Volume: 10 Issue: XII Month of publication: December 2022

DOI: https://doi.org/10.22214/ijraset.2022.47928

International Journal for Research in Applied Science & Engineering Technology (IJRASET)
ISSN: 2321-9653; IC Value: 45.98; SJ Impact Factor: 7.538
Volume 10 Issue XII Dec 2022- Available at www.ijraset.com

A GIS-based Interpolation Technique to Predict Urban Ground Water Quality

Siddhant Jain[1], Dr. Prachi Singh[2]
[1]M.Tech Student, Department of Civil Engineering, MITS Gwalior
[2]Assistant Professor, Department of Civil Engineering, MITS Gwalior

Abstract: The freshwater resources of our country include groundwater as a significant component. It is essential to supplying the country's numerous user-sectors with the water they need. Without first evaluating the water quality, the natural resource cannot be used and maintained in an optimum manner. Using ArcMap 9.3, a base map has been created after the data gathering. In order to create thematic maps that demonstrate the distribution of different water quality criteria, after doing an analysis, the water quality information is used as an attribute database. The water quality index has been calculated using a number of variables, such as pH, turbidity, total hardness (TH), chloride, total dissolved solids (TDS), calcium, nitrate, iron, and fluoride. A map of the Water Quality Index is also created. In order to better comprehend the current water quality situation in the research region, the data are provided as maps. Analysis shows that the area's groundwater has to undergo field-specific treatment before being used.
Keywords: Freshwater resource, water quality index, pH, turbidity, total hardness (TH), chloride, total dissolved solids (TDS), calcium, nitrate, iron, and fluoride.

I. INTRODUCTION

Human health, poverty alleviation, gender equality, food security, livelihood, environmental protection, as well as community economic development and social development are all strongly correlated with water quality (IAH, 2008; UNESCO, 2015). Globally, increasing levels of urbanization, industrialisation, and agricultural activity have a negative impact on the quality of both surface and groundwater. Groundwater, a dependable source of fresh water, is under a lot of pressure to provide the growing water requirements of the world's population, particularly in emerging nations like India. With an average annual groundwater consumption of 230 km3, According to the World Bank, India uses groundwater more than any other country (2010). India is dealing with a groundwater crisis in the twenty-first century as a result of its over exploitation (CGWB, 2017) and the rise of pollution from both local and external sources (SoE, 2009). In contrast to surface water pollution, groundwater contamination is concealed and difficult to detect. Once contaminated, groundwater may stay that way for many years or even a century owing to the sluggish water movement and pollutants in the groundwater. Therefore, the creation of efficient management techniques for the conservation and sustainable use of vital groundwater supplies is urgently needed. Due to the importance of improving management and development of vital groundwater resources, it is crucial to have an adequate method or strategy for monitoring and analyzing groundwater levels on a broad scale. The development of water quality indicators as a means of providing an all-encompassing evaluation of the quality of both surface water and groundwater is yet another strategy to management that may be considered. The Water Quality Indicators (WQI) is a simple mathematical instrument that, when applied to significant water quality measurements, may provide an accurate picture of the overall water quality status in a given region (Abbasi and Abbasi, 2012). Simple to understand and helpful in increasing public awareness of groundwater contamination, WQI-based maps. Additionally, these maps assist in the enforcement of appropriate waste management regulations and in the restriction of groundwater discharge, all of which may contribute to the efficient management of groundwater. Pollution prevention measures for groundwater protection schemes (e.g., Saeedi et al., 2010; Vadiati et al., 2016). In the last several decades, the WQI approach was used by a significant number of researchers all around the globe (e.g., Bolton et al., 1978; Babiker et al., 2007; Nasiri et al., 2007; Machiwal et al., 2011; Vicente et al., 2011; Zhao et al., 2013; Jasmin and Mallikarjuna, 2014; Boateng et al., 2016; Selvaganapathi et al., 2017). Lumb et al. (2011) gave a detailed evaluation of the evolution of the WQI throughout the years. They brought to light fundamental constraints that were inherent in the index creation process and offered ideas for overcoming hurdles.

Fewer groundwater-related research were conducted in the past WQI investigations, which were often mostly surface water-focused. It is significant to note that while biological characteristics (bacteria, algae, etc.) and physico-chemical structures (temperature, turbidity, color, dissolved oxygen, pH, etc.) are important parameters for surface water quality testing, hydro-chemical properties (large cations and anions) are important parameters for groundwater quality monitoring (Vadiati et al., 2016).

International Journal for Research in Applied Science & Engineering Technology (IJRASET)
ISSN: 2321-9653; IC Value: 45.98; SJ Impact Factor: 7.538
Volume 10 Issue XII Dec 2022- Available at www.ijraset.com

As a consequence, the many water quality parameters employed in groundwater quality assessments and data restrictions often hinder the creation of the Groundwater Quality Index (GQI). Probably the first technique of determining the quality of drinking water using a water quality indicator was created by Tiwari and Mishra in 1985. (Lumb et al., 2011; Vadiati et al., 2016). Numerous studies on the growth of GQI in various regions of the globe were undertaken in acknowledgement of its practice (Lumb et al., 2011). Several scholars have already evaluated groundwater quality and examined regional variability in groundwater quality metrics using GIS-based GQI. Babiker et al(2007) .'s first proposal for the creation of a GIS-based GQI that uses a statistical approach to generate the index based on WHO drinking water criteria was accepted. this approach extensively to assess groundwater levels and their regional variety. Numerous research have been carried out to assess the acceptability of drinking water using GQI in addition to analyzing its suitability using GQI. For instance, Stigter et al. (2006) employed GQI groundwater as a test method for Portuguese agricultural districts, whereas Soltan (1999) assessed the quality of groundwater in sites in Egypt for GQI-based irrigation efficiency. Using the lowest values of groundwater quality limitations, the Groundwater Quality Index (GQI) may be easily calculated, and the results are simple to understand. However, a significant flaw in conventional WQIs (surface and groundwater) is that they don't take into account the inputs and uncertainties included in environmental risk assessments (Silvert, 2000), particularly when water quality is the focus of the evaluation.

II. STUDY AREA

The Gwalior district in northern Madhya Pradesh, India, on the Indo-Gangetic Plain, with coordinates (latitude 26° 5'-26° 25' N and longitude 78° 10'-78° 25' E), is the research area for this project effort (Figure 2.1). Old Gwalior is located in the north of the city, Lashkar is located in the southwest, and Morar is located in the east. Extreme temperatures and unpredictable rainfall patterns characterize the semi-arid environment that predominates in this area. Geologically, the Gwalior group of litho units, It is composed of ferruginous shale with bands of chert-jasper and comprises the base erinaceous Par form. It is overlain by volcano-sedimentary stages of the Morar formation, lie awkwardly over Bundelkhand and granite. Its administrative center is located in the ancient city of Gwalior. The distance between it and Delhi and Bhopal is about identical. One of the major railway junctions, GUA is well-served by air, land, and national highway No. 3, which connects it to the north-south corridor. A daily service from here is run by Air India to Delhi and Mumbai. Additionally, the city has air service to Jabalpur and Bhopal thanks to new aircraft introductions by the Madhya Pradesh government (Ventura). Additionally, it is in a prime location for both road and rail access to all areas of the nation. Antari, Bilaua, Tekanpur, Dabra, and Bhitarwar are further cities and towns that are located in this district. These towns and cities are situated either beside the main national highways or close to the railway lines. The 720-foot-high Tighara Water Reservoir is situated there. It provides the residents of the GUA with a lifeline. From here, water is available virtually all year long. Its administrative center is located in the ancient city of Gwalior. The distance between it and Delhi and Bhopal is about identical. Railways, roads, and airplanes are all accessible from GUA, one of the major railway junctions, through national highway No. 3 and the North-South corridor. From here, Air India offers daily flights to Delhi and Mumbai. Jabalpur and Bhopal are also linked to the city through air thanks to new aircraft introductions by the Madhya Pradesh government (Ventura). Its position makes it easy to travel by road and train to any area of the nation. Antari, Bilaua, Tekanpur, Debra, and Bhitarwar are more cities and towns that are part of this district. These towns and cities are situated either beside the main national highways or close to the railway lines. Numerous ancient sites, including the Gwalior Fort, Tansensamadhi, Surya Temple, Chhattries of Sindhia, Gurgermahal, Sas-Bahumahal, and Jai Vilas Palace, are situated inside the GUA (702 ft).

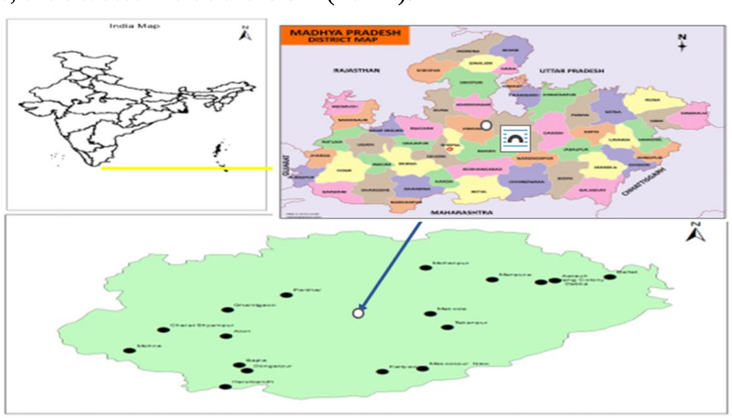

Figure 1: Location map of the Study Area-Gwalior, Madhya Pradesh

III. MATERIALS AND METHODOLOGY

Groundwater is a vital source of freshwater both in urban and rural parts of the world. However, its careless water abstraction and rapidly increasing pollution are posing a severe threat to the sustainability of the world's water supply. A more affordable way to analyze groundwater quality and its variability on a larger scale is to use the Groundwater Quality Index (GQI)-based groundwater quality evaluation. The quality of the ground water was evaluated in this research using a variety of water quality measures. Here is a list of these parameters; 1) pH, 2) Electrical Conductivity, 3) HCO_3, 4) Cl, 5) SO_3, 6) NO_3, 7) F, 8) SiO_2, 9) Total Hardness (TH), 10) Calcium (Ca), 11) Mg, 12) Na.

A. Water Quality Index

A well-liked instrument for assessing the quality of surface water is the water quality indicator (WQI) model. It makes use of aggregation methods to reduce the vast amount of data on water quality to a single value or index. Based on the problem of local water quality, the WQI model has been used globally to approximate water quality (surface water and groundwater). It has gained popularity since its creation in the 1960s as a result of its small size and simplicity of use. The overall organization of WQI models is shown in and demonstrates that the majority of WQIs consist of four key phases, namely:

1) Parameter decision for the water quality monitoring: At least one water quality parameter is chosen.
2) Parameter intensities are transformed to unit-less sub-indices during the creation of the parameter sub-indices.
3) Weight values for the parameters are allocated based on their importance to the evaluation.
4) When computing the water quality index using an aggregation function, the various parameter sub-indices are combined using the weightings to produce a single overall index. Based on the total index score, a rating system is often employed to categorize or classify the water quality.

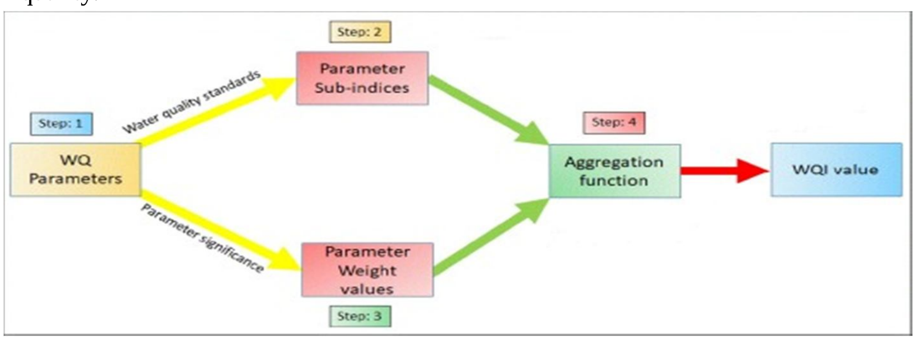

Figure 2: WQI Model Structure

Table 1 Data for Ground Water Quality Parameters

Parameter	Average	Min Value	Max Value	Standard Deviation
pH	7.460556	7.1	7.9	0.245104
EC	864.1667	234	2105	428.6934
CO_2	0	0	0	0
HCO_3	314.1111	91	563	128.2809
Cl	81	12	462	104.8775
SO_4	25.61111	9	90	18.84032
NO_3	28.16667	8	102	22.09139
F	0.698333	0.18	1.4	0.359481
PO4	0	0	0	#DIV/0!
SIO2	31.72222	22	42	5.929047
TH	270.3333	79	723	138.1423
Ca	75.5	20	216	45.21355
Mg	19.5	5	43	12.07452
Na	69.83333	16	185	47.25183
K	2.616667	0.8	15.6	3.432243

Table 2. WQI and their range

WQI	Range
0-25	Excellent
26-50	Good
51-75	Poor
76-100	Very Poor
>100	Unfit for consumption

B. GIS

For the purpose of gathering, organizing, analyzing, and presenting all types of geographically related information for a city, GIS combines hardware, software, and data. A city may view, query, and comprehend data in many different ways thanks to GIS technology. GIS-based maps, reports, and charts make it extremely simple to spot linkages, patterns, and trends. GIS assists in finding solutions to issues and queries. Data about a city is readily understood and shared when displayed in the context of geography. Any city's enterprise information system structure may include GIS technology. With geography serving as a unifying factor across all of these different data sources, GIS offers the unique capacity to a) integrate data from many sources; b) graphically present this data; and c) assist in deciphering patterns and correlations between these data pieces. This would make it much easier to make informed decisions when transforming current cities into smart cities or when creating brand-new smart cities from scratch. GIS may play a crucial role in facilitating government interaction where individuals can voice complaints, provide feedback on the state of municipal infrastructure, and comprehend the remedial measures adopted by the city authorities, in addition to helping cities become more efficient and "green". Additionally, residents have access to municipal master plans and are encouraged to voice their opinions on the development plans. The planning, developing, carrying out, and administration of many activities of a smart city are all covered in this white paper. The principles have been shown with a few instances, however there are other options.

C. Methodology for Spatial Interpolation

A number of interpolation methods, including as IDW, Kriging, and splines, are incorporated right into GIS (Colin, 2004). Mainly, these methods are used in investigations of air pollution (Jha et al., 2011; Wong et al. 2004). Therefore, the most appropriate approach is chosen from the ones listed below depending on the availability of data and the precision with which the concentration of the unknown points can be predicted.

D. Inverse Distance Weighing Method

The Inverse Distance Weighing technique gives more importance to nearby points than far-off ones when determining the values of unsampled locations. In order to operate, IDW requires a densely packed network of evenly spaced observations. The evaluation of weighted moving average is performed here.

The weights are determined by a linear function of the distance between the point sets and the sampled points. For this technique, the beginning point is determined by the size of the region being interpolated. Unknown cell values are determined by averaging the values of sampled points in neighbouring cells. When the related to surface variability that has to be examined is sufficiently big and the point collection is sufficiently dense to capture this variation, IDW is used. It estimates grid numbers using a linear main constraint of a set of data and is a function of two variables: the distance between sampling sites and the place at which the interpolation must be done. (Gunnink and Burrough, 1996). When interpolating pollutant concentrations, data points closer to the interpolation point will be given more weight.

According to the formula, weight decreases as the square of the distance travelled.

$$ZJ = \frac{\sum_{i=1}^{n} WiZi}{\sum_{i=1}^{n} Wi} \text{ And } Wi = \frac{1}{djiP} \quad (1)$$

Where Zj is the significance of intensity at the j^{th} prediction point.

Wi is the weight of the noted i^{th} point.

dji is the gap between the i^{th} point and the j^{th} point.

P is the power, and n is the overall number of nearby locations with known values.

IV. RESULTS AND DISCUSSION

Data has been extracted from the Ground water yearbook 2019 published by Central of ground water board, Ministry of Jal shakti Government of India. Using the ARCGIS software, Spatial Interpolation technique-IDW method has been used for assessing ground water quality of the Gwalior region and generating the geo spatial maps of the area.

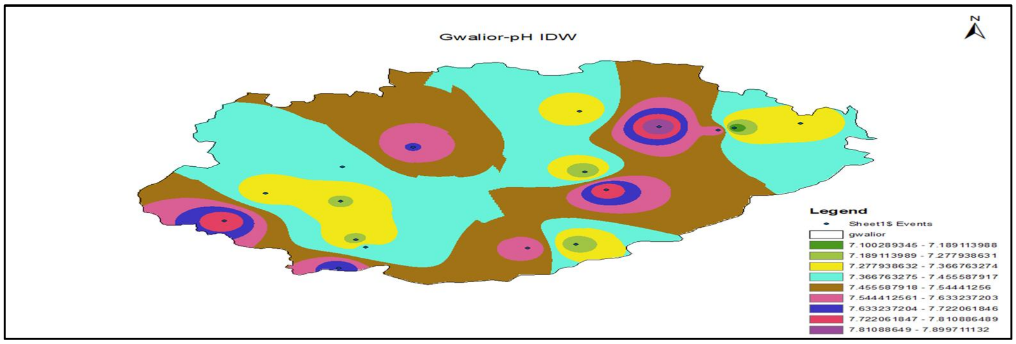

Figure 3: Spatial Interpolation for pH using IDW method

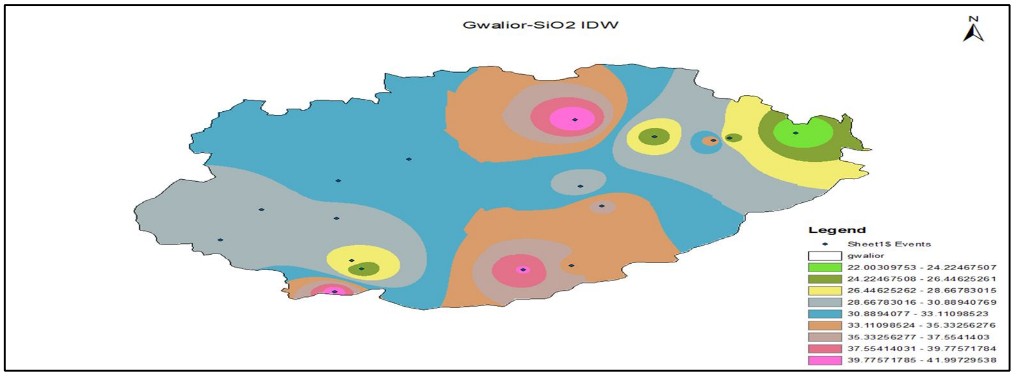

Figure IV: Spatial Interpolation for SiO_2using IDW method

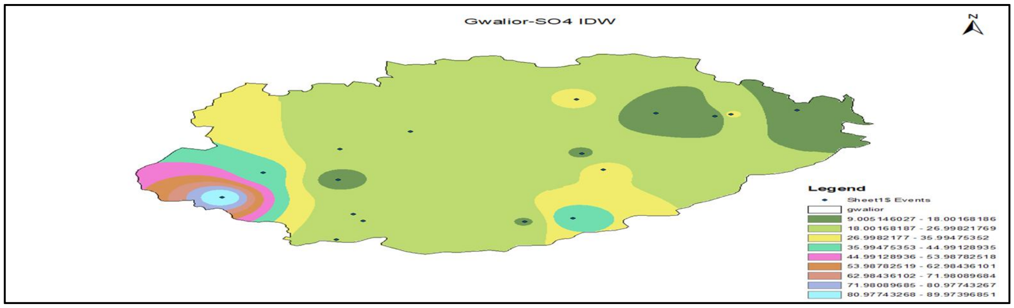

Figure 5: Spatial Interpolation for SO_4 using IDW method

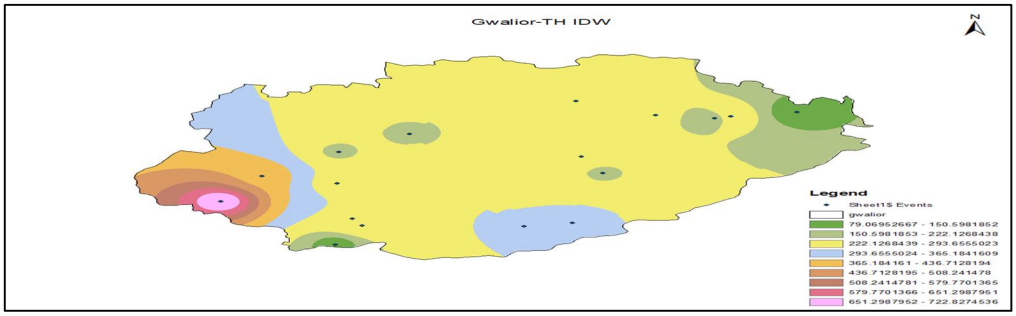

Figure 6: Spatial Interpolation for TH using IDW method

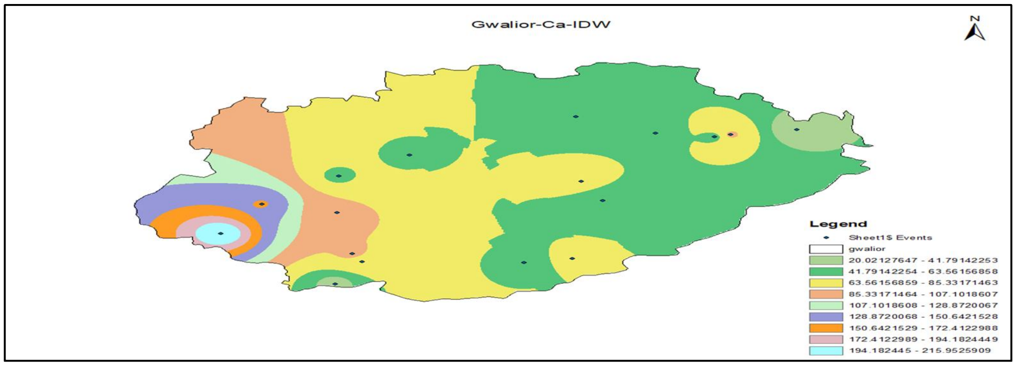

Figure7: Spatial Interpolation for Ca using IDW method

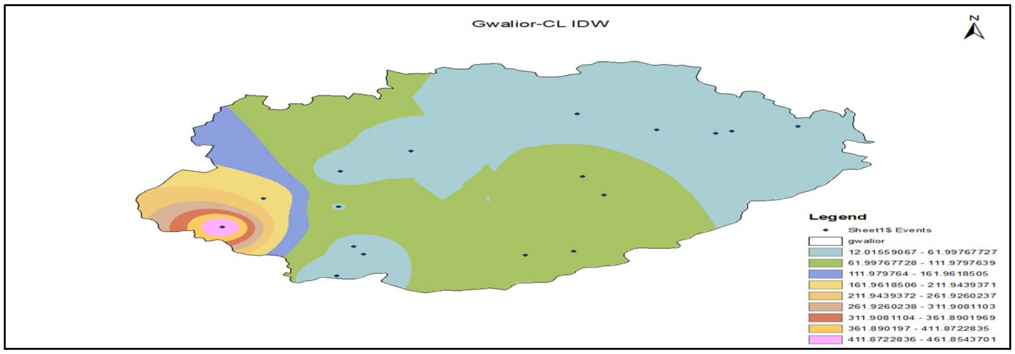

Figure 8 : Spatial Interpolation for Cl using IDW method

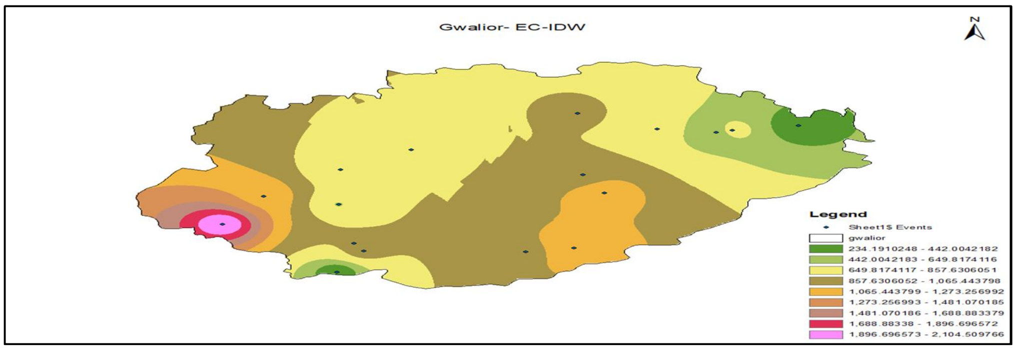

Figure 9 : Spatial Interpolation for EC using IDW method

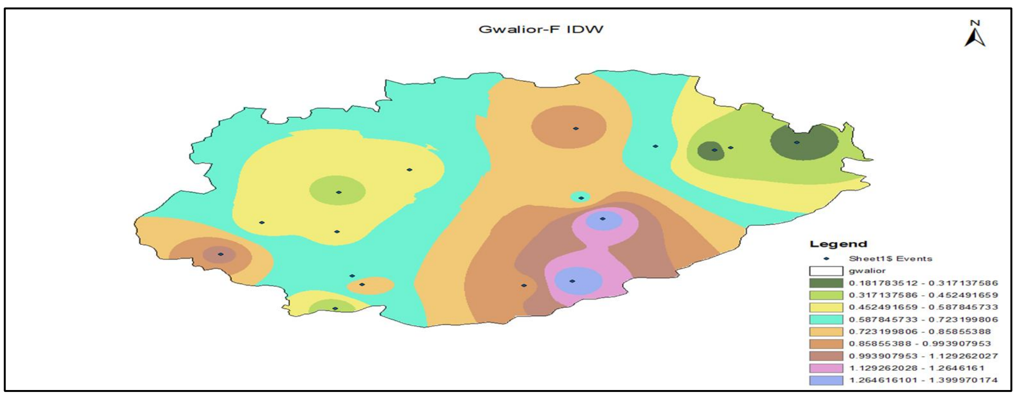

Figure 9: Spatial Interpolation for F using IDW method

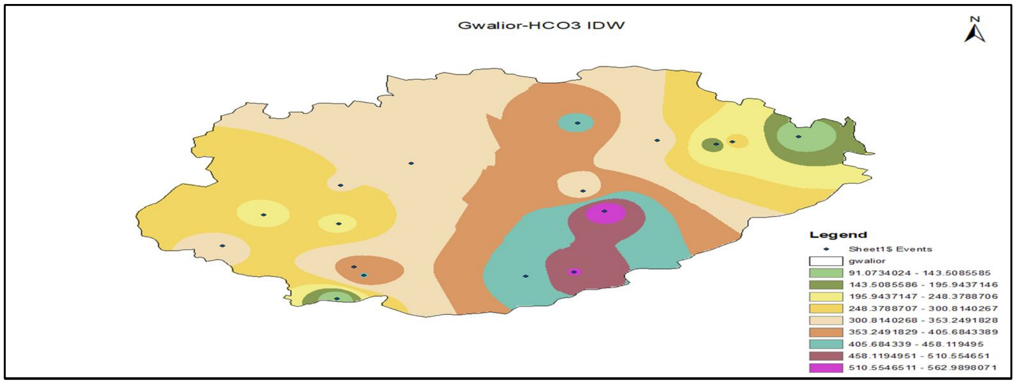

Figure 10: Spatial Interpolation for HCO_3 using IDW method

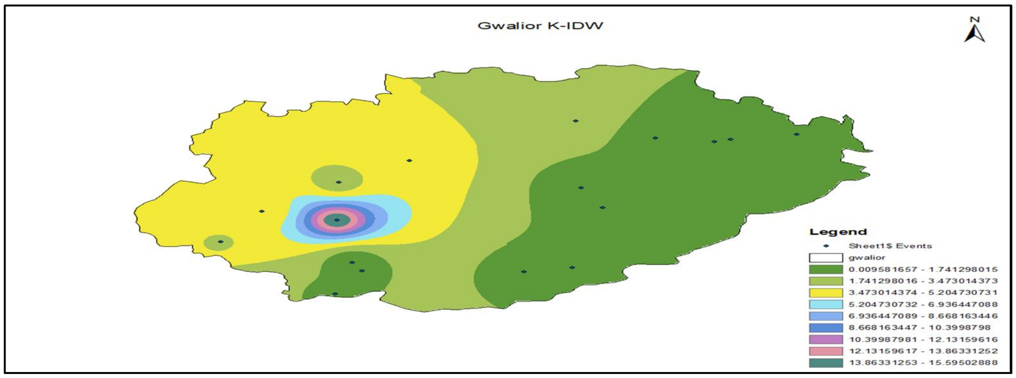

Figure 11: Spatial Interpolation for K using IDW method

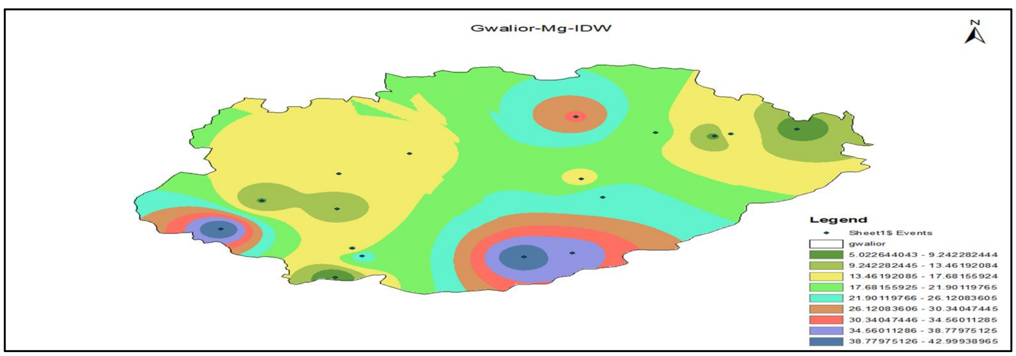

Figure 12: Spatial Interpolation for Mg using IDW method

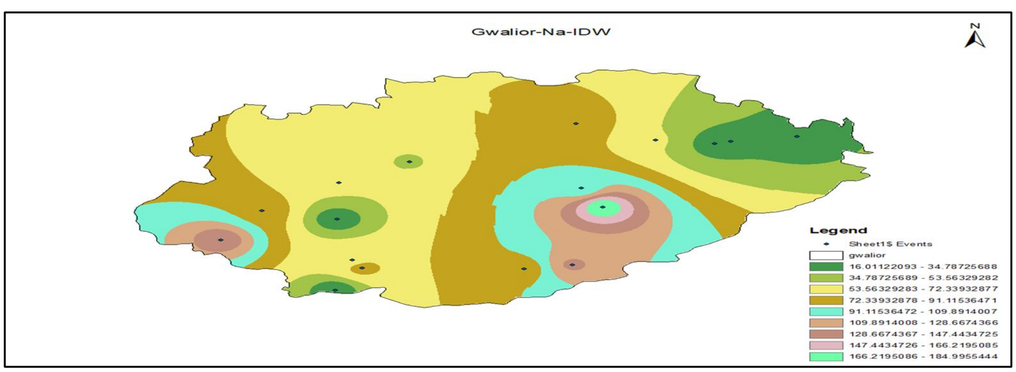

Figure 13 : Spatial Interpolation for Na using IDW method

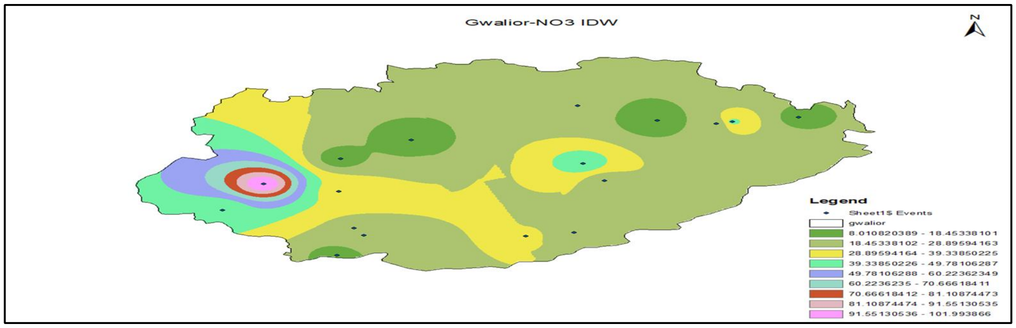

Figure 14: Spatial Interpolation for NO_3 using IDW method

The water quality index was conceived as a means of investigating the interconnected impact that various water quality indicators have on the drinking standard. The water quality index is a numerical figure that is computed as a means of condensing the large amount of data on water quality into a single value. The water quality index is a measurement that determines how many different water quality parameters have contributed to the overall water quality in a given location.

Each of the 12 parameters (pH, Ca, Mg, Na, K, Cl, NO3, F, EC, TH, SiO2, HCO3, and SO4) has been given a weight (wi) in the first stage based on how significant it is to the overall quality of the water for drinking. (Table 5.2).

Table 3: WQI calculation

Parameter	BIS Standard (Sn)	1/Sn	SUM(1/Sn)	K=1/(1/Sn)
pH	8.5	0.117647	1.274869	0.784394318
CL	250	0.004	1.274869	0.784394318
SO4	200	0.005	1.274869	0.784394318
NO3	45	0.022222	1.274869	0.784394318
F	1	1	1.274869	0.784394318
SIO2	1000	0.001	1.274869	0.784394318
TH	200	0.005	1.274869	0.784394318
Ca	200	0.005	1.274869	0.784394318
Mg	100	0.01	1.274869	0.784394318
Na	200	0.005	1.274869	0.784394318
K	10	0.1	1.274869	0.784394318

1) Step 1

$$K=1/(\Sigma 1/SN)$$

The following expression is used in the second stage to determine the relative weight (W_i):

Wi = wi / 1 n i wi = ∑ Where, W_i = The relative weight

Wi = The importance of each variable

and n = parameters.

2) Step 2

$$Q_{Ph} = (V_{pH}-7)/(8.5-7)*100$$

In the third step, a quality rating scale, or qi, is assigned to each parameter. This is done by dividing the parameter's concentration for each sample by the standard associated with that concentration, applying the specifications provided by the Bureau of Indian Standards, and then multiplying the resulting number by 100.

$q_i = (C_i/S_i) *100$

Table IV: The relative and actual weights of the various chemical parameters

wi=k/Sn	Ideal Value	Mean Value (V_n)	V_n/S_n	$100(V_n/S_n)$
0.09228168	7	7.460555556	0.307037	30.7037
0.00313758	0	81	0.324	32.4
0.00392197	0	25.61111111	0.128056	12.80556
0.01743098	0	28.16666667	0.625926	62.59259
0.78439432	0	0.698333333	0.698333	69.83333
0.00078439	0	31.72222222	0.031722	3.172222
0.00392197	0	270.3333333	1.351667	135.1667
0.00392197	0	75.5	0.3775	37.75
0.00784394	0	19.5	0.195	19.5
0.00392197	0	69.83333333	0.349167	34.91667
0.07843943	0	2.616666667	0.261667	26.16667

3) Step 3

$$WQI=\Sigma(W_nQ_n)/\Sigma(W_n)$$

Table 5 WQI value calculation for the region

BIS Standard (Sn)	1/Sn	SUM(1/Sn)	K=1/(1/Sn)	$w_i = k/S_n$	Ideal Value	Mean Value (V_n)	Vn/Sn	$100(V_n/S_n)$	$W_n.Q_n$
8.5	0.117647	1.274869	0.784394318	0.09228168	7	7.460555556	0.307037	30.7037	2.833389
250	0.004	1.274869	0.784394318	0.00313758	0	81	0.324	32.4	0.101658
200	0.005	1.274869	0.784394318	0.00392197	0	25.61111111	0.128056	12.80556	0.050223
45	0.022222	1.274869	0.784394318	0.01743098	0	28.16666667	0.625926	62.59259	1.091051
1	1	1.274869	0.784394318	0.78439432	0	0.698333333	0.698333	69.83333	54.77687
1000	0.001	1.274869	0.784394318	0.00078439	0	31.72222222	0.031722	3.172222	0.002488
200	0.005	1.274869	0.784394318	0.00392197	0	270.3333333	1.351667	135.1667	0.53012
200	0.005	1.274869	0.784394318	0.00392197	0	75.5	0.3775	37.75	0.148054
100	0.01	1.274869	0.784394318	0.00784394	0	19.5	0.195	19.5	0.152957
200	0.005	1.274869	0.784394318	0.00392197	0	69.83333333	0.349167	34.91667	0.136942
10	0.1	1.274869	0.784394318	0.07843943	0	2.616666667	0.261667	26.16667	2.052498
-				1.0000002	7	612.4422222	4.65007	465.007	61.8763

The water quality index calculated for the period exhibited poor quality for the Gwalior region.

V. CONCLUSION

The goal of the current research was to assess and describe the groundwater quality in the study region, typically for drinking purposes. To show the change in the spatial pattern of the groundwater quality in the research region, a GIS-based water quality index approach has been used. When compared to IS 10500 norms, the water quality index derived for the aforementioned time showed a higher proportion of poor quality. This had suggested excessive rock salt extraction, dissolving, and concentration, as well as human activities such industrial effluent discharge, excessive fertilizer and pesticide usage in agriculture, and incorrect residential waste disposal into possible river systems and water streams. It is advised to develop appropriate artificial recharge structures in places where natural recharge is inadequate in order to increase the groundwater potential on both a qualitative and quantitative level. It has been found that level of total hardness, calcium (Ca) and chloride ion is beyond the permissible limit near Mohna area. Fluoride ion is also above the level of standard near Masoorpur and Kariywati area. Magnesium level is also increased in nearby places of kariyawati in Gwalior region.

It has also been found that sodium level in the water is above the permissible limit of drinking water in nearby places of Tekarpur of Gwalior region. From the above interpolated graphs, it is recommended that places where pollutant levels are not within the permissible limit, shall be recommended for fresh water supply by other alternative sources. Supply of alternative source of water in these regions of Gwalior can avoid the upcoming disaster of diseases in Gwalior city. Mitigation measures and water treatment facility for the supply of clean drinking water shall be taken for these recommended areas.

Table 6: Result for water quality parameter and its comparison with IS 10500 standards (Drinking water standards)

Sr. No.	Parameter	Actual Result (Range for Gwalior region)	IS 10500 :2012 (Standards)/ BIS standard
1.	pH	7.1-7.89	6.5-8.5
2.	SiO_2	22.00-41.99	1000
3.	SO_4	9.005-89.97	200
4.	TH-Total Hardness	79.06-722.0	200
5.	Ca	20.02-215.95	75
6.	Cl	12.01-461.85	250
7.	EC	234.19-2104.50	-
8.	F	0.18-1.399	1.0
9.	HCO_3	91.07-562.98	-
10.	K	0.009-15.59	10
11.	Mg	5.02-42.99	30
12.	Na	16.01-184.99	200
13.	NO_3	8.01-101.99	45

The created groundwater quality index map in this research is simple to understand and transmit information about water quality to the beneficiaries and local management, making it feasible for groundwater to be used and managed properly. The approach used in this study's methodology is readily transferable to different fields for the enhancement and design of effective groundwater usage and management policies to ensure appropriate utilization and avoid groundwater quality deprivation. Therefore, it is evident from this research that the GIS and the water quality index approach are promising instruments for managing and mapping hydro chemical characteristics, assessing the water quality, and appropriately recommending remedial actions.

REFERENCES

[1] ESRI, 2015 ArcGIS Desktop 10.5 Help.
[2] Ground Water Yearbook - Madhya Pradesh (2019-20), Central Ground Water Board, Ministry of Jal Shakti, Government of India
[3] Madan Kumar Jha, Ankit Shekhar, M.Annie Jenifer 1 July 2020, Assessing Groundwater quality for drinking water supply using hybrid fuzzy-GIS-based water quality index
[4] I.S. babiker, M.A. Mohamed, T.Hiyama 2007, Assessing Groundwater quality using GIS
[5] Indian Standard for Drinking Water: Specification (Second Revision)
[6] P.W. Bolton, 1978, Index to improve water quality classification
[7] Sadi, S.S., Vuppala, P., Reddy, A.M.A., 2007. Remote Sensing and Techniques for evalution of Ground water quality in municipal Corporation of Hyderabad (Zone-V) India. International journal of environmental Research and public Health, 4(1), 45-52.
[8] Balakrishnan, P., Salaam, A., and Mallikarjun, N.D., 2011. Groundwater quality mapping using geographic information system (GIS). A case study of Gulbarga City, Karnataka, India. African Journal of Environmental Science and Technology. Vol. 5(12), 1069-1084.
[9] Razmkhah, Homa & Mohammadi, Eisa & Rostami Ravari, Amin & Fararouie, Alireza. (2022). Comparing interpolation techniques of groundwater quality mapping in different seasons.
[10] Sham, Noraishah & Anual, Zurahanim & Shaharudin, Rafiza. (2022). GIS based interpolation method to urinary metal concentrations in Malaysia. Food and Chemical Toxicology. 163. 112949. 10.1016/j.fct.2022.112949.
[11] Balaji, L. & Muthukannan, Muthiah & Devi, R.Kanniga. (2022). A GIS-Based Study of Air and Water Quality Trends in Madurai City, India. Nature Environment and Pollution Technology. 21. 21-32. 10.46488/NEPT.2022.v21i01.003.
[12] Nadirsha Nawab, Athira Santhosh, "GIS-Based Interpolation Approach for Mapping Groundwater Quality Parameters for Sustainable Water Management", Water and Energy International 64, December 2021.
[13] Ahmad, Ayesha & Saleh, Imane & Perumal, Balakrishnan & Al-Ghouti, Mohammad. (2021). Comparison GIS-Based Interpolation Methods for Mapping Groundwater Quality in the State of Qatar. Groundwater for Sustainable Development. 13. 100573. 10.1016/j.gsd.2021.100573.
[14] Sinha, Manish & Rajput, Preeti & Baier, Klaus & Azzam, Rafig. (2021). GIS-Based Assessment of Urban Groundwater Pollution Potential Using Water Quality Indices. 10.1007/978-3-030-68124-1_15.

[15] Nawab, Nadirsha & Santhosh, Athira & Abubakar, Gado & Muthukumar, Anbazhagi & Muthuchamy, Muthukumar. (2021). GIS-Based Interpolation Approach for Mapping Groundwater Quality Parameters for Sustainable Water Management. Water and Energy International. 64.
[16] Khouni, Imen & Louhichi, Ghofrane & Ghrabi, Ahmed. (2021). Use of GIS based Inverse Distance Weighted interpolation to assess surface water quality: Case of Wadi El Bey, Tunisia. Environmental Technology & Innovation. 24. 101892. 10.1016/j.eti.2021.101892.
[17] Nagarajan, M. & Gauns, Arvind & Lalitha, R. & Baskar, M. (2020). GIS-based Assessment of Groundwater Quality for Drinking and Irrigation by Water Quality Index. International Journal of Current Microbiology and Applied Sciences. 9. 2361-2370. 10.20546/ijcmas.2020.903.269.
[18] Tiwari, Kuldeep & Goyal, Rohit & Sarkar, Archana. (2017). GIS-Based Spatial Distribution of Groundwater Quality and Regional Suitability Evaluation for Drinking Water. Environmental Processes. 4. 10.1007/s40710-017-0257-4.
[19] Ahmad, Engr. Mehmood & Wajid, Abdul & Khan, Mehmood & Shakoor, Aamir & Abbas, Qalib. (2016). Evaluate Different Interpolation Techniques In Gis For Ground Water Quality Mapping.
[20] Radhakrishnan, Nagalakshmi & Prasanna, K. & Chandar, S.. (2016). Water quality analysis using gis interpolation method in serthalaikadu Lagoon, east coast of India. 9. 634-640.
[21] Gharbia, Abdalkarim & Gharbia, Salem & Abushbak, Thaer & Wafi, H.N. & Aish, Adnan & Zelenakova, Martina & Pilla, Francesco. (2016). Groundwater Quality Evaluation Using GIS Based Geostatistical Algorithms. Journal of Geoscience and Environment Protection. 4. 89-103.
[22] Teli.Muzaffar, & Kuchhay, Nisar & A Rather, Manzoor & Ahmad, umar Firdous & Malla, Muzaffar & Dada, Mudasir. (2014). Spatial Interpolation Technique For Groundwater Quality Assessment Of District Anantnag J&K. International Journal of Engineering research and Development,. 10. 55-66.
[23] Kumar, Mogaraju & Sunitha, V. & Reddy, M.Ramakrishna. (2013). Determination of an optimal interpolation technique to represent the spatial distribution of groundwater quality at urban and peri-urban areas of Proddatur, Y.S.R district, Andhra Pradesh, India. INTERNATIONAL JOURNAL OF GEOMATICS AND GEOSCIENCES. 4.
[24] S, Selvam & Manimaran, G & Sivasubramanian, Poovalingam & Balasubramanian, Nagarajan & T, Seshunarayana. (2013). GIS-based Evaluation of Water Quality Index of groundwater resources around Tuticorin coastal city, south India. Environmental earth sciences. 71. 10.1007/s12665-013-2662-y.
[25] Jha, Dilip & Das, Anup & Saravanane, N. & Nazar, A.K Abdul & Kirubagaran, Ramalingam. (2010). Sensitivity of GIS-based interpolation techniques in assessing water quality parameters of Port Blair Bay, Andaman. Journal of the Marine Biological Association of India 0025-3146. 52. 55-61.
[26] Morio, Maximilian & Finkel, Michael & Martac, Eugen. (2010). Flow guided interpolation - A GIS-based method to represent contaminant concentration distributions in groundwater. Environmental Modelling and Software. 25. 1769-1780. 10.1016/j.envsoft.2010.05.018.
[27] Nas, Bilgehan & Berktay, Ali. (2009). Groundwater Quality Mapping in Urban Groundwater Using GIS. Environmental monitoring and assessment. 160. 215-27. 10.1007/s10661-008-0689-4.