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Qualitative Assessment of Water Quality through Index Method: A Case Study of Hapur City, Uttar Pradesh, India

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Abstract: *The present study attempts to assess the groundwater quality of Hapur city, Uttar Pradesh. Groundwater samples were collected from 20 shallow wells and analyzed for physico-chemical characteristics. Water quality index (WQI) was calculated to show the overall water quality status in a single term. The results of this study revealed that the concentration of alkalinity, total dissolved solids, total hardness, nitrate, fluoride and chlorides is higher than the permissible limits as prescribed by the Bureau of Indian standards. The WQI for all samples were found in the range of 12 to 211.This study indicates that the drinking water of the city do not conform to the recommended standards and hence it is suggested to take rational steps to manage water quality in this region before it becomes a crisis, as this will affect the economy and will also lead to various water-borne diseases.*

Keywords: *Physico-chemical parameters, Groundwater, Water quality index, Rain water harvesting*

1. Introduction

Groundwater is an important source of water supply, due to its low susceptibility to pollution as compared to surface water and having large storage capacity. Mohrir et al. [1] reported that about one third of the world's population dependent upon groundwater for domestic purposes and more than 50% of the world's population survival depends on ground water. Around 99% of the United State's and 80% of India's population depend on groundwater for drinking [2]. In many instances water for human consumption is directly supplied from underground without any prior treatment therefore the level of contamination has become a major cause for concern [3]. Water pollution is a prime concern for India as more than 70% of its surface sources and a large number of its groundwater reserves are already contaminated by organic and inorganic pollutants [4]. Groundwater quality deterioration occurs when its quality parameters are changed beyond a certain limit i.e. either by addition or removal of certain elements [5]. Human interference in natural system, over exploitation of groundwater resources for various purposes as well as natural factors is affecting the quality as well as quantity of valuable resource [6].

In this study the physico-chemical characteristics of groundwater collected from shallow depth India mark ii hand pumps (less than 40 meter below ground level) located in and around the residential areas of Hapur city were assessed and on the basis of test results water quality index was calculated.

2. Study Area

Hapur city is the headquarter of Hapur district, situated in western Uttar Pradesh and about 60kms east of New Delhi, India. It is located at 28.72°N latitude 77.78°E longitude. The city Hapur has a humid subtropical climate characterized by extreme hot summers and cool winters. Summers are extremely hot and last from the month of April to late July; temperature varies in between 43-48°C. The monsoon arrives by mid-July and continues up to mid of September. The city experienced a mild and dry winter season from late October to the end of February. The rainfall varies in between 90-100 cm/annum. Most of the rainfall is received during the monsoon seasons and humidity varies from 30-100%.

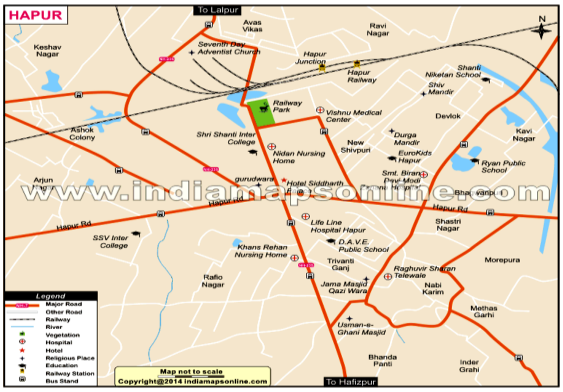

Figure 1: *Map of Hapur city*
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3. Material and Methods

Twenty representative groundwater sampling sites were demarcated and water samples were collected from the sampling stations as shown in Table 1. The groundwater sampling stations covered extensively populated areas so as to obtain good representation. Samples were analyzed for pH, turbidity, TDS, total hardness, chloride, sulfate, total alkalinity, fluoride,

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iron and nitrate in the laboratory of Jal Nigam, Hapur. Sampling, their preservation and procedures for the examination of water samples were performed according the Standard Methods [7].

***Table 1**: Sampling Stations with names*

S.No.	Name of sampling sites	S.No.	Name of sampling sites
S_1	Bhagwan Puri, near flour mill	S_{11}	Avas Vikas Ambedkar colony
S_2	Raghubeer Ganj near R/O Rameshwar	S_{12}	Municipal Board compound
S_3	Majeed Pura near master nursery	S_{13}	Idgah road new colony
S_4	Bulandshahar road near old chungi	S_{14}	Shrinagar colony near R/O Mona
S_5	Shivgarhi near R/O councillor	S_{15}	Devlok colony in Jalkal compound
S_6	Sotawali near water works compound	S_{16}	Inderlok colony near R/O Ankur
S_7	Swarg Ashram road near Radhika palace	S_{17}	Pakka Bagh near Shakumbhari co.
S_8	Navjyoti colony near gate	S_{18}	Keshv Nagar near R/O Chamn yadav
S_9	Chah Kamal near tubewell	S_{19}	New Shiv Puri near R/O Shri Ram
S_{10}	Sanjay Vihar ZPS compound	S_{20}	Tyagi Nagar near flour mill of Mr Pathak

R/O: residence of

4. Results

***Table 2**: Physico-chemical properties of Groundwater Samples*

Sampling station	Turbidity	TDS	pH	Cl^-	F^-	SO_4^{--}	Fe^{++}	NO_3^-	TH	Alkalinity
S_1	2.14	1120	7.36	21.4	0.42	70	0.40	42.0	300	400
S_2	1.20	1400	7.32	22.7	0.51	74	0.64	34.0	420	420
S_3	0.76	1460	7.44	19.2	0.28	52	0.20	20.0	420	360
S_4	0.92	1370	7.40	42.1	0.26	32	0.64	24.0	360	320
S_5	2.94	1610	7.10	224.4	0.13	77	0.57	44.0	520	380
S_6	0.74	1730	7.77	286.0	0.06	12	0.02	13.1	240	392
S_7	4.01	1260	6.70	143.5	0.28	50	0.14	28.6	500	560
S_8	3.63	1340	7.28	111.8	0.38	78	0.72	64.2	419	408
S_9	7.50	1570	7.60	211.8	0.20	95	0.91	26.4	520	360
S_{10}	1.36	1120	7.60	71.3	0.11	7.0	0.08	76.6	200	169
S_{11}	3.13	1710	7.46	381.3	0.11	51	0.06	58.7	400	322
S_{12}	0.89	1270	7.62	124.4	0.08	34	0.17	40.0	480	403
S_{13}	1.22	1390	7.40	16.9	0.20	36	0.16	40.0	360	320
S_{14}	1.62	1040	7.40	12.0	0.24	28	0.12	24.0	320	300
S_{15}	2.86	1130	7.19	14.6	0.23	16	0.62	23.0	360	320
S_{16}	1.44	1020	7.42	17.2	0.60	33	0.38	38.0	280	410
S_{17}	1.60	1220	7.42	23.2	0.27	32	0.26	22.0	340	300
S_{18}	1.72	1430	7.70	14.7	0.38	32	0.22	22.0	420	380
S_{19}	2.42	1460	7.38	40.9	0.24	24	0.17	28.0	460	320
S_{20}	2.17	1270	7.69	60.2	0.62	38	0.42	19.0	400	280

All parameters in mg/L expect turbidity in NTU and pH.

5. Physico-chemical properties of groundwater

The results obtained were presented in table 2. These results were compared and assessed in accordance with the standards as prescribed by Bureau of Indian Standards [8].

5.1 Turbidity

Turbidity is a physical characteristic defined by how clear or transparent water is. The presence of suspended matters such as clay, organic, inorganic and microorganisms make water turbid [9]. Turbidity causes the degradation in transparency. In this study turbidity of water samples ranged 0.74 to 7.5 NTU. The highest value of turbidity 7.5 NTU was found at sampling station S_9.

5.2 Total Dissolved Solids

The TDS value in water indicates the presence of contaminants. General nature of salinity and aesthetic characteristics of water depends upon TDS. The TDS values in this study vary from 1020 to 1730 mg/l.

All the water samples were found above the desire limit 500 mg/l as prescribed by BIS which clearly indicate that the groundwater in some of the locations is very hard and unsuitable for drinking purposes. Water with high TDS is of inferior palatability and may induce an unfavorable physiological reaction in the transient consumers and gastrointestinal irritation. Naturally occurring total dissolved solids arise from the weathering and dissolution of rocks and soils.

5.3 pH

The pH is a measure of the concentration of hydrogen ions in water and it determines the intensity of acidity or alkalinity. Except sampling station no S_7, pH values were found more than 7.0, hence nature of water were alkaline. pH values ranged from 6.7 to 7.77 during the study period. All the samples were found within the limits specified by BIS i.e., 6.5 to 8.5 [8].

5.4 Chlorides

In the present study, chlorides content of groundwater varied from 12 to 381.3 mg/l. Samples collected from S_6 and S_{11} were found above the desirable limit 250 mg/l specified by BIS. Chloride produces salty taste at 250-500 mg/l [10]. No adverse health effects have been reported from intake of higher concentration of Cl^- in drinking water [11].

5.5 Fluorides

The F^- content in the study area ranged from 0.06-0.62 mg/l and found below the BIS desirable limit i.e., 1.0 mg/l. Fluoride as a trace element is beneficial for living organisms including human beings, which protects tooth decay and facilitates proper development of bones [12].

5.6 Sulfate

Sulfate is an important parameter in determining the acceptability of water for industrial and public water supplies. The SO_4^{2-} content in the study area ranged from 7.0-95.0 mg/l. In all the groundwater samples sulfate content were observed below the desirable limit 200 mg/l of BIS.

5.7 Iron

Iron concentration was varied from 0.02-0.91 mg/l. In 45% samples the iron concentration was found above the BIS standard limit 0.30 mg/l. Highest value of iron was found 0.91mg/L at sampling station S_9. Acute exposure to iron is characterized by vomiting, gastrointestinal bleeding, coma and jaundice [13].

5.8 Nitrate

The nitrate concentration varied from 13.1 to 76.6 mg/l. The highest value of nitrate was found 76.6 mg/l at sampling station S_{10}. In 15% samples nitrate content were found above the BIS limit i.e., 45.0 mg/l. The greatest source of nitrogen percolation in groundwater water is sewage waste. The nitrate concentration in drinking water is limited to 45 mg/l.

5.9 Total Hardness

Total hardness indicates concentration of calcium and magnesium and certain multivalent cations such as: Sr^{++}, Fe^{++} and Mn^{++} ions in water. The TH of the samples varied between 200-520 mg/L. Around 95% of samples were found above the BIS limit of 200 mg/l. According to the total hardness classification, the groundwater is said to be hard (150–300 mg/l) to very hard (>300 mg/l) [14]. Hardness of water is undesirable because they may lead to more soap consumption, scaling of boilers, corrosion, incrustations in pipes and making food tasteless etc. [15].

5.10 Alkalinity

The alkalinity values varied from 169-560 mg/l. Around 95% of water samples were found above the BIS standard limits of 200 mg/l. Alkalinity is caused due to the presence of carbonates or hydroxides of sodium, potassium, calcium and magnesium or bicarbonates of calcium and magnesium. The alkalinity in groundwater is generally occurred naturally by dissolution of rocks such as limestone and salts of carbonates, silicates, etc.

6. Water Quality Index (WQI) Estimation

Water quality index is used as a tool to provide information based on the cumulative effect of several water quality parameters. The aim of the WQI is to turn complex water quality data into simple information which is understandable and useable by the public. Studies on water quality of various sources have been assessed on the basis of computed water quality indices [16,17]. The suitability of water for human consumption can be determined on the basis of calculated WQI values [18]. The WQI is a statistical calculation used to transform large quantities of water quality data into a single number which represents the level of water quality [19]. WQI of groundwater were calculated using the methods as proposed by Horton (1965) [20] and modified by Tiwari and Mishra (1985) [21].

The quality rating was calculated using observed, ideal and standard values of water quality parameters according to their role on the overall quality of groundwater. Calculation of WQI was carried out in this work by using following four equations:

- Quality rating $Q_n = 100[(V_n - V_i) / (V_s - V_i)]$

  V_n : Actual amount of n^{th} parameter
  V_i : The ideal value of parameter ($V_i = 0$) and for pH $V_i = 7.0$
  V_s : Recommended standard of corresponding parameter
- Assigned unit weight (W_n)
  $W_n = K/ S_n$
  Where K: Constant
  $\Sigma W_n = 1$
  n=10
- Sub-indices, $(SI)_n = (Q_n)^{W_n}$
  n= 10
- The overall WQI= Anti $\log_{10}[\Sigma W_n \log_{10} Q_n]$
  n=1

The physico-chemical parameters with their BIS limits, corresponding assigned weightage factor (W_n) and ideal values (V_i) are presented in Table 3.

WQI calculations were made from equations number 3 and 4. The Water quality index results based classification of all the water samples is presented in Table 4.

***Table 3**: BIS limits with assigned unit weights*

Sl. No.	Parameters	Standard values (Vs) as per BIS:10500:2012	Ideal value (V_i)	Assigned unit weight (W_n)
1	Turbidity in NTU	1.0	0	0.181492
2	TDS in mg/l	500.0	0	0.000363
3	pH	6.5-8.5	7	0.024200
4	Chloride in mg/l	250.0	0	0.000726
5	Fluorides in mg/l	1.0	0	0.181500
6	Sulfate in mg/l	250.0	0	0.000908
7	Iron in mg/l	0.3	0	0.605000
8	Nitrate in mg/l	45.0	0	0.004033
9	Hardness in mg/l	200.0	0	0.000908
10	Alkalinity in mg/l	200.0	0	0.000908

***Table 4**: Classification of water based on WQI values*

WQI value range	Water quality status	Nos of sampling Stations
0-25	Excellent, Fit for human consumption	1
26-50	Good	4
51-75	Bad, Moderately Contaminated	4
76-100	Very bad, Excessively contaminated	2
>100	Severely contaminated Unfit for human consumption	9

The Table 4 revealed that the WQI values of sampling locations S_1, S_2, S_4, S_5, S_8, S_{15}, S_{16} and S_{20} are more than 100. So the water of these locations is severely contaminated and not suitable for drinking purposes. The WQI values of locations S_{17} and S_{18} varies between 76 and 100. So the water quality of these locations is excessively contaminated. Groundwater of these locations is not fit for human consumption. Water quality index of locations S_3, S_7, S_{13} and S_{19} varied from 51 to 75. Groundwater of these locations was moderately polluted and this category of water is not fit for drinking purposes, but may be used other purposes. The higher values of WQI found at these locations due to the higher values of magnesium, hardness, alkalinity, iron, pH, cadmium, lead, calcium and TDS in the groundwater samples. Water quality index values of rest groundwater samples of locations S_6, S_{10}, S_{11}, S_{12} and S_{14} were less than 50. Water quality of these locations is falling under excellent and good category and fit for drinking purposes.

7. Conclusions

Interpretation of physico-chemical characteristics reveals that the groundwater in Hapur city is hard and alkaline. The results of WQI revealed that about 55% of the groundwater samples included under excessively and severely contaminated category. This indicates that the underground water of these areas was not suitable for drinking purposes. From the study it is observed that groundwater sources are poorly managed and show sign of degradation. This may be due to over-exploitation and use in uncontrolled manner of water resources. In the present state, groundwater of Hapur city is not safe for drinking purpose. Drinking water supplying agencies and general public should be advised to consume water taken from deep bores or use properly

treated water for drinking purposes. Therefore, it is highly recommended to have periodical monitoring of groundwater quality in the region for future sustainability. For dilution of the high concentration of the chemical parameters, rain water harvesting system may be used to recharge the ground water aquifers.

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