May – June 2020
ISSN: 0193-4120 Page No. 298 - 311

Assessment of Ground Water Quality by Water Quality Index in Udupi District, Karnataka State, India.

[1]Deepika B V, [2]C R Ramakrishnaiah, [2]Dr. C. Sadashivaiah
[1]Department of Civil Engineering, Shri MadhwaVadiraja Institute of Technology and Management, Bantakal, Udupi
[2]Department of Civil Engineering, BMS College of Engineering, Bangalore
[3]Department of Civil Engineering, HMS Institute of Technology, Tumkur

Article Info
Volume 83
Page Number: 298 - 311
Publication Issue:
May - June 2020

Article History
***Article Received**: 11August 2019*
***Revised**: 18November 2019*
***Accepted**: 23January 2020*
***Publication**:07May2020*

Abstract:

Water is a precious natural resource which is required for survival of living things. Groundwater is a major source for a large range of beneficial uses. It is a vital parameter of the economy and the environment. Recent studies indicate that groundwater is over-exploited category and polluted to the maximum extent in Karnataka state. Water Quality Assessment and evaluation is of greater importance for treatment and supply of drinking water. Groundwater contributes 80% of domestic water requirement in the selected study area. In the study, the groundwater quality analysis was conducted for 106 water samples in pre-monsoon season to determine its suitability for drinking. This study involves assessing the water quality in comparison with drinking water quality standards BIS 10,500; 2012 by giving weightage and rating to each water quality parameter. For calculating WQI, 16 parameters such as totalCalcium, magnesium,hardness, pH, Bicarbonates, chlorides, total dissolved solids, fluorides, manganese, iron, nitrate, sulphate, turbidity, phosphate, potassium, and sodium were considered. The WQI of these samples ranges from 32 to 294. This analysis categories the area based on Water Quality Index. The result acts as a decision support system for ground water quality management. This kind of analysis helps in saving natural resources, providing good quality water and safeguarding the health of an individual. Statistical analysis such as standard deviation,median,mean, regression analysis, co-relation coefficient indicates the proper relationship between the various characteristics of water. The aim of the analysis is to ascertain the water quality index of the present study area and to classify the areas into different categories for domestic usage.

***Keywords**: Water Quality Index (WQI), Ground Water Quality, Rating and Weightage*

I. INTRODUCTION

Water is a valuable ecological asset of our planet. Groundwater being a main source of water for a wide range of uses. It is the most significant freshwater resource on the planet Earth. Groundwater is having wide requirementworldwide for the household, commercial, irrigation and industrial usage. Owing to the rapid population growth and the increased speed of industrialization, the demand for freshwater has risen exponentially in recent decades. (C R Ramakrishnaiah et al., 2009). The rapid growth in population and the over exploitation of groundwater resources led to depletion in quality of ground water.(Pophare et al., 2014)

Groundwater quality depends on the specific chemical constituents; their concentration and land use/land cover (Singh et al., 2009)(K S Rawat et al., 2019)(Rawat, Singh, 2018)(Rawat et al., 2017). Groundwater contamination and pollution have become a serious concern particularly in metropolitan areas due to rise in population, excess use and consumerism (Singh and Kamal, 2017).

Human activities have a adverse impact on quality of water in aquifers; Rapid industrialization and urbanization area resulting in a significant loss to groundwater by polluting the water to a larger extent. If the water is contaminated, remediation of the same is difficult. The analysis of groundwater is very much required to protect and preserve the quality of the aquifer. The ground water quality can vary according to the depth of the water table. It also depends on the geological aspects of area and also on changes in the season. It is assessed by magnitude and concentration of salts in dissolved form basedon the source of subsurface environment and soil condition.The qualitative aspects of groundwater deteriorates in two ways, due to chemical reactions in soils and subsurface water, and by the supply through inadequate irrigation channels / drainage. (K S Rawat et al., 2019)

Water quality depends on various physicochemical composition of groundwater. Analyzing the physicochemical composition of water is really important to know the qualitative aspects of water. Hence determination of Water Quality Index is required for taking remediation measures. It helps in prioritizing the areas into different zones based on the Index value.

The present study was done for Udupi district. In this selected geographical area the dependency on groundwater for various beneficial uses is more than the surface water. This study will be helpful in early detection of poor areas with respect to the quality of water to take up remedial measures. This kind of study has not been done in the selected geographical area before. There is much more need for this kind of study in the area as main water source is sub surface aquifer water. This is the continuous study which should be done for each season as water quality varies widely from day to day. The aim of the analysis is to define the water quality index of the selected study area and to differentiate the areas into different categories for domestic usage. This kind of study is very much helpful for the implementation of a better water quality management policy and to mitigate the problem of drinking water contamination.

1. Materials and Methodology

2.1 Study area

The Udupi is the seaside district of Karnataka which is in the peninsular region of India (Fig.1) which is isolated from the remaining peninsular partby Western Ghats. The study area is located across74^{o}35’ and 75 ^{o}12’ East longitude and 13^{o}04’ and 13^{o} 59’ North latitude having a total area of 3575 km^{2}. Udupi is having length of 88 Km, width of 80Km which is surrounded by Shimogaand Chickmaglur district in the East and to south there is Dakshina Kannada district, Uttara Kannada district in the North. The district encompasses three taluks, Kundapura, KarkalaandUdupi. TheUdupi regionis blessed by various endowments of Nature.

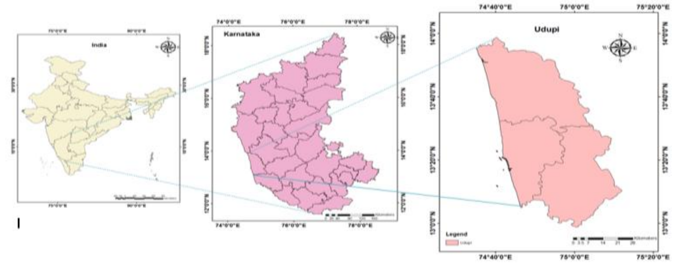
This marine, agro-climate river basin flowing west is influencedby a maritime climate. It spreads to a parts of Shirva,Mulki,Swarna,Baindur,Sita, Yennehole, Sankadagudi, Chakravani, Kollur,Haladi, andMadisala. In normal rainfall years these rivers are perennial, while branches and minor rivers remain dry in summer season. The existing high elevation terrain and precipitation, during monsoon contributes to the larger quantity of water in the streams. Such streams enter the Arabian Sea and are have effect of marshes on the inland area to greater length(Udupi brochure (2012) Groundwater information booklet Udupi district, 2012).

The map of the selected Udupi area was scanned usingtoposheets. Boundary map of the study area was prepared by digitization and creating geo-referenced boundary map with latitude and longitude at each point. The fig.1 indicates the map of the Udupi district.

May – June 2020
ISSN: 0193-4120 Page No. 298 - 311

Fig 1: Map of theUdupi district

The Udupi district is having geological features rocks such as Granitic gneisses which dominate the region with laterite caps sometimes with coastal sediments and streams. Gneiss, is extensive at varying degree in



the distinct outcrops, particularly along the river courses. Groundwater in the study area exists in different geologic formations such as beach coastal sediments,alluvium, fractured granitic gneisses and laterites. Shallow open wells are the subsurface extractionsavailable in lateritic soil. The Physico-chemical characteristics of groundwater of Udupi District has not been studied earlier.

2.2 Hydrogeology:

The geological features such aslaterites,beach alluvium, coastal sediments, and in weathered and fractured granitic gneisses under phreatic and semi-confined to confined conditions occur in the present study area. (Udupi brochure (2012) Groundwater information booklet Udupi district, 2012)

The hydrogeology map (fig. 2) of the present study area, taken from mines and geology department was scanned. This map of the Udupi district was obtained by odigitization and creating geo-referenced latitude and longitude at each point using shapefile of Udupi. The map shows the geological features of Udupi district.The stepwise method for determination of Water Quality Index is presented through a flowchart (fig. 3). The regions groundwater falls in an unconfined aquifer. The depth of the groundwater table varies between minimum of 2.8 mbgl and maximum of 14.44 mbgl in pre-monsoon and 1.75 mbgl and to 10.45 mbgl in post-monsoon (Udupi brochure (2012) Groundwater information booklet Udupi district, 2012).

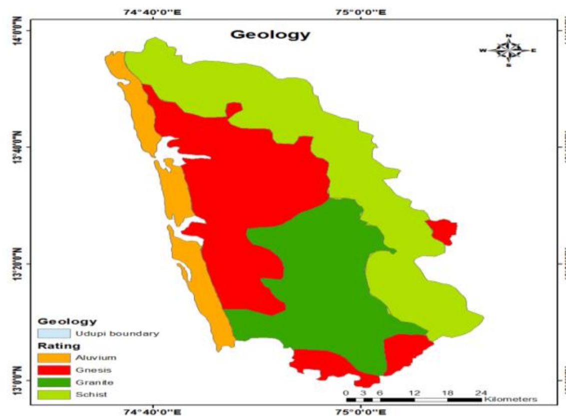


fig 2. Geology map of udupi

2.3 Sampling and analysis of water

The methodology adopted in the present study is depicted in fig 3.

Selection of study area
↓
Map digitization andgeoreferencing
↓
Sample collection → Sampling points mapping using Arc
↓
Water quality analysis as per APHA 2000
↓
Statistical Analysis
↓
Water Quality Index
↓
Pie chart and water quality mapping

Fig. 3: Flowchart of methodology

Sampling of 106 water samples were done from aquifers of Udupi district in pre-monsoon season of 2017. Collection of the water sample is done using a clean pre-rinsed bottle of 1litre. Grab sampling was done according to the standard procedure of water sampling APHA 2000.

The analysis was conducted in the laboratory as per the standard protocol in APHA 2000 using standardized laboratory equipment's. The parameters were selected based on human health concern. Among the various physical, chemical and biological characteristics of drinking water, 16 characteristicslike pH, total hardness, calcium, magnesium, Bicarbonates, chlorides, total dissolved solids, fluorides, manganese, iron, nitrate, sulphate, turbidity, phosphate, potassium, sodium, conductivity and e-coli were considered for analysis. The samples were collected using cleaned sampling cans for water quality analysis. The sampling locations co-ordinates were noted using GPS instrument. The sampling locations were mapped using Arc GIS 10.3 as shown in fig 4.

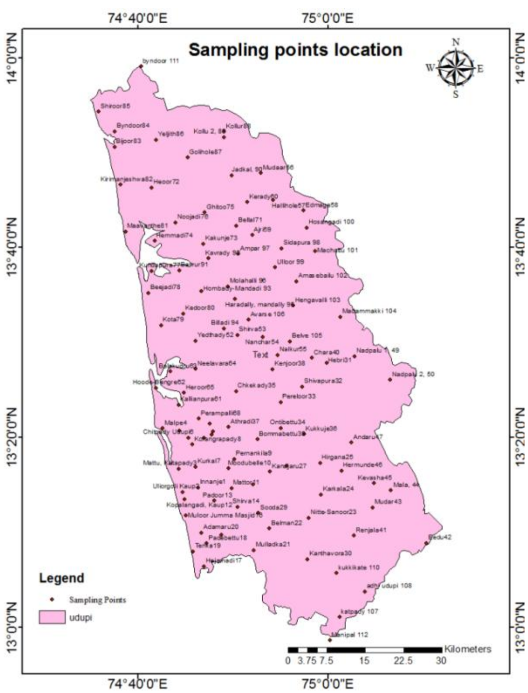


Fig 4: Groundwater sampling locations

The various standard methodology used in the Physico-chemical analysis of sampled water are given in the table1.

Groundwater quality analysis is a multiparameter analysis. After the analysis, the resultant data were subjected to normal distribution analysis and Pearson correlation. The Normal distribution analysis gives the distribution ofvarious parameters in water over the entire area. Statistical analysis of water sampleslike mean, median, correlation coefficient,standard deviation, regression analysis was carried out. The statistical analysis explains the entire data set of water quality with mean, median, maximum, minimum and standard deviation (Samson and Elangovan, 2017) Mean is the central tendency of data set represented in the form of arthematic average. Standard deviation is the root of arthematic average of squares of deviation. The location of particularvalue in the set of datais obtained in relation withthe mean using standard deviation. Linear regression gives a strong correlation between the two parameters. For the regression analysis parameters such as Ca, SO_4, Mg, NO3,Cl,(HCO_3+CO_3) andNaare taken as independent variables and TDS as dependent variable. If dependent variable is measured from various locations, the regression equation can be used to determine the independent variable. The correlation analysis describes that all the water quality parameters are correlated to each other. The correlation coefficient is the relationship between the two variables which shows their relation between each other.

The various parameters studied and the standard methodology adopted for analysis is shown in table 1.

2.4 Water Quality Index

It is a means using which water quality of different parameters is summarized in a consistent manner. It is a unique weightage and rating system which presents the total quality of water in a individual number by giving composite power to each water quality parameter. WQI is a computational tool for combining the complex data of water quality into a numerical score representing the overall water quality status (Ambiga and Annadurai, 2015).In this method, the weightage of different water quality characteristics is considered to be in inverse proportionality to the

May – June 2020
ISSN: 0193-4120 Page No. 298 - 311

criteria proposed for the resulting characteristics(Yogendra, 2008). The standards used in Water Quality Index determination is BIS drinking water standards 10,500; 2012. It helps in identifying the source of pollution and helps to take up measures to remediate the problem. Water Quality Index determination involves three steps:

Step 1: Based on significance of individual water quality characteristics in the total quality of water for drinking and domestic usage, the suitable weights (wi) assigned. Due to their greater significance in the qualitative assessment of water, the highest weight of 5 was provided to the characteristics like nitrate (Neerja karla et al., 2012).The other characteristics, such as potassium, sodium, magnesiumand calciumwere given a weightage between 1 to 5 based on their significance for the total quality of drinking water.

Step: 2

Further, relative weight (Wi) of the each parameter is determined using a weighted arithmetic index formula (Tiwari and Mishra, 1985)(Brown et al., 1970)(Horton, 1965)

$Wi= \{wi / \sum wi\}$……… (1)

Where,

Wi = Relative weight,

wi = Weight of each parameter

In third step, the concentration of individual water quality characteristic of a sample (Ci) was divide by its relevant standard (Si)to obtain quality rating scale (Qi) according to the BIS drinking water standard 10,500; 2012 which is then multiplied by 100.

$Qi = (Ci / Si) \times 100$

In the fourth step, the Subindex of i^{th} parameter that is SIi, obtained for each and every chemical parameter, and the result is used in calculating the WQI using below equation.

$SIi= Wi \times Qi$

In the last step, Water Quality Index is obtained by doing the summation of SIi of all the water quality characteristics.

$WQI=\sum SIi$

Where,

SIi is the sub-index value

2. Result And Discussion

The Physico-chemical characteristics of subsurface water, its percentage compliance and the BIS 10,500; 2012 for domestic usagewater is given in table 2. The subsurface water quality is compared with BIS requirements for potable drinking water standards 10500, 2012 shows the highest variation in pH, turbidity, iron, hardness, magnesium and chloride concentration in water. Percentage compliance of pH is 18.8%. The pH of the groundwater samples varies from 5.01 to 7.6 in the study area. Water samples are acidic in a majority of the places literature say that it is due to the presence of lateritic soil in most of the places in the study area which induces acidity to the water and pH will be quite low. The total alkalinity value of water is important in calculating the dose of alum and biocides in water (Rawat et al., 2018), as coagulation and floc formation occurs in the alkaline condition in the water. The alkalinity value rangesfrom 26 to 240mg/l. Expect few water samples all the samples analyzed are within the acceptable limit of 200mg/l according to BIS 10,500; 2012. The percentage compliance is 96%.

The excessive chloride content in the water makes the water saline and leads to corrosion and incrustation of pipes during water supply and also chlorides in water changes the taste of the water. The chloride concentration varies from 11.9 to 361.25 mg/l. According to BIS 10500; 2012 the acceptable limit is 250mg/l. Variation of chlorides is due to the seawater intrusion, sewage and industrial effluent infiltration. Percentage compliance of chlorides is 93.5%. Chloride causes deposition inside the water supply pipes and varies the taste of water. Iron content in the water increases corrosive action of water, causes stain on the clothes, leads to the growth of iron bacteria. Iron content range from 0 to a maximum of 4.2 mg/l

May – June 2020
ISSN: 0193-4120 Page No. 298 - 311

against the acceptable limit of 0.3 mg/l. Percentage compliance of iron is 44.34%. This excessive iron content in many of the water samples is due to lateritic soil which induces iron to the water due to its leaching effect.

Total Hardness is one among the essential parameter in reducing the toxic impacts of the poisonous element (Rawat et al., 2018).As geological features induce hardness to the water, and also due to industrial discharge and runoff water which leads to the infiltration into the aquifer. Hard water will not give lather with the soap. It causes incrustation of boilers and taste of water also varies. Magnesium content is high in the most of the samples. The hardness ranges from 16 mg/l to 275 mg/l and the acceptable limit for hardness is 200 mg/l. Many of the water samples are in the range of hard water category. The Durfor and Becker's [1964] hardness classification in water indicates majority of samples lies in range of 180 and above which is very hard category, This kind of hard subsurface water will increase the calcification of arteries, bladder disease, kidney problem,urinary concretions(Sharma and Rout, 2011)(Rawat et al., 2018).

The high quantity of iron and hardness in the industrial region is mainly due to improper disposal of industrial wastewater. Industrial effluent should be managed properly and should be disposed of after the treatment. Due to infiltration, percolation and runoff, it reaches the groundwater.

Total dissolved solids are the solids present in water in dissolved form, it is the result of summation of cations and anions i.e. Na, Mg, Ca, K, HCO, CO, Cl, PO and SO. The weathering or degradation of soil and rocks in water produces ions(Kishan S. Rawat et al., 2019). TDS represents the inorganic load to a water body [K S Rawat et al..]. In the samples analyzed the TDS ranges from 43.2mg/l to 900.25mg/l and the acceptable limit is 500mg/l. The percentage compliance of TDS is 10.38%. TDS indicates the high electrical conductivity i.e., ability of ions to carry charges. The ion exchange and solubilization in the aquifer results in higher Electrical conductivity of the water samples(Sanchez Perez et al., 2003)(Rawat and Singh, 2018)].

If there no other means of drinkablesource of water for supply, the BIS limit is 2000 mg/l. The samples sampled and analyzed in Udupi are having the TDS within 2000 mg/l.

Themost excessively distributed element in the study area is chloride in all types of rocks and has a good correlation with sodium. So, its level is more in groundwater. In the coastal region due to seawater intrusion concentration of chlorides are higher. Soil characteristics like permeabilityand porosityleads to excessive quantity of chlorides especially nearseashore. In the rural region of Udupi the chloride content has been observedto be well within the permissible levels except in few areas along the seashore. Sandy soil and lateritic soil have high permeability which increases the infiltration of water. As the aquifers are shallow the soil media will not act as a filtration media.

Fluoride concentration in water is considered as two-edged sword due to its major effect when it is less as well as more. The acceptable limit is 0.5 to 1.5 mg/l. If it is less than 0.5mg/l leads to dental caries which causes decaying of enamel content of the teeth and the concentration more than 1.5 mg/l causes discoloration of teeth and also weakening of bones called skeletal fluorosis. The value varies between 0.2 to 2.5 mg/l and the percentage compliance with BIS 10500; 2012 is 63.21%.

Turbidity is the ability of turbid particles to scatter light. In the water samples analyzed all samples have turbidity more in comparison with acceptable limit of 1NTU. The percentage compliance is 0. The value varies from 1.2 to 13.6 mg/l.

E coli indicates the contamination of water by pathogens. In the study area, 10 samples indicates the presence of pathogens. This is by seepage of sewage and effluent from industries into the aquifer. Due to the very shallow water table in the area and in most of the places septic tank and soak pits are nearby to wells the faecal matter may seep into the well water making it contaminated.

The water quality statistics obtained for pre-monsoon season is given in table 3. It indicates the general characteristics of the water quality distribution in the area.The variation of mean, median among the sample are negligible. It shows that the water quality characteristics are normally distributed in the entire study area with minimal variation among the few samples. The higher variation in chlorides and Nitrate indicates that they are not normally distributed throughout the area. The variation of the actual value from the average value is indicated by the standard deviation.

Standard deviation is not showing much variation which indicates the uniformity in the water quality.Quartile gives the value for 25% of the data below (Q1) and the result for which 25% of the data is above (Q3). The difference between Q3 and Q1 gives the Interquartile Range (IQR).

The normal distribution analysis using the statistical tool gives the distribution of water quality over the entire geographical area. The correlation matrix shows that TDS have a positive and strong correlation with Total hardness, Ca and Mg, HCO_3 and Cl.Total hardness has a positive, effective and strong correlation with magnesium, calcium and bicarbonates which indicates the greater dependency of these parameters with each other. The regression equation obtained by considering TDS with other parameters will be helpful in further analysis.

The correlation coefficient matrix of water quality characteristicsenables the rapid monitoring of water samples. Pearson Correlation coefficient matrix (r) of water quality parameters are shown in table 4. Correlation matrix determines the interrelationship between two variables. The linear relationship among any two parameters is given by value r. The value of correlation coefficient(r) varies from 1 to -1. If the value of r is nearer to 1 or -1 higher will be the correlation and the positive value indicates positive relation, a negative value indicates inverse relation and the value 0 or nearer to this gives that there is no correlation. The table shows that TDS have positive and significant correlation with Total hardness(r=0.87), Ca(r=0.83), Mg(r=0.77), HCO_3(r=0.69) and Cl(r=0.65). Total hardness has a positive and relatively strong correlation with magnesium, calcium and bicarbonates which indicates the greater dependency of these parameters with each other. A systematic statistical analysis of the coefficient of correlation of water quality characteristics not only enables to measure the total quality of water quality but also offers the requisite towards introducing water quality analysis in a faster way(Samson and Elangovan, 2017).

As the correlation matrix gives the positive significant relationship between TDS and various other parameters such as Mg, Ca, HCO_3 and Cl, for the regression analysis and linear plot, TDS isthe dependent variable andremaining parameters as the independent variable.

The linear regression equation is given by y=ax + b

Where,

y -Independent variable

x - Dependent variable

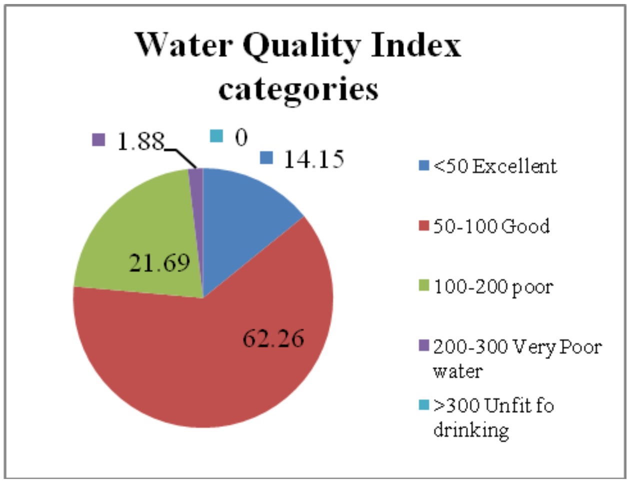
The relationship between significantly correlated parameters is given in table 5.

As the first step in determining the Water Quality Index relative weightage of water quality characteristics are determined, considering BIS 10,500;2012 drinking water standards which being shown in table 6 (Standards)., 2012)Weightage is assigned based on the parameters relative significance in water quality analysis.

The determined WQI values are categorised as five classes, “excellent water” to “water, unsuitable for drinking” (C R Ramakrishnaiah et al., 2009)

May – June 2020
ISSN: 0193-4120 Page No. 298 - 311

In Udupi, the WQI values ranges from 32.35 to 294.065 which was classified into four classes “excellent water” to “water very poor and unsuitable for drinking” (C R Ramakrishnaiah et al., 2009) Table 7 displays the different classes of water on percentage basis. The higherWQI value at the stations wasprimarily due to excessive concentration of total dissolved solids, hardness, chloridesandiron.



The pie chart depicts the percentage of water samples according to the different range of Water Quality Index value. The WQI ranges from 32.35 to 294.065. Among the water analysed 21.69 percentage of the water samples analysed exceed the upper limit of water quality standard for drinking purpose. The higher WQI is primarily the outcome of the higher concentration of calcium, magnesium, chlorides. Chloride concentration in well water along the seashores has chloride concentration more Fig 5: Different categories of Water Quality Index

Than the BIS drinking water limit. As 21.69% of water is under poor condition immediate action is required to take up remediation measures.

Fig 5 indicates the pie chart of Water Quality Index where 1.88 % of the water sample in the study comes under very poor quality. 21.69% of water sample belongs to a poor category of water quality index. 62% is good and 14% is a very good category. The present study indicates the poor and very poor percentage of water samples where the measures should be taken to treat the water before domestic usage. The higher WQI valuesat the study area were recorded due to the increased groundwater levels of iron, fluorides, hardness, TDS, nitrate, manganeseand bicarbonate.(C R Ramakrishnaiah et al., 2009). The WQI has the capacity to take decisions and handle pollution of concern, forecasts potentially harmful situations, directs actions and funds in maintaining goals, assesses negative effects of water quality, communicates the summative information for decision making at management level, monitors the epidemic diseases in the area(Rawat and Singh, 2018)

The distinct categories of water quality index obtained are depicted in the form of a map which is shown in the fig. 5. The map is generated in a GIS environment using Arc GIS 10.3. The map indicates that the poor category of areas is very near to seashores as well as in the industrial area.

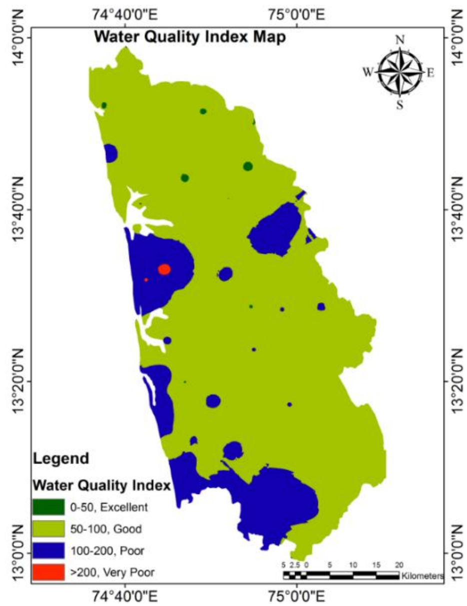


Fig 6: Map showing different categories of Water Quality Index

The poor category (100-200) of groundwater is mainly due to seawater intrusion and excessive iron, TDS, less pH in water samples analyzed. The effluent from industries and runoff from precipitation may also infiltrate into the aquifer.

May – June 2020
ISSN: 0193-4120 Page No. 298 - 311

The map fig. 6 classifies the Udupi region groundwater quality into different categories. The map acts as a decision support system to take up the preventive measures to reduce the groundwater pollution in the areas. The map satisfies the aim of categorizing the area into a different category of WQI. The analysis yields essential knowledge and significant information on the requirement for management of groundwater quality in different parts of Udupi district. Using this map the areas that fall under very poor and poor category can be given priority in groundwater management program.

Conclusion

This study determines the physicochemical properties of groundwater in the region studied varies widely on a seasonal basis. This laboratory analysis is essential to prevent waterborne disease and also various other dangerous diseases.

- Statistical studies indicate the normal distribution of water quality parameters within the study area accept for a few parameters. The correlation between the water quality characteristics such as TDS and hardness is given by Correlation coefficient. The regression equation obtained will further help to make the assessment faster and can be implemented for the rapid management programs for maintaining good water quality.
- Water quality index used is a mathematical tool which gives the single number which is the combination of all the analyzed parameters which help in deciding the overall quality of water. The study describes clearly that 21.69% of the water samples analyzed were not managed properly and falls under poor category and 1.88% under the very poor category where proper planning and management is necessary to mitigate the pollution aspects.
- The present study creates awareness among the people about the importance of managinggroundwater quality. It also demonstrates the utility of GIS in data management and analysis such as locating the sampling points and mapping the distinct categories of Water Quality Index. This study indicates the importance of water quality assessment in the selected area which helps in immediate need for implementing better water quality management policy.

References:

1. Ambiga, K., Annadurai, R., 2015. Development of Water Quality Index and Regression Model for Assessment of Groundwater Quality. Int. J. Adv. Remote Sens. GIS 4, 931–943.
2. APHA, 2005, 2000. American Public Health Association, American Water Works Association, Water Pollution Control Federation, & Water Environment Federation.
3. Brown, R.M., McClelland, N.I., Deininger, R.A., Tozer, R.G., 1970. A WATER QUALITY INDEX- DO WE DARE. Water Sew. Work. Vol. 117, 1970, pp. 339- 343.
4. C R Ramakrishnaiah, Sadashivaiah, C., Ranganna, G., 2009. Assessment of Water Quality Index for the Groundwater in Tumkur Taluk , Karnataka State , India. E-Journal Chem. 6, 523–530. https://doi.org/doi: 10.1155/2009/757424
5. Horton, R.K., 1965. An index number system for rating water quality. J. Water Pollut. Control Fed. 37, 300–306.
6. Neerja karla, Kumar, R., Yadav, S.S., Singh, R.T., 2012. Water quality index assessment of ground water in Koilwar block of Bhojpur (Bihar). J. Chem. Pharm. Res. 4, 1782–1786.
7. Pophare, A., Lamsoge, B., Katpatal, Y., P Nawale, V., 2014. Impact of over-exploitation on groundwater quality: A case study from WR-2 Watershed, India, Journal of Earth System

Science. https://doi.org/10.1007/s12040-014-0478-0

8. Rawat, K.S., Jacintha, T.G.A., Singh, S.K., 2018. Hydro-chemical Survey and Quantifying Spatial Variations in Groundwater Quality in Coastal Region of Chennai , Tamilnadu , India – a case study 50.
9. Rawat, K S, Mishra, A.K., Singh, S.K., 2019. Mapping of groundwater quality using Normalized Difference Dispersal Index of Dwarka sub-city at Delhi National Capital of India 1277795, 1–27.
10. Rawat, K.S., Singh, S.K., 2018. Water Quality Indices and GIS-based evaluation of a decadal groundwater quality. Geol. Ecol. Landscapes, 24, 240-255 9508. https://doi.org/10.1080/24749508.2018.1452462
11. Rawat, K.S., Singh, S.K., Jacintha, T.G.A., Nemčić-Jurec, J., Tripathi, V.K., 2017. Appraisal of long term groundwater quality of peninsular India using water quality index and fractal dimension. J. Earth Syst. Sci. 126, 122. https://doi.org/https://doi.org/10.1007/s12040-017-0895-y
12. Rawat, Kishan S., Sudhir Kumar Singh, Gautam, S.K., 2019. Assessment of groundwater quality for irrigation use : a peninsular case study. Appl. Water Sci. December 1–58.
13. Samson, S., Elangovan, K., 2017. Multivariate statistical analysis to assess groundwater quality in Namakkal district, Tamil Nadu, India. Indian J. Geo-Marine Sci. 46, 830–836. https://doi.org/https://doi.org/10.1007/s12524-014-0442-0
14. Sánchez Pérez, J., Vervier, P., Garabétian, F., Sauvage, S., Loubet, M., L. Rols, J., Bariac, T., Weng, P., 2003. Nitrogen dynamics in the shallow groundwater of a riparian wetland zone of the Garonne, SW France: Nitrate inputs, bacterial densities, organic matter supply and denitrification measurements, Hydrology and Earth System Sciences. https://doi.org/10.5194/hess-7-97-2003
15. Sharma, A., Rout, C., 2011. Assessment of Drinking Water Quality: A Case Study of Ambala Cantonment Area, International Journal of Environmental Science.
16. Singh, G., Kamal, R.K., 2017. Heavy metal contamination and its indexing approach for groundwater of Goa mining region, India. Appl. Water Sci. 7, 1479–1485. https://doi.org/10.1007/s13201-016-0430-3
17. Singh, S.K., Singh, C.K., Kumar, K.S., Mukherjee, S., 2009. Spatial-Temporal Monitoring of Groundwater Using Multivariate Statistical Techniques in Bareilly District of Uttar Pradesh , India SPATIAL-TEMPORAL MONITORING OF GROUNDWATER USING MULTIVARIATE STATISTICAL TECHNIQUES IN BAREILLY DISTRICT OF UTTAR PRADESH ,. https://doi.org/10.2478/v10098-009-0005-1
18. Singh, S.K., Srivastava, P.K., Singh, D., Han, D., Gautam, S.K., Pandey, A.C., 2015. Modeling groundwater quality over a humid subtropical region using numerical indices, earth observation datasets, and X-ray diffraction technique: a case study of Allahabad district, India. Environ. Geochem. Health 37, 157–180. https://doi.org/https://doi.org/10.1007/s10653-014-9638-z
19. Standards)., B. (Bureau of I., 2012. BIS 10500;2012. Drink. water Specif. (First Revis. Bur. Indian Stand. IS 105002012.
20. Tiwari, T.N., Mishra, M.A., 1985. A preliminary assignment of water quality index of major Indian rivers. Indian J. Environ. Prot. 5, 276–279.
21. Udupi brochure (2012) Ground water information booklet Udupi district, Karnataka, 2012. Udupi brochure.
22. Yogendra, K., 2008. Determination of Water Quality Index and Suitability of an Urban Waterbody in Determination of Water Quality

TEST Engineering & Management

May – June 2020
ISSN: 0193-4120 Page No. 298 - 311

Index and Suitability of an Urban Waterbody in Shimoga Town , Karnataka. Proc. Taal2007 12th World Lake Conf. 342-346 Determ.

Tables

Table 1: Methodology used for water quality analysis

Sl No	Parameters	Methodology
1	pH	Recorded by digital pH meter
2	Total Hardness(TH)	EDTA titration
3	Calcium	EDTA titration
4	Magnesium	EDTA titration
5	Bicarbonates	Neutralizing with standard HCl, titrimetric method
6	Chlorides	Mohr's method
7	Total Dissolved Solids(TDS)	Evaporation method, TDS meter
8	Fluorides	Spectrophotometric method
9	Manganese	Titrimetric method
10	Nitrates	Spectrophotometric method
11	Iron	Phenonthroline method
12	Sulphates	Spectrophotometric method
13	Turbidity	NepheloTurbidimeter
14	Sodium	Flame photometric method
15	Potassium	Flame photometric method
16	Phosphate	Spectrophotometric method
17	Conductivity	Measured by conductivity meter
18	E-Coli	Bacteriological test

Table 2:Percentage compliance of groundwater quality with BIS drinking water standards

SL No	Parameters	BIS 10,500:2012 Acceptable limit	Percentage compliance(%)
1	pH	6.5-8.5	18.8
2	Total Hardness(TH)	200	93.4
3	Calcium	75	98.2
4	Magnesium	30	41.6
5	Bicarbonates	200	96
6	Chlorides	250	93.4
7	Total Dissolved Solids(TDS)	500	89.62
8	Fluorides	1	63.21
9	Manganese	0.1	44.34

TEST Engineering & Management

May – June 2020
ISSN: 0193-4120 Page No. 298 - 311

10	Nitrates	45	100
11	Iron	0.3	44.34
12	Sulphates	200	100
13	Turbidity	1	0
14	E-Coli	Nil	90

Table 3:Statistical characterization of groundwater of Udupi coastal region

SL No	Chemical Parameters	Minimum	Maximum	Arthematic Mean	Standard Deviation	Covariance	Quartile-1	Median	Quartile-3
1	pH	5.01	7.6	6.6058	0.53753	8.137	5.98	5.98	6.04
2	Total Hardness(TH)	16	275.98	77.792	52.263	67.183	57	66	78
3	Calcium	7	125	27.99	17.859	63.804	24	24	24
4	Magnesium	0	212	49.8	49.32	99.036	33	34.5	46
5	Bicarbonates	26	240	90.81	47.18	51.954	60	80	80
6	Chlorides	11.994	361.25	43.35	67.172	154.95	23.99	21.989	19.99
7	Total Dissolved Solids(TDS)	43.2	900.25	270.54	155.44	57.455	215.12	220.12	235.115
8	Fluorides	0.2	2.35	0.879	0.481	54.721	0.72	0.74	0.78
9	Manganese	0.01	1.3	0.242	0.2669	110.28	0.2	0.19	0.12
10	Nitrates	0	9	1.313	2.111	160.77	2.4	0.253	1.7
11	Iron	0	4.2	0.5344	0.606	113.39	0.78	0.335	0.65
12	Sulphates	2	25	6.97	4.578	65.681	9.3	5	6
13	Turbidity	1.2	13.6	4.648	2.612	56.196	3.6	3.9	4.2
14	Phosphate	0	6	2.916	1.16	39.780	2.4	3.1	3.2
14	Potassium	1	16	7.415	3.383	45.623	9	7	5
15	Sodium	15	257	36.65	38.65	105.45	25	25	22
16	Conductivity	94.2	1820.3	523.22	316.92	60.571	398.98	414.115	460.7

All units except Electrical conductivity and pH are in mg/l

Table 4: Correlation matrix of groundwater quality

Parameters	pH	TH	Ca	Mg	HCO_3	Cl	TDS	FL	Mn	NO_3	Fe	SO_4
pH	1											
TH	0.28	1										
Ca	0.34	0.33	1									
Mg	0.17	0.93	-0.01	1								
HCO_3	0.20	0.86	0.18	0.85	1							
Cl	0.24	0.38	0.59	0.18	0.26	1						
TDS	0.18	0.87	0.83	0.77	0.69	0.65	1					
FL	-0.006	0.04	-0.02	0.05	0.006	-0.07	-0.01	1				
Mn	-0.02	-0.15	-0.12	-0.12	-0.17	-0.09	-0.15	0.17	1			
NO_3	-0.11	-0.04	0.08	-0.07	-0.19	0.07	0.03	0.52	0.04	1		
Fe	-0.03	0.14	-0.12	0.19	0.08	-0.07	0.02	0.12	0.16	0.15	1	
SO_4	0.05	0.01	0.08	-0.01	-0.13	0.16	0.12	0.40	0.10	0.63	0.22	1

May – June 2020
ISSN: 0193-4120 Page No. 298 - 311

Table 5: Relationship among significantly correlated parameters

Sl No	Y(Independent variable)	X (Dependent variable)	a	b	Regression Equation
`	Ca	TDS	0.043088	14.66852	Ca=0.043088TDS+14.66852
2	HCO_3	TDS	0.291385	18.1093	HCO_3=0.291385 TDS+18.1093
3	Cl	TDS	0.110775	0.816049	Cl=0.110775TDS+0.816049
4	SO4	TDS	0.004272	5.907739	SO_4=0.004272TDS+5.907739
5	Na	TDS	0.066939	12.57187	Na=0.066939TDS+12.57187
6	NO_3	TDS	0.000309	1.236611	NO_3=0.000309TDS+1.236611
7	Cond	TDS	2.064546	34.3345	Con=2.064546 TDS-34.3345

Table 6: Physico-chemical parameter weightage and relative weights

SL No	Parameters	BIS 10,500:2012 Acceptable limit	Parametric Weights (wi)	Relative weight of individual parameter(Wi)
1	pH	6.5-8.5	4	0.093023256
2	Total Hardness(TH)	200	2	0.046511628
3	Calcium	75	2	0.046511628
4	Magnesium	30	2	0.046511628
5	Bicarbonates	200	3	0.069767442
6	Chlorides	250	3	0.069767442
7	Toal Dissolved Solids(TDS)	500	4	0.093023256
8	Fluorides	1	4	0.093023256
9	Manganese	0.1	4	0.093023256
10	Nitrates	45	5	0.11627907
11	Iron	0.3	4	0.093023256
12	Sulphates	200	4	0.093023256
16	Turbidity	1	2	0.046511628
			Sum wi=43	**Sum Wi=1.000000**

May – June 2020
ISSN: 0193-4120 Page No. 298 - 311

Table7: Water quality classification based on WQI value

Water Quality Index (WQI) Value	Different categories of water quality	Percentage of water samples in each category (%)
<50	Excellent	14.15
50-100	Good	62.26
100-200	poor	21.69
200-300	Very Poor water	1.88
>300	Unfit for drinking	0