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Assessment and mapping of ground water quality of southern parts of Bhadravati town in Shivamogga district, Karnataka, India using GIS techniques

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Abstract
Among the cations, Na concentration exceeded the threshold limit of either international or WHO standards in 62.5 percent ground water samples. In cent percent of ground water samples the concentration of both chloride and fluoride exceeded the threshold limits (250-500 and 0.8-2.0 mg L^{-1} respectively) of either international or WHO standards. In nearly 9 percent water samples, nitrate concentration was more than the lower limit of either international or WHO standards. Water pH of ground water samples was slightly alkaline and however it was within the permissible limit (6.5-8.5) as per WHO. Pearson correlation was also positive between pH and both carbonates and bicarbonates and however this relation was significant only with bicarbonate (0.312*). Water soluble salt concentration exceeded the permissible limit (0.25 dS m^{-1}) of WHO and thus in cent percent study area groundwater quality was poor with respect to EC. EC was positively and significantly correlated with Ca^{2+} (0.608**), Mg^{2+} (0.384*), Na^{+} (0.358*), Cl^{-} (0.765**) and NO_3^{-}(0.462**) while carbonates (-0.301) were negatively correlated with EC.
Nearly one third of the ground water samples recorded the TDS less than the permissible limit and rest of the samples witnessed high value for TDS. TDS were strongly and positively correlated with Ca^{2+} (0.388*), Na (0.362*), Cl^{-} (0.496**) and SO_4^{2-} (0.482**). Total hardness (TH) of water exceeded the international and WHO standards in 93.75 per cent of ground water samples. The TH was strongly and positively correlated with Ca^{2+} (0.891**), Mg^{2+} (0.651**) and Cl^{-} (0.540**) which suggested that contribution of permanent hardness to TH is much more than the temporary hardness.

Keywords: ground water quality, anions, cations, TDS and TH

1. Introduction

Mother Nature is highly dynamic and bestowed with diversity, complexity and heterogeneity rather than simplicity and homogeneity and thus water is also not exceptional as it is one of the important renewable natural resources. Nearly 97 % of total water on earth surface is brackish and remaining 3 % is fresh water. Nearly 70 % of total fresh water is locked up in glaciers, ice and snow. Nearly 25 and 5 % of total fresh water is fresh ground water and surface water (lakes, swamps and rivers) respectively. Thus fresh ground water continues to play an important role in domestic, agriculture and industrial usage.

Ground water pollution may be either geogenic and or anthropogenic. Rain water as it is slightly acidic dissolves the soluble rocks and minerals and adds chemical constituents such as Ca^{2+}, Mg^{2+}, Na^{+}. F^{-}, SO_4^{2-}, Cl^{-} *etc*., to the ground water and thus mineralogical composition of rocks and minerals is a geogenic factor. Use of high doses of chemical fertilizers and agrochemicals in modern agriculture, mining activities, improper disposal of sewage/drain water, industrial effluents are the major anthropogenic activities which deteriorates the ground water quality. Soil is a natural physical, chemical and biological filter as it exhibits the ion exchange phenomena the most widely occurring natural process next only to the photosynthesis and is bestowed with billions together microbes which degrade the harmful chemicals and toxicants. However, when the concentration of the pollutants in soil is beyond the filtration capacity of soil then the pollutants reach the ground water and when the concentration of these pollutants in ground water exceeds the permissible limits, the water quality deteriorates. Ground water is a renewable natural resource, which is replenished annually by the precipitation.

Rain water is the important source of ground water and thus in the recent past construction of ground water recharge wells have been given importance to facilitate the rain water fallen on earth to percolate into the earth instead of allowing it to run away as the ground water level is shrinking day by day as the rate of extraction of ground water exceeded exorbitantly the rate of recharge of groundwater.

Recent day's ground water quality is gaining much more importance due to rapid industrialization and unplanned urbanization in addition to increased population as well as too much use of fertilizers and pesticides in agriculture (Joarder *et al.*, 2008) [6]. Consumption of ground water having the nitrate concentration more than 50 mg L^{-1} causes blue baby syndrome in infants. Hence, it is very important to assess the groundwater quality at a regular interval as it is influenced by both geogenic and anthropogenic factors for present and future consumption. Thus the present investigation was taken up to know the ground water quality of Bhadravati town and to map the same for future use to take up corrective measures to improve the ground water quality of the area.

2. Material and methods

Bhadravati town in Shivamogga district of Karnataka was selected for the study and thirty two bore well water samples were collected using GPS from southern regions of Bhadravati (Fig.1) which fall under command area and is flanked by both paper and steel industries. Geologically study area is characterized by schist and climatologically it enjoys semiarid climate. Bore wells were run for 15 minutes and then water samples were collected in plastic containers, labeled and transported to the laboratory within 24hrs. These water samples were tested for carbonates immediately and then these water samples were kept in refrigerator for the analysis of the rest of the water quality parameters and however rest of the water quality parameters were analyzed within a week from the date of water samples collection.

Water samples were analyzed for pH, EC, anions (NO_3^-, Cl^-, $CO_3^=$, HCO_3^-, $SO_4^=$, F^-), cations(Na^+, Ca^{++}, Mg^{++}, K^+), Total Hardness (TH) and Total Dissolved Solids (TDS) following the standard procedures (Jackson, 1973) [4] to know whether the water quality is within the permissible limit (Table 1) or not. Statistical tool Pearson correlation was employed to find out the relation between water quality parameters (pH, EC, TDS and TH) and both cationic and anionic species. Maps pertaining to location of study area, water sampling bore well points and spatial distribution of ground water quality parameters in the selected area of Bhadravati town were generated using ArcGIS techniques.

Table 1: Threshold limits of water quality parameters for human consumption

Water quality parameters	Threshold limits for human consumption
pH	6.5-8.5 (WHO)
EC	0.25 dS m^{-1}(WHO)
NO_3	10-50 mg L^{-1} (WHO)
SO_4	250-500 mg L^{-1} (WHO)
Chloride	200-250 mg L^{-1} (WHO)
Flouide	0.8-2 mg L^{-1} (WHO)
Ca	300 mg L^{-1} (WHO)
Mg	100 mg L^{-1}(International standard)
Na	180-200 mg L^{-1}(WHO)
TDS	300 mg L^{-1}(WHO)
TH	300 L^{-1} (WHO)

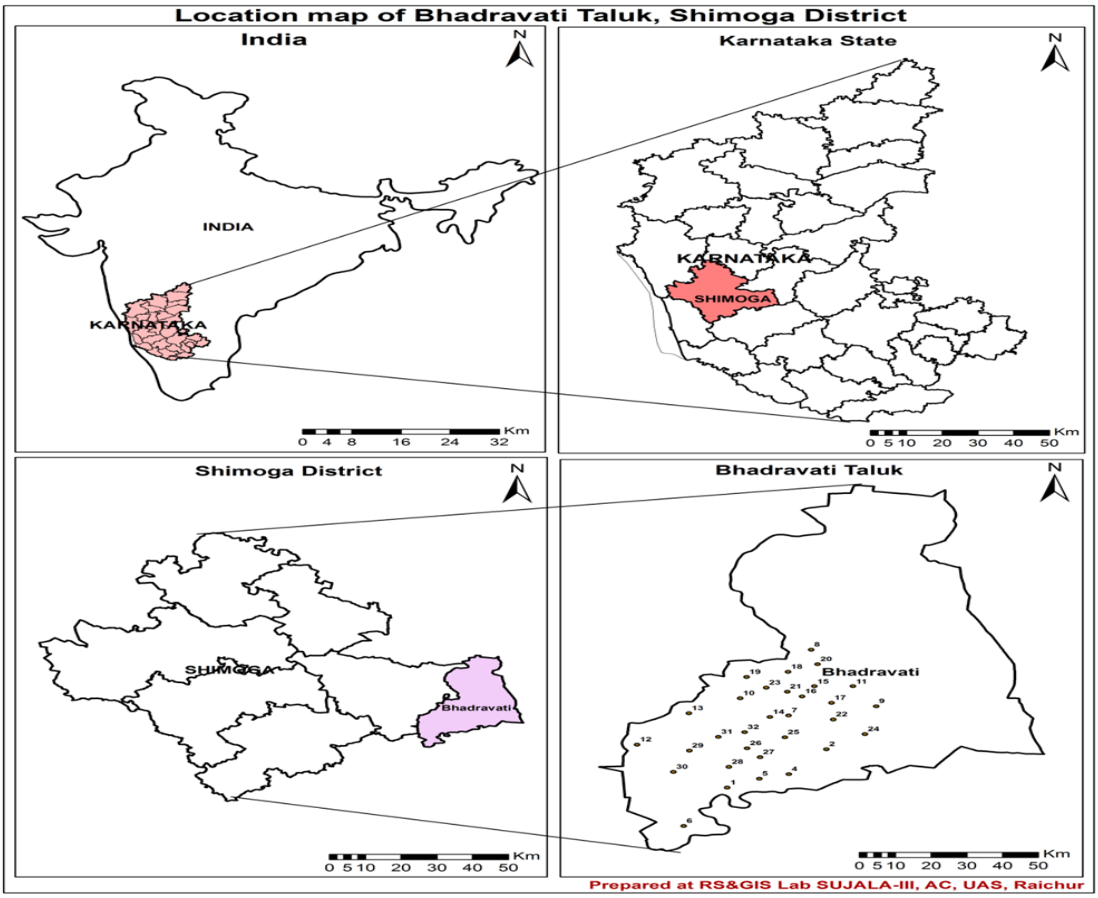

Fig 1: Spatial distribution water samples of selected area in Bhadravati town

3. Results and Discussion

3.1 Concentration of cationic species

The concentration of sodium was more (219.58 mg L^{-1}) in the ground water as compared to that of other cationic species (Table 2) and this could be attributed to both geogenic and anthropogenic factors. Existing schist geology might be dominated by sodium plagioclase feldspar which might have added sodium to ground water upon weathering. In addition to geogenic factor the contribution of anthropogenic factors such as indiscriminate use of irrigation water and chemical fertilizers to the agricultural lands as the study area falls under command area and even industrial effluents as the study area is surrounded by paper and steel industries might have added sodium to ground water through percolation. Concentration of both Ca and Mg was within the permissible limits of either international or WHO standards in cent percent ground water samples where as Na concentration exceeded threshold limit of either international or WHO standards in 62.5 per cent (Fig. 2) ground water samples,.

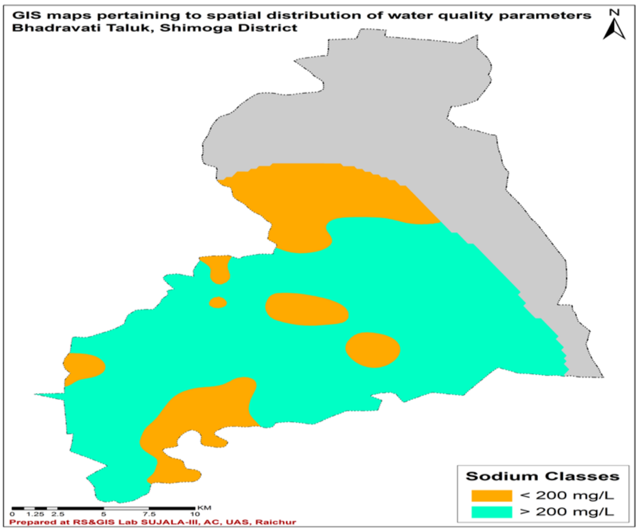

Fig 2: Spatial distribution of Sodium in ground water of selected area in Bhadravati town

3.2 Concentration of anionic species

Cent percent of ground water samples (Fig. 3 and 4) studied exceeded the threshold limits of either international or WHO standards with respective chloride (250-500 mg L^{-1}) and fluoride (0.8-2.0 mg L^{-1}) concentration respectively. Higher level of both chloride and fluoride in ground water could be attributed to the geogenic factor namely dissolution of chloride and fluoride bearing minerals such as fluoroapatite, chloroapatite, hornblende *etc.*, associated with the schist geology of the study area. Anthropogenic factors such as sewage, septic tank, industrial effluents and landfills might have added these anions to the ground water. Only 9.4 percent of water samples exhibited nitrate concentration less than the lower limit of either international or WHO standards. In remaining 90.6 percent water samples, nitrate concentration (Fig. 5) was less than the upper limit of either international or WHO standards. Atmosphere, decaying organic wastes, animal excreta, sewage effluents, septic tanks, natural drains carrying municipality wastes in addition to use of high doses of nitrogenous fertilizer in modern agriculture are the important source of nitrate in ground water.

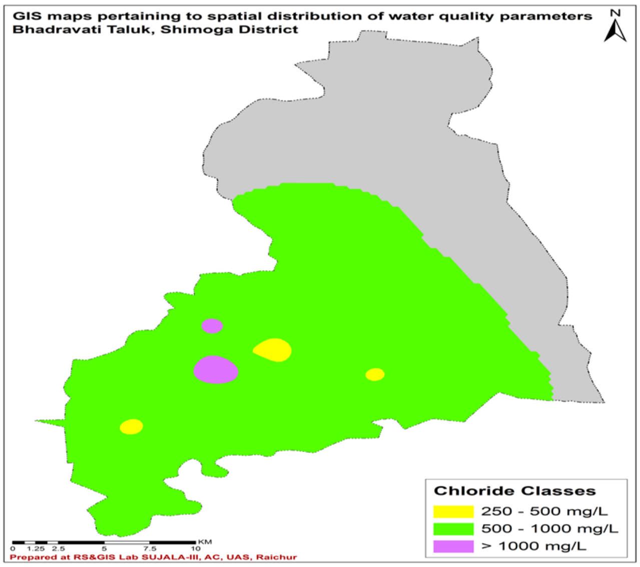

Fig 3: Spatial distribution of Chloride in ground water of selected area in Bhadravati town

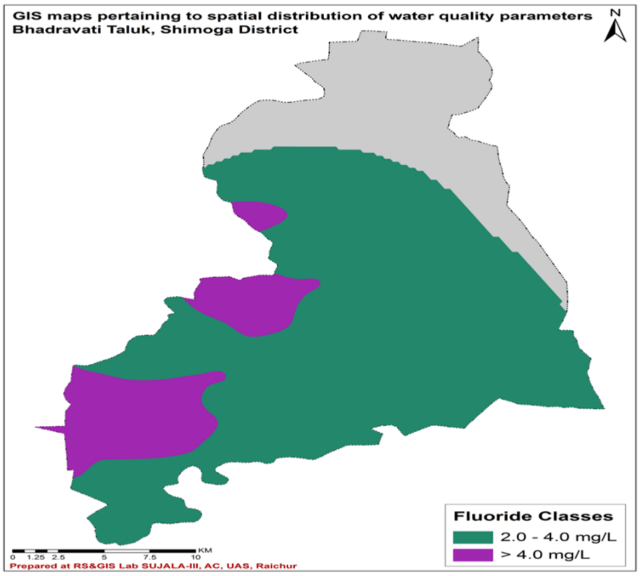

Fig 4: Spatial distribution of Fluoride in ground water of selected area in Bhadravati town

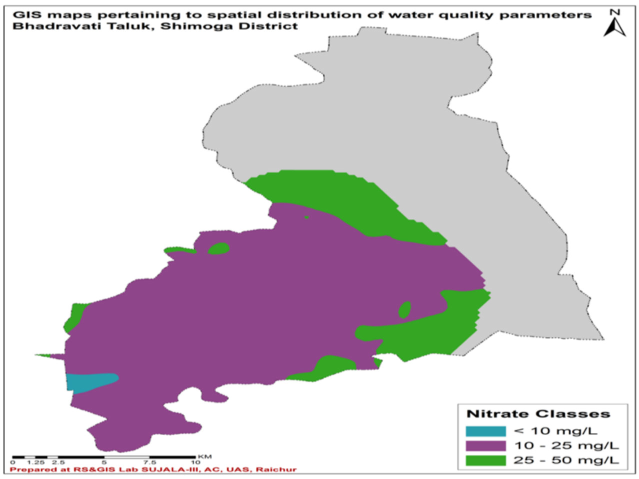

Fig 5: Spatial distribution of Nitrate in ground water of selected area in Bhadravati town

3.3 Ground water quality parameters

Water pH of ground water of study area was slightly alkaline and however it was within the permissible limit (6.5-8.5) as per WHO. The pH is the vital physico-chemical property of water and all the biochemical reactions which operate in water are pH specific. Chemical as well as organic constituents of water will do affect the water pH. Ionic composition such as carbonates and bicarbonates of sodium and calcium shoots up the pH. Pearson correlation (Table 3) was also positive between pH and both carbonates and bicarbonates and however this relation was significant only with bicarbonate (0.312*).

Both the range and mean EC values (Table 2) exceeded the permissible limit (0.25 dS m^{-1}) of WHO and thus in cent percent study area (Fig. 6) groundwater quality was poor with respect to EC. Electrical conductivity measures the concentration of water soluble salts. Contribution of chloride, sulphate, nitrates and fluoride salts to EC was more than that of carbonate and bicarbonate salts as the former salts dissolve completely and it was supported by the correlation of EC with both cationic and anionic species where EC was positively and significantly correlated with Ca^{2+} (0.608**), Mg^{2+} (0.384*), Na^+ (0.358*), Cl^- (0.765**) and NO_3^-(0.462**) while carbonates (-0.301) were negatively correlated with EC as carbonate salts dissociate incompletely unlike chloride and nitrate salts. High EC of the water samples could be attributed to both anthropogenic and geogenic factors. The study area falls under command area and in command area use of both chemical fertilizers and irrigation water in excess are the common practices and thus the anthropogenic factors namely excessive water along with excessive chemical fertilizers might have percolated and reached the ground water. As the study area is dominated by intermediately siliceous rock schist which is composed of easily weatherable ferromagnesian bearing minerals olivine, amphiboles and pyroxenes in addition to orthoclase and plagioclase feldspars might have added water soluble salts to ground water upon weathering.

The TDS refers to mineral constituents dissolved in water and water with high dissolved solids would pose problems like brackish taste and laxativity and the intensity of these problems vary with both type and quantity of minerals. Nearly one third of the ground water samples recorded the TDS less than the permissible limit (Fig. 7) and rest of the samples witnessed high value for TDS and this could be attributed to the presence of anions such as sulphates, chlorides, bicarbonates, carbonates, in association with calcium and sodium in appreciable amount and it was further supported by strong positive correlation (Table 3) of TDS with Ca^{2+} (0.388*). Na (0.362*), Cl^- (0.496**) and SO_4^{2-} (0.482**). Similar kind of observations was made by Deepali *et al.* (2001) [2].

Total hardness (TH) of water exceeded the international and WHO standards in 93.75 per cent of ground water samples (Fig. 8). Hardness caused by carbonates and bicarbonate salts was temporary hardness while that of sulphates and chloride salts was permanent hardness and total hardness is the sum of the temporary and permanent hardness. The TH was strongly and positively correlated with Ca^{2+} (0.891**), Mg^{2+} (0.651**) and Cl^- (0.540**) which suggested that contribution of permanent hardness to TH is much more than the temporary hardness. Gabriel *et al.* (2010) [3] also observed better correlation of both cations and anions with water quality parameters.

Analytical data on groundwater quality parameters suggested that in cent per cent of selected area of Bhadravati town chloride, fluoride and water soluble salts concentration exceeded the threshold limits of either WHO or international standards. In 62.5, 70 and 96 cent per cent of selected area of Bhadravati town sodium, TDS and TH respectively exceeded the threshold limits of either WHO or international standards. Water reaction (pH) was alkaline and within the permissible limits in the ground water samples of area under study. In more than 90 percent of selected area of Bhadravati town, nitrate concentration of ground water samples was more than the permissible lower limit and however it did not exceed the upper limit of either WHO or international standards. Water quality parameters such as EC, TDS, TH, Cl^-, F^- and NO_3^- suggested that most of the ground water samples fall under category of no potable and similar kind of observations were made by Balakrishnan *et al*. (2011) [1] on groundwater quality of Gulbarga city in Karnataka and Jeihouni *et al.* (2014) [5] on ground water quality of industrial city Tabriz in north west of Iran.

In command area excessive use of irrigation water and chemical fertilizers that too nitrogenous fertilizers must be avoided and use of these inputs in agriculture must be scientific and judicious. The sewage, municipality wastes and industrial effluents must be treated before letting them into the water bodies and while dumping the solid wastes in landfills these wastes must be mixed with laterite earth as it is rich is sequioxides which prevent the heavy metals to reach the groundwater. In addition to construction of ground water recharge wells to dilute the salt concentration of ground water through percolating rain water and to conserve the later the assessment and monitoring of ground water quality at regular interval is need of the hour to minimize the chances of getting deterioration of ground water.

Table 2: Water quality parameters and ionic species of groundwater

Parameters	pH	EC (dS m^{-1})	TH (mg L^{-1})	TDS (mg L^{-1})	Cations (mg L^{-1})				Anions (mg L^{-1})					
					Ca^{2+}	Mg^{2+}	Na^+	K^+	Cl^-	SO_4^{2-}	NO_3^-	F^-	CO_3^{2-}	HCO_3^-
Range	6.9 to 7.9	0.60 to 1.40	300 to 800	159 to 910	80.0 to 220.0	18.0 to 66.0	112.90 to 367.20	0.82 to 93.37	390.50 to 1455.50	13.20 to 157.00	8.02 to 43.89	2.74 to 4.95	0.00 to 840.00	0.00 to 1525.00
Mean	7.3	0.90	528.125	457.875	149.06	37.31	219.58	19.83	676.72	49.58	21.46	3.78	255	707.22

Table 3. Correlation between water quality parameter and ionic composition of ground water

Water quality parameter	Ionic composition of ground water (mg L^{-1})									
	Ca^{2+}	Mg^{2+}	Na^+	K^+	Cl^-	SO_4^{2-}	NO_3^-	F^-	CO_3^{2-}	HCO_3^-
pH	-0.135	0.161	0.18	0.018	-0.21	-0.11	-.410*	-0.096	0.221	0.312*
EC (dS m^{-1})	.608**	.384*	.358*	0.035	.765**	0.309	.462**	0.18	-0.301	0.197
TH (mg L^{-1})	.891**	.651**	0.234	0.023	.540**	0.266	0.329	-0.11	-0.124	0.013
TDS (mg L^{-1})	.388*	0.185	.362*	0.005	.496**	.482**	0.255	0.282	0.087	0.262

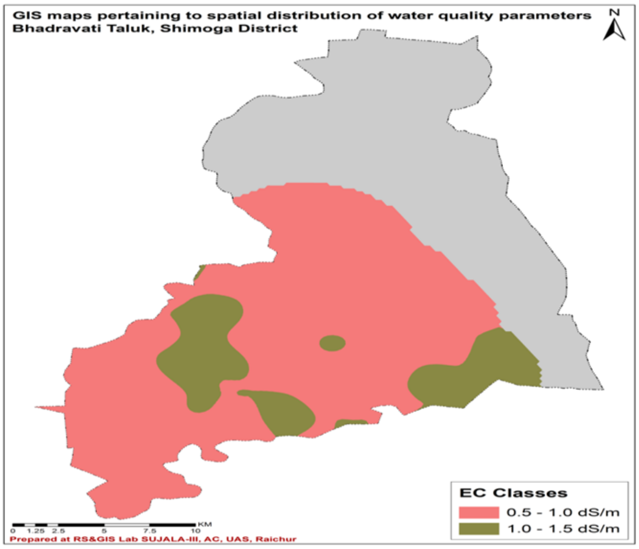

Fig 6: Spatial distribution of water soluble salts in ground water of selected area in Bhadravati town

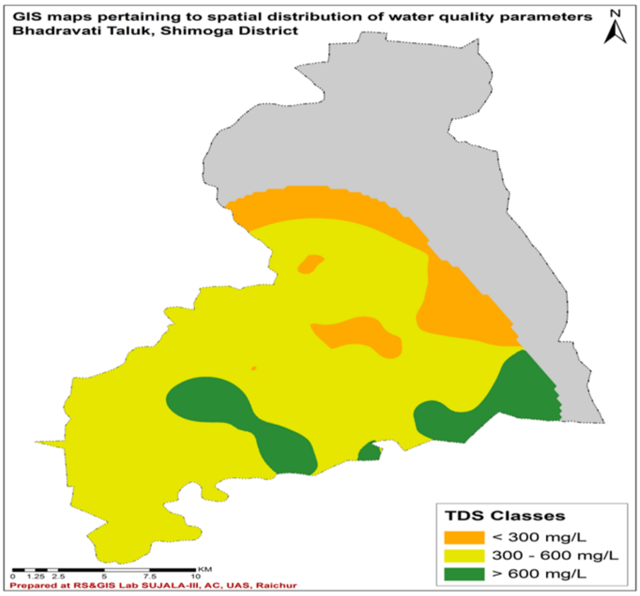

Fig 7: Spatial distribution of total dissolved solids in ground water of selected area in Bhadravati town

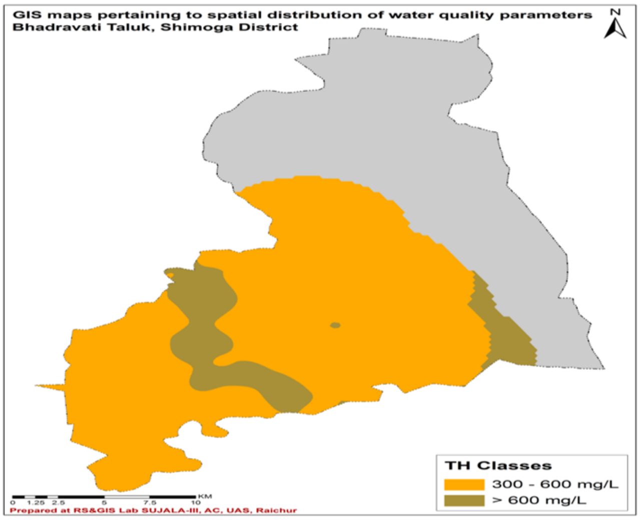

Fig 8: Spatial distribution of total hardness in ground water of selected area in Bhadravati town

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