Session HS8.2.1- ‘The Role of Groundwater Flow Systems in Solving Water Management and Environmental Problems.’

“Groundwater Quality Assessment Using CCME WQI and GIS Technique for Ujjain City, India.”

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INTRODUCTION

- Water is one of the most fundamental needs of all living things. There can be no life without water (Rajankar et al. 2009).
- Groundwater is a significant source of freshwater for people all around the world. About 97.2 % of the water on earth is saline, with only 2.8 % available for usage as fresh water, of which approximately 20 % is groundwater (Asadi et al. 2016).
- In India, a majority of the populace relies on groundwater for drinking. For this, the determination of groundwater quality (GWQ) is of great importance (Jhariya et al. 2017).
- The water quality index (WQI) is an effective tool which determines the suitability of groundwater for drinking (Hamlat et al. 2017).

THEORETICAL BACKGROUND

WATER QUALITY INDEX (WQI)

- The WQI is described as an index that reflects the combined impact of several water quality parameters that are analyzed and accounted for while calculating the water quality index.

❑ ***Different Types of Water Quality Indices:***

- Weighted Arithmetic Water Quality Index (WA WQI).
- Groundwater Quality Index (GWQI).
- The Canadian Council of Ministers of the Environment Water Quality Index (CCME WQI).
- National Sanitation Foundation Water Quality Index (NSF WQI).
- Suitability of a specific WQI depends on the availability of the data.

The Canadian Council of Ministers of the Environment Water Quality Index (CCME WQI):

- The CCME WQI is a systematic approach for assessing water quality that was developed by Canadian authorities.
- The formula used for determining CCME WQI is given by,

$$\text{CCME WQI} = 100 - \frac{\sqrt{F1^2 + F2^2 + F3^2}}{1.732}$$

Where, F1 represents the number of variables with unaccomplished goals (failed variables), F2 measures the ratio of individual tests with unaccomplished goals (failed tests), and F3 is the percentage of test failure values with unaccomplished goals.

OBJECTIVE

- The objective of this study is to assess the suitability of groundwater for drinking using CCME WQI.
- Integration of CCME WQI with GIS to outline the spatial distribution maps of eight physicochemical parameters and CCME WQI maps.

LITERATURE REVIEW

Sr No.	Research Paper	Author-Year	Results and Conclusion
1.	Water quality categorization using WQI in rural areas of Haridwar, India.	N. Kamboj G. Matta M. Bharti A. Kumar (Year - 2018)	**Results:** For assessing the groundwater quality, samples were taken from six distinct locations. The examined quality of water as per WQI in Haridwar district is less than 50. **Conclusion:** The WQI shows that the ground water quality is excellent (WQI<50) and acceptable for purpose of drinking.
2.	Groundwater Quality assessment using Water Quality Index (WQI) in parts of Varanasi District, Uttar Pradesh.	A. K. Chaurasia H. K. Pandey S.K. Prakash P. Pandey (Year - 2019)	**Results:** Twenty-two water quality parameters were assessed using WQI and GIS in Varanasi district. Majority of samples were find suitable for drinking. **Conclusion:** According to the study's findings, 20% of the area is unfit for human consumption, while the rest is classified as good, moderate, bad, or extremely poor according to the WQI.
3.	Groundwater quality assessment using water quality index (WQI) under GIS framework.	A. Ram S. K. Tiwari S. Singh (Year - 2020)	**Results:** conducted research in the district of Mahoba in Uttar Pradesh, India, where 20 water quality parameters were assessed and found within the suitable range. **Conclusion:** The research area's overall WQI suggests that the groundwater is drinkable.
4.	Applications of Water Quality Index for Groundwater Quality Assessment on Tamil Nadu and Pondicherry , India.	J. Sirajudeen A. Vahith (Year - 2021)	**Results:** Eight groundwater samples were collected, five from Pondicherry and three from Tamil Nadu, India. Electrical conductivity, BOD, COD, and Cl were all above the maximum permitted limit in all samples. **Conclusion:** It is asserted that this water is unfit for human consumption.

STUDY AREA

- Ujjain is a historic city in the Madhya Pradesh state of India.
- Ujjain city's latitude and longitude are 23°10'58"N and 75°46'38"E, respectively.
- The annual rainfall is 892.9 mm, with a warm monsoon climate.
- The elevation is 491 meters on average.

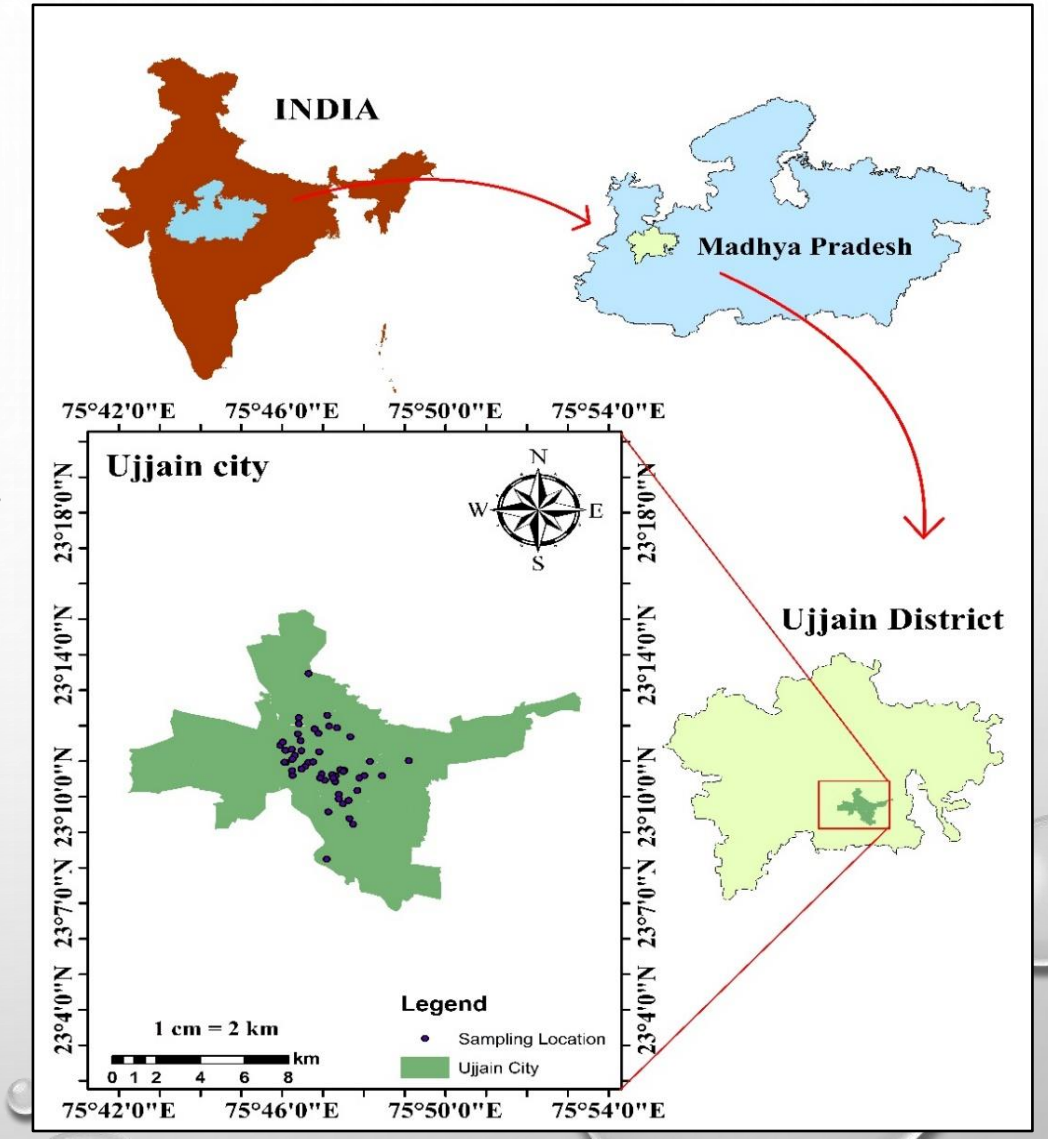

Figure 1. Index Map of Study Area

METHODOLOGY

❑ STEPS TO FOLLOW:

- Collection of Groundwater sample.
- GIS analysis and mapping of parameters.
- Statistical Analysis using BIS 10500:2012.
- Water quality parameter maps
- Groundwater quality modelling using CCME WQI.
- Groundwater quality mapping
- Results and discussion.

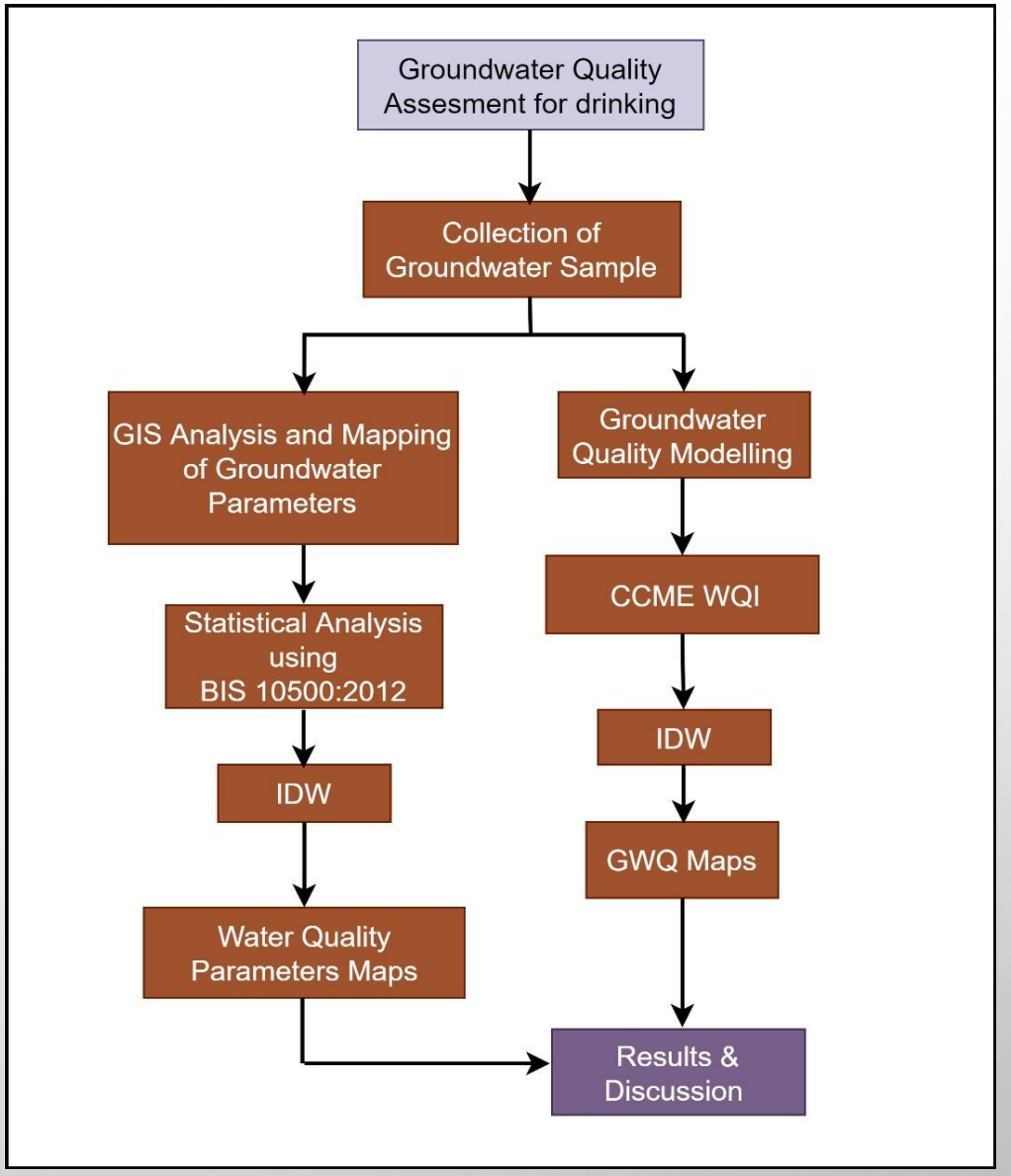

Figure 2. Flow Chart of Methodology

COLLECTION OF GROUNDWATER SAMPLES

- In this study, eight physicochemical properties such as pH, turbidity, electrical conductivity (EC), total dissolved solids (TDS), alkalinity, hardness, chloride (Cl-), and fluoride (F-) were selected from 54 groundwater samples.

- They were collected from dug wells, bore wells, and hand pumps, which were assessed and compared with BIS 10500:2012 for drinking purposes.

- The samples were collected at distances with reference to other locations to provide a broad investigation of the study area's water quality.

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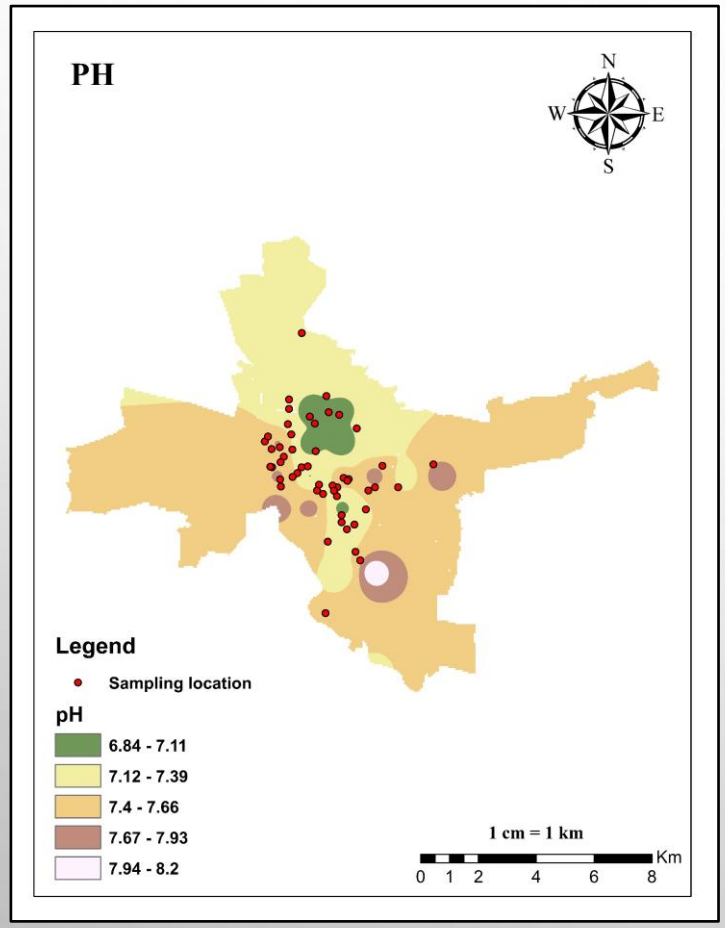
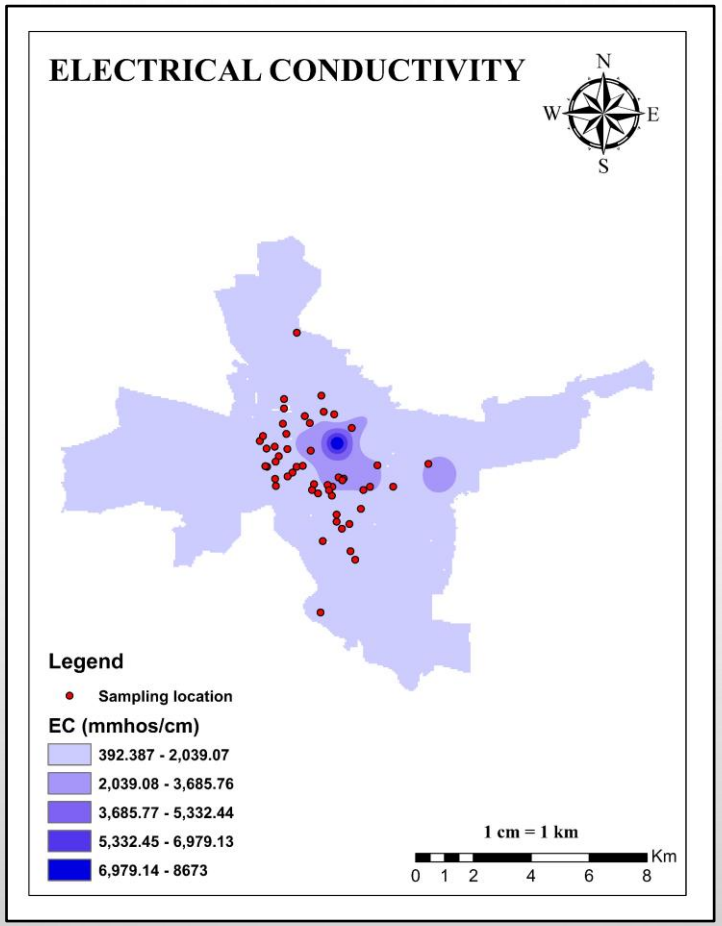
GIS ANALYSIS AND MAPPING OF PARAMETERS

- Groundwater quality mapping was implemented using IDW in ArcGIS 10.8 for the eight physicochemical parameters.



(a)



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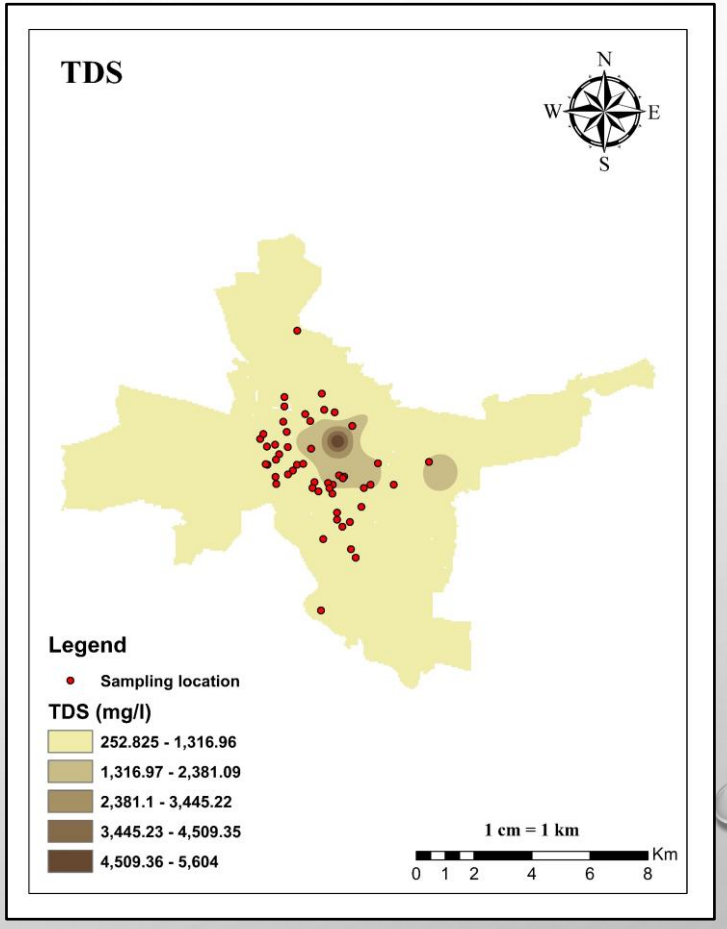

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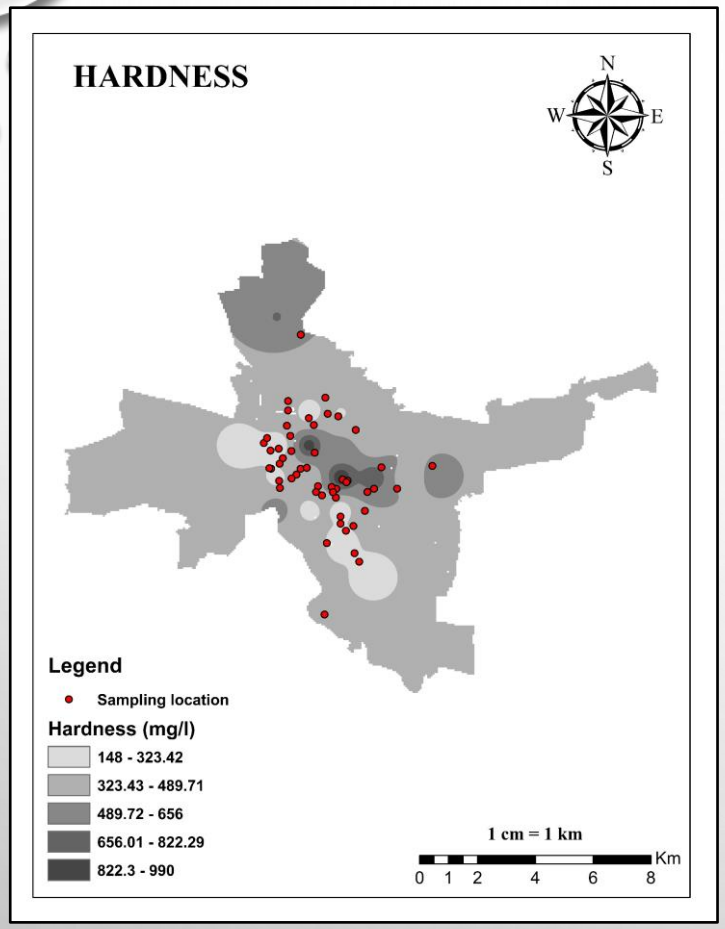
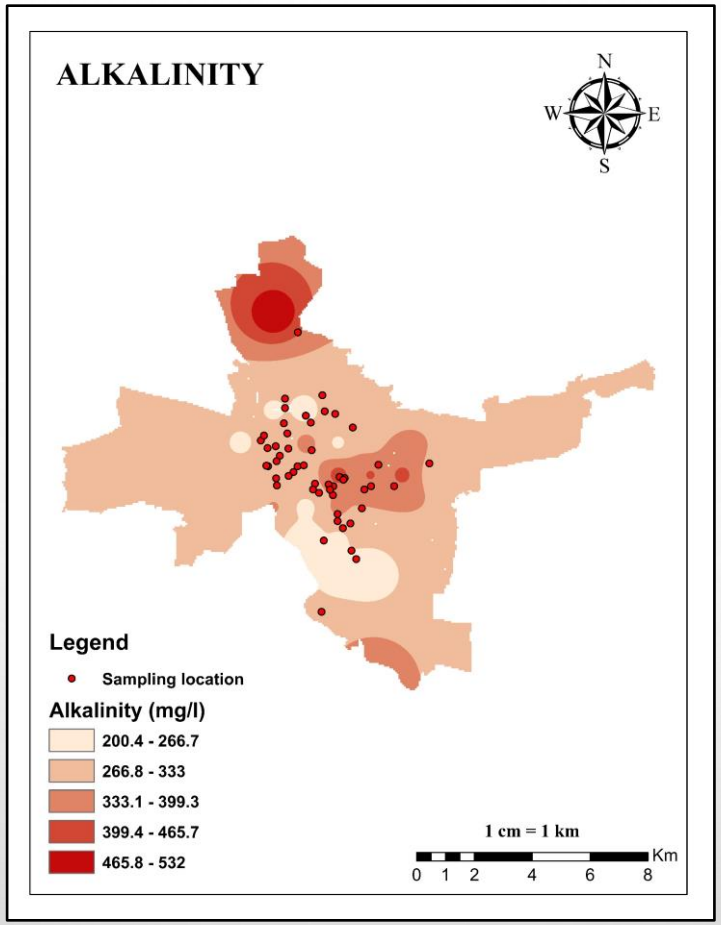
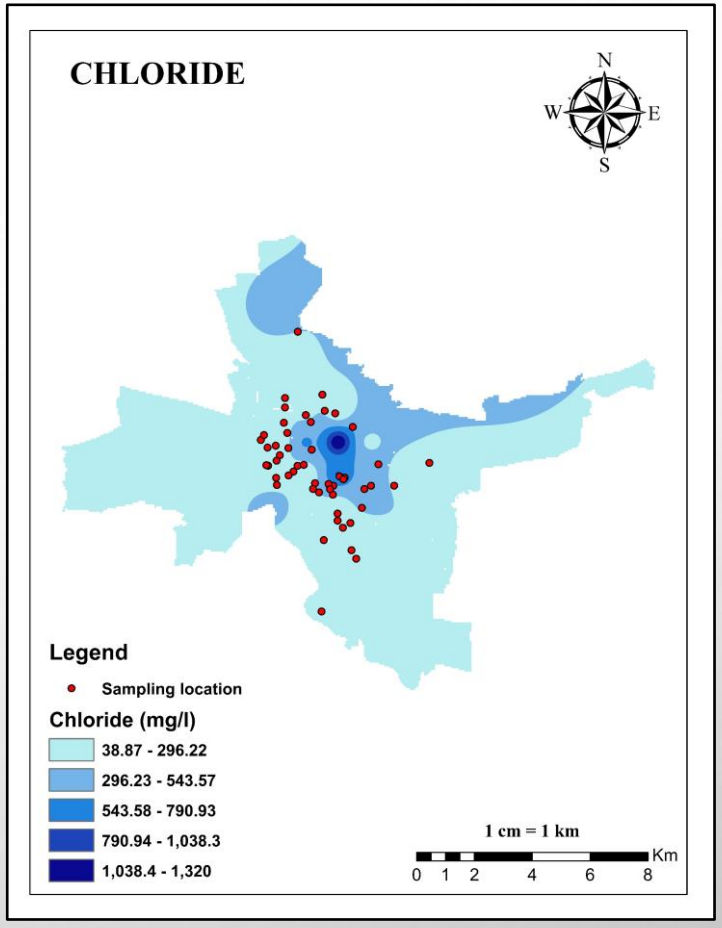

HARDNESS
N
W
E
S
Legend
Sampling location
Hardness (mg/l)
148 - 323.42
323.43 - 489.71
489.72 - 656
656.01 - 822.29
822.3 - 990
1 cm = 1 km
0 1 2 4 6 8
Km

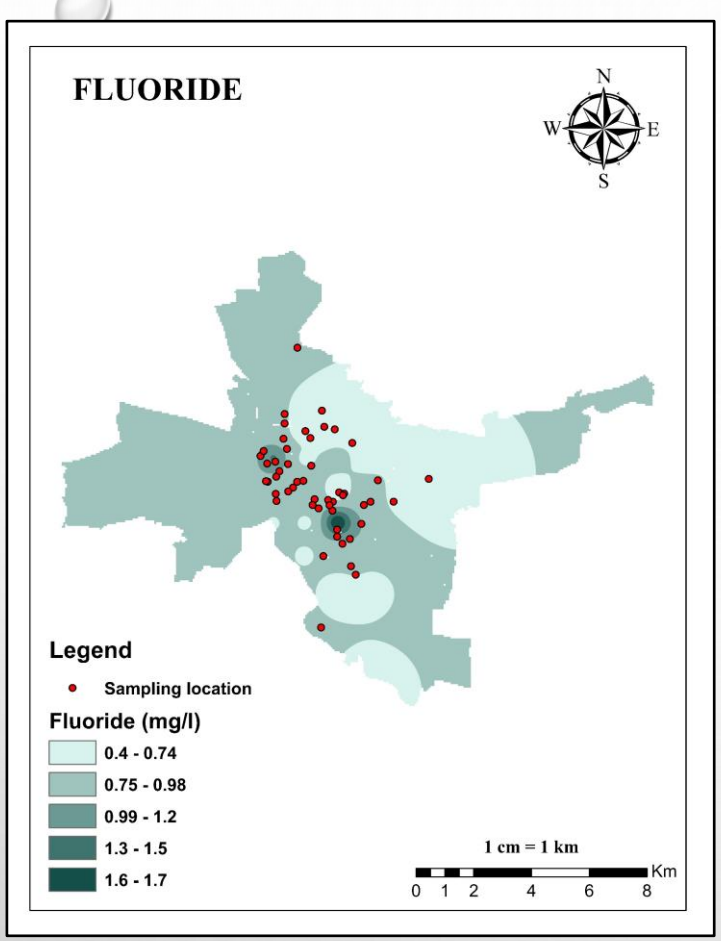
(d)


ALKALINITY
N
W
E
S
Legend
Sampling location
Alkalinity (mg/l)
200.4 - 266.7
266.8 - 333
333.1 - 399.3
399.4 - 465.7
465.8 - 532
1 cm = 1 km
0 1 2 4 6 8
Km

(e)


CHLORIDE
N
W
E
S
Legend
Sampling location
Chloride (mg/l)
38.87 - 296.22
296.23 - 543.57
543.58 - 790.93
790.94 - 1,038.3
1,038.4 - 1,320
1 cm = 1 km
0 1 2 4 6 8
Km

(f)



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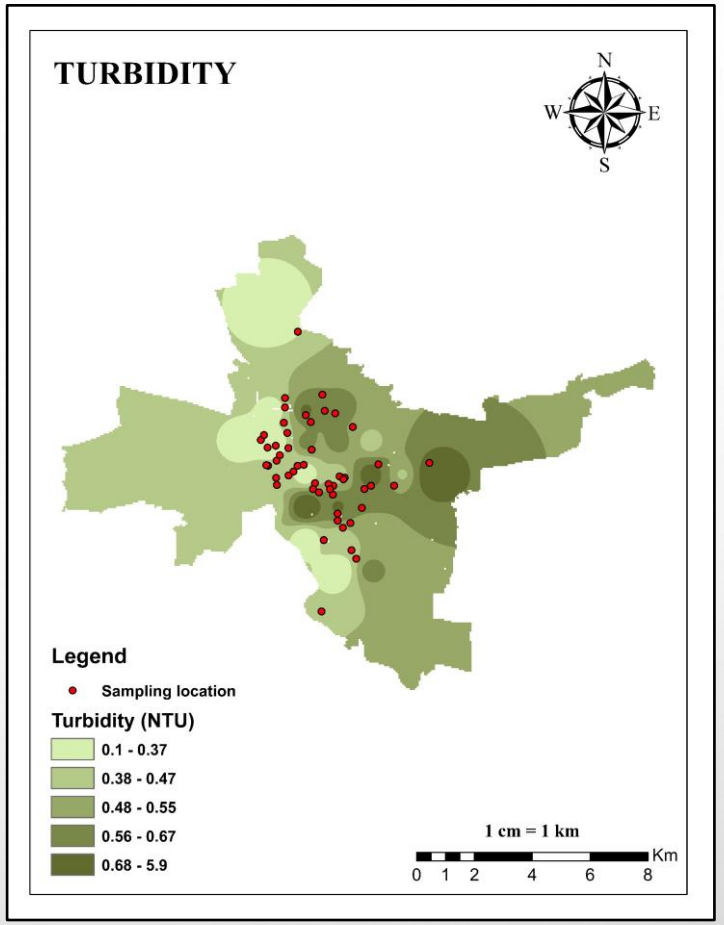

(h)

Figure 3a-h. Groundwater quality maps for physicochemical parameters using IDW in ArcGIS 10.8

STATISTICAL ANALYSIS USING BIS 10500:2012

- Table 1 below illustrates the statistical analysis of the analyzed groundwater quality

Table 1: Statistical analysis of analysed physicochemical properties.

Parameter	Maximum	Minimum	Mean	Standard deviation
pH	8.2	6.8	7.335	0.349
EC (µmho/cm)	195	8673	1288.407	1332.390
Hardness (mg/l)	148	990	395.22	203.352
TDS (mg/l)	125	5604	831.907	854.581
Alkalinity (mg/l)	200	532	307.019	73.229
Chloride (mg/l)	38	1320	270.519	291.621
Fluoride (mg/l)	0.4	1.7	0.77	0.256
Turbidity (NTU)	0.1	5.9	0.549	0.775

GROUNDWATER QUALITY ASSESSMENT USING CCME WQI

- According to CCME WQI, the value is graded on a scale of 0 to 100, with 0 being the lowest and 100 representing the finest water quality.
- Here each parameters are given equal amount of weights in contrast to other indexes.
- CCME WQI, employs the harmonic mean or its square, for indexing drinking water quality.
- CCME WQI divides the quality of water into **five** classes.

Table 2: Classification of Groundwater samples for drinking based on CCME WQI

Sr. No	CCME WQI	Status of Water Quality for drinking
1	95-100	**Excellent**
2	80-94	**Good**
3	65-79	**Fair**
4	45-64	**Marginal**
5	0-44	**Poor**

RESULTS AND DISCUSSION

❑ Groundwater Quality parameters:

- All 54 samples were examined for the eight parameters using the procedures outlined by the American Public Health Association (APHA 2017).
- As shown in fig. 3a-h, groundwater quality mapping was implemented using IDW in ArcGIS 10.8 for the eight physicochemical parameters. The results of maximum and minimum range of the eight parameters taken into account in the study are shown in the table below.

Table 3: Maximum and minimum range of the physicochemical parameters.

Parameter	Minimum	Maximum
pH	6.8	8.2
EC (µmho/cm)	195	8673
Hardness (mg/l)	148	990
TDS (mg/l)	125	5604
Alkalinity (mg/l)	200	532
Chloride (mg/l)	38	1320
Fluoride (mg/l)	0.4	1.7
Turbidity (NTU)	0.1	5.9

❑ CCME WQI:

- The obtained CCME WQI range is **8.52** to **89.43**, i.e., from good to poor categories.
- The calculation of CCME WQI is done, such sample calculation of ward 1 is shown below.

Table 4: Calculation of CCME WQI for ward 1.

Parameters	Observed value (V_o)	Standard value (S_n)	Scope value (F_1)	Frequency value (F_2)	Amplitude Value (F_3)	CCME WQI	Status
pH	6.5-8.5	7.12					
Turbidity	5	0.2					
EC	300	1081					
TDS	500	690	62.5	62.5	43.19529	**43.19**	**Marginal**
Alkalinity	200	532					
Chloride	250	310					
Hardness	300	660					
Fluoride	1	0.86					

- Figure 4 illustrates the plot of CCME WQI for each ward.
- The plot reveals that minimum CCME WQI of **8.52** is observed in ward **36**.
- And maximum CCME WQI of **89.43** is observed in ward **47**.

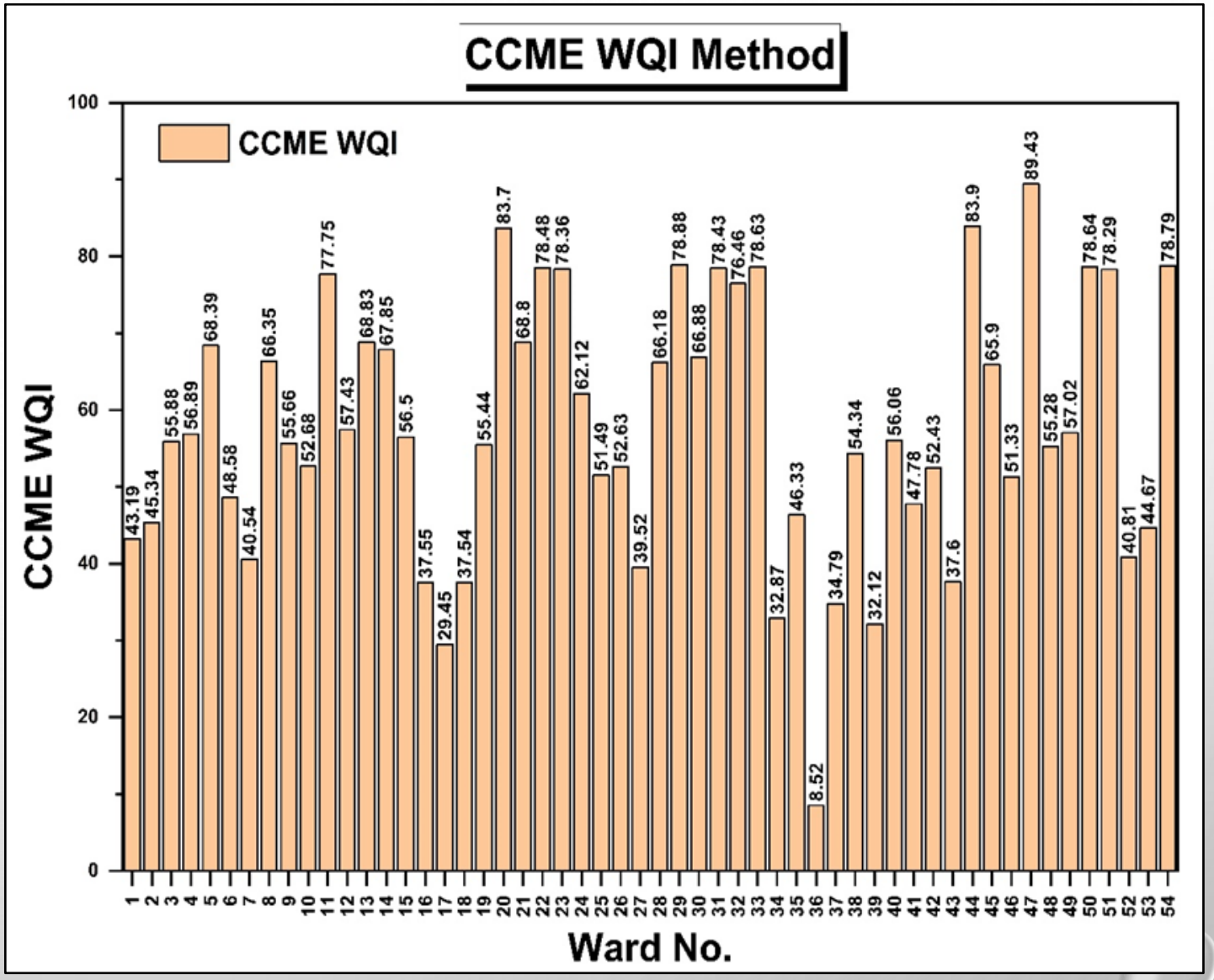

Figure 4. Plot showing CCME WQI for each ward

- Using GIS spatial distribution CCME WQI map was prepared.
- The CCME WQI map reveals the distribution of ward in different status of water quality according to their determined CCME WQI value.

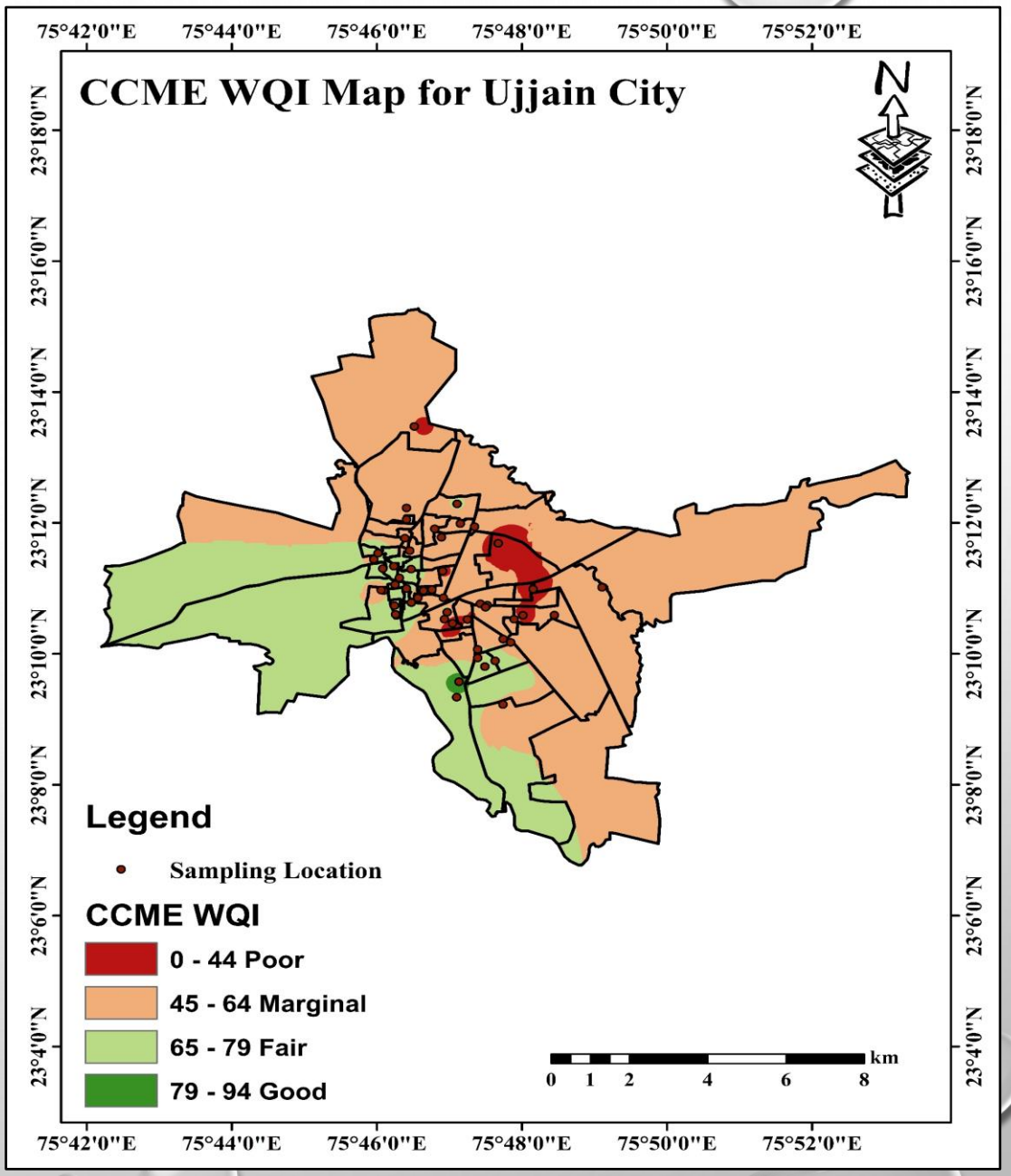

Figure 5. CCME WQI Map for Ujjain City

- Figure 6 reveals the percentage wise distribution of water quality status based on CCME WQI.
- The study area was classified into four categories viz., Poor, Marginal, Fair, and Good.

Table 5: Classification of 54 groundwater samples for drinking based on CCME WQI

Class	Rating	Ward No.	No. of Samples	%. of Samples
Excellent	95-100	-	-	-
Good	80-94	20,44,47	3	6
Fair	65-79	5,8,11,13,14,21,22,23,28,29,30,31,32,33,36,45,50,51,54	19	35
Marginal	45-64	2,3,4,5,9,10,12,15,19,24,25,26,35,38,40,41,42,46,48,49,53	21	39
Poor	0-44	1,7,16,17,18,27,34,37,39,43,52	11	20

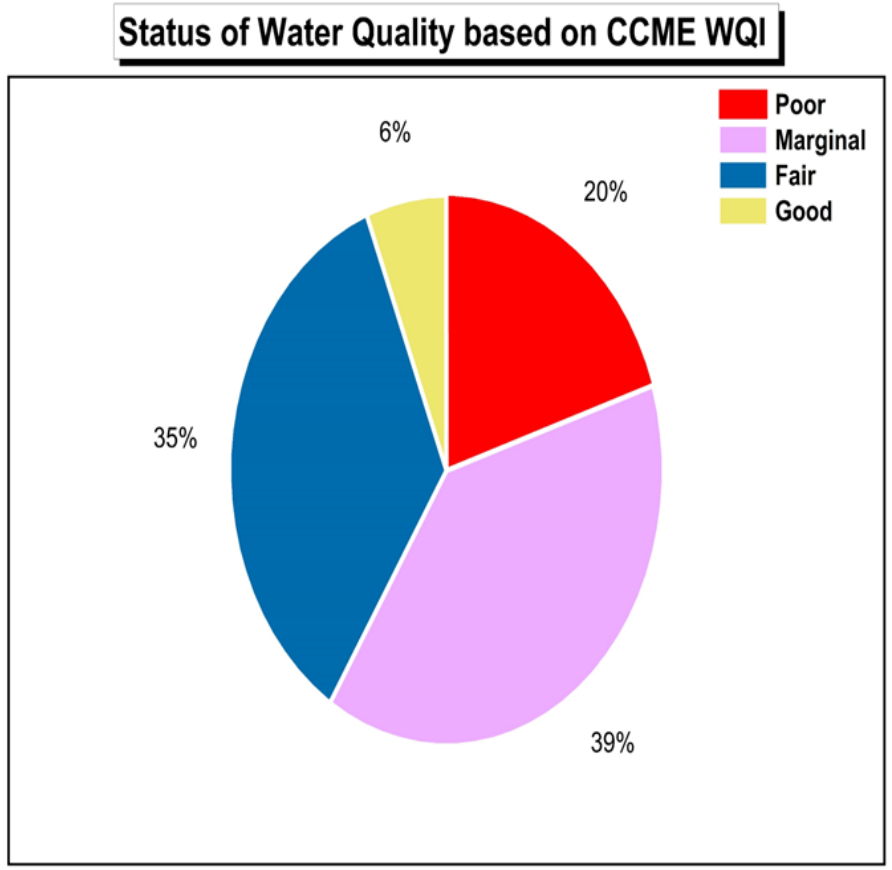

Figure 6. Percentage wise status of water quality based on CCME WQI.

LIMITATION OF THE STUDY

- **Lack of data availability:** Only eight parameters were available for pre-monsoon season.
  - Only CCME WQI technique was used for assessment.
  - No comparison has been done between post and pre-monsoon quality of water.

FUTURE SCOPE

- Comparative assessment using different WQI techniques.
- Integrating WQI,GIS and MSA.
- Integrated approach using WQI-fuzzy logic and fuzzy-AHP.

CONCLUSION

- Following are the concluding remarks from the study:

- CCME WQI is one of the best method to assess the groundwater quality of an area, as it uses harmonic mean.
- CCME WQI reveals 80% of samples to be in the good to marginal category.
- GIS aids in the conversion of point data into spatial data, allowing for the classification of areas as excellent to poor water quality.
- The CCME WQI spatial distribution map (Figure 5) clearly depicts the area's finest drinking locations.
- From the outcomes of the study, it is clear that the majority of the water is in good condition and thus suitable for drinking, with the exception of a few locations that require treatment.

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THANK YOU