Groundwater Quality Assessment Using Water Quality Index and GIS: A study of Vishwamitri Watershed, Gujarat

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Abstract :

Water supply in India is going to be a serious challenge due to various reasons. The most serious concern is the growing population which is likely to increase to 1.66 billion by 2050. The per capita water availability in the country as a whole is reducing progressively due to increase in population. The average annual per capita availability of water in the country, taking into consideration the population of the country as per the 2001 census, was 1816 cubic meters which decreased to1545 cubic meters as per the 2011 census.

Ground water is the main sources of water for drinking, industrial and domestic purposes and often, it is over exploited. Groundwater quality is therefore a major environmental aspect which needs to be analysed and managed depending on its spatial distribution. Also, continuous monitoring of groundwater is required by establishing a planned monitoring network in the study area for regular assessment of the WQI which will be useful in proper management of the water resource.

The main goal of WQI is to transform complicated water quality data in an informative way which is easy to understand and commonly used by the people. Basing on several factors, WQI can give a simple note on water quality. By this a particular idea is generated in public regarding the issues of water quality in a specific region. Water quality index (WQI) is a very promising tool for evaluation. Generally, the WQI and Geographic Information System (GIS) are used to evaluate and map the spatial distribution of groundwater quality.

Hence, the study of Water Quality Index of Vishwamitri watershed was computed using Geospatial technology. Water quality for 10 parameters such pH, Alkalinity, TDS, Hardness Calcium, Magnesium, Nitrate, Sulphates, Chloride, and Fluoride for two times period 2010-11 and 2016-17 are compared for water quality estimation. Water Quality Index maps are also generated. This study intends to demonstrate the utility of GIS combined with analytical data to assess and mapping of groundwater quality.

Index Terms- Geo-Spatial, Ground Water, Spatio-temporal variation, WQI, Vishwamitri watershed

I. INTRODUCTION

Utilization of land varies from place to place due to rapid urbanization and industrialization, without following the strict environmental norms, causing a lot of variation of quality of groundwater within a short distance, which constrains the developmental activities drastically everywhere (SubbaRao 1997, 2006). The urban aquifers are the only natural resource for drinking water supply, they are often perceived as of lesser relevance for the drinking water supply, leading to crisis in terms of drinking water scarcity, becoming increasingly polluted thereby decreasing their potability (Dixit et al. 2005; Tiwari et al. 2012). Once contamination of groundwater in aquifers occurs by means of industrial activities and urban development, it persists for hundreds of years because of very slow movement of water in them (Jerry 1986) and prompts investigations on their quality.

Water Quality Index is an important factor to judge environment changes, which are strongly associated with social and economic development. This index allows a general analysis of water quality on many levels and provides a numeral value to designate the overall water quality at a certain location. This was derived by weightages arithmetic method. It is one of the most effective ways to communicate information on water quality trends to policy makers to shape strong public policy and implement the water quality programs. WQI is defined as a rating that reflects the composite influence of different water quality parameters.
For creating the spatial distribution maps, GIS has emerged as a powerful tool. GIS can be used for storing, displaying, and analyzing spatial data. By using this data, we can make decisions in several areas including environmental and engineering field

GIS is an effective tool for groundwater quality mapping and essential for monitoring the environmental change detection. A study on Ground Water Quality mapping in Municipal Corporation of Hyderabad using GIS techniques was done by S.S. Asadi; et.al. (2007.Other studies have used GIS as a database system in order to prepare maps of water quality according to concentration values of different chemical constituents. In such studies, GIS is utilized to locate groundwater quality zones suitable for different usages such as irrigation and domestic Babiker et al., proposed a GIS-based groundwater quality index method which synthesizes different available water quality data by indexing them numerically relative to the BSI standards. The use of GIS technology has greatly simplified the assessment of natural resources and environmental concerns, including groundwater. Researchers S. Krishnaraj et al,(2015) B.Bhatt et al 2011a and b, A. Ambica et al 2017, P Anil Kumar et al, 2017 and others have applied GIS and WQI for different areas.

Study Area:
Vishwamitri River, which falls in the semi-arid region of Gujarat alluvial plain, is a major tributary of the Dhadhar river basin. Located in eastern part of Gujarat, river originates from Pavagadh hill at about 22º.28´ N latitude and 73 º.45´ E longitude at elevation of more than 600 m. The total length of the river from the head to its outfall into the Dhadhar is about 80km.Vishwamitri watershed is located in the centre of the golden corridor is witnessing rapid industrialization, urbanization and

shift from primary to secondary activity. There is thus increased pressure on land, water and environment. A major area of the upstream basin is dominantly under agricultural use. This is under continuous stress of transformation owing to increase in land price and expansion of the built-up area from Halol town and Vadodara city. In addition, the industrial area between Vadodara – Halol beside the highway is developing as a stretch of a major industrial hub. Downstream: Lower catchment falls in the urban area of Vadodara city as it flows for about 28km from the Vadodara city (urban stretch) has a special impact.

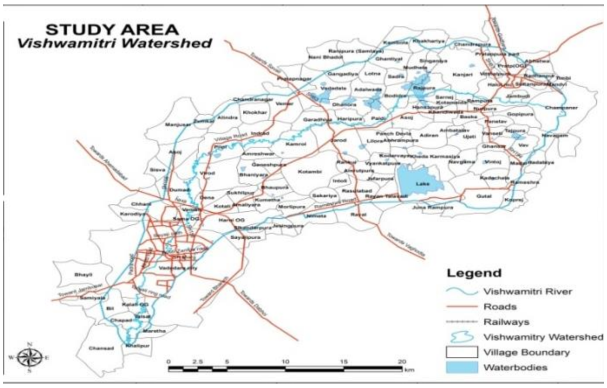

Fig.-1 Map of the Study Area

Objectives :

1) To analyse the ground water quality
2) Determination of water quality index by using statistical approach.
3) To create spatial maps for water quality and highlight the areas under environmental stress.

Methodology:

The study uses a secondary source of groundwater samples were collected from a deep tube well. (CGWB). A total of 75 in 2010-11 and in 2016-17 water samples from different sites in Savali, Waghodia, Vadodara Taluka in Vadodara District and Halol Taluka in Panchamahal District. Water samples were analyzed for 10 chemical parameters as such pH, Alkalinity, TDS, Hardness Calcium, Magnesium, Nitrate, Sulphates, Chloride, and Fluoride are considered for water quality estimation using the BIS method.

All geo-processing has done using ArcGIS 10.1 software. All thematic layers are prepared and integrated into the GIS environment. These layers are reclassified by assigning suitable weights to each thematic feature after considering their relative contribution characteristics towards the groundwater pollution. The datasets derived have different degrees of influence on groundwater pollution. In this method, the weights assigned to the different layers according to their suitability.

Estimation of water quality index (WQI)

In this study the WQI was calculated by Horton's Method using the standards of drinking water quality recommended by BIS (2nd revision of IS 10500; 2004). The weighted arithmetic index method has been used for the calculation of WQI. Total 10 parameters (such pH, Alkalinity, TDS, Hardness Calcium, Magnesium, Nitrate, Sulphates, Chloride, and Fluoride) were selected for calculating the WQI. (Figure 2)

There be n water quality parameters where the quality rating or sub index (qn) corresponding to the nth parameter is a number reflecting the relative value of this parameter in the polluted water with respect to its standard permissible value. The value of qn is calculated using the following expression:

$$qn = 100[(Vn-Vid)/(Sn-Vid)] \qquad (1)$$

Where,

qn = quality rating for the nth water quality parameter.
Vn = observed value of the nth parameter.
Sn = standard permissible value of nth parameter.
Vid = ideal value of nth parameter in pure water.

All the ideal values (Vid) are taken as zero for drinking water except for pH=7.0

Calculation of quality rating for pH

For pH the ideal value is 7.0 (for natural water) and a permissible value is 8.5 (for polluted water). Therefore, the quality rating for pH is calculated from the following relation:

$$qpH = 100[(VpH-7.0)/(8.5-7.0)]$$

Where,

VpH = observed value of pH during the study period.

Calculation of unit weight (Wn)

Calculation of unit weight (Wn) for various water quality parameters are inversely proportional to the recommended standards for the corresponding parameters.

Wn = K/Sn

Where,
Wn = unit weight of nth parameters
Sn = standard value for nth parameters
K = constant for proportionality and is given as
K=1/ [∑1/ Sn= 1,2,………..5n]

Calculation of WQI
WQI is calculated from the following equation n n

$$WQI=\sum^{n} q_n W_n/\sum^{n} W_n$$

Result and Discussion:
The statistical parameters like minimum and maximum concentration of physico-chemical parameters, major ion concentrations are tabulated in Table 1.

	2010-11		2017		BIS standard (1991)
Water Quality Parameter	Minimum	Maximum	Minimum	Maximum	
pH	7.38	8.35	7.13	8.49	6.5–8.5
Alkalinity(Mg/l)	152	808	28	600	200
TDS(Mg/l)	230	2814	102	1726	500
Hardness(Mg/l)	76	880	24	600	300
Calcium(Mg/l)	11	131	8	99	75
Magnesium(Mg/l)	12	132	1	100	30
Nitrate (Mg/l)	0.8	160.32	0.34	44.89	45
Sulphates(Mg/l)	2	710	1.16	145.08	200
Chloride(Mg/l)	10	760	8	640	250
Fluoride(Mg/l)	0.31	2.84	0.06	1.48	

Table 1 Concentration of selected physico-chemical parameters

1. pH: The pH indicates the strength of the water to react with the acidic or alkaline material present in the water. It controls by carbon dioxide, carbonate and bicarbonate equilibrium (Hem 1985). The combination of CO2 with water forms carbonic acid, which affects the pH of the water. The permissible limit of pH is 6.5–8.5.The value of pH in watershed is within permissible limits
2. Alkalinity: It is the ability of water to kill corrosive. When a water body has a high alkalinity, it can limit pH changes due to acid rain, pollution or other factors. The alkalinity of a stream or other body of water is increased by carbonate-rich soils (carbonates and bicarbonates) and decreased by sewage outflow and aerobic respiration.

3.Total dissolved solids (TDS): Total dissolved salts in the groundwater is between 373.52 and 4,669 mg/l.The occurrence of high TDS is due to the influence of anthropogenic sources, such as domestic sewage, septic tanks and agricultural activities. According to WHO, TDS up to 500 mg/l is the highest desirable and up to 1,500 mg/l is maximum permissible. Overall TDS is significantly higher in area.

4. Total hardness (TH) The classification of groundwater based on total hardness (TH) shows that a majority of the ground water samples fall in the hard water category. The maximum allowable limit of TH for drinking purpose is 500 mg/l and the most desirable limit is 100 mg/l as per the WHO standard. Groundwater exceeding the limit of 300 mg/l is considered to be very hard. The study area has very hard water as the limits exceeds significantly.

5. Calcium and Magnesium (Ca and Mg): calcium and magnesium in waters are generally used to classify the suitability of water. Calcium and magnesium are directly related to hardness of the water and these ions are the most abundant elements in the surface and groundwater and exist mainly as bicarbonates and to a lesser degree in the form of sulphate and chloride.. The concentration of Ca2 is between 11 mg/l to 131 mg/l, and 8 mg/l to 99 mg/l in 2011 and 2017 respectively while concentration of Mg2 varied

from 12 mg/l to 132 mg/l and between 1 mg/l to 100 mg/l. Although the overall concentration of Ca and Mg have reduced but they are still above permissible limits

6. Nitrate: Nitrogen compounds are the most widespread contaminants in subsurface environments, mainly originating from agricultural sources. Epidemiological evidence suggests that nitrogen exposure is strongly associated with several diseases, such as methemoglobinemia (blue baby syndrome), gastric cancer, thyroid disease and diabetes (Krishna Kumar et al., 2011).The value was very high in 2011 but is within permissible limits in 2011

7. Sulphate (SO4): The concentration of sulphate is likely to react with human organs if the concentration exceeds the maximum allowable limit of 400 mg/l and causes a laxative effect on human system with the excess magnesium in groundwater. However, the sulphate concentration in groundwater of the study area is within the maximum allowable limit in the entire sample.

8. Chloride (Cl) The chloride ion is the most predominant natural form of the element chlorine and is extremely stable in water. The chloride in groundwater may be from diverse sources like, domestic, municipal effluents etc. The range of chloride is found to vary between 10 to 760 in 2011 and 8-260 mg/l in 2016-17 for water samples. As per Indian standards (BIS, 1991) the desirable limit for chloride is 250 mg/l. For the study area it has been found that in certain locations the chloride concentration exceeds the maximum permissible limit

9. Fluoride: Groundwater usually contains fluoride dissolved by geological formation. Fluoride is beneficial for human beings as a trace element; this protects tooth decay and enhances bone development, in combination with exposure to fluoride from other sources, can give rise to a number of adverse effects. The desirable limit of Fluorides is 0.5 - 1.5 mg/l, beyond this limit the water is considered as poor quality. Fluoride may be kept as low as possible. High fluoride may cause fluorosis. In the study area fluoride content is high.

Parameter	**Standard Permissible Value (Sn)**	**1/Sn**	**Unit Weight**
pH	8.5	0.118	0.084
Hardness (mg/l)	300	0.003	0.002
Nitrate (mg/L)	45	0.022	0.016
Fluoride (mg/L)	1.0	1.000	0.711
Chloride (mg/L)	250	0.004	0.003
Sulphate (mg/L)	200	0.005	0.004
Alkalinity (mg/l)	200	0.005	0.004
Calcium (mgl)	75	0.013	0.009
Magnesium (mg/l)	30	0.033	0.024
TDS (mg/L)	500	0.002	0.001

Table 2. Drinking water standards, recommending Indian Standard (BIS) and unit weights

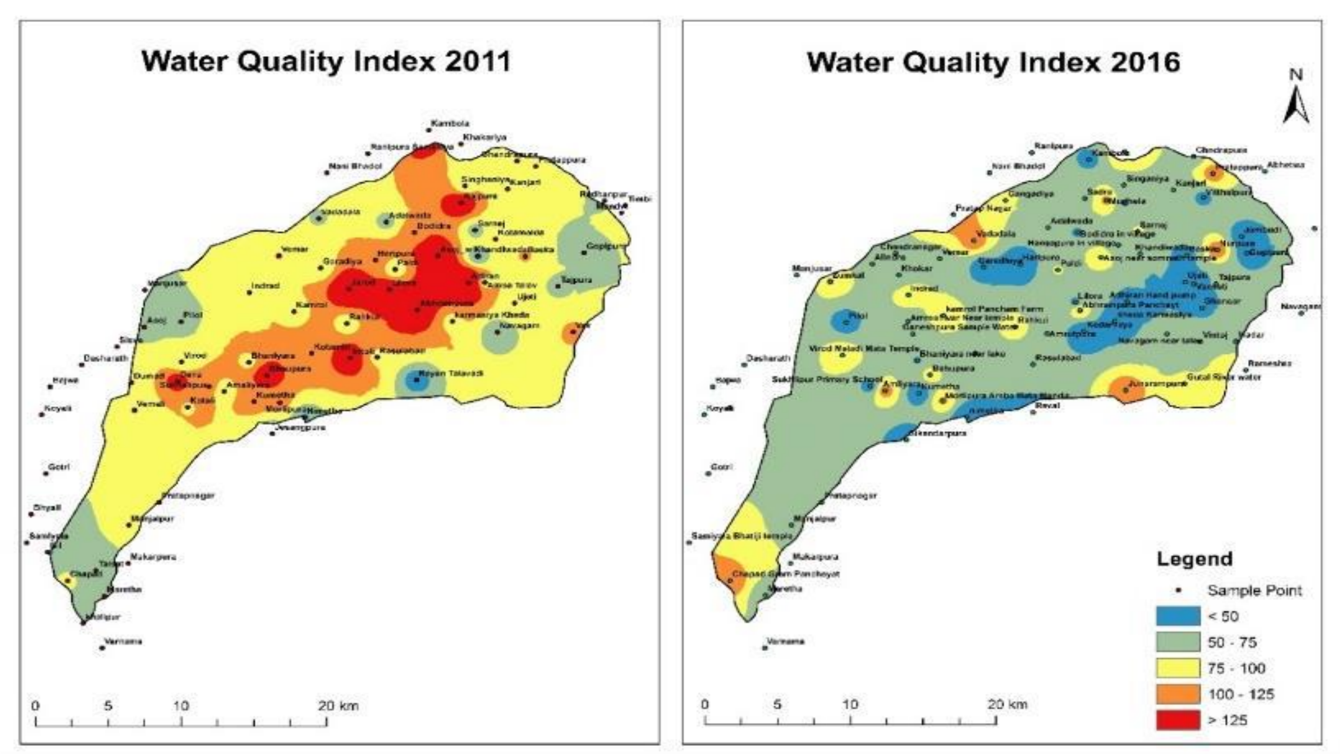

Fig.2 Water Quality Index

WQ Value	WQ Status
<50	Excellent
50-75	Good
75-100	Poor
100 -125	Very Poor
> 125	Unfit For Drinking

Table 3 Water quality classification based on WQI value

Conclusion:

Water quality has shown slight improvement but still there are some parameters which are higher than prescribed limits .Awareness and attitude change is a priority to be instilled in the authorities and the community. The entire improvement process can take decades, but gradual progress is better than no progress at all. The study demonstrates the potentials of spatial analysis and interpretations of the groundwater quality of the study area using GIS methodology. A geographical information system is developed for spatial analysis and mapping of the groundwater characteristics. GIS can be used as an effective tool for developing solutions for water resources problems for assessing and mapping of ground water quality, understanding the natural environment and managing water resources on a required scale, assessing groundwater vulnerability to pollution

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