Assessment and Mapping of Fluoride Contamination of Groundwater of the Hatigaon Area of Assam, India Using Geographic Information System

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Abstract: For this study, the Hatigaon area of Guwahati City of the state Assam, India has been selected to assess the groundwater quality with special reference to fluoride contamination. Spatial variations in groundwater quality with reference to fluoride contamination in the Hatigaon area have been studied using Geographic Information System (GIS). For this study, a total of 115 groundwater samples were collected from 115 pinpoint locations (wells) in the Hatigaon area. The groundwater samples were analyzed for fluoride using Spectroquant Pharo 100 Spectrophotometer and compared with the Bureau of Indian Standards (BIS) and World Health Organization (WHO) standards. Mapping of spatial distributions of fluoride contamination of groundwater of the Hatigaon area was done using ArcGIS and the groundwater fluoride distribution map was obtained. The results revealed that fluoride contents in the groundwater samples ranged between 0.22-11 mg/l. The results obtained in this study and the spatial database established in GIS will be helpful for monitoring and managing groundwater contamination due to fluoride in the study area.

Keywords: ArcGIS, fluoride, groundwater, water quality

1. Introduction

Groundwater is a major source for all purposes of water requirements in India. In India more than 90% of the rural population and nearly 30% of the urban population depend on groundwater for drinking purpose [1]. Till recently it had been considered as a dependable and generally a safe source of drinking water. Groundwater resources are under increasing threat from contamination by physical, chemical and biological parameters with far reaching consequences for the health of the living beings. Contamination of groundwater can result in poor drinking water quality and potential health problems. Thus groundwater quality is a growing concern throughout the world. Groundwater quality analysis gives information about the health of the groundwater. Thus, water quality assessment is one of the prime concerns all over the world. It involves evaluation of the physical, chemical, and biological nature of water in relation to natural quality, human effects, and intended uses, particularly uses which may affect human health and the health of the aquatic system itself [7].

Fluoride is found in both surface water and groundwater. It is a natural groundwater contaminant that results from dissolution from rocks and soils due to chemical weathering and erosion. Groundwater, especially borehole water contains varying concentrations of fluoride. Drinking water, when derived from fluoride contaminated groundwater exceeding the maximum permissible limit of fluoride concentration of 1.5 mg/l (standard set by WHO and BIS for drinking water) is the cause of fluorosis. Therefore higher concentration of fluoride is considered to be an indicator of groundwater contamination. The factors responsible for the natural concentration of fluoride in groundwater are the physical, geological and chemical distinctiveness of the aquifer, the porosity and acidity of the soil and rocks, the temperature, the action of other chemical elements and the depth of wells. The existence of fluoride toxicity in the groundwater is a matter of great concern in India today. In the state Assam, reports of its presence are pouring in day by day. In Assam, earlier though fluoride endemicity was concentrated in some areas of Karbi-Anglong and Nagaon districts only but presently the gateway of north-east, the city of Guwahati too stands as a victim [2].

Geographic Information System (GIS) has emerged as a powerful tool for storing, analyzing, and displaying spatial data and using the data for decision making in engineering and environmental fields [3,6]. Groundwater can be most advantageously used only when its quantity and quality is properly assessed. GIS can be used as a database system in order to prepare maps of groundwater quality according to concentration values of different groundwater quality parameters such as fluoride. It can be utilized to locate groundwater quality zones suitable for different usages such as drinking purpose. For any area, a groundwater quality map is important to evaluate the safeness of water for drinking purpose and also as a deterrent indication of potential environmental health problems.

Considering the above aspects of groundwater contamination and use of GIS in groundwater quality mapping, the present
study was undertaken to map the groundwater quality with special reference to fluoride contamination in the Hatigaon area of Guwahati city in Kamrup district of the state Assam, India, which is taken as the study area.

2. Research Objectives

This study aims to visualize the spatial distribution of the fluoride levels in groundwater of the study area through GIS. The main objective of the research work is to make a groundwater quality map using GIS based on the laboratory tests done on 115 groundwater samples representing groundwater resource that were collected from 115 pinpoint locations (wells) in the Hatigaon area of Assam, India. Therefore, the objectives of this research work can be summarized as follows:

1) To assess and provide an overview of present groundwater quality of the Hatigaon area with special reference to fluoride contamination.
2) To determine the spatial distribution of groundwater quality parameter fluoride and to generate the fluoride contamination map for the Hatigaon area.

3. Materials and Methods

3.1 Study Area

The Hatigaon area is a locality in southern part of Guwahati city in Kamrup district of the state Assam, India. It is situated at latitude of 26.1279°N and longitude of 91.7855°E, at the mean sea level of 55.64 m and referred in Survey of India (SOI) topographic sheet no. n16 (Figure 1). It is surrounded by Ganeshguri, Bhetapara, Sijubari, Beltola Tiniali and Beltola Survey localities.

Hatigaon area has warm summers and cold winters. Winters are also accompanied by occasional rainfalls that bring down the temperature further. Monsoon season commences from the month of June. Monsoons are usually accompanied by severe thunderstorms along with heavy showers. This helps in infiltration and thus recharge of groundwater in this area.

The geology of the study area is represented by the Precambrian Gneissic basement which is intruded by Porphyritic Granites. The basement complex is composed of Granite Gneiss, Biotite Gneiss, Biotite Schist and Quartzite [4, 5]. Fills of varying thickness composed of unconsolidated sand, silt and clay are deposited over the basement Gneissic complex. High fluoride regions occur mostly in all the Gneissic and the Granitic areas. The crystalline Precambrian rocks of the study area are traversed by a number of lineaments, representing fracture zones. These structures facilitate weathering and water seepage. Fluoride ions leach out more from the fractures.

The hydrology of the study area consists of the surface drainage, wetlands and the dug-wells and bore-wells. The Basistha-Bahini river is the trunk channel near this area and along with its host of tributaries form the main conduit for surface water runoff.

3.2 Groundwater sample collection and analysis

For the sampling of groundwater samples of the study area, groundwater samples from different sites (pinpoint locations) were collected from sources (wells) representing underground groundwater. Since the groundwater sources were known to vary with time, grab samples were collected with frequency of one. The samples were taken during September 2016 and were analyzed for the chemical parameter fluoride. Each samples for fluoride analysis were collected in PET bottles of half litre size. Before filling, the bottles used for water sample collection were rinsed out two or three times with the water being collected. Samples from wells were collected only after the well has been pumped to insure that the sample represents the actual groundwater. A total of 115 groundwater samples were collected from 115 pinpoint locations of the study area (Table 3). Sufficient information was recorded to provide positive sample identification at a later date, such as the name from whom the sample was collected, exact location (pinpoint location), source and depth. After collection of the samples, the samples were shifted to the District Level Laboratory (DDL) of Public Health Engineering Department (PHED) of Kamrup district of Assam, India for analysis. The latitude and longitude data of the pinpoint locations were recorded using the GPS instrument GARMIN GPS-60 receiver.

Chemical analysis was carried out to determine the fluoride contents and compared with standard values recommended by WHO and BIS (Table 1). As the groundwater in the study area is extensively used for drinking purpose and previous studies report that groundwater contamination is mainly due to fluoride (PHED, Kamrup district, Assam, India), the groundwater quality analysis in the present study is restricted to measurement of fluoride contents and determination of potential contamination.

Table 1: Recommended permissible limits for fluoride in drinking water

<table>
<thead>
<tr>
<th>Name of organization</th>
<th>Acceptable limit (desirable limit)</th>
<th>Maximum permissible limit</th>
</tr>
</thead>
<tbody>
<tr>
<td>World Health Organization (WHO)</td>
<td>1.0</td>
<td>1.5</td>
</tr>
<tr>
<td>Bureau of Indian Standards (BIS)</td>
<td>1.0</td>
<td>1.5</td>
</tr>
</tbody>
</table>

The fluoride contents of the groundwater samples were determined by Spectroquant Pharo 100 Spectrophotometer having wavelength range of 320-1100 nm. For the determination of fluoride content in water samples, the Spectroquant Pharo 100 Spectrophotometer method is one of the most effective and efficient methods because it is quick, accurate and hardly takes few minutes for each sample to be tested. The procedure and the reagent system consisted of the approved method for fluoride and analytical grade reagents (Merck). The determination of fluoride contents was achieved at 570 nm wavelength by measuring the absorbance.
3.2 Preparation of well (sampling) location feature map and the spatial distribution map

The method that was followed to develop a groundwater quality map (with special reference to fluoride contamination) from thematic maps is explained in this section. The ArcGIS software was utilized in the study. The locations of 115 wells (pinpoint locations) all over the study area were obtained by using a handheld GPS instrument GARMIN GPS-60 receiver. GPS technology proved to be very useful for enhancing the spatial accuracy of the data integrated in the GIS. The well location data was then imported to ArcGIS using GCS_Everest_India_Nepal projection and attributes were assigned to each well sample. The digitized maps of India, Assam, Greater Guwahati and SOI topographic sheet no. n16 were used in ArcGIS to generate the final study area map. Based on the location data obtained, well (sampling) location feature map was prepared showing the position of 115 wells from where 115 groundwater samples were collected (Figure 1).

The GPS data and the well location map thus obtained forms the spatial database. From the 115 numbers of wells, the 115 groundwater samples that were collected were analyzed to obtain the fluoride contents. The water quality data thus obtained forms the non-spatial database. It is stored in excel format and linked with the spatial data in ArcGIS. The values of fluoride levels for various sample locations were classified into five classes in ‘Layer Properties’ and plotted in the integrated map. ‘Graduated colour’ scheme symbology was used so that the five classes can be pictorially identified having different symbols and colours. Thus the spatial and the non-spatial database formed are integrated using the ArcGIS software for the generation of spatial distribution map of the groundwater quality parameter fluoride for the study area (Figure 2).

3.3 Criteria for acceptability and rejection in water quality

In this stage, the criteria for suitability and non-suitability of the groundwater samples were elucidated for analysis. This was performed based on the water quality standards stipulated by the WHO and BIS. Table 1 shows the corresponding permissible limits of fluoride for drinking purpose as recommended by WHO and BIS. Ranks were assigned for the wells depending on the respective tested fluoride values, as given in the Table 2.

Table 2: Criteria for acceptability and rejection in water quality

<table>
<thead>
<tr>
<th>Parameter</th>
<th>Rank</th>
<th>Criteria</th>
<th>Remarks</th>
</tr>
</thead>
<tbody>
<tr>
<td>Fluoride</td>
<td>1</td>
<td>&lt;1.0 mg/l</td>
<td>Desired</td>
</tr>
<tr>
<td></td>
<td>2</td>
<td>1.0-1.5 mg/l</td>
<td>Acceptable</td>
</tr>
<tr>
<td></td>
<td>3</td>
<td>&gt;1.5 mg/l</td>
<td>Non acceptable</td>
</tr>
</tbody>
</table>
4. Results and Discussions

The fluoride contents in the groundwater samples that were analyzed and their levels in different locations of the study area are shown in Table 3. Fluoride contents were found to be very high in the groundwater samples of the study area. From Table 3, it can be seen that the fluoride concentrations in the groundwater samples of the study area range between 0.22-11 mg/l. A very high fluoride content of 11 mg/l is found in the Hatigaon Lakhiminagar area (Sample no. 35) which poses a great risk for the residents of the study area. As against it, a low fluoride content of 0.22 mg/l is found in the Hatigaon Lakhininagar site (Sample no. 2) which is within the acceptable limit (1.0 mg/l).

Table 3: Details of the groundwater samples and analysis results.

<table>
<thead>
<tr>
<th>Sample no.</th>
<th>Pinpoint location</th>
<th>Latitude (N) in degrees</th>
<th>Longitude (E) in degrees</th>
<th>Source</th>
<th>Depth in feet</th>
<th>Fluoride in mg/l</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>Dr. Utpal Kumar Misra, Hatigaon</td>
<td>26.13500</td>
<td>91.78767</td>
<td>D.T.W.</td>
<td>750</td>
<td>5</td>
</tr>
<tr>
<td>2</td>
<td>Kesab Ch. Baishya, Lakhiminagar, H. No. 7</td>
<td>26.13942</td>
<td>91.78484</td>
<td>S.T.W.</td>
<td>20</td>
<td>0.22</td>
</tr>
<tr>
<td>3</td>
<td>Th. Jagjit Singh, Hatigaon</td>
<td>26.13694</td>
<td>91.77306</td>
<td>S.T.W.</td>
<td>40</td>
<td>0.3</td>
</tr>
<tr>
<td>4</td>
<td>Narendra Ch. Das, House No. 106</td>
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<td>91.77889</td>
<td>Boring</td>
<td>380</td>
<td>3.7</td>
</tr>
<tr>
<td>5</td>
<td>Nirupama Devi, Lakhiminagar</td>
<td>26.14000</td>
<td>91.78389</td>
<td>Boring</td>
<td>500</td>
<td>9.7</td>
</tr>
<tr>
<td>6</td>
<td>N. Bhuyan, Lakhiminagar</td>
<td>26.14000</td>
<td>91.78389</td>
<td>Boring</td>
<td>378</td>
<td>4.4</td>
</tr>
<tr>
<td>7</td>
<td>D.N. Das, House No. 9</td>
<td>26.13944</td>
<td>91.78472</td>
<td>Boring</td>
<td>275</td>
<td>1.71</td>
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<tr>
<td>8</td>
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<td>Boring</td>
<td>450</td>
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</tr>
<tr>
<td>9</td>
<td>Shahid Ali, House No. 2</td>
<td>26.13944</td>
<td>91.78583</td>
<td>Boring</td>
<td>650</td>
<td>6.7</td>
</tr>
<tr>
<td>10</td>
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<td>D.T.W.</td>
<td>660</td>
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<tr>
<td>11</td>
<td>Harendra Chakraborty, House No. 24</td>
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<td>Kamal Ch. Das, Namghar Path</td>
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<tr>
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<td>240</td>
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<td>250</td>
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<tr>
<td>19</td>
<td>Mr. Sharma, Sharma store</td>
<td>26.13889</td>
<td>91.78222</td>
<td>Boring</td>
<td>260</td>
<td>5.3</td>
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<tr>
<td>20</td>
<td>Ruhini Das, Lakhiminagar</td>
<td>26.13861</td>
<td>91.77639</td>
<td>D.T.W.</td>
<td>425</td>
<td>7.9</td>
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<td>Dimpanjal Hazarika, Lakhiminagar</td>
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<td>650</td>
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<tr>
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<td>Manjushree Deka, Lakhiminagar</td>
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<td>400</td>
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<tr>
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<td>530</td>
<td>9</td>
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<td>460</td>
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</tr>
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</table>

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<th>Source</th>
<th>Depth in feet</th>
<th>Fluoride in mg/l</th>
</tr>
</thead>
<tbody>
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<td>33</td>
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<td>D.T.W.</td>
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<td>D.T.W.</td>
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<tr>
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<td>91.78000</td>
<td>D.T.W.</td>
<td>360</td>
<td>5.7</td>
</tr>
</tbody>
</table>
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<tr>
<th>Sample no</th>
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<th>Fluoride in mg/l</th>
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</thead>
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<td>91.7728</td>
<td>H.T.W.</td>
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<td>75</td>
<td>Nishi Jyoti Das, Juripar</td>
<td>91.7768</td>
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<td>Jiaur Rahman, Kalapahar Path</td>
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<td>Sadullah, Vinayak Path</td>
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<td>78</td>
<td>Anju Das, Sanjog Path</td>
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<td>Debakanta Das, Sanjog Path</td>
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<td>H. Talukdar, Jyoti Path</td>
<td>91.8000</td>
<td>D.T.W.</td>
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<td>Prabodh Kr. Barman, Lakhminaginar</td>
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<td>Aman Ali Ahmed, S.K. Path</td>
<td>91.8067</td>
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<td>83</td>
<td>Salima Khutun, Lakhminaginar</td>
<td>91.8429</td>
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<td>150</td>
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<td>84</td>
<td>Dr. Rumi Dev, Lakhminaginar</td>
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<td>Dhaejendra N. Das, Lakhminaginar, H. No. 6</td>
<td>91.78554</td>
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<td>86</td>
<td>Jina Sarma, Lakhminaginar</td>
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<td>D.T.W.</td>
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<td>87</td>
<td>C.R. Das, Namghar Path</td>
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<td>88</td>
<td>Narayan Das, Sewali Path</td>
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<td>89</td>
<td>B.C. Khound, Sewali Path, House No. 21</td>
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<td>90</td>
<td>Mr. Nuna, Sewali Path, House No. 8</td>
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<td>91</td>
<td>Dr. I. Bordoloi, Sewali Path</td>
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<td>92</td>
<td>Narayan Deka, Lakhminaginar</td>
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<td>93</td>
<td>Nalini Baishya, Lakhminaginar</td>
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<td>94</td>
<td>Amor Konwari, Lakhminaginar</td>
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<td>S.T.W.</td>
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<td>95</td>
<td>Rajendra Das, Lakhminaginar, House No. 3</td>
<td>91.78587</td>
<td>D.T.W.</td>
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<td>0.76</td>
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<td>96</td>
<td>Gautam Das, Lakhminaginar, House No. 8</td>
<td>91.8481</td>
<td>D.T.W.</td>
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<tr>
<td>97</td>
<td>Hiramoni Basumatary, Kalapahar Road</td>
<td>91.76774</td>
<td>D.T.W.</td>
<td>180</td>
<td>1.13</td>
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<tr>
<td>98</td>
<td>A.K. Patgiri, Namghar Path</td>
<td>91.77925</td>
<td>D.T.W.</td>
<td>180</td>
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<td>99</td>
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<td>91.77896</td>
<td>D.T.W.</td>
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<td>Umesh Das, Namghar Path, House No. 18</td>
<td>91.77921</td>
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<td>101</td>
<td>Monoranjan Das, Lakhminaginar, H. No. 5</td>
<td>91.78566</td>
<td>D.T.W.</td>
<td>90</td>
<td>1.18</td>
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<td>102</td>
<td>Pratap Ch. Borah, Kalapahar Path</td>
<td>91.76767</td>
<td>D.T.W.</td>
<td>160</td>
<td>1.14</td>
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<td>103</td>
<td>Nareshwar Bayan, Medhi Phukan Path</td>
<td>91.80600</td>
<td>D.T.W.</td>
<td>275</td>
<td>1.04</td>
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<td>104</td>
<td>Ramananda Das, Samannay Path, H. No. 25</td>
<td>91.7823</td>
<td>D.T.W.</td>
<td>110</td>
<td>1.09</td>
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<td>105</td>
<td>Kulen Barpujari, Lakhminaginar</td>
<td>91.7769</td>
<td>D.T.W.</td>
<td>100</td>
<td>1.46</td>
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<tr>
<td>106</td>
<td>B.S. Raj Medhi, Kalapahar Path</td>
<td>91.7681</td>
<td>D.T.W.</td>
<td>190</td>
<td>1.23</td>
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<tr>
<td>107</td>
<td>N. Kalita, Kalapahar Path</td>
<td>91.76701</td>
<td>D.T.W.</td>
<td>178</td>
<td>0.91</td>
<td></td>
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<tr>
<td>108</td>
<td>Ratan Deka, Lakhminaginar, House No. 62</td>
<td>91.77859</td>
<td>D.T.W.</td>
<td>135</td>
<td>1.44</td>
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</tbody>
</table>
Table no. 3: Details of the groundwater samples and analysis results.

<table>
<thead>
<tr>
<th>Sample no.</th>
<th>Pinpoint location</th>
<th>Latitude (N) in degrees</th>
<th>Longitude (E) in degrees</th>
<th>Source</th>
<th>Depth in feet</th>
<th>Fluoride in mg/l</th>
</tr>
</thead>
<tbody>
<tr>
<td>109</td>
<td>Tapan Bhuyan, Lakhiminagar, House No. 28</td>
<td>26.14142</td>
<td>91.78303</td>
<td>D.T.W.</td>
<td>90</td>
<td>1.29</td>
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<tr>
<td>110</td>
<td>Gopal Ch. Das, Samanay Path, H. No. 24</td>
<td>26.13859</td>
<td>91.78290</td>
<td>D.T.W.</td>
<td>100</td>
<td>0.72</td>
</tr>
<tr>
<td>111</td>
<td>Mahendra Nath, Lakhiminagar, H. No. 9</td>
<td>26.13936</td>
<td>91.78469</td>
<td>S.T.W.</td>
<td>60</td>
<td>0.82</td>
</tr>
<tr>
<td>112</td>
<td>Abdul Malik Ansary, Samanay Path</td>
<td>26.13892</td>
<td>91.78294</td>
<td>S.T.W.</td>
<td>60</td>
<td>0.78</td>
</tr>
<tr>
<td>113</td>
<td>N.A. Laskar, Samannay Path</td>
<td>26.13878</td>
<td>91.78293</td>
<td>D.T.W.</td>
<td>170</td>
<td>1.31</td>
</tr>
<tr>
<td>114</td>
<td>Nilima Pathak, Jatia, Hatigaon</td>
<td>26.14152</td>
<td>91.78630</td>
<td>D.T.W.</td>
<td>140</td>
<td>0.39</td>
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<tr>
<td>115</td>
<td>Mrigen Bora, Jatia, Hatigaon</td>
<td>26.14140</td>
<td>91.78605</td>
<td>D.T.W.</td>
<td>180</td>
<td>1.29</td>
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</tbody>
</table>

Fluoride concentrations have complied with a value above 1.5 mg/l for 79 wells (68.70%) out of 115 wells (pinpoint locations) that exceeded the maximum contaminant level of 1.5 mg/l given in WHO and BIS standards. On the contrary, 36 wells (31.30%) out of 115 wells have complied with fluoride content values below the maximum permissible limit of 1.5 mg/l. However, only 17 wells (14.78%) in the study have the desired and acceptable level of fluoride content of 1.0 mg/l according to the standards. Table 4 shows the wells with the ranks that were assigned depending on the respective tested fluoride values.

Table 4: Wells with the ranks assigned depending on the respective tested fluoride values

<table>
<thead>
<tr>
<th>Parameter</th>
<th>Rank</th>
<th>Criteria</th>
<th>No. of Wells</th>
<th>Remarks</th>
</tr>
</thead>
<tbody>
<tr>
<td>Fluoride</td>
<td>1</td>
<td>&lt;1.0 mg/l</td>
<td>17</td>
<td>Desired</td>
</tr>
<tr>
<td></td>
<td>2</td>
<td>1.0-1.5 mg/l</td>
<td>19</td>
<td>Acceptable</td>
</tr>
<tr>
<td></td>
<td>3</td>
<td>&gt;1.5 mg/l</td>
<td>79</td>
<td>Non acceptable</td>
</tr>
</tbody>
</table>

Groundwater quality maps are useful in assessing the usability of the water for different purposes. Figure 2 shows the spatial distributions of the levels of fluoride of the pinpoint locations in the study area. The spatial integration for groundwater quality mapping with special reference to fluoride contamination was carried out using ArcGIS and a groundwater quality map is created depicting the spatial distributions of fluoride contamination of groundwater. The
spatial distributions map of fluoride contamination of groundwater of the study area derived shows a small region in the study area where the groundwater is potable (with reference to fluoride levels). It can be seen from the map that a few regions have groundwater that is potable only after proper fluoride removal/reduction treatment. However in the remaining parts of the study area, the water is non-potable due to fluoride contamination. From the fluoride contaminated groundwater quality map, it can be said empirically that the fluoride levels in groundwater in the study area are above the prescribed limits and are not potable and require to be processed before consumption.

5. Conclusion

The Hatigaon area is located on a land with bedrocks beneath it containing high fluoride levels. The main source of fluoride in drinking water in this area is the bedrock structure underground that can reach the aquifer. With the application of down-the-hole boring technology for piercing the bedrock under alluvium layers to exploit rock-fractured-water, the people are in fact extracting more fluoride.

The spatial distribution map of fluoride contamination of groundwater of the study area indicates that the fluoride levels are above maximum permissible limits for 68.70% of the sample wells. The spatial distribution map of groundwater quality in the study area indicated that majority of the samples collected are not satisfying the drinking water quality standards prescribed by the WHO and BIS. The results obtained give the necessity of making the public, local administrator and the government to be aware on the contamination of groundwater by fluoride prevailing in the study area. The government needs to make a scientific and feasible planning for identifying an effective groundwater quality management system and for its implementation. Since, in future the groundwater will have the major share of water supply schemes, plans for the protection of groundwater quality is needed. Present status of groundwater necessitates for the continuous monitoring and necessary groundwater quality improvement methodologies implementation.

References