GIS Based Ground Water Quality Index (GWQI) of Jashpur District, Chhattisgarh, India

Leelambar Singh¹ and J. Jacinth Jennifer²
¹Department of Civil Engineering, National Institute of Technology, Tiruchirappalli, Tamil Nadu, INDIA
²Department of Civil Engineering, National Institute of Technology, Tiruchirappalli, Tamil Nadu, INDIA
E-mail: leeli.singh@gmail.com

Abstract: Ground water is a very important source of drink water in all over the world. The dependency and protection are very necessary on the ground water with the rapid development of industrial and agriculture sector, and due to that, it is needs greater than before. Therefore, the chemical fertilizers, chemical dumping, sewage dumping, untreated effluent runoff from industrial sectors, domestic sewage waste etc., affect ground water quality. Hence, it is necessary to investigate ground water quality as human health impacted by contamination. In this study, we have investigated the ground water quality of Jashpur district of Chhattisgarh, India. Ground water quality parameters like pH, electric conductivity (EC), hardness, calcium (Ca), magnesium (Mg), sodium (Na) etc. of 39 different sites were taken and compare concerning World Health Organization (WHO) water standards by using GIS techniques within the study area. Geographical information system (GIS) is an effective tool to monitor and investigate the status of ground water quality, and results are efficient for assessment of ground water. This analysis indicates that the south-west of study area needs to be protection from contamination.

Keywords: Ground water, GIS, spatial analysis, water quality.

1. INTRODUCTION

Ground Water is the most important nature source in the earth for the survival of life and economic development (e.g., Zektser 2000; Steube et al. 2009). It is very difficult to visualize the existence of life without this resource. Knowing this fact, People are continuously polluting the water without considering the sustainability. Now, Drinking water is a most critical issue all over the world and many countries facing this problem. Ground water is an important and limited source for drinking where surface water resources are significantly low. Ground water fully depends upon the hydrological process (Quality of recharge water, precipitation, and infiltration). In India, around 85 % water depends upon ground water resources and 65 % water used for the irrigation purpose. Water pollution not only affects the quality of water but it also influences the human health and economic and social development (Miloanovic 2007; Tiwari 2015). Since from past decades, India’s reducing its ground water resources quality and quantity both through many driving factors. Ground water contamination is mostly affected by the natural and human activities. Ground water is greatly affected due to urbanization, industrialization and agriculture activities (Jat et al. 2009; Bouwer 2000; Evans and Sadler 2008). In India most of the regions which are facing scarcity of water problem and over dependency on ground created huge water demand for agriculture, domestic, industrial area has resulted in misuse in different state of India such as Haryana, Panjab, Uttar Pradesh, Gujrat and Tamil Nadu among others (Yadav et al. 2003; CGWB 2006; Garg and Hassan 2007; Rodell et al. 2009). Monitoring of quality parameters is giving an idea for the assessment of the particular ions. Water Quality Index is one of the best tools for the evaluate the ground and surface water quality (Abassi 1999; Pradhan et al. 2001). The study area (Jashpur district), situated in hill terrain of Chota-Nagpur plateau Nearly 90 % of area covered with granitoids and remaining area is occupied by deccan trap, laterite and lametias. The quality of ground water has also worsened due to the excessive use of ground water and agriculture activities in many district of Chhattisgarh, including Jashpur district. Thus, there is an urgent need to seriously measure the quality of ground water in most parts of India to ensure the sustainable use of important groundwater resources (including the study area). A WQI should be specific to a water use or a set of goals (Schultz 2001). Despite the fact that a correct evaluation water quality is mandatory for sustainable water resource management, one is accepted globally, the cost-effective and easily constructed groundwater quality index is presently lacking (Hueting 1991). Besides, water quality is sometimes difficult evaluate a large number of sample
points (Chapman 1992; Pesce and Wunderlin 2000). Although there are no hard and fast rules for this
Construction of Water Quality Index, two steps generally necessary first, it is necessary that choose a
group of water quality standards that measure important physical, chemical and microbiological water
characteristics. The selection of water quality parameters will depend upon the usefulness of water.
Once it is selected and scientific characteristics are known, a rule is necessary to summarise all
information into quality index (unique number). Provencher and Lamontagne (1977) proposed one
pioneering Water Quality Index. It is based on several parameters using the same changes, generally
but not always linear,

Geographical information system (GIS) has a powerful tool for the capturing, storing, analyzing and
displaying the spatial information data and using these data for addressing issues including
environmental and engineering fields (Burrough and McDonnell 1998; Lo and Yeung 2003). The main
aim of this paper is to investigate the ground water quality and characterization of its spatial variation of
Chhattisgarh (i.e. Jashpur District) by using the Geographical information system (GIS) techniques.

2. MATERIAL AND METHODS

2.1. Study area

The study area is situated in the north-east state border of Chhattisgarh of India. It lies between 22°0’
and 23°30’ north latitude to 83°0’ to 84 ° 30’ east longitudes, covering a geographical area of 6,205 km².
It consists of 6 blocks (viz., Jashpur Nagar, Pathalgaon, Kunkuri, Bagicha, Farsabahar, Kansabel,
Manora and Duldula). The study area is basically geographically divided into two part upper and lower
ghat. Upper ghat is 200m above from mean sea level, covered by the dense forest and Lower ghat is
flat.

2.2. Data description

The ground water quality parameters data collected from Central Ground Water Board (CGWB) for the
year of pre-monsoon period May 2013 at 39 selected sites, when concentration of ions was maximum.
The major 12 ions were sampled at each site viz pH, electrical conductivity(EC), bicarbonate(HCO₃),
chloride(Cl), calcium(Ca), magnesium(Mg), total hardness(TH), sodium(Na), potassium(K),
sulphate(SO₄), nitrate(NO₃), fluoride(F), and total dissolved solid(TDS).

2.3. Spatial analysis of ground water quality

Spatial map generated by the Inverse Distance Weighted (IDW) method of twelve elected ground water
quality parameters using arc map 10.3 software and ground water quality standards used for these 12
parameters are prescribed by World Health Organization (WHO).
2.4. Ground water quality index

For calculating Groundwater Quality Index (GWQI), it involved following steps,

Step 1: Normalized difference map

The mean annual concentration maps (C) of 12 parameters representing concentrations of the groundwater quality parameters were analyzed by inverse distance weighting interpolation technique using arc map 10.3 software. After that, observed mean annual concentrations (Cobs) of the water quality parameters were related to their maximum desirable limits (Cmdl) prescribed by the WHO (2006) on a pixel basis using a GIS-based normalized difference index (NDI), which is given as (Babiker et al. 2007):

\[ NDI = \frac{C_{obs} - C_{mdl}}{C_{obs} + C_{mdl}} \]  

Where NDI value ranging from -1 to +1
NDI value gives upper and lower limit of contamination of ions.

Step 2: Rank map

The NDI maps were weighted between 1 and 10 to generate the rank map. Rank 1 indicates the low impact on groundwater quality, while rank 10 indicates most impact. The Minimum NDI (-1) value was set to equal to 1, the median value(0) was set to equal to 5, and maximum equal was set to 10 Ranking assigned.
According to following polynomial equation

\[ r = 0.5 \times (\text{NDI})^2 + 4.5 \times (\text{NDI}) + 5 \]  

(2)

Where \( r \) is the rank for each pixel of NDI value

Step 3

**Ground water quality index**

Ground water quality index calculate according to Babiker et al. 2007

\[ GWQI = 100 - \left( \frac{r_1w_1 + r_2w_2 + r_3w_3 + \ldots + r_nw_n}{N} \right) \]  

(3)

Where \( r \) is the rate of the rank map (1–10), \( w \) is the relative weight of each parameter which corresponds to the mean rating value \( (r) \) of each rank map (1–10), and \( N \) = total number of parameters.

The entire process of analysis shown in Figure 2. The index value classification of parameters is based on the Chung and Fabbri (2001). As per their classification, ground water quality indices fixed interval on their area percentage

### 3. RESULTS AND DISCUSSION

Twelve ground water quality parameters pH, EC, TDS, F, Cl, NO₃, Ca, Mg, Na, SO₄, HCO₃ and hardness, analyzed with GIS techniques prescribed by WHO maximum desirable limit for drinking purpose for spatial variation. The mean annual concentration of variation map shown is figure a-l. It is clear from Figure 3(a) pH remains within the desirable limit (7-8.5) of WHO (2006) in the whole study area. Mean electric conductivity reveal that doubtful to be used in some part of south and south-west because of >750 μS/cm [Figure3 (b)]. Figure 3(c) reveals the mean concentration of total dissolved solid (TDS) remain within the permissible limit (500-1500 mg/L) in the whole study area. Figure 3(d) shows the mean concentration of fluoride is more than the permissible limit (1.5 mg/L) in the south-west of study area. The mean concentration spatial map of chloride [Figure 3(e)] reveals that most of the (98
%) has chloride concentration, within the desirable limit where as 2% area and within the permissible limit in the study area. Figure 3(f) shows the mean concentration of nitrate is within the desirable limit (45mg/L).

**Figure 3 (a-f) Spatial Distribution of Groundwater Quality Based on the WHO Standards for Drinking Water**

**Figure 4 (g-l) Spatial Distribution of Groundwater Quality Based on the WHO Standards for Drinking Water**

Figure 4(g) reveals the concentration of hardness is within the permissible limit (500mg/L) in whole study area expect small area 1.2% in south-west under beyond permissible limit. It is clear from the Figure 4(h) mean concentration of calcium remain within the desirable limit (<75mg/L) in 93% of the study area.
and within the permissible limit (75-200mg/L) 7% of the study area. A major portion 97% of study area contain magnesium within the desirable limit (<30mg/L) and about 7% of magnesium within the permissible limit (30-150mg/L).

![Figure 5 Ground Water Quality Index Map of the Study Area](image)

The mean concentration of sodium, [Figure 4(j)] are within the desirable limit (<200mg/L). Similarly sulfate [Figure 4(k)] and bicarbonate [Figure 4(l)] are also within the desirable limit (200mg/L, 300mg/L) respectively.

<table>
<thead>
<tr>
<th>Parameter</th>
<th>Maximum</th>
<th>Minimum</th>
<th>Mean</th>
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<tbody>
<tr>
<td>pH</td>
<td>4.95</td>
<td>4.78</td>
<td>4.87</td>
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<tr>
<td>EC</td>
<td>6.34</td>
<td>1.61</td>
<td>3.11</td>
</tr>
<tr>
<td>TDS</td>
<td>6.29</td>
<td>1.60</td>
<td>3.07</td>
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<tr>
<td>F</td>
<td>7.44</td>
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<td>3.04</td>
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<tr>
<td>Cl</td>
<td>5.74</td>
<td>1.24</td>
<td>2.00</td>
</tr>
<tr>
<td>NO3</td>
<td>7.54</td>
<td>1.00</td>
<td>2.67</td>
</tr>
<tr>
<td>SO4</td>
<td>2.22</td>
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<tr>
<td>HCO3</td>
<td>4.13</td>
<td>1.40</td>
<td>2.91</td>
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<tr>
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<tr>
<td>Na</td>
<td>2.53</td>
<td>1.07</td>
<td>1.64</td>
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</table>

Index map of ground water quality for study area

The mean Ground Water Quality Index (GWQI) spatial map of Jashpur district reveal the ground water quality of Jashpur is generally good (GWQI > 75, maximum GWQI = 100). Ground water quality identified in ten classes of the study area at 10% interval. The lowest three classes (0-30%) represent a "low quality". Next four classes (30-70%) as a "moderate quality" and last three classes (70-100%) as "high quality". Statistics of the 12 mean rank maps (parameter) used to compute Groundwater Quality Index are represent in Table 1.
It is clear from the Table 1 the parameter of hardness and pH influences the spatial map of ground water quality which is due to their mean rank value Figure 5 reveals that the high GWQI in the north part of the study area, while the groundwater quality decreases in south and south-west of study area. Moreover, gradients of ground water quality can be seen in the study area (Figure 5). First, there is a decrease in ground water quality from north to southwest. Degradation of quality is mainly from the shallow ground water table in the southwest. The growth of pollutants input from chemical fertilizers applies to agricultural areas because southwest of study region is very close to the industrial area of raigarh district. According to Ground Water Quality Index map, north region have the best quality of ground water for drinking and irrigation and other household purposes. High ground water quality is a credit to the very good quality of vadose zone to attenuate the contaminant percolation in the north. It is revealing that the developed GWQI method is not a biological (Total coliform and faecal coliform), aesthetic (odour, colour and floating substances) and radioactive indicator due to lack of these type of data. Thus, Ground Water and Quality Index (GWQI) denote physio-chemical ground water quality of study region.

4. CONCLUSIONS

This study is carried out in the Jashpur District of Chhattisgarh, Central India to evaluate and characterize ground water quality for the Pre-Monsoon 2015 of 39 ground water well location sites. The spatial variation of quality parameters is analyzed in the study area by the GIS techniques. The quality of ground water was evaluated by the ground water quality index. The mean concentration maps of 12 quality parameters indicate that except pH and hardness all other parameters are within the maximum permissible limit. GWQI maps indicate that relatively good ground water quality in the north of study area. However, the south-west part having low ground water quality of the study area based on the maximum desirable limit of drinking. Hence, pH and hardness parameters are most sensitive in this study, and they need regular monitoring with high precision. The method used is very easy, and it can easy to apply another area of India. The developed GWQI can be compare among themselves because the classification scheme used in this study reduce the subjectivity in identifying 'low', 'moderate' and 'high' water quality classes. Researcher and decision maker should estimate and formulate efficient ground water utilization and management plan and policy for the study and insure for the human health and environment.

5. REFERENCES


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