



(RESEARCH ARTICLE)



## Physico-chemical & biological study of groundwater at different locations of Lucknow City

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### Abstract

Water plays a crucial role in supporting life on our planet. Initially, groundwater was deemed a reliable source for drinking, but with the passage of time, it has faced contamination stemming from the release of untreated industrial waste and other human actions. This contamination of water has emerged as a significant factor in the proliferation of various illnesses, including hepatitis, jaundice, typhoid, dysentery, and diarrhea. In the city of Lucknow, the capital of Uttar Pradesh, both surface water and groundwater serve as sources of drinking water.

The purpose of study was to evaluate the current quality of groundwater in Lucknow. Two stations were selected within the city to collect groundwater and surface water samples, which underwent a thorough physico-chemical and biochemical analysis. Parameters such as temperature, turbidity, conductivity, total dissolved solids (TDS), chloride, fluoride, total hardness, alkalinity, nitrate, phosphate, sulphate, Bod, Cod, E Coli & T Coli were measured using standard methods.

The findings were compared with the IS drinking water standard 10500, and it was observed that some parameters at all sampling stations were above & some were within the acceptable limits. However, some parameters like TDS, total hardness, alkalinity & chloride exceeded the standard limits at certain stations. Whereas T Coli & E Coli was found in slight increases at both the stations. This highlights the importance of monitoring and managing water quality to ensure a safe and healthy water supply for the residents of Lucknow

**Keywords:** Groundwater; Physico-chemical parameter; Biochemical parameter; IS:10500 Drinking water Standards

### 1. Introduction

The extent of environmental pollution is progressively on the rise. Groundwater plays a pivotal role as a primary water resource, catering not just to drinking purposes but also for industrial and agricultural needs [1]. Approximately one-third of the world's population depends on groundwater for their drinking water supply [2], leading to continuous exploitation [1]. Initially, groundwater was safe to drink, but with time, it has become contaminated due to the leaching of chemicals like phosphate, nitrate, pesticides, heavy metals & pathogens. This contamination is primarily caused by the discharge of untreated industrial effluents, agricultural septic tanks, domestic wastewater, and other sources [3], resulting in waterborne diseases such as hepatitis, jaundice, typhoid, dysentery, and diarrhoea.

In Uttar Pradesh, 80 cities rely on groundwater for their drinking and irrigation needs. The uncleanness of water supplied for drinking purpose is quiet a major issue in developing countries [2]. Due to excessive human exploitation, groundwater levels are depleting, and its quality is deteriorating, largely dependent on land use and the quality of wastewater discharged into the rivers and terrain [3].

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Lucknow, the capital of Uttar Pradesh, lies in the Ganga plains and Bundelkhand plateau[4] . Around 85% of Lucknow City's land area is situated on the Central Ganga alluvial plain, with an underlying large thickness of Quaternary alluvial sands and occasional silty clay aquitards.

Groundwater is the water that infiltrates into the ground through soil particles, sand, and gravel, originating from rain, sleet, snow, and hail. It accumulates beneath the earth's surface until it reaches a depth where groundwater occurs. This water is found in soil pore spaces and fractures of rock formations [5].

India is the largest consumer of groundwater in the world, estimated at almost 230 cubic kiloliters per year [6]. Groundwater is a vital freshwater resource, particularly for fulfilling the need for safe drinking water. This study aims to compare the quality of groundwater from hand pumps and bore wells with prescribed standards and assess its potability based on various parameters like pH, TDS, chloride, fluoride, alkalinity, total hardness, calcium, magnesium, sulphate, phosphate, nitrate, BOD, COD, E-Coli, T-Coli. The analysis involved grab water samples from two different stations randomly selected during January – June 2023.

## 2. Material and methods

Monitoring was conducted at two monitoring stations from January 2023 to June 2023 to assess the quality of groundwater. The objective was to determine the status of groundwater quality. Groundwater sources selected for sampling included both bore wells and hand pumps. Sampling bottles were utilized to collect water samples.

The gathered samples underwent analysis for a range of physico-chemical parameters and bacteriological parameters. These parameters encompassed Temperature (Temp.), pH, Turbidity (Turb.), Conductivity (Cond.), Total Dissolved Solids (TDS), Alkalinity (Alkal.), Chloride(Cl<sup>-</sup>), Fluoride (F<sup>-</sup>), Total Hardness (T.H.), Calcium (Ca<sup>2+</sup>), Magnesium (Mg<sup>2+</sup>), Sulphate (SO<sup>4</sup>-Phosphate (PO<sup>4</sup>-), and Nitrate Nitrogen (NO<sub>3</sub><sup>-</sup>-N), as well as Biochemical Oxygen Demand (BOD)[9], Chemical Oxygen Demand (COD), E. coli, and Total Coliforms (T-Coli).

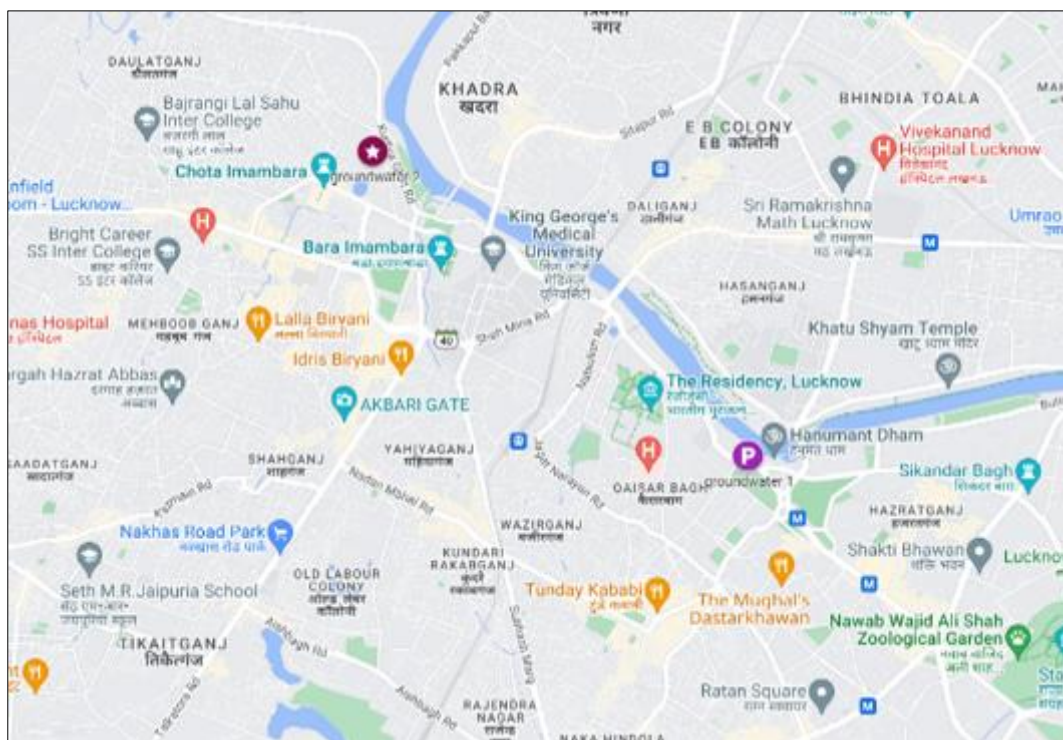
All the analyses were performed following the Standard Methods for the Examination of Water and Wastewater [20]

### 2.1. Study Area

To evaluate the groundwater quality of Lucknow City, we identified two specific sampling locations. The coordinates of these sampling stations are detailed in Table-1.

**Table 1** Sampling station with their GPS location

Station code	Stations	GPS Location
GW1	Ghanta Ghar Chowk	26° 52'17.1"N to 80° 54'53.5"E
GW2	Near Hanumant Dham Qaisar Bagh	26° 51'25.4"N to 80° 56'10.5"E



**Figure 1** Lucknow map showing sampling stations

**Table 2** Average concentration of various physico- chemical parameter of two sites sampling stations

S. No.	Parameters and Unit	IS: 10500 Drinking Water Standards	GW1	GW2
1.	Temp. (°C)	20	21.16±2.25	21.13±2.01
2.	pH	6.5-8.5	8.2±0.11	8.1±0.20
3.	Turb.(NTU)	1	< 1	<1
4.	Cond. (µmhos/cm)	2500	1360±20	714±20
5.	TDS (mg/L)	500	641.67 ±20	485.67±20
6.	Alkalinity(mg/L)	200	457±10	256±10
7.	Cl <sup>-</sup> (mg/L)	250	365.83 ± 10	482.167 ± 10
8.	F <sup>-</sup> (mg/L)	1.0	0.19±0.01	0.04±0.01
9.	T.H. (mg/L)	200	486.67 ± 10	264.67 ± 10
10.	Ca <sup>++</sup> (mg/L)	75	134.167 ±10	84.83 ± 10
11.	Mg <sup>++</sup> (mg/L)	30	52.5 ± 10	43 ± 10
12.	SO <sub>4</sub> <sup>==</sup> (mg/L)	200	57.33 ± 10	31.5 ± 10
13.	PO <sub>4</sub> <sup>==</sup> (mg/L)	0.05	0.009267 ± 0.0001	0.005683 ± 0.0001
14.	NO <sub>3</sub> <sup>-</sup> N (mg/L)	45	13±5	11±5

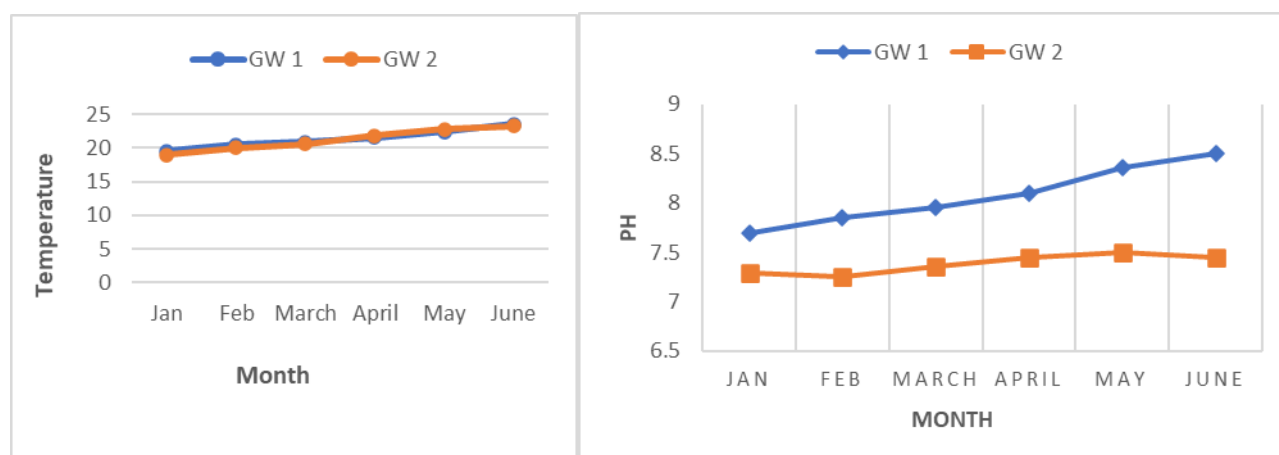
**Table 3** Average values of various biochemical parameter taken from two different sites samples

S.No.	Parameters & unit	IS: 10500 Drinking Water Standards	GW1	GW2
1.	BOD	<5 mg/L	3.1	3.06
2.	COD	<250 mg/L	54.83	55.5
3.	T Coli (MPN/100)ml	Nil	15.16	9.67
4.	E Coli (MPN/100)ml	Nil	2.29	1.008

### 3. Results and discussion

Temperature & pH plays a crucial role in both chemical and biochemical reactions within water and its living organisms. Previous studies have linked temperature variations primarily to atmospheric conditions and weather patterns. During the research, the minimum temperature recorded was 19.56°C near Ghanta Ghar Chowk (GW1), while the maximum temperature was 22.87°C near Hanumant Dham Qaisar Bagh (GW2). While pH level were also examined during the study, with the minimum pH of 7.23 near Ghanta Ghar Chowk (GW1) and the maximum pH of 8.12 at near Hanumant Dham Qaisar Bagh (GW2). It was observed that the pH remained within an acceptable range at all stations. Significance of pH level in a water body is for assessing water quality as it influence other chemical reaction like metal toxicity and solubility. Here monthly variation of both temperature and pH is shown by the help of Bar Chart.

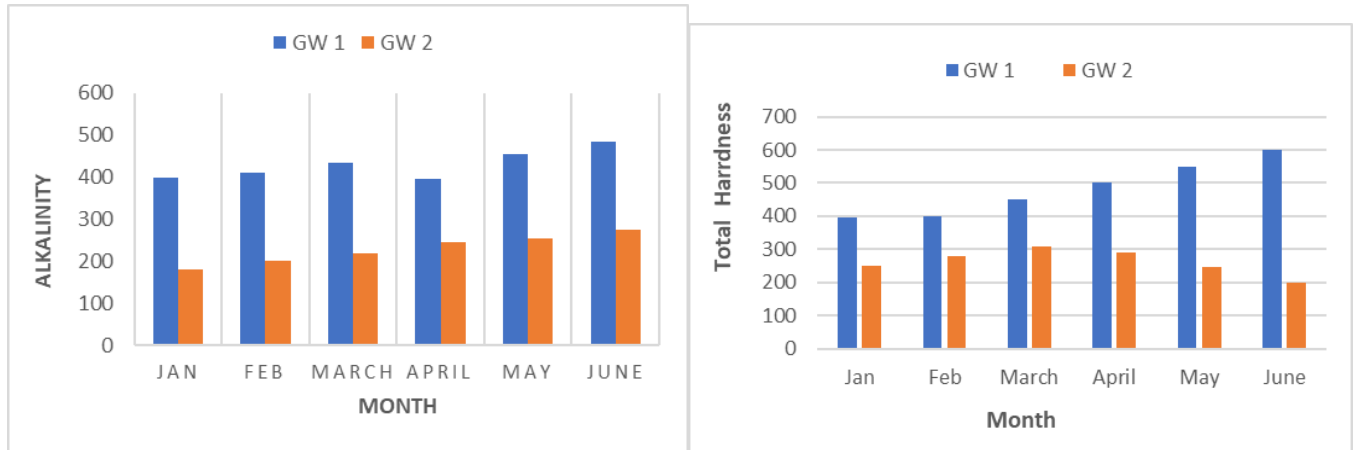
Turbidity and electrical conductivity are vital parameters for assessing water quality. Turbidity, representing light scattering, directly influences water clarity. Elevated turbidity values indicate reduced water clarity, whereas lower values suggest higher clarity levels [2]. In this research, the turbidity measurements at all sampling points were found to be below 1.0 NTU, which complies with the acceptable limit specified by BIS 10500-2012. Electrical conductivity (EC) assumes a pivotal role as a primary indicator of water quality, reflecting a water body's ability to conduct electricity [5,6]. Additionally, it serves as a quick means to assess the total dissolved ions and is closely associated with the overall solid content. Elevated levels of dissolved solids are in sync with increased ion concentrations[7]. The lowest conductivity of 700µmhos/cm was observed at near Hanumant Dham Qaisar Bagh (GW2), while the highest conductivity of 1360 µmhos/cm was recorded near Ghanta Ghar Chowk (GW1)

**Figure 2 and 3** Monthly Variation Line Graph of Temperature & pH

#### 3.1. Monthly Variation in Ions

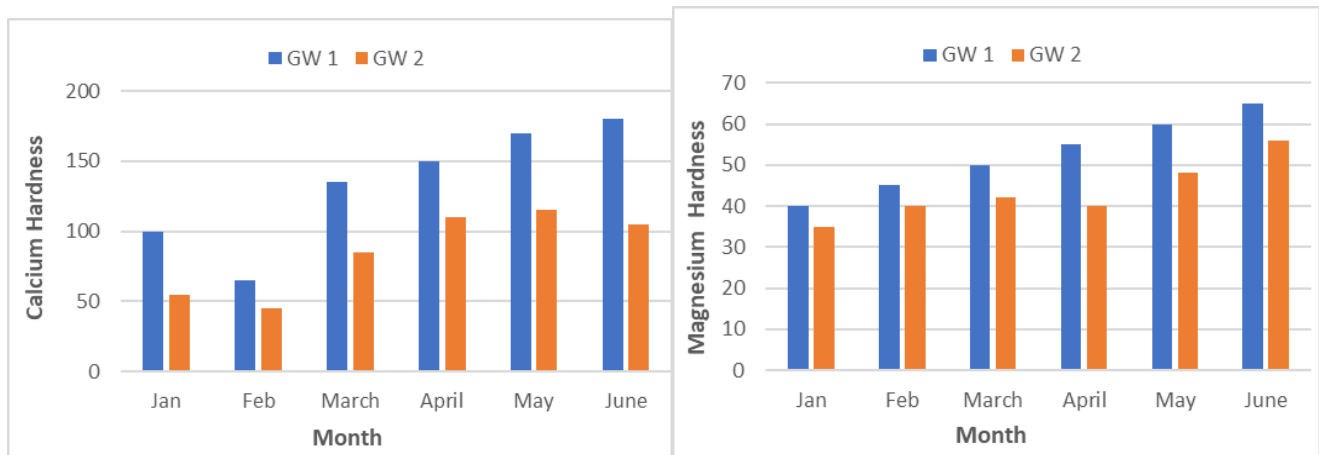
Alkalinity, which refers to the neutralizing capacity of water against acids without significant pH [8] changes, ranged from a minimum of 165.55 mg/L at Near Hanumant Dham Qaisar Bagh (GW2) to a maximum of 457 mg/L at Ghanta Ghar Chowk (GW1). The elevated alkalinity at GW1 exceeded the desirable limit of 200 mg/L as per BIS (2012) [10] though it doesn't pose health risks, but may give a bitter taste to water at higher concentrations. Total Hardness in water results from the presence of multivalent metallic cations like calcium and magnesium salts[13]. The total hardness ranged from a minimum of 200 mg/L at Hanumant Dham Qaisar Bagh (GW2) to a maximum of 600 mg/L at Ghanta Ghar Chowk (GW1). While hardness can be beneficial in some cases, it may impact pipe corrosion and heavy metal entry into water. Calcium levels ranged from a minimum of 40 mg/L at Hanumant Dham (GW2) to a maximum of 170 mg/L at

Ghanta Ghar Chowk (GW1). Similarly, magnesium levels ranged from 35 mg/L at Hanumant Dham (GW2) to 65 mg/L near Ghanta Ghar Chowk (GW1).



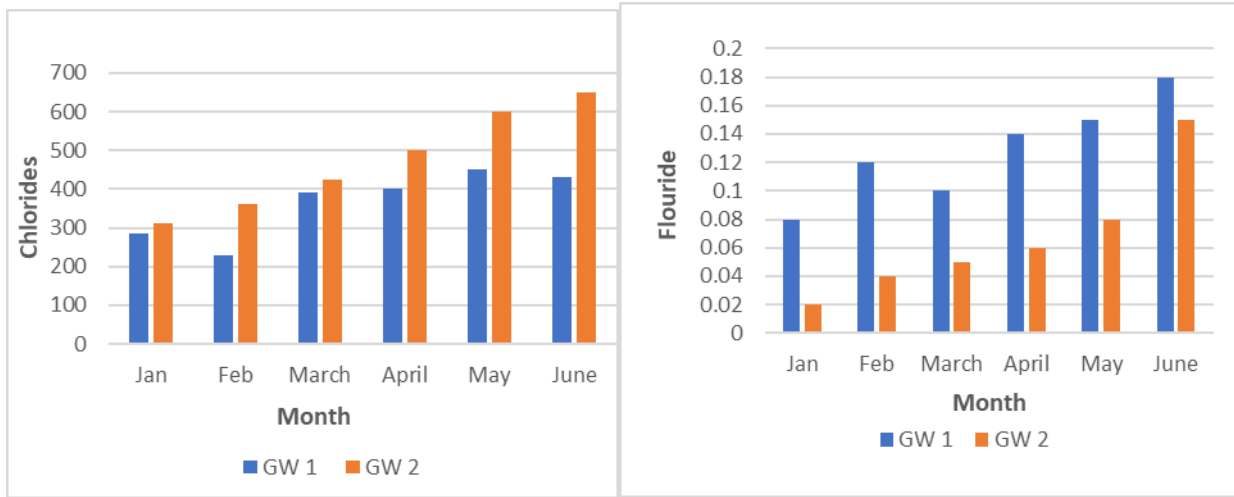
**Figure 4 and 5** Monthly Variation bar Chart of Alkalinity & Total Hardness

Calcium levels fluctuated from a lowest value of 40 mg/L at Hanumant Dham (GW2) to highest value of 170 mg/L at Ghanta Ghar Chowk (GW1). Similarly, magnesium levels ranged from 35 mg/L at Hanumant Dham (GW2) to 65 mg/L near Ghanta Ghar Chowk (GW1).



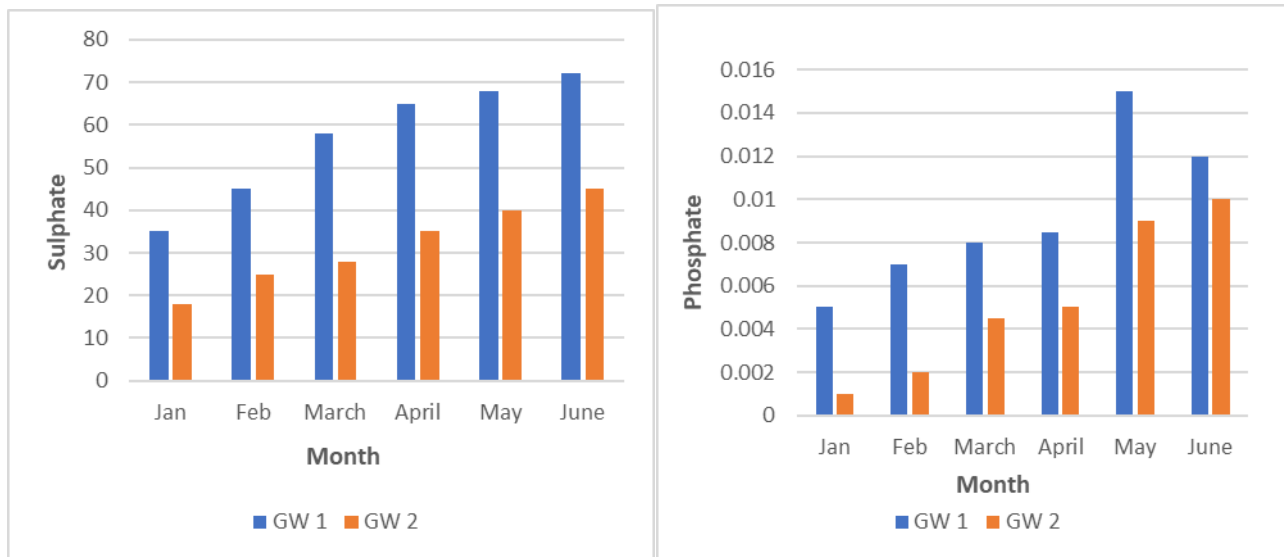
**Figure 5 and 6** Monthly Variation Bar Chart of Calcium hardness & Magnesium hardness

Chloride levels fluctuated by a lowest value of 210 mg/L at Ghanta Ghar Chowk (GW1) to highest value of 650 mg/L at near Hanumant Dham (GW2). Higher Chloride value is generally due to increased discharge of wastewater near the river bank which generally seeps down to contaminate the subsurface water. Fluoride content ranged from a minimum of 0.02 mg/L at Near Hanumant Dham Qaisar Bagh (GW2) to a maximum of 0.19 mg/L near Ghanta Ghar Chowk (GW1). Fluoride is essential in water but can cause health issues in excessive amounts. A concentration of 1.5 ppm can lead to dental fluorosis and skeletal fluorosis [11,14].

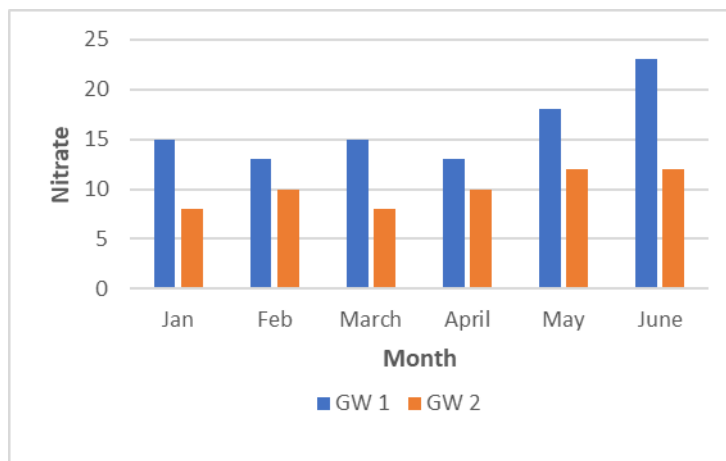


**Figure 7 and 8** Monthly Variation Bar charts of Fluoride & Chlorides

Sulphate concentrations fluctuates from a least of 24mg/L (GW2) to highest of 65 mg/L near Ghanta Ghar Chowk (GW1). Sulphates may cause catharsis, dehydration, and gastrointestinal irritation, and they often occur naturally from various sources[12]. Phosphate levels ranged from a minimum of 0.009 mg/L at Hanumant Dham (GW2) to a maximum of 0.019 mg/L at Ghanta Ghar Chowk (GW1). Phosphate pollution can be influenced by agricultural runoff containing fertilizers and wastewater with detergents. Nitrate concentrations varied from a minimum of 6 mg/L at Hanumant Dham (GW2) to a maximum of 22 mg/L at Ghanta Ghar Chowk (GW1). Increased nitrate levels in drinking water can lead to health issues[15], and agricultural activities are often the primary source of nitrate contamination in groundwater.[9.]



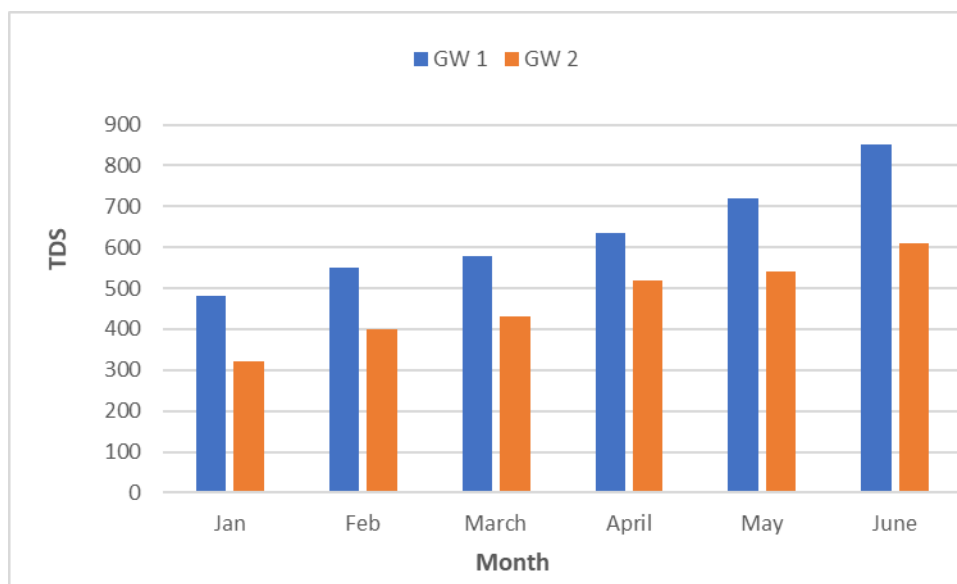
**Figure 9 and 10** Monthly variation Bar chart of Sulphate & Phosphate



**Figure 11** Monthly Variation Bar Chart of Nitrate

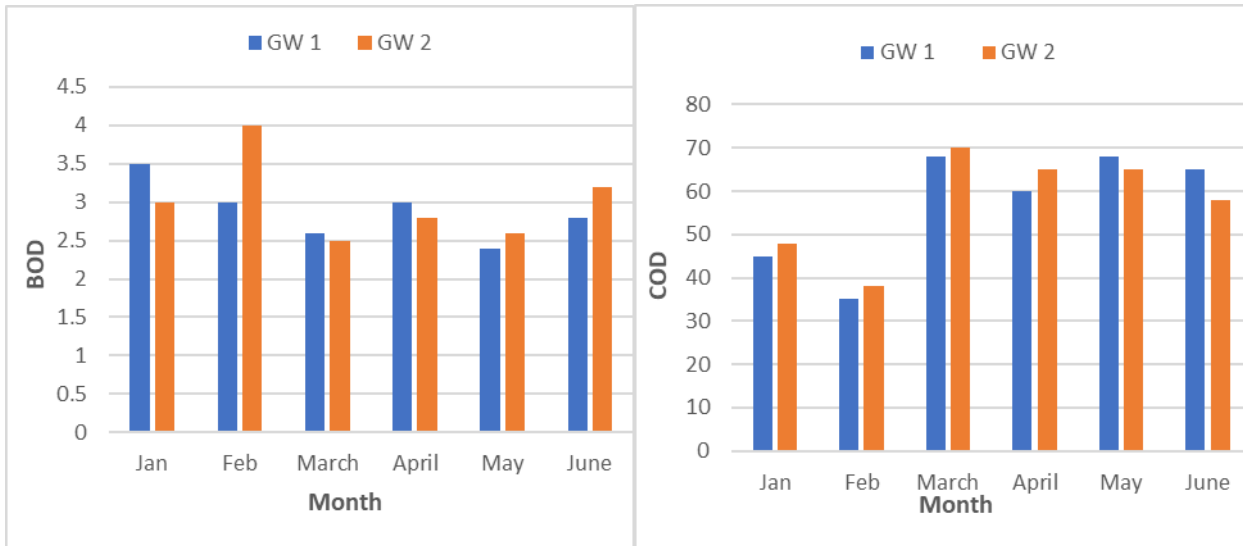
### 3.2. Monthly Variation in other contaminants

Total dissolved solids (TDS) were measured as the weight of residue left after evaporation of a water sample. The minimum TDS of 325.55 mg/L was found at Near Hanumant Dham Qaisar Bagh (GW2), and the maximum of 850 mg/L was observed near Ghanta Ghar Chowk (GW1). TDS analysis is crucial for assessing water quality for drinking, agricultural, and industrial purposes.



**Figure 12** Monthly variation Bar Chart of TDS

Biochemical oxygen demand was found approximately equal to 3.1 mg/L in both the two stations. BOD (Biochemical Oxygen Demand) serves as an analytical metric that quantifies the quantity of dissolved oxygen (DO) utilized by aerobic bacteria as they metabolize organic substances within a water sample. This measurement occurs under specified conditions of temperature and over a defined time interval. Chemical Oxygen demand (COD) was found minimum at 34 mg/L at near Ghanta Ghar Chowk (GW1) and maximum at 68 mg/L near Hanumant Dham (GW2). Chemical Oxygen Demand (COD) denotes the quantity of oxygen required for the oxidation of organic materials found in a water sample. COD testing is employed to ascertain the extent of oxidation that will transpire and to quantify the organic content within the water sample.



**Figure 13 and 14** Monthly Variation Bar Chart of BOD & COD

T-coli was found minimum at Hanumant Dham 8 MPN/100 ml (GW2) and maximum at Ghanta Ghar Chowk 25 MPN/100 ml (GW1) and E-Coli was found minimum at Hanumant Dham (GW2) 0.56 MPN/100 ml and maximum at Ghanta Ghar Chowk 4.23 MPN/100 ml.

T-Coli is a term used to describe bacteria present in soil, water affected by surface water, and in human or animal waste. Within this category, E-Coli is a subset of F-Coli, and F-Coli, in turn, is a subset of T-Coli, collectively referred to as Total Coliform bacteria. E-Coli is a Gram-negative bacterium that is facultatively anaerobic and rod-shaped. It belongs to the genus Escherichia and is typically found in the lower intestines of warm-blooded organisms. While most strains of E. coli are not harmful, certain serotypes like EPEC and ETEC can be pathogenic, leading to severe food poisoning in their hosts. These pathogenic strains are occasionally linked to food contamination incidents that necessitate product recalls.



**Figure 15 and 16** Monthly Variation Line Graph of E Coli & T Col

#### 4. Conclusion

This study make known that Turbidity, Total dissolved solid, Alkalinity, Chloride, Total Hardness, Calcium Hardness and magnesium hardness was found higher than the prescribed limit [10,18] while pH, Temperature, Conductivity, fluoride, Sulphate, phosphate, Nitrate were found below the prescribed permissible limit as per (IS 10500:2012). It was found



that GW2 station near Hanumant Dham Qaisar Bagh was having quiet better standard quality as compared to station 1 Groundwater. Most of the sampling stations recorded elevated levels of Total Dissolved Solids (TDS), surpassing the established drinking water standards [10]. This increase can be attributed to enhanced dissolution or evaporative concentration. Furthermore, human activities have likely impacted TDS levels in groundwater, including the application of synthetic fertilizers, manures, and the infiltration of wastewater, all of which contribute to salt content in groundwater [17,19].

Elevated TDS values exert various effects, such as altering the water's taste, increasing hardness, and promoting corrosive properties they lead to scaling of boilers, water pipe, household appliances etc. The hardness is primarily introduced through seepage and runoff from the soil[16]. Typically, hardness is regarded as an aesthetic factor in water quality due to the undesirable taste resulting from high concentrations of calcium and other ions. It also diminishes the ability of soap to create lather and promotes scale formation in plumbing fixtures and pipes. The sulphate, phosphate, Nitrate concentration was below standard limit thereby good for both the stations as these stations were less agriculture land occupied that's why use of pesticides was quiet less which results in lower concentration of these physico-chemical parameter thereby making the groundwater less toxic in nature[15]. The Biochemical parameter study reveals that BOD, COD were found within standard limits at both the stations having average values of BOD at station-1 is 3.1 mg/L and station-2 is 3.06 mg/L which was less than 5mg/L prescribed by [10]. The average COD value at both the station came to approx. 55 mg/L which was again under prescribed limit. The T-Coli was having the magnitude at station1 is 15.16(MPN/100) and at station 2 was 9.67 (MPN/100 ml) and T-Coli subset E-Coli having values at the corresponding stations was 2.29 (MPN/100 ml) at GW1 and 1.008 (MPN/100 ml) at GW2. Hence these values moderately differed from their standard limit which is assigned null for drinking water.

Hence, making the Groundwater slightly incompatible for drinking purpose as having pathogens in it but still GW2 station near Hanumant Dham have better groundwater quality as compared to first station near Ghanta Ghar Chowk.

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## Compliance with ethical standards

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### *Disclosure of conflict of interest*

The authors declare that they have no competing interests.

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