundwater is rated as excellent, good, poor, very poor and unfit for consumption.

B. Determination of Water Quality Index

Water quality index is a single parameter which accounts for all the physicochemical parameters and gives one number , which indicates quality of that water. The WQI has been calculated as follows;

WQI = Antilog $[\sum W_{n=1}^{n} \log_{10} q_n]$ .....(1)

W = Weight age factor (Table 1) computed as follows

$W_n = \frac{K}{S_n}$ ……(2)

K = Proportionality constant derived from equation (3)

$K = [1 / (\sum_{n=1}^{n} 1 / S_n)]$.....(3)

S_n is the recommended drinking water standards as per B.I.S

Quality rating q is calculated using the formula,

$q_{ni} = [(V_{actual} - V_{ideal})/(V_{standard}-V_{ideal}) X 100]$.....(4)

q_{ni} = quality rating of i^{th} parameter for a total of n parameters.

V_{actual} = Value of water quality parameter obtained from laboratory analysis

V_{ideal} for pH = 7 and equivalent to zero for other parameters.

$V_{standard}$ = B.I.S standards of parameters.

The allowable standards for the water quality parameters chosen for the study as per BIS and their respective weight age factors are shown in Table 1. Based on the WQI values, the groundwater is rated as excellent, good, poor, very poor and unfit for consumption WQI scale shown in Table 2.

TABLE 1

Water Quality Parameters, Standards & Unit Weights:

Parameter	Standard (S_n)	Weightage(W_n)
pH	8.5	0.026
Chloride	250	0.00088
Nitrate	45	0.00049
TDS	500	0.00044
Fluoride	1	0.22
Iron	0.3	0.73

TABLE 2

Water Quality Index Categories

Water Quality Index	Category	
0 -25	Excellent	(E)
26- 50	Good	(G)
51- 75	Poor	(P)
76- 100	Very poor	(VP)
> 100	Unfit for drinking (UFD)	

V. RESULTS AND DISCUSSIONS

For different physico- chemical parameter and for Water Quality Index values the thematic maps are prepared by using ARC-GIS to demonstrate the spatial distribution of groundwater quality in the Pavagada taluk. The maps are very useful for characterizing the water types and to evaluate the suitability of water for domestic purposes.

A. pH:

pH is a measure of negative logarithmic of hydrogen ion (H^+) and is represented as the reciprocal of the logarithm of the hydrogen ion activity. pH in the present study ranged from 7.13 to a maximum of 8.58 with a mean value of 7.85. The variation pH levels is shown Figure 3. The results show that the groundwater of the study area is of slightly alkaline in nature. It is little more than ISO standard and its may be because of areas lithology.

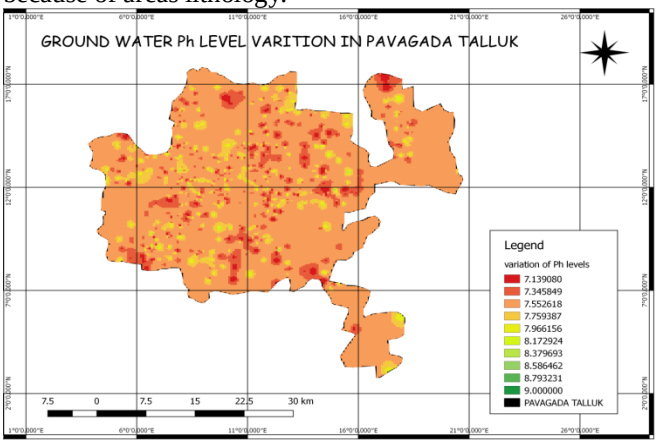

Figure 3: Variation of ground water pH levels in Pavagada Taluk.

B. Total Hardness:

Total hardness of water is a measure of the total amount of minerals present in water, primarily calcium and magnesium. Excess intakes of calcium have been associated with increased risks of osteoporosis, nephrolithiasis (kidney stones), colorectal cancer, hypertension and stroke, coronary artery disease, insulin resistance and obesity. Increased intake of magnesium salts may cause diarrhea. Figure 4 presents the variation of total hardness of the water samples. The variation ranged from a minimum of 50 mg/l, to a maximum of 700 mg/l. As per BIS specifications the desirable limit is 300 mg/l and permissible limit is 600 mg/l. Out of 1435 samples only 527 samples are exceeded the desirable limit of total hardness (600 mg/l) ie., only 37% of ground water samples are exceeded the desirable limit of total hardness.

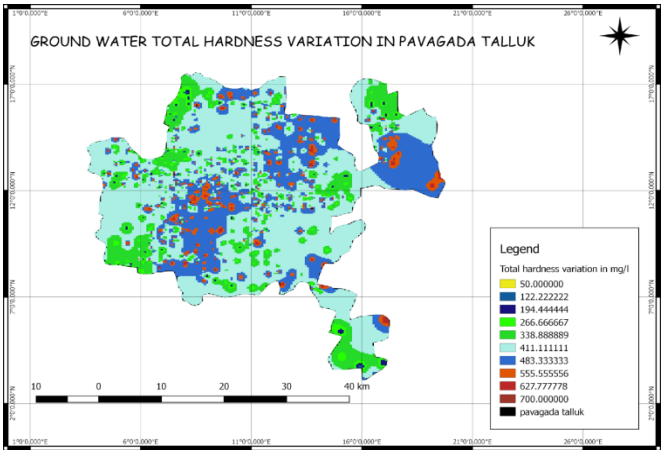

Figure 4: Variation of Ground Water Total Hardness Levels in Pavagada Taluk.

C. Fluorides:

The main source of fluoride in Pavagada is groundwater surrounded by rocks which are very rich in fluoride mineral.. 95% of population affected by high fluoride concentration(>1.5%) in groundwater lives in villages of Pavagada taluk. Figure 5, presents the variation in fluoride content of drinking water samples. The variation ranged from a minimum of 0.77 ppm, to a maximum of 5.0 ppm. Out of 1435 ground water samples 528 ground water samples are having fluoride ion concentration greater than 1.5 ppm.

TABLE 3:
Statistical Evaluation of Drinking Water Fluoride Ion Concentration In Pavagada Taluk.

Fluoride ion concentration In mg/litre.	Number of water sample out of 1435	Percentage of sample
Lesser than 1	468	32.61
1 to 1.5	439	30.59
1.5 to 2	416	28.98
Greater than 2	112	7.8

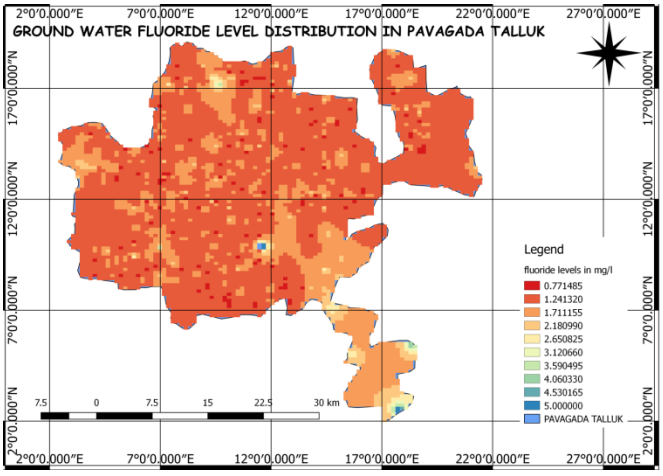

Figure 5: Variation of ground water fluoride levels in Pavagada Taluk.

D. Chlorides:

Chloride is often associated with sodium since sodium chloride is a common constituent of some water source Figure 6 (a), represents the spatial representation of variation in chloride content of the drinking water samples. The variation of chloride ion concentration ranged from a minimum of 0 mg/L, to a maximum of 1100 mg/l. Consuming chlorides via drinking water usually is very dangerous to human health. In the present study all 26 water samples show chloride content less than desirable limit. According to BIS specification desirable limit is minimum 250mg/L and permissible limit is 1000 mg/l. Only 1.8 % of samples of drinking water samples are not in desirable limit it is very less & less effect from chloride constituents.

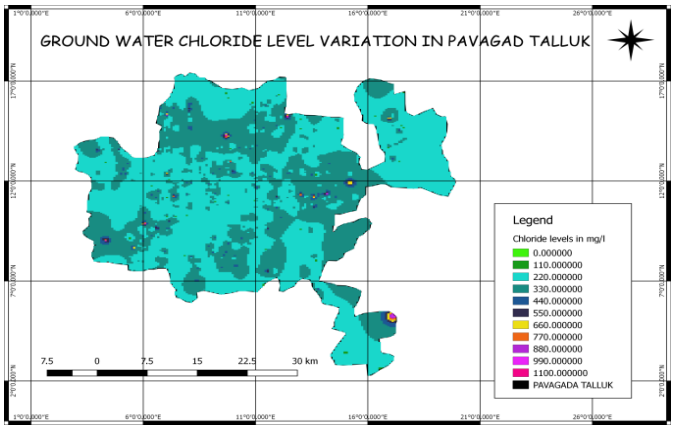

Figure 6: (a) Variation of Groundwater Chloride Levels in Pavagada Taluk.

E. Iron:

Iron is a contaminant/impurity which is not safe for human consumption if it is present beyond permissible limit taste and appearance are affected, has adverse effect on domestic use and water supply structures, and promote iron bacteria [BIS 2009]. Iron and Manganese in water are cause of discolor and distaste [Sajad *et al*, 2009]. Figure 6(b) represents the variation in total iron content of the water samples. The variation ranged from a minimum of 0 mg/l, Chikkadalavata to a maximum of 0.6 mg/l. Among the 1435 samples collected, 126 contain iron more than permissible limits of 0.3 mg/l,

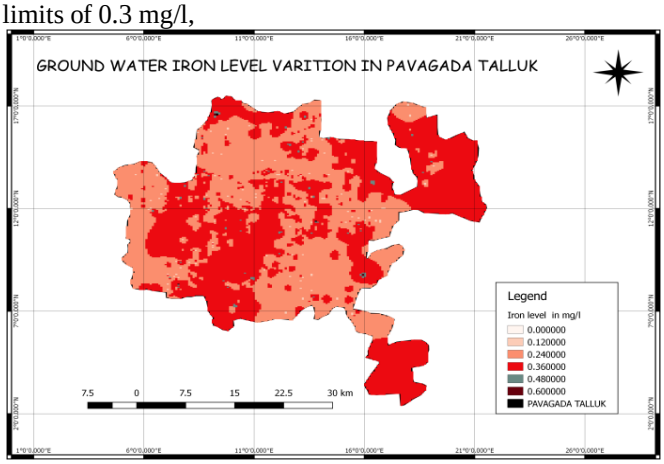

Figure 6: (b) Variation of Groundwater Iron Levels in Pavagada Taluk.

F. Nitrates:

Nitrate represents the final product of biochemical oxidation of ammonia. Nitrate is considered to be of low toxicity, but excess exposure to the human body.results in Methemoglobinemia (blue-baby syndrome), various cancers and birth defects. Figure 7, represents the variation in nitrate

content of the water samples. The variation ranged from a minimum of 5 mg/l, to a maximum of 50 mg/l. Only the 2 samples out of 1435 collected from 266 villages of Pavagada taluk which contents are more than permissible limit. According to BIS specification the desirable and permissible limit is 45 mg/l.

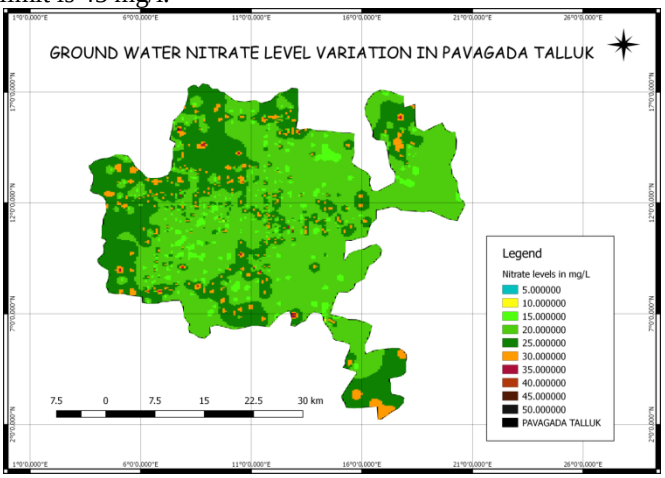

Figure 7: Variation of ground water Nitrate levels in Pavagada Taluk.

A detailed study of Table.4 reveals that total hardness, fluoride and iron concentrations exceed the permissible limits. Almost 60% of the samples exceeded the desirable limit of Fluoride, Chloride, Total hardness, Iron and Nitrate. WQI calculated is calculated based on these values and the water is rated as excellent, good, poor, very poor and unfit for consumption (Table 5). WQI map for the taluk is presented in Figure 8

By analyzing the data in Table 5 there are 1021 drinking water samples are not potable. This includes poor (17.28%), very poor (35.74%), unfit for drinking (18.11%). So that 71.11% of the water samples exceeded the permissible limits of Indian Standard.

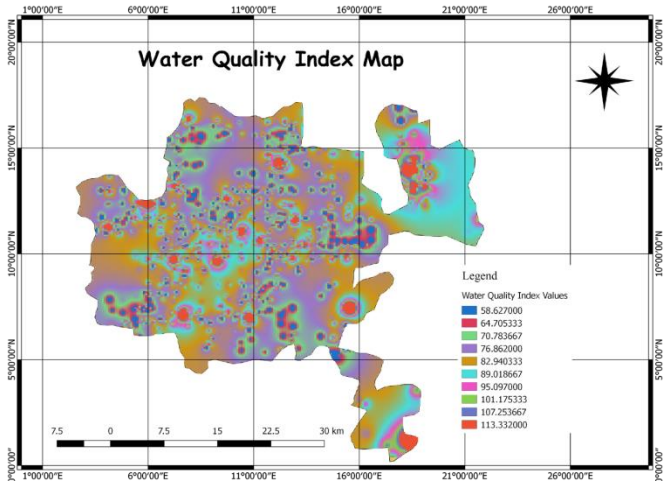

Figure 8: Ground water quality distribution in Pavagada Taluk.

G. Effects of Bad Water Quality:

Figure 8: Peoples suffering from dental and skeletal flurosis:

Table 4:
Ground Water Quality Statistics of Pavagada Taluk.

Sl no	Parameter	Limit	Total Number of Samples	No. of Samples Exceeds the Limit	Statistical Values		
					Average	Maximum	Minimum
1	pH	6.5-8.5	1435	Nil	7.95	8.58	7.32
2	Total hardness	300-600 mg/l	1435	527	375	700	50
3	Fluoride	1-1.5 mg/l	1435	528	2.885	5	0.77
4	Chloride	250-1000 mg/l	1435	26	1100	0	1100
5	Iron	0.3-1 mg/l	1435	126	0.6	0	0.6
6	Nitrate	0-45 mg/l	1435	2	27.5	5	50

Table 5:
Water Quality Index Value Statistics of Pavagada Taluk.

SL NO	Water Quality Index	Category	Number of Samples Out of 1435	Percentage of Sample
1	0 -25	Excellent (E)	0	0
2	26- 50	Good (G)	414	28.85
3	51- 75	Poor (P)	248	17.28
4	76- 100	Very poor (VP)	513	35.74
5	> 100	Unfit for drinking (UFD)	260	18.11

VI. CONCLUSIONS AND RECOMMENDATIONS

The composition of the groundwater in the Pavagada Taluk is strongly influenced by the activities like quarry or mining of granite and gneiss rocks and Fluoride enters groundwater through chemical reactions with rock that contains fluoride bearing minerals. This in turn results in the unsuitable ground waters for drinking purposes in various locations. About 71.11% of the samples studied were not suitable for drinking as per the water quality index values. The major ion evolution sequence of the groundwater from the study area suggests that the chemical evolution of the recharge area was controlled mainly by processes of water and rock interaction and the effluents related to mining activities progressively increased the ion concentrations. The adaptation of proper land use and land management practices might have considerable impact on water quality parameters. Water treatment facility (water purification filters) shall have to be designed for providing potable water to peoples. Further drilling of bore wells for irrigation purpose has to be temporarily stopped till the situation improves. Rain water harvesting and artificial recharge of groundwater such as Farm ponds, Check dams, gully plugs together with contour bunding and nala bunding are constructed to reduce further stress on groundwater resources of the Pavagada Taluk.

A conclusion section is not compulsory, but we recommend it. Although a conclusion may review the main points of the paper, do not replicate the abstract as the conclusion. A conclusion might elaborate on the importance of the work or suggest applications and extensions. Try to emphasize your scientific contribution and the differences from previous works in the literature. The conclusion is a text only section - do not use equations, graphs or cite references in this section. Make sure that the whole text of your paper observes the textual arrangement on this page.

ACKNOWLEDGMENT

I would like to thank “Dr.K.S.Sharma”, chairman fluorosis mitigation research and resource center, Hubli, karnataka for providing the influence of government of Karnataka and man power, to carry out this project.

I am highly grateful to “Smt. Pruthvi”, chief engineer, drinking water and sanitation department government of Karnataka, to providing the 8 ion selective electrodes for carrying out water quality tests.

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