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# Groundwater Quality Assessment in the Southwestern Peri-urban Guwahati City

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**Abstract:**
The southwestern peri-urban Guwahati City is a potential site for future urban development. The current study aims to assess the groundwater quality of the area for human consumption. Important parameters such as pH, calcium, magnesium, sodium, potassium, iron, sulphate, chloride, TDS, and total hardness are analyzed for both pre-and post-monsoon season. The water samples are collected from household tubewell in a well-distributed regular interval. The results are visualized in a GIS environment using the IDW interpolation technique. The results show the parameters are within the permissible limit as per the Bureau of Indian Standards except for iron which is found dominant and beyond permissible limit in 18 out of 19 surveyed locations. The Water Quality Index was calculated using the formula given by Brown et al. 1975, showing that 93.6 % of the area is very poor to unsuitable for drinking due to the presence of high iron concentrations. The Piper trilinear diagram shows most of the sample falls under the Ca-Mg-bicarbonate type. The study shows 18 out of 19 surveyed locations need iron treatment before human consumption.
**Key Words:** Groundwater, WQI, GIS, Piper trilinear diagram, urban expansion, Guwahati City

**Introduction:**
Providing a uniform definition of Rural-Urban Fringe (RUF) or peri-urban zones is challenging due to their rapidly changing nature and difficulties in real-time data collection resulting from the rural-urban dichotomy (Simon, 2008). Although there is no visible built-up environment, these areas experience pressure from both sides, with urban economic and lifestyle attractions pulling and urban overcrowding and congestion pushing (Piorr et al., 2015). Urbanization involves a large population, creating a significant demand for water supply, extensive ground use for discharge, and a large network of waste disposal, leading to aquifer depletion, locally rising groundwater levels, and contamination of shallow groundwater (Brindha and Schneider, 2019). Surface and subsurface urban infrastructure alterations change the topography by increasing 'impervious cover,' affecting water table elevation, permeability fields, and groundwater recharge (Sharp, 2010). Unsustainable groundwater use causes the over-exploitation of 20% of aquifers globally and the deterioration of groundwater quality. The United Nations (2015) aims to reverse these trends in its 2030 agenda, targeting 17 Sustainable Development Goals (SDGs), where the availability and sustainable management of water are key objectives (Guppy et al., 2018). Groundwater should be safe for drinking, as 80% of diseases are water-related, according to WHO (Haseena et al., 2017). Groundwater quality and quantity are affected by effluents from industry and agriculture, urban expansion, and population growth (Zhang et al., 2019). The neglect of peri-urban areas arises as authorities prioritize addressing the water needs of large cities through infrastructure expansion and supply augmentation, leading to informal, unplanned settlements experiencing the lowest levels of basic service provision (Grönwall & Oduro Kwarteng, 2018). The implications of water quality decline associated with the changing relationships between urban and peri-urban areas are less acknowledged (Karpouzoglou et al., 2018).
The study aims to assess the physico-chemical parameters of groundwater resources in the southwestern peri-urban Guwahati City with a perspective of sustainable future urbanization. In this study, an attempt has been made to determine the groundwater quality for drinking and irrigation purposes. Borah et al. 2020 analyzed the surface and groundwater quality near the Bharalu River, a natural channel for storm water runoff connecting the river Brahmaputra within the main Guwahati city, and reported high contamination in surface water and poor-quality

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groundwater. Dutta et al. 2022 identified high health risks associated with potentially toxic elements in the groundwater of the upper Brahmaputra floodplains of Assam. Lahkar and Bhattacharya, 2019 have reported the presence of Cd, Pb, and Fe above the maximum contamination level in different locations of the city.

**Study Area**

The study area is situated on the southwestern fringe of Guwahati City and encompasses two peri-urban blocks, namely 'Rani' and 'Chayani Borduar.' The total area under study is 423.03 sq. km and comprises 130 villages. The dominant land use of the area is agricultural lands covering 230.68 sq. km (54.53%), these areas are easily accessible with only a short drive from the airport, making them appealing for future infrastructure investments. Currently, the agricultural landscape is gradually transforming into small and large-scale industries. The development of apartment complexes is on the rise due to the limited open space within the main city. Additionally, the proximity to the airport has spurred the growth of business complexes, hotels, and other commercial establishments. Other land-use classes in the area include forest cover (27.16%), water bodies (22.54 sq. km), wastelands (12.93 sq. km), and grasslands (15.68 sq. km). The study area is bounded by the mighty Brahmaputra River to the north, Guwahati City to the northeast, the Shillong Plateau of Meghalaya to the southeast and south, and the Kulshi River to the west. Major geological formations comprise alluviums from the Brahmaputra River and its tributaries, along with Precambrian rocks from the Meghalaya Plateau. Notable geomorphic features include floodplains, alluvial plains, piedmont zones, and denudational hills. The region experiences a tropical monsoon-type climate with rainfall occurring between June and September. The average temperature ranges from 35ºC in summer to 9ºC in winter.

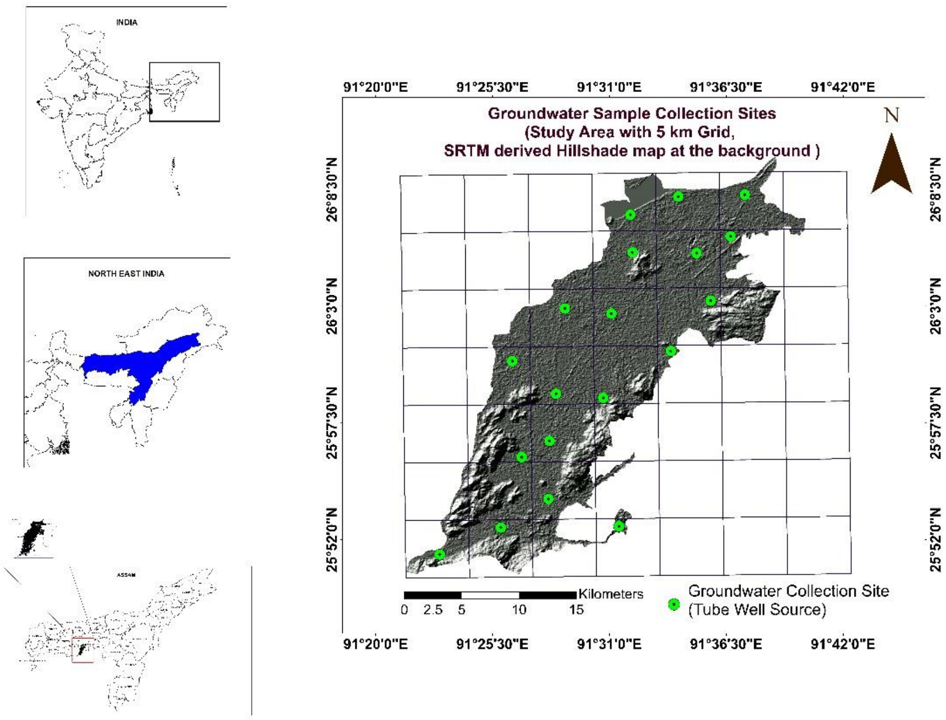


**Fig1: Study Area Map**

**Materials And Methods**

Drinking water sources within the study area are mainly tube wells and dug wells. Before the field visit for groundwater sample collection, the area is divided into 5km × 5km grid using ArcGIS 10.2 software so that samples will be collected at regular intervals with proper representation of the entire study area. Water samples are collected for both the pre-monsoon (April-May) and post-monsoon season (November-December). For groundwater quality analysis, samples are mainly collected from household tube wells as dug wells are often not properly well maintained and contain lots of contamination. A total of 19 samples have been collected as shown in figure 1. The samples are collected using plastic bottles (USEPA, 2016), filled, and sealed off immediately to avoid exposure to air. Before collecting samples, the tube wells are pumped for 3-4 minutes to exclude the residual water. Each sample is given proper labeling using a permanent marker and the geographic coordinates of the wells are marked using handheld GPS. After collection, these samples are analyzed in the Assam Public Health Engineering Department (PHED) Laboratory to determine various physico-chemical parameters. The following parameters are analyzed to ensure the suitability of groundwater for domestic and agricultural uses:

**Hydrogen Ion Concentration (pH)**

pH means 'potential for hydrogen' and is a measure of how acidic the groundwater is. The value of pH below 7 indicates acidic and above 7 means basic or alkaline. The U.S. Environmental Protection Agency (EPA) has recommended a range of pH between 6.5 to 8.5 to maintain its aesthetic taste. Acidic groundwater can be corrosive and leach metals from pipes and fixtures while alkaline one may be bitter.

**Calcium and Magnesium**

The concentration of calcium and magnesium determines the hardness of groundwater. Carbonate hardness or temporary hardness can be removed by boiling the water whereas non-carbonate or permanent hardness requires special treatment. Groundwater percolating through limestone and dolomite usually contains Ca and Mg (Sengupta, 2013). Drinking water with a deficiency of Ca and Mg may cause cardiovascular diseases, growth retardation, and other health-related issues (Rapant et al. 2017).

**Alkalinity**

Bicarbonate ($HCO_3^-$) and carbonate ($CO_3^{-2}$) are conjugate bases of inorganic carbon mainly derived by the action of carbon dioxide and water on carbonate rocks such as limestone and dolomite which neutralizes acid by consuming $H^+$ and produces an alkaline environment (Technical Document: Canadian Drinking Water Quality). Both carbonate and bicarbonate are measured by titration with standardized hydrochloric acid. In the case of carbonate, phenolphthalein is used and for bicarbonate, methyl orange is used as an indicator. The presence of carbonate is indicated when the pH value reaches 8.3. Below this carbonate are converted into an equivalent amount of bicarbonates (Patil et al. 2012). Bicarbonates of Ca and Mg can affect steam boilers forming scale and releasing carbonic acid gas (NGWA).

**Sodium and Potassium**

$Na^+$ and $K^+$ are commonly found in rocks and soils. They are reactive metals and often found in combination with chlorine and bromine which readily dissolve in water. Potassium in fertilizer leaches through the soil profile into the groundwater in coarse-textured soil. Rocks containing sodium and potassium release these ions slowly in solution. For healthy individuals, there are no direct health-related problems with the limit of Na and K intake. However, people with heart or kidney problems and insomnia are advised to take low sodium content. Potassium is also important in balancing water levels inside the body, controlling blood pressure and neural transmission (Banerjee and Prasad, 2020).

**Iron and Manganese**

Iron (Fe) and Manganese (Mn) are metals occurring naturally in soils, rocks, and minerals. Their migration and dissolution to groundwater depends on factors such as reducing conditions, residence time, well depth, and salinity (Zhang et al. 2020). Though Fe and Mn do not have any health impact, their presence can cause the coloring of water, unpleasant taste, and odor, staining in clothes, and bacterial growth in water distribution pipes (Elsheikh et al. 2017).

There are both ex-situ and in-situ techniques for iron and manganese removal. In the ex-situ technique, groundwater is purified after collection using filtration, aeration followed by filtration, ion exchange method, etc. In the in-situ technique, vyredox method has been adopted where the highly oxidized zone is created around the well by injection of oxygen-rich water (Ahmed, 2012).

**Turbidity**

Turbidity is a quicker estimation of the amount of sediment present in a water sample. The presence of suspended and dissolved materials in groundwater such as mud, fine sand, silt, organic and inorganic particles, chemicals, plankton, and other microscopic organisms scatter the incident light rather than transmission in a straight line. This optical behavior is known as turbidity. Turbidity is usually measured by a nephelometer (Bash and Berman, 2001).

Several studies found that drinking water turbidity has a close relationship with gastrointestinal illness (Allen et al. 2008).

**Sulfate**

Sulfate occurs naturally in groundwater as a combination of sulfur and oxygen. When water percolates through soil and rock formations containing sulfate minerals, some of these minerals get dissolved and are released into groundwater. High levels of sulfate may give water a bitter or medicinal taste and cause diarrhea and dehydration. Infants are more sensitive to sulfate than adults (Bashir et al. 2014).

**Chlorides**

Chloride ($Cl^-$) is a major anion occurring in most aqueous environments and its high concentrations can be indicative of the presence of other toxic contaminants. The contribution of aerosols or volcanic gases in natural precipitation or snowmelt may result in chloride precipitation. When rain or snow reaches the ground, evaporation, and evapotranspiration increase the $Cl^-$ concentration ten or more times than its original concentration, and finally through mineral dissolution, it reaches the groundwater regime. On earth's crust largest contributor of $Cl^-$ is the mineral halite (NaCl). Anthropogenic sources of chloride are human sewage, livestock waste, water conditioning salt, synthetic fertilizer, road salt runoff, etc. (Kelly et al. 2012).

Excess chloride makes the water salty. There is no proven health implication of chloride consumption on the human body. Chloride increases the electrical conductivity of water increasing its corrosivity (WHO, 2003).

**Fluoride**

Fluoride in groundwater occurs naturally from weathered fluoride-bearing rocks and minerals such as fluorite, hornblende, biotite, and apatite through the infiltration of rainfall. Another natural source is volcanic ash which easily gets dissolved in water. Anthropogenic causes such as the use of fertilizer and the combustion of coal also add fluoride to groundwater (Brindha and Elango, 2011). Consumption of fluoride above the WHO recommended limit i.e. 1.5 mg/L can cause dental and skeletal fluorosis, osteoporosis, arthritis, infertility, brain damage, Alzheimer's, and thyroid (Valdez-Alegría et al. 2019). Different techniques adopted for the removal of fluoride in drinking water are coagulation-precipitation, membrane process, ion exchange, and adsorption processes (Rafique et al. 2012).

**TDS**

Total Dissolved Solid (TDS) is used to indicate a wide range of inorganic salts such as potassium, calcium, sodium, bicarbonates, chlorides, magnesium, sulfates, etc., and small amounts of organic matter dissolved in water. The presence of these minerals or salts affects the taste and appearance of water. High TDS in water indicates higher mineralization. There is no proven report available regarding over-TDS consumption on human health but persons suffering from kidney and heart diseases are vulnerable to high concentrations (Meride and Ayenew, 2016). The high value of TDS (above 500 mg/l) causes excessive scaling in water heaters, pipes, and household utensils, and reduces their efficiency (Pushpalatha et al. 2022).

**Total Hardness**

The common understanding of hardness in water can be realized simply by washing hands with soap. In hard water, it requires a larger amount of soap to form lather. Hard water also makes precipitation of insoluble metals, soaps, or salts in containers. Ca and Mg mainly cause hardness but there is a contribution from other cations such as aluminum, barium, iron, manganese, strontium, and zinc.

The groundwater fitness for drinking purposes was assessed by calculating the water quality index using the standard equations. The Piper trilinear diagram is also plotted to understand the hadrochemical facies of water.

## Results

**Spatial Distribution Maps:** The spatial distribution maps of a total of 13 water quality parameters i.e. pH, TDS, TH, calcium, magnesium, chlorine, sulfate, iron, alkalinity, fluoride, manganese, sodium, potassium are prepared using Inverse Distance Weighted (IDW) interpolation techniques in ArcGIS 10.2 software. The results are shown in the figures for both the seasons. Except for iron and manganese, other parameters are found within the permissible limit.

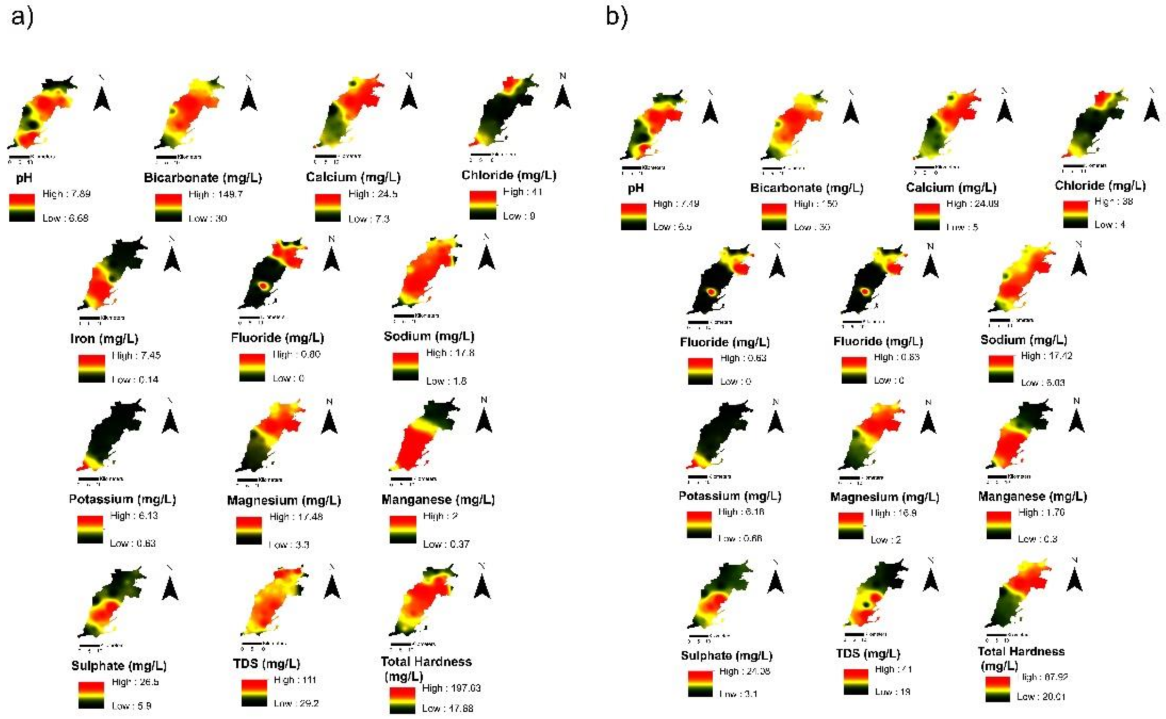


**Fig. 2 Spatial distribution map of water quality parameters in a) pre-monsoon season and b) post-monsoon season**

**Water Quality Index:** The weighted arithmetic water quality index by Brown et al. 1975 (Ram et al. 2021) is used in calculating the water quality index (WQI). The parameters used for the calculation are pH, TDS, TH, Calcium, Magnesium, Chlorine, Sulfate, and Iron. The following equations are used for the calculation of WQI.

$$\boldsymbol{WQI = \frac{\sum_{i=1}^{n} W_i \quad Q_i}{\sum_{i=1}^{n} W_i}}$$

Where, $W_i = \frac{K}{S_n}$ and $K = \frac{1}{\sum \frac{1}{S_n}}$ , n = number of parameters, $W_i$ = unit weight for the i$^{th}$ parameter, Qi = sub index of the i$^{th}$ quality parameter, K= proportionality constant, $S_n$ = standard value of the i$^{th}$ parameter, $Q_i = 100 \frac{(V_0 - V_i)}{(S_n - V_i)}$ , Vo = observed value of ith parameter at a given sampling site, $V_i$ = ideal value of i$^{th}$ parameter in pure water. The groundwater quality map is prepared using Arc GIS 10.2 software interpolating the WQI values using IDW interpolation techniques, the area is classified into 0-25 (excellent), 26-50 (Good), 51-75 (poor), 76-100 (very poor), above 100 (unsuitable for drinking). The high value of WQI is due to the presence of a high concentration of iron resulting in the groundwater condition of the study area being poor to unsuitable for drinking. Only 2.8% of the area has good quality drinking water, with 93.6% of the area found to be very poor to unsuitable for drinking. However, other parameters are found to be within the permissible limit. Proper treatment of iron will ensure the improvement of the groundwater's good to excellent quality for drinking.

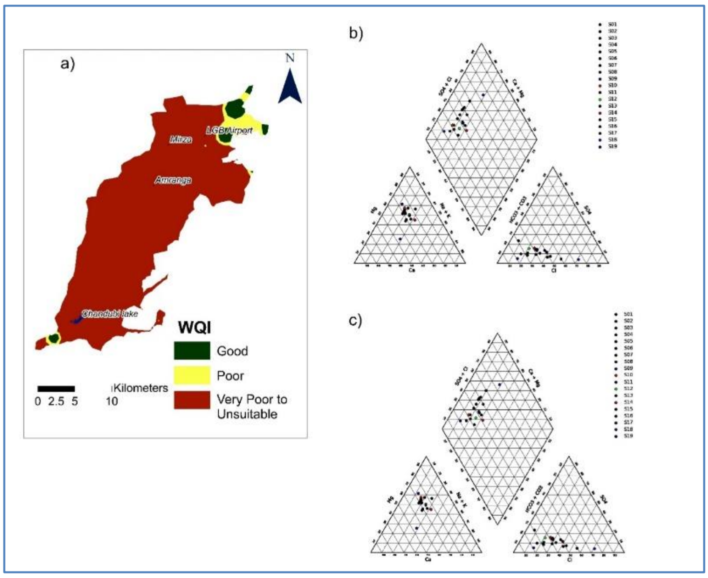


**Fig. 3 a) Water Quality Index Map, b) Piper Trilinear Diagram plot for pre-monsoon season, c) for post-monsoon season**

**Hydro chemical Facies Analysis:**

***Piper Trilinear Diagram:*** The Piper trilinear diagram is a statistical distribution diagram that gives a better understanding of the hydrochemical facies of groundwater. The cation and anion compositions of numerous samples are depicted together on a single graph which helps in the visual identification of significant groupings or trends within the data (Nwankwoala & Udom, 2011). In the present study, the Aquifer App developed by Hatari Labs is used to plot the piper diagram. The Piper plot consists of two triangles, one on the left for cations and one on the right for anions indicating the relative content of each ion in milliequivalents per liter with a central diamond representing the general hydochemical characteristics of the water sample (Gao et al. 2019). For cations, almost 74% of the samples fall under Zone C followed by the remaining 26% under Zone B. For anions, almost 89% of samples fall under Zone E followed by 10% under Zone G and 1% under Zone B. The diamond plot indicates that almost 84% of samples fall under Zone 5 indicating Ca-Mg-bicarbonate-type water denoting temporary hardness, vigorous recharge, or presence of soluble silicate within the aquifer (Tay, 2021). The remaining 16% of samples fall under Zone 9 indicating mixed type.

**Conclusion:** The groundwater quality for drinking purposes was assessed using the WQI method in the southwestern peri-urban Guwahati city. Water samples are collected from household tube wells for both pre- and post-monsoon seasons. The WQI values are found very high in 93.6% of the study area indicating very poor to unsuitable quality of drinking water for human consumption. The presence of iron beyond permissible limits is the major cause of such deterioration. Aeration followed by rapid sand filtration, floc filtration, and adsorptive filtration are some suggestive measures for the removal of iron (Sharma, 2001). The piper trilinear plot shows the hydrochemistry of the groundwater to be Ca-Mg-bicarbonate-type depicting the probable influence of geological setting. The study will contribute to sustainable water resource management, particularly in the context of peri-urban development.

**Reference**

[1] Simon D. Urban Environments: Issues on the Peri-Urban Fringe. *Annu Rev Environ Resour*. 2008; 33: 167-185.

[2] Piorr A., Ravetz J., Tosics I. Peri-Urbanisation in Europe. *University of Copenhagen / Academic Books Life Sciences*; 2011.

[3] Brindha K., Schneider M. Impact of Urbanization on Groundwater Quality. In: Venkatramanan S., Viswanathan P. M., Chung S. Y., eds. GIS and geostatistical techniques for groundwater science. Elsevier; 2019:179-196.

[4] Sharp J.M. The impacts of urbanization on groundwater systems and recharge. *AQUAmundi*. 2010; 1:51-56.

[5] Guppy L., Uyttendaele P., Villholth K.G., Smakhtin, V. Groundwater and Sustainable Development Goals: Analysis of Interlinkages. *UNU-INWEH Report Series*. 2018; 04: 1-23.

[6] Haseena M., Malik M.F., Javed A., Arshad S., Asif N., Zulfiqar S., Hanif J. Water pollution and human health. Environ Risk Assess Remediat. 2017; 1(3): 16-19.

[7] Zhang Z., Xiao C., Adeyeye O., Yang W., Liang X. Source and Mobilization Mechanism of Iron, Manganese and Arsenic in Groundwater of Shuangliao City, Northeast China. *Water*. 2020; 12(2): 1-17.

[8] Grönwall J., Oduro Kwarteng S. Groundwater as a strategic resource for improved resilience: a case study from peri-urban Accra. *Environ Earth Sci*. 2017; 77: 1-13.

[9] Karpouzoglou T., Marshall F., Mehta Lyla. Towards a peri-urban political ecology of water quality decline. *Land Use Policy*. 2018; 70:485-493.

[10] Borah M., Das P.K., Borthakur P., Basumatary P., Das D. An Assessment of Surface and Ground Water Quality of Some Selected Locations in Guwahati. *Int J Appl Environ Sci.* 2020; 15: 93-108.

[11] Dutta S., Barman R., Radhapyari K., Datta S., Lale K., Ray B., Chakraborty T., Srivastava S.K. Potentially toxic elements in groundwater of the upper Brahmaputra floodplains of Assam, India: water quality and health risk. *Environ Monit Assess*. 2022; 194:923.

[12] Lahkar M., Bhattacharyya K.G. Heavy Metal Contamination of Groundwater in Guwahati City, Assam, India. Int Res J Eng Technol. 2019; 6(6): 1520-1525.

[13] Sengupta P. Potential Health Impacts of Hard Water. *Int J Prev Med.* 2013; 4(8): 866–875.

[14] Rapant S., Cvečková V., Fajčíková K., Sedláková D., Stehlíková B. Impact of Calcium and Magnesium in Groundwater and Drinking Water on the Health of Inhabitants of the Slovak Republic. *Int J Environ Res Public Health*. 2017; 14(3): 278.

[15] Health Canada. Guidelines for Canadian Drinking Water Quality: Guideline Technical Document — pH. *Water and Air Quality Bureau, Healthy Environments and Consumer Safety Branch*. 2015; Health Canada, Ottawa, Ontario.

[16] Patil P.N., Sawant D.V, Deshmukh R.N. Physico-chemical parameters for testing of water – A review. *Int J Environ Sci*. 2012; 3(3):1194-120.

[17] https://www.ngwa.org/

[18] Banerjee P., Prasad B. Determination of concentration of total sodium and potassium in surface and ground water using a flame photometer. *Appl Water Sci*. 2020, 10:113.

[19] Zhang Z., Xiao C., Adeyeye O., Yang W., Liang X. Source and Mobilization Mechanism of Iron, Manganese and Arsenic in Groundwater of Shuangliao City, Northeast China. *Water*.2020, 12:534.

[20] Elsheikh M., Guirguis H., Fathy A. Removal of iron and manganese from groundwater: a study of using potassium permanganate and sedimentation. *MATEC Web of Conferences*.2018, 162:1-7.

[21] Ahmed M. *Iron and Manganese removal from groundwater*, Dissertation. University of Oslo; 2012.

[22] Bash J., Berman C. Effects of Turbidity and Suspended Solids on Salmonids. *Washington State Transportation Commission*. 2001.

[23] Allen M.J., Brecher R.W., Copes R., Hrudey S.E., Payment P. Turbidity and Microbial Risk in Drinking Water. *Prepared for The Minister of Health, Province of British Colombia, pursuant to Section 5 of the Drinking Water Act (S.B.C. 2001)*. 2008.

[24] Bashir M.T., Ali S., Bashir A. Health Effects from Exposure to Sulphates and Chlorides in Drinking Water. *Pakistan J Med Health Sci*. 2012,6(3): 648-652.

[25] Kelly W.R., Panno S.V., Hackley K. The Sources, Distribution, and Trends of Chloride in the Waters of Illinois. *Bulletin B-74*, *University of Illinois.* 2012.

[26] World Health Organization. *Chloride in Drinking-water*. 2003.

[27] Brindha K., Elango L. Fluoride in Groundwater: Causes, Implications and Mitigation Measures. In: Monroy, S.D., eds. Fluoride Properties, Applications and Environmental Management. Nova Publishers; 2011: 111-136.

[28] Valdez-Alegría CJ, Fuentes-Rivas R.M., García-Rivas J.L., Fonseca-Montes de Oca R.M.G., García-Gaitán B. Presence and Distribution of Fluoride Ions in Groundwater for Human in a Semiconfined Volcanic Aquifer. *Resources*. 2019; 8(2):116.

[29] Rafique A., Awan M.A., Wasti A., Qazi I.A., Arshad, M. Removal of Fluoride from Drinking Water Using Modified Immobilized Activated Alumina. *J Chem*. 2013: 1-7.

[30] Meride Y., Ayenew B. Drinking water quality assessment and its effects on residents health in Wondo genet campus, Ethiopia. *Environ Syst Res*. 2016; 5(1):1-7.

[31] Pushpalatha N., Sreeja V., Karthik R., Saravanan G. Total Dissolved Solids and Their Removal Techniques. *Int J Environ Sustain Dev*. 2022, 2(2): 13-30.

[32] Brown R.M., Mccleiland N.J., Deiniger R.A., O'Connor M.F. Water quality index-crossing the physical barrier. *Proceedings of the International Conference on Water Pollution Research, Jerusalem*. 1972. 6:787–797

[33] Ram A., Tiwari S.K., Pandey H.K., Chaurasia A.K., Singh S., Singh Y.V. Groundwater quality assessment using water quality index (WQI) under GIS framework. *Appl Water Sci*. 2021, 11:46.

[34] Nwankwoala H.O., Udom G.J. Hydrochemical Facies and Ionic Ratios of Groundwater in Port Harcourt, Southern Nigeria. *Res J Chem Sci*. 2011, 1(3):87-101.

[35] Gao Z., Liu J., Feng J., Wang M., Wu G. Hydrochemical Facies and Ionic Ratios of Groundwater in Port Harcourt. *Water*. 2019. 11(8):1577.

[36] Tay C.K. Hydrogeochemical framework of groundwater within the Asutif‑North District of the Brong‑Ahafo Region, Ghana. *Appl Water Sci*. 2021. 11:72.

[37] Sharma S.K. *Adsorptive Iron Removal from Groundwater*. [Doctoral dissertation]. Delft, The Netherlands: Wageningen University; 2001.

Pre-Monsoon Water Quality Results

| Sample_code | Long | Lat | Source | Na | K | SO4 | Fe | HCO3 | Ca | TDS | Cl | FL | TTH | pH | Mn | Mg |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| S01 | 91.62283 | 26.13752 | TW | 11 | 0.63 | 12.89 | 0.14 | 60.316 | 16 | 97 | 16 | 0 | 110 | 6.9 | 0.37 | 10.2 |
| S02 | 91.570637 | 26.136148 | TW | 11.8 | 0.86 | 9.97 | 1.09 | 86.311 | 15 | 86 | 29 | 0 | 97 | 7 | 0.69 | 11.7 |
| S03 | 91.53313 | 26.12179 | TW | 11 | 0.71 | 6.77 | 1.2 | 83.986 | 12 | 111 | 41 | 0.67 | 112 | 6.9 | 0.77 | 9.8 |
| S04 | 91.611834 | 26.104832 | TW | 13.1 | 0.87 | 11.9 | 1.2 | 82.532 | 18 | 72 | 17 | 0.56 | 149 | 7.2 | 0.66 | 11 |
| S05 | 91.585078 | 26.091541 | TW | 14 | 1.11 | 13.46 | 1.38 | 96.112 | 18 | 77 | 18 | 0.63 | 171 | 7.4 | 0.62 | 12.8 |
| S06 | 91.534723 | 26.092091 | TW | 11.89 | 0.98 | 9.44 | 1.33 | 97.086 | 16 | 71 | 28 | 0.71 | 123 | 7.3 | 0.62 | 11 |
| S07 | 91.59614 | 26.0544 | TW | 16.9 | 1.33 | 12.98 | 1.7 | 107.98 | 21 | 69 | 10 | 0.76 | 198 | 7.5 | 0.81 | 15.2 |
| S08 | 91.564902 | 26.015221 | TW | 14.2 | 1.32 | 12.98 | 1.99 | 110.01 | 18 | 78 | 14 | 0 | 164 | 7.5 | 1.3 | 12.2 |
| S09 | 91.51816 | 26.04431 | TW | 12 | 1.33 | 8.45 | 1.1 | 149.89 | 21 | 75 | 11 | 0 | 188 | 7.9 | 1.1 | 17.5 |
| S10 | 91.481773 | 26.048188 | TW | 12.6 | 1.15 | 12.88 | 2.88 | 116.11 | 17 | 75 | 16 | 0 | 176 | 7.4 | 1.1 | 12.5 |
| S11 | 91.44048 | 26.00689 | TW | 10.3 | 0.97 | 8.67 | 5.19 | 74.015 | 7.3 | 74 | 12 | 0 | 127 | 7 | 1.87 | 7 |
| S12 | 91.474792 | 25.981177 | TW | 14.2 | 1.28 | 17 | 4.33 | 101.01 | 13 | 81 | 14 | 0 | 152 | 7.3 | 1.9 | 8.5 |
| S13 | 91.51186 | 25.97807 | TW | 14.1 | 1.66 | 26.61 | 1.79 | 114.16 | 17 | 89 | 9 | 0 | 155 | 7.4 | 1.88 | 10.3 |
| S14 | 91.46967 | 25.94429 | TW | 17.9 | 1.11 | 22 | 7.47 | 119.99 | 12 | 85 | 18 | 0.81 | 159 | 6.9 | 1.9 | 7.9 |
| S15 | 91.447921 | 25.931525 | TW | 15 | 1.23 | 19.9 | 5.98 | 97.976 | 12 | 79 | 18 | 0 | 142 | 7.2 | 2 | 7.6 |
| S16 | 91.46883 | 25.89876 | TW | 12.6 | 1.51 | 17.43 | 5.88 | 88.013 | 12 | 91 | 18 | 0 | 129 | 7.7 | 1.98 | 7.6 |
| S17 | 91.431476 | 25.876325 | TW | 11.1 | 3.11 | 12.11 | 3.9 | 74.021 | 13 | 76 | 22 | 0 | 127 | 7.6 | 1.88 | 7.2 |
| S18 | 91.38361 | 25.85515 | TW | 6.4 | 5.88 | 5.9 | 0.17 | 30.098 | 12 | 71 | 33 | 0 | 87 | 7.1 | 1.2 | 3.3 |
| S19 | 91.524214 | 25.877385 | TW | 12.6 | 2.21 | 14.89 | 4.42 | 90.341 | 14 | 68 | 17 | 0 | 98 | 7.3 | 1.78 | 7.6 |

Post Monsoon Results

| Sample_code | Long | Lat | Source | Na | K | SO4 | Iron | Alkalinity | Ca | TDS | Cl | Fl | Tot_hardne | Nitrate | PH | Mn | Mg |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| S01 | 91.62283 | 26.13752 | TW | 10.84 | 0.68 | 10.02 | 0.13 | 60 | 15 | 19 | 14 | 0 | 52 | NIL | 6.6 | 0.3 | 9 |
| S02 | 91.570637 | 26.136148 | TW | 11.7 | 0.9 | 8.1 | 1.06 | 86 | 14 | 24 | 26 | 0 | 55 | NIL | 6.8 | 0.54 | 10 |
| S03 | 91.53313 | 26.12179 | TW | 10.81 | 0.75 | 5.9 | 1.09 | 84 | 10 | 25 | 38 | 0.32 | 48 | NIL | 6.8 | 0.5 | 9 |
| S04 | 91.611834 | 26.104832 | TW | 12.96 | 1.08 | 9.63 | 0.96 | 82 | 17 | 22 | 16 | 0.26 | 62 | NIL | 6.9 | 0.49 | 11 |
| S05 | 91.585078 | 26.091541 | TW | 13.51 | 1.32 | 9.13 | 1.34 | 96 | 17 | 23 | 16 | 0.33 | 65 | NIL | 7.1 | 0.57 | 12 |
| S06 | 91.534723 | 26.092091 | TW | 11.73 | 1.05 | 7.5 | 1.33 | 97 | 14 | 25 | 26 | 0.26 | 58 | NIL | 7 | 0.62 | 11 |
| S07 | 91.59614 | 26.0544 | TW | 16.25 | 1.86 | 9.2 | 1.59 | 108 | 20 | 21 | 8 | 0.56 | 80 | NIL | 7.4 | 0.5 | 15 |
| S08 | 91.564902 | 26.015221 | TW | 13.61 | 1.54 | 11.22 | 1.91 | 110 | 17 | 26 | 12 | 0 | 66 | NIL | 7.2 | 0.84 | 12 |
| S09 | 91.51816 | 26.04431 | TW | 11.5 | 1.5 | 6.1 | 1.02 | 150 | 20 | 23 | 10 | 0 | 88 | NIL | 7.5 | 0.69 | 17 |
| S10 | 91.481773 | 26.048188 | TW | 12 | 1.37 | 9.15 | 2.25 | 116.48 | 15 | 26 | 13 | 0 | 63 | NIL | 7.1 | 0.89 | 12 |
| S11 | 91.44048 | 26.00689 | TW | 9.93 | 1.07 | 6.3 | 5.17 | 74 | 5 | 28 | 8 | 0 | 28 | NIL | 6.8 | 1.17 | 6 |
| S12 | 91.474792 | 25.981177 | TW | 13.34 | 1.66 | 15.25 | 4.26 | 101.42 | 11 | 30 | 11 | 0 | 42 | NIL | 6.9 | 1.4 | 8 |
| S13 | 91.51186 | 25.97807 | TW | 13.25 | 1.97 | 24.1 | 1.74 | 114 | 15 | 38 | 4 | 0 | 44 | NIL | 7.2 | 1.65 | 10 |
| S14 | 91.46967 | 25.94429 | TW | 17.45 | 1.35 | 18.7 | 7.4 | 110 | 10 | 24 | 16 | 0.57 | 40 | NIL | 6.6 | 1.77 | 7 |
| S15 | 91.447921 | 25.931525 | TW | 14.61 | 1.76 | 15.64 | 5.88 | 98 | 11 | 30 | 16 | 0 | 40 | NIL | 6.8 | 1.5 | 7 |
| S16 | 91.46883 | 25.89876 | TW | 12.15 | 1.53 | 13.7 | 5.86 | 88 | 10 | 41 | 14 | 0 | 40 | NIL | 7.4 | 1.37 | 7 |
| S17 | 91.431476 | 25.876325 | TW | 10.72 | 3.48 | 10.81 | 3.82 | 74 | 12 | 32 | 19 | 0 | 36 | NIL | 7 | 1.13 | 6 |
| S18 | 91.38361 | 25.85515 | TW | 6.03 | 6.07 | 3.1 | 0.16 | 30 | 10 | 26 | 28 | 0 | 20 | NIL | 6.5 | 0.51 | 2 |
| S19 | 91.524214 | 25.877385 | TW | 12.43 | 2.48 | 13.37 | 4.39 | 90.26 | 13 | 33 | 15 | 0 | 43 | NIL | 7.1 | 1.28 | 7 |