Spatial Analysis and Mapping of Groundwater Quality in Uppal Kalan, Hyderabad

Durgasrilakshmi Hari 1*, Y Rudraksh Goud2, Dodla Meghana2

1*,2 Vardhaman College of Engineering, Hyderabad, India.

1* harisrilakshmi@gmail.com

Abstract: Water is an essential element intended for the continued survival of life on the planet earth in which groundwater is the chief sources of drinking and other uses. Groundwater quality will become essentially important in water scarce areas. The study considered is in Uppal Kalan area, which comes under Medchal-Malkajgiri District of Telangana State. The present study carried out to analyse the physicochemical parameters of groundwater quality such as pH, Turbidity, Colour, Total Dissolved Solids (TDS), Conductivity, Dissolved Oxygen (DO), Alkalinity, Total Hardness, Calcium, Magnesium, Fluoride, Potassium, Phosphate, Nitrate, Chloride and Sulphate for 50 sample well locations. The results of Physicochemical analysis are spatially analysed and mapped using Geographic Information System (GIS) interpolation techniques to visualize the groundwater quality status in the study area. Spatial analysis showed that the groundwater is highly contaminated and the majority of quality parameters are not within the BIS Standards of drinking. Even for domestic use proper treatment is necessary as Colour, Conductivity, Total Hardness, Calcium, Magnesium, Fluoride, Phosphate, Nitrate and Sulphate are at higher levels. Hence, the study area has an exceptional concern about groundwater quality and requires periodic pollution monitoring.

1. Introduction

The water which percolates through pores of the soil and rocks and is stored below the ground is called groundwater. Groundwater quality is the status of water that exists below the earth’s surface. Groundwater is an essential source of freshwater, accounting for about 30.1% of the world’s available freshwater. However, groundwater resources are being rapidly used up at an alarming and unsustainable rate in many areas of the world. While the presence of various dissolved, suspended substances and toxic compounds in water may cause potential risk for groundwater contamination. Improper disposal of wastes from the industrial and domestic sectors on land is the major cause of groundwater pollution. Septic tanks, deep well injections and poisonous leachates from waste dumping yards also will contribute significant groundwater pollution which may be irreversible. Drinking water must be free from contaminants, which may include toxic chemicals, pathogens and excessive mineral matter that may be hazardous to health. Groundwater contamination is severe, especially when the water is used for drinking or crop irrigation and even for domestic use. Therefore, preventing ground water from contamination is essential to the conservation of groundwater resources. GIS (Geographic Information System) is a significant tool for decision making and developing solutions for environmental management, water resources, spatial analysis, infrastructure and...
urban development planning on a regional scale. GIS is a modern technology to assess the groundwater quality by means of water quality parameters spatial interpolation.

2. Study Area Description

The present study area considered is Uppal Kalan; it is the third most populated sub district, located in Medchal-Malkajgiri district of the State Telangana in India. Having Latitude of 17°24'7'' N and Longitude of 78° 34'11''E, at the mean sea level of 494 meters. It covers an area of 7.25 sq. km and has a total population of 384,835 as per the Census 2011. Average annual rainfall is about 786.8 cm and Annual average temperature of 26.7 °C. The study area is identified as a multi-cluster as part of the Study area boarders Musi River and includes Uppal Industrial Development Authority (IDA) having different industries, waste dumping yard. Figure 1 shows the Study Area Map.

![Study Area Map](image)

Figure 1. Study Area Map

2.1 Purpose of the Study

As per 2018 statistics, about 350 million litres of contaminated water, domestic and industrial sewage per day is released into Musi River which causes pollution of groundwater in Uppal Kalan Area. The scary reality that turbidity of water ranges from reddish brown to yellowish. In addition to this industrial effluent from IDA Uppal contain appreciable amounts of inorganic and organic chemicals as their by-products also contaminating groundwater in the study area. Drinking water is a major problem in Uppal area. It is supplied on alternate days or once in two days. Even the quantity of water supplied is meagre. As a result, people living in about 30 colonies in the area are worst-hit. Effluents from many industries in Nacharam area also flow into Uppal Lake. As a result, the sewage and hazardous materials seep into the ground and contaminate the groundwater in the areas. Colonies in the area like North Kalyanpuri, Giri Colony and Balaji Colony are beset with the problem of unsafe groundwater. Majority of people in Uppal Kalan Area are dependent and using groundwater for drinking and domestic purpose. So regular water quality assessment is to be done, as groundwater resources may be damaged and human health may get affected.
2.2 Objectives of the Study

- To analyse the physicochemical parameters of groundwater
- To create spatial distribution maps of groundwater quality to visualize and understand the relationship among the measured points and areal extent of contamination in the study area

3. Methodology

3.1 Data Collection

The groundwater samples from the study area were collected from 50 different bore wells. The well locations were chosen so that they portray the impact of the existing groundwater quality in the study area. The groundwater bore well locations are represented on the map as given below Figure 2. Study area sampling locations along with their Latitudes and Longitudes are presented in Table 1 below.

Figure 2. Groundwater sampling locations map
Table 1. Study Area Sampling Locations

| S. No | Location Name                  | Area Name              | Latitude | Longitude |
|-------|--------------------------------|------------------------|----------|-----------|
| 1     | Mahindra Service Center        | Swaroop Reddy Colony   | 17.403   | 78.573    |
| 2     | Bharath Petrol Bunk            | Srinivasa Colony       | 17.4     | 78.58     |
| 3     | Shanthi Nagar                  | Srinivasa Colony       | 17.4     | 78.581    |
| 4     | Beside Aditya Hospital         | Shanti Nagar           | 17.401   | 78.578    |
| 5     | Sri Venkateshvara Service      | Shanti Nagar           | 17.401   | 78.574    |
|       | Center                         |                        |          |           |
| 6     | Abhishek Industries            | Shanti Nagar           | 17.399   | 78.575    |
| 7     | Hemalatha Nilayam              | Shanti Nagar           | 17.4     | 78.571    |
| 8     | Bharath Mess                   | Shanti Nagar           | 17.401   | 78.573    |
| 9     | Jyothi Nilayam                 | Shanti Nagar           | 17.397   | 78.571    |
| 10    | Ganesh Curry Point             | Hanumasi Nagar         | 17.4     | 78.564    |
| 11    | Sunny Nilayam                  | Sairam Colony          | 17.398   | 78.566    |
| 12    | Sri Sai Hostel                 | Vijapuri Colony        | 17.399   | 78.565    |
| 13    | Seshadri Nilayam               | Venkateshvara Colony   | 17.4     | 78.561    |
| 14    | Bajaj Service Center           | Venkateshvara Colony   | 17.398   | 78.561    |
| 15    | Sri Jagadeshwara Motors        | Raj Nagar Colony       | 17.396   | 78.56     |
| 16    | Green Honda Services           | Survey Colony, IDA     | 17.396   | 78.555    |
| 17    | Chemveda Industries            | Industrial Development | 17.396   | 78.55     |
|       | Area Uppal                      |                        |          |           |
| 18    | Maa Durga Industries           | Industrial Development | 17.392   | 78.551    |
|       | Area Uppal                      |                        |          |           |
| 19    | Stax Laboratory                | Industrial Development | 17.394   | 78.549    |
|       | Area Uppal                      |                        |          |           |
| 20    | Ps Industries                  | Industrial Development | 17.394   | 78.545    |
|       | Area Uppal                      |                        |          |           |
| 21    | Expro Industries               | Industrial Development | 17.4     | 78.548    |
|       | Area Uppal                      |                        |          |           |
| 22    | Maruthi Service Center         | Industrial Development | 17.398   | 78.553    |
|       | Area Uppal                      |                        |          |           |
| 23    | Core Crush Tech                | Industrial Development | 17.393   | 78.553    |
|       | Area Uppal                      |                        |          |           |
| 24    | BMS Crush Tech                 | Industrial Development | 17.392   | 78.555    |
|       | Area Uppal                      |                        |          |           |
| 25    | Annapurna Apartments           | Prashanthi Nagar       | 17.405   | 78.557    |
| 26    | Durga Temple                   | P&T Colony             | 17.403   | 78.56     |
| 27    | S.R Food Court                 | Beerppa Nagar          | 17.402   | 78.561    |
| 28    | D.M.S Boys Hostel              | Sri Nagar Colony       | 17.403   | 78.562    |
| 29    | Postal Staff Quarters          | Kummari basthi         | 17.403   | 78.564    |
| 30    | Lahari Apartments              | Beerappaguda           | 17.402   | 78.567    |
| 31    | MGR Factory                    | Espi Road              | 17.404   | 78.547    |
| 32    | Phoenix Towers                 | Habsiguda              | 17.411   | 78.549    |
Physicochemical analysis of 16 different parameters for the Collected 50 water samples was performed as per the customary methods and procedures. Table 2 shows the Parameters, testing methods, instruments and chemicals used for the study.

### Table 2. Parameters, testing method, instruments and chemicals used;

| S. No | Parameters                     | Testing Method       | Instruments used | Chemicals used                      |
|-------|--------------------------------|----------------------|------------------|-------------------------------------|
| 1.    | pH                             | Electrometric Method | pH meter         | Buffer                              |
| 2.    | Turbidity                      | Electrometric Method | Nephelometric    | Turbidity meter                     |
| 3.    | Colour                         | Spectrophotometric method | UV-Spectrophotometer |                              |
| 4.    | Total dissolved solids (TDS)    | Electrometric Method | TDS meter        | Standard KCl Solution               |
| 5.    | Conductivity                   | Wheat-Stone Bridge Principle | Digital Conductivity meter | Potassium Chloride Solution         |
| 6.    | Dissolved Oxygen (DO)          | Membrane electrode method | DO Meter         | Sulphuric acid, Methyl orange indicator, Phenolphthalein indicator |
| 7.    | Alkalinity                     | Titration Method     | Pipette, Burette, Conical flask | EDTA, Buffer solution, EBT Indicator |
| 8.    | Total Hardness                 | Titration Method     | Pipette, Burette, Conical flask |                                 |
9. Calcium Titration Method Pipette, Burette, Conical flask EDTA, Muroxide indicator, NaOH
10. Magnesium Titration Method Pipette, Burette, Conical flask EDTA, Buffer solution, EBT Indicator, Muroxide indicator, NaOH
11. Fluoride Spectrophotometric method UV-Spectrophotometer Acid- zirconyl SPANDS reagent, Sodium arsenite solution
12. Potassium Spectrophotometric method UV-Spectrophotometer Sodium hydroxide, Tetracycline boron powder Phosphates Reducing Reagent, Phosphate acid reagent
13. Phosphate Spectrophotometric method UV-Spectrophotometer Nitrate Spectrophotometric Grade Tablets
14. Nitrate Spectrophotometric method UV-Spectrophotometer Nitrate Spectrophotometric Grade Tablets
15. Chloride Titration Method Pipette, Burette, Conical flask Potassium Chromate indicator, Silver Nitrate
16. Sulphate Spectrophotometric method UV-Spectrophotometer Sulphate reagent

3.3 Spatial Analysis and Mapping of groundwater quality Using GIS

The Geographic Information System (GIS) is a hardware-assisted software technology and methodology useful for various geospatial applications. GIS has numerous functions like geographic data Collection, Storage, management, Retrieval, Conversion, Analysis, Modelling and display. GIS interpolation techniques are commonly used in groundwater pollution studies to create spatial decision making. GIS interpolation permits to calculate water quality of unknown location using known values to produce complete groundwater quality of the entire area depending on several physicochemical quality parameters. In the present study, the results of the physicochemical analysis of 50 groundwater samples integrated with QGIS. Using the Inverse Distance Weighted (IDW) interpolation method in QGIS Spatial distribution maps of groundwater quality were generated.

4. Results and Analysis

4.1 Physicochemical Analysis

The collected 50 groundwater samples of the study area Uppal Kalan were analyzed in laboratory for 16 water quality parameters such as pH, Turbidity, Colour, Total Dissolved Solids, Conductivity, DO, Alkalinity, Total Hardness, Calcium, Magnesium, Fluoride, Potassium, Phosphate, Nitrate, Chloride and Sulphate using various specific analytical instruments and standard procedures. The physicochemical analysis results are shown in Table 3. According to BIS 10500 (2012), the desirable limit and permissible limit for drinking water have been produced. The Comparative statistical summary of the physicochemical parameters analyzed with BIS standards is shown in Table 4.
| S. No | DO (ppm) | Calcium (ppm) | Magnesium (ppm) | Fluoride (ppm) | Potassium (ppm) | Phosphate (ppm) | Nitrate (ppm) | Chloride (ppm) | Sulphate (ppm) |
|-------|----------|---------------|-----------------|----------------|----------------|----------------|--------------|----------------|----------------|
| 1     | 3.48     | 1360          | 505             | 1.77           | 0.23           | 0.56           | 1.77         | 4.3            | 2.49           |
| 2     | 3.49     | 1830          | 785             | 1.68           | 0.53           | 0.99           | 1.77         | 5.2            | 2.49           |
| 3     | 3.5      | 2000          | 1077            | 1.62           | 0.53           | 0.99           | 1.77         | 5.3            | 2.49           |
| 4     | 3.51     | 2170          | 1205            | 1.61           | 0.53           | 0.99           | 1.77         | 5.3            | 2.49           |
| 5     | 3.52     | 2340          | 1300            | 1.60           | 0.53           | 0.99           | 1.77         | 5.3            | 2.49           |
| 6     | 3.53     | 2500          | 1390            | 1.59           | 0.53           | 0.99           | 1.77         | 5.3            | 2.49           |
| 7     | 3.54     | 2650          | 1490            | 1.58           | 0.53           | 0.99           | 1.77         | 5.3            | 2.49           |
| 8     | 3.55     | 2800          | 1580            | 1.57           | 0.53           | 0.99           | 1.77         | 5.3            | 2.49           |
| 9     | 3.56     | 2950          | 1670            | 1.56           | 0.53           | 0.99           | 1.77         | 5.3            | 2.49           |
| 10    | 3.57     | 3100          | 1760            | 1.55           | 0.53           | 0.99           | 1.77         | 5.3            | 2.49           |
| 11    | 3.58     | 3250          | 1850            | 1.54           | 0.53           | 0.99           | 1.77         | 5.3            | 2.49           |
| 12    | 3.59     | 3400          | 1940            | 1.53           | 0.53           | 0.99           | 1.77         | 5.3            | 2.49           |
| 13    | 3.6      | 3550          | 2030            | 1.52           | 0.53           | 0.99           | 1.77         | 5.3            | 2.49           |
| 14    | 3.61     | 3700          | 2120            | 1.51           | 0.53           | 0.99           | 1.77         | 5.3            | 2.49           |
| 15    | 3.62     | 3850          | 2210            | 1.50           | 0.53           | 0.99           | 1.77         | 5.3            | 2.49           |
| 16    | 3.63     | 4000          | 2300            | 1.49           | 0.53           | 0.99           | 1.77         | 5.3            | 2.49           |
| 17    | 3.64     | 4150          | 2390            | 1.48           | 0.53           | 0.99           | 1.77         | 5.3            | 2.49           |
| 18    | 3.65     | 4300          | 2480            | 1.47           | 0.53           | 0.99           | 1.77         | 5.3            | 2.49           |
| 19    | 3.66     | 4450          | 2570            | 1.46           | 0.53           | 0.99           | 1.77         | 5.3            | 2.49           |
| 20    | 3.67     | 4600          | 2660            | 1.45           | 0.53           | 0.99           | 1.77         | 5.3            | 2.49           |
| 21    | 3.68     | 4750          | 2750            | 1.44           | 0.53           | 0.99           | 1.77         | 5.3            | 2.49           |
| 22    | 3.69     | 4900          | 2840            | 1.43           | 0.53           | 0.99           | 1.77         | 5.3            | 2.49           |
| 23    | 3.7      | 5050          | 2930            | 1.42           | 0.53           | 0.99           | 1.77         | 5.3            | 2.49           |
| 24    | 3.71     | 5200          | 3020            | 1.41           | 0.53           | 0.99           | 1.77         | 5.3            | 2.49           |
| 25    | 3.72     | 5350          | 3110            | 1.40           | 0.53           | 0.99           | 1.77         | 5.3            | 2.49           |
| 26    | 3.73     | 5500          | 3200            | 1.39           | 0.53           | 0.99           | 1.77         | 5.3            | 2.49           |
| 27    | 3.74     | 5650          | 3290            | 1.38           | 0.53           | 0.99           | 1.77         | 5.3            | 2.49           |
| 28    | 3.75     | 5800          | 3380            | 1.37           | 0.53           | 0.99           | 1.77         | 5.3            | 2.49           |
| 29    | 3.76     | 5950          | 3470            | 1.36           | 0.53           | 0.99           | 1.77         | 5.3            | 2.49           |
| 30    | 3.77     | 6100          | 3560            | 1.35           | 0.53           | 0.99           | 1.77         | 5.3            | 2.49           |
| 31    | 3.78     | 6250          | 3650            | 1.34           | 0.53           | 0.99           | 1.77         | 5.3            | 2.49           |
Table 4. Comparative statistical summary of the Physicochemical parameters analysed with BIS standards:

| S. No | Water Quality parameter | BIS Standards (IS 10500: 2012) | Study Area Ranges |
|-------|-------------------------|--------------------------------|------------------|
|       |                         | Desirable - Permissible        | Min              | Max |
| 1     | pH                      | 6.5 to 8.5 - No relaxation     | 3.48             | 6.91 |
| 2     | Turbidity (N T U)       | 1 - 5                          | 0.40             | 4.9  |
| 3     | Colour (HU)             | 5 - 15                         | 4                | 400  |
| 4     | Total dissolved solids (TDS) (ppm) | 500 - 2000 | 297             | 1360 |
| 5     | Conductivity (µS/cm)    | 300 - 600 (WHO/ICMR)           | 461              | 2920 |
| 6     | Dissolved Oxygen (DO) (ppm) | 5 (ICMR) - Not defined | 0.8              | 4.5  |
| 7     | Alkalinity (ppm)        | 200 - 600                      | 60               | 780  |
| 8     | Total Hardness (ppm)    | 200 - 600                      | 240              | 2435 |
| 9     | Calcium (ppm)           | 75 - 200                       | 95               | 790  |
| 10    | Magnesium (ppm)         | 30 - 100                       | 100              | 2205 |
| 11    | Fluoride (ppm)          | 1.0 - 1.5                      | 0.47             | 2.03 |
| 12    | Potassium (ppm)         | 2 - 10 (WHO)                   | 1.5              | 9.3  |
| 13    | Phosphate (ppm)         | 0.1 - Not defined (WHO)        | 0.03             | 0.56 |
| 14    | Nitrate (ppm)           | 45 - No relaxation             | 0.04             | 59   |
| 15    | Chloride (ppm)          | 250 - 1000                    | 2.49             | 49.99|
| 16    | Sulphate (ppm)          | 200 - 400                     | 29               | 77   |
4.2 Spatial Distribution of groundwater quality parameters

The analysed physicochemical parameters were compared with the BIS 10500 limits (2012). Spatial distribution thematic maps for all the analysed groundwater quality parameters were mapped based on the IDW (Inverse Distance Weighted) interpolation using the open-source software, QGIS. Spatial distribution maps show the spatial variation of different water quality parameters of the overall study area. About 16 thematic maps were generated and colour coded according to the Desirable, Permissible levels and concentrations more than permissible levels as per water quality standards are presented in Figure 3 to 18.
Figure 7 Spatial distribution map of Conductivity

Figure 8 Spatial distribution map of DO

Figure 9 Spatial distribution map of Alkalinity

Figure 10 Spatial distribution map of Total Hardness

Figure 11 Spatial distribution map of Calcium

Figure 12 Spatial distribution map of Magnesium
Figure. 13 Spatial distribution map of Fluoride

Figure. 14 Spatial distribution map of Potassium

Figure. 15 Spatial distribution map of Phosphate

Figure. 16 Spatial distribution map of Nitrate

Figure. 17 Spatial distribution map of Chloride

Figure. 18 Spatial distribution map of Sulphate
The results of spatial analysis indicating that most of the study area having pH value less than 6.5 and groundwater is moderately acidic. Chloride values in the overall study area are within the desirable limits. Turbidity, TDS, Alkalinity and Potassium values are within permissible limits. Colour, Conductivity, DO, Total Hardness, Calcium, Magnesium, Sulphate, Phosphate, Fluoride are at higher concentrations and not within permissible limits in the entire study area. Nitrate concentration is more than permissible limits in Kalyanpuri, Sai Nagar, Anand Nagar Colony, Mallikarjuna Nagar, Chilka Nagar, Bank Colony, Azmat Nagar, Prasanth Nagar, Sri Ram Nagar in the study area. The water quality spatial assessment at all the sampling points and in entire Uppal Kalan shows that Groundwater quality is very poor. This noticeably points outs that Groundwater samples in the study area are highly polluted. Hence, it is essential to assess the groundwater quality especially in the area which includes industrial and dumping yard clusters. Groundwater quality spatial assessment helps in the overall assessment of the water management issues for any area for taking necessary administrative decisions. It can provide useful insights into the development of the water management plan for the entire study area.

5. Conclusion

Groundwater quality is a primary priority as most of the population depends on it for various uses. The present study demonstrates that GIS is an effective tool for groundwater quality spatial analysis and mapping. Spatial distribution maps help to visualize the groundwater quality status, pollution levels and to understand the relationship among the measured points and areal extent of contamination in the study area. In this study 16 selected physiochemical parameters are calculated and spatially analysed using IDW interpolation. The groundwater within Uppal Kalan area has a very high concentrations of Colour, Conductivity, Total Hardness, Calcium, Magnesium, Sulphate, Phosphate, Fluoride and Nitrate. Proving that the industrial effluents, domestic sewage and pollution from nearby Musi river are not only causing direct contamination of groundwater but are also responsible for health hazards. Groundwater quality is poor and not within the BIS standards and guidelines for drinking as well as for domestic use in the study area. Groundwater is very hard and polluted not recommended for direct domestic use without proper treatment. Preventing the leaking sewage from the damaged sewers and lining of sewer drains is essential in order to avoid the contamination of groundwater. Groundwater treatment facility should be planned in order to provide potable water to meet the constantly increasing need in the study area. Collecting and augmenting rainwater with the groundwater resources by recharging it through rainwater harvesting is the best practice to maintain the groundwater quality. Treatment of waste and wastewater is essential before being discharged on to the land or water to reduce the intensity of pollutants. Aquifers are being stressed to meet ever growing water demands. Hence timely groundwater quality assessment is a major concern because of the potential health threats. Practices that could be legalized at the local level include drilling depth, distance between wells, installation of treatment units at the source of pollution to achieve sustainability of aquifers and local level groundwater management.

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