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Assessment of Groundwater Quality using Water Quality Index (WQI) as a Tool, in Unnao District, Uttar Pradesh, India

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ABSTRACT

Unnao is one of the major industrial towns adjacent to Kanpur city having large number of leather industry, slaughter house, handloom and textiles units. A dedicated Leather Technology Park in Banthar, Unnao is established for leather industries. Unnao industrial area is situated at the left bank of river Ganga having more than 70 industrial units, mainly tanneries, catering the need of nation. A large population of the urban and semi urban region of the developed and developing countries especially in India depends on groundwater for drinking as well as for irrigation. The study carried out to assess the groundwater quality of Unnao district in Uttar Pradesh using adequate number of water samples. The present investigation is focused to assess the groundwater quality by using water quality index (WQI). A water quality index is a means to summarize large amounts of water quality data in to simple terms for reporting to management and the public in single/ consistent manners. The groundwater monitoring was performed in 16 blocks of Unnao district and samples collected were analyzed for the various physicochemical parameters such as pH, Electrical Conductivity (EC), Total Hardness (TH), Total Dissolved Solids (TDS), Chlorides (Cl^-), Sulphate (SO_4^{2-}) and Nitrate (NO_3^-), Fluoride (F^-) Calcium (Ca^{2+}), Magnesium (Mg^{2+}), Sodium (Na^+), Potassium (K^+), Total Chromium (Cr_T). These 13 parameters were considered to compute the Water Quality Index (WQI). As per Water Quality Index calculation, area has been categorised as Excellent at 10 blocks and Good at 6 blocks of Unnao District in U.P. India. Bichia and Nawabganj these blocks are nearer to the industrial clusters which are dominated by industries such as tanneries, textiles, and chemicals etc. are water intensive units may be the reason of deterioration of water quality and approaching towards the poor Water Quality Index, *i.e.*, 40 and 43. It infer that groundwater of Unnao district does not reflect any significant abnormalities in terms of its suitability for anthropogenic activities. Although their quality varies from location to location and meets the prescribed norms as per IS: 10500 (except Turbidity, Color, TDS, Total Hardness, Calcium, Magnesium Fluoride and chromium at few locations).

INTRODUCTION

During last few decades, the increasing threat to groundwater quality due to anthropogenic activities has become a matter of great concern. Most of the groundwater quality problems are caused by contamination and by over-exploitation, or by combination of both. Rapid urbanization and industrialization in India have resulted in steep increase in generation of wastes. Due to lack of adequate infrastructure and resources, the waste is not properly collected, treated and disposed leading to accumulation and infiltration causing groundwater contamination. The problem is severe in and around large cities where large industrial clusters exist.

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Groundwater is required for domestic, irrigation and industrial uses. In India, a large part of drinking water supply is satisfied by groundwater, thereby increasing its vital importance. As most part of country, groundwater is only sources of drinking water, thus a large population is exposed to risk of consuming contaminated water (Ansari *et al.*, 1999). There are spatial and temporal variations in the quality of groundwater and this is primarily governed by the extent and composition of dissolved solids present. Water pollution not only affects water quality but also threats human health, economic development and social prosperity (Ansari *et al.*, 2000).

Many researchers have carried out work on fluoride as well as heavy metal pollution in the Unnao-Kanpur region. Ansari *et al*. (1998, 1999, 2000), Singh *et al*. (2012), Tewari *et al*. (2012), Jha *et al*. (2009) and Dwivedi and Vankar (2014) carried extensive research work to highlight pollution status of Unnao. As the Unnao city area is closer to the industrial cluster particularly Tanning units as well as other kind of processing industries which has got potential to contaminate the groundwater in the vicinity area. Many committees worked to study the fact associated with the pollution (Jameel and Sirajudeen, 2006).

In this scenario, a committee was constituted by The Ministry of Water Resources, Govt. of India to carry out a detailed monitoring programme for the assessment of groundwater quality in Unnao district of Uttar Pradesh (Ministry of Water Resources, 2013). They have reported the higher concentration of hardness, TDS, sulphate, Fluoride, Nitrate Hexavalent Chromium, Iron, Manganese, Nickle and Lead at few locations in Unnao district. Objective of the study was to assess the ground water quality of all 16 blocks in Unnao district to find out the facts of its suitability for drinking purpose. In order to achieve the objectives of the study, groundwater samples from the different blocks of Unnao district were collected during pre-monsoon seasons in 2012 and analysed. The groundwater quality was assessed using Water Quality Index. Water Quality Index is one of the most effective toosl to communicate information on the quality of any water body. WQI is a mathematical equation used to transform large number of water quality data into a single number (Dar *et al.*, 2011). It is simple and easy to understand for decision makers about quality and possible uses of any water body. It serves the understanding of water quality by integrating complex data and generating a score that describes water quality status. This study will be helpful to the planners, decision makers, scientists and engineers concerned with the management and protection of groundwater quality in the country.

Methodology:

Unnao district is a part of Central Ganga Plain of the Uttar Pradesh state covering an area of 4558 sq.km. and lies between North latitudes 26°06’ and 26°55’ and East longitudes 80°03’ and 81°03’ with total population of 03,108,367 as per 2011 census. Samples were collected from all 16 blocks (Table 1 and Map 1) during study from hand pumps mostly installed in public places i.e. schools, bus stands, hospitals, community centres etc. Detail of the sampling location in Unnao district is tabulated at table number 1.

The physico-chemical analysis of the groundwater samples for parameters such as pH, Electrical Conductivity (EC), Total Hardness (TH), Total Dissolved Solids (TDS), Chlorides (Cl^-), Sulphate (SO_4^{2-}) and Nitrate (NO_3^-), Fluoride (F^-) Calcium (Ca^{2+}), Magnesium (Mg^{2+}), Sodium (Na^+), Potassium (K^+) and Total Chromium (Cr_T) were carried out using APHA (1998) method. The sampling locations have shown in the Table 1. Water samples collected using PVC bottles of 3.0 litres from India Mark-II hand pumps. The bottles were thoroughly cleaned with hydrochloric acid and then washed with tap water rendered free of acid and then washed with distilled water twice and again rinsed with the water sample to be collected and then filled up the bottle with the sample leaving only a small air gap at the top, placed the stopper and sealed the bottle with paraffin wax. All the glassware, casserole and other pipettes were first cleaned with tap water thoroughly and finally with deionised distilled water. The pipettes and burette were rinsed with solution before final use. The chemicals and reagent were used for analysis were of Analytical grade. The groundwater samples were determined using standard methods and the results were compared with the values of World Health Organization (WHO, 2007).

Water Quality Index (WQI):

Water Quality Index, indicating the water quality in terms of a number, offers a useful representation of overall quality of water. Horton (1965) defined Water Quality Index as a reflection of composite influence of individual quality characteristics on the overall quality of water (Desai B. and Desai H., 2012). WQI is used to assess water quality trends for management purpose. For calculation of WQI, selection of parameters has great importance. Since, selection of many number of parameters widen the water quality index and importance of various parameters depends on the intended use, average concentration of thirteen physico-chemical parameters (table 2) namely pH, Electrical Conductivity (EC), Total Hardness (TH), Total Dissolved Solids (TDS), Chlorides (Cl^-), Sulphate (SO_4^{2-}) and Nitrate (NO_3^-), Fluoride (F^-) Calcium (Ca^{2+}), Magnesium (Mg^{2+}), Sodium (Na^+), and Potassium (K^+), were used to calculate WQI**.** Concentration of Chromium has not been considered for the calculation of the WQI as it was found at only one location, *i.e.*, at Nawabganj.

Determination of Water Quality Index:

To determine the suitability of groundwater for drinking purpose, Water Quality Index was computed using Eq. (1)

$$WQI = \left(\sum_{i=1}^{n} q_i W_i \Big/ \sum_{i=1}^{n} W_i \right) \quad (1)$$

Where, W_i is a Weightage factor computed using Eq.

$$W_i = K/Si \quad (2)$$

Where, Si = Standard value of the i^{th} water quality parameter, K is a proportionality constant, which is taken as 1.0, n is the total number of water quality parameters (Srinivas P. *et al* 2011)

Quality rating (qi) is computed using Eq.

$$q_i = \{[(V_a - V_i)/(S_i - V_i)] \times 100\} \quad (3)$$

Where, q_i = Quality rating for the i^{th} water quality parameter, V_a= Actual value of the i^{th} quality parameters obtained from laboratory analysis, V_i = Ideal value of the i^{th} water quality parameter obtained from standard tables, V_i for pH = 7 and for other parameters it is equivalent to zero.

RESULTS AND DISCUSSION

Concentration of thirteen water quality parameters, determined as per APHA (1998) indicated in table 2 and detail of groundwater samples collected from fifty different locations are given in table 1. Standard values prescribed by WHO (WHO, 2007), ideal values and weightage factors of water quality parameters are listed in Table 3. Status of water quality based on WQI is given in Table 4.

During the study, team has collected samples from the study area and analysed for different pollution sensitive parameters. Concentration of different parameters at studied locations have been considered for calculation of average at a block concerned which was further taken care for the calculation of water quality index and discussed as under. The analysis showed that the pH ranged from 7.1 - 7.7 (Table 2). The pH value at all the locations was found well within the prescribed standard by Indian Bureau of Standard (BIS, 1991) and World Health Organisation (WHO, 2007).

Electrical conductivity is the ability of water to allow electric current through it. Conductivity of fresh waters normally found in the range of 5 to 500 µmhos /cm whereas in this study the maximum value 9440 µmhos/cm was observed near auto stand village Pariar, Block Sikandarpur Sirosi and minimum value observed 491 µmhos /cm at Village Benta Bhijawar, 2 km away from Sai River, Block Ganj Moradabad. Concentration of dissolved solids (TDS) in groundwater decides its applicability for drinking, irrigation or industrial purposes. Major constituents of TDS are Bicarbonates (HCO_3^-), Sulphates (SO_4^{2-}) and Chlorides (Cl^-) of Calcium, Magnesium, Sodium and Silica (Goyal, 2010). Groundwater containing more than 1000 mg/l of total dissolved solids is generally referred as brackish water. In this study TDS ranged from 219 to 5974 mg/l with minimum at Pandit Dev Krishna Inter College Campus, Sagwar Block – Bighapur and maximum at Village: Bhadni, near Rameshwar Temple, Bhadni Nala, Block Safipur.

Hardness in water caused primarily by the presence of carbonates and bicarbonates of calcium, magnesium, sulphates, chlorides and nitrates. Total hardness is a measure of calcium (Ca^{2+}) and magnesium (Mg^{2+}) content in water and is expressed as equivalent of $CaCO_3$ (Jeevanandan M., 2007). Water with a hardness of less than 75 mg/l is considered generally as soft. In this study minimum value found 175.4 mg/l at Village: Dalwar, Block – Nawabganj and maximum value of 2055 mg/l was found at Karyalaya Khand Vikas Adhikari, Block – Sikandarpur sirosi.

Fluoride concentration is one of the most common elements in the earth's crust and is most electro-negative of all elements. It occurs in water as fluoride. It is found in both igneous and sedimentary rocks in flat topography and semi arid regions. The formation of high fluoride in groundwater is governed by composition of bedrock and hydrogeology. High fluoride in groundwater may also be formed as a result of evapotranspiration along the groundwater flow path. Fluoride concentration in groundwater of the study area ranges from 0.083-1.57 mg/l. Fluoride of drinking water should ideally be between 1.0 to 1.5 mg/l. During the study minimum concentration was observed 0.083 mg/l at Bhadni of Safipur block while maximum of 1.57 mg/l at Makur village of Nawabganj. The results indicate that the concentration of fluoride is well within the limit except one location where value exceed the desirable limit but under the permissible limit.

Presence of Chloride in groundwater may be due to constituents of igneous and metamorphic rocks like sodalite and chlorapatite etc. and due to sewerage waste disposal and leaching of saline residues in the soil. In this study it ranges from 2.8 mg/l - 1993 mg/l. The minimum value observed near auto stand in village Pariar under Sikandarpur Block and maximum in village Patti Hamid under Fatehpur Charasi Block.

Nitrate enters groundwater through nitrogen cycle. In this study the nitrate concentration ranges from 0.783 mg/l - 63.6 mg/l. Minimum was observed at Industrial area (Inside Powerhouse campus), Banthar under Achalganj block and maximum value was observed at Village – Jagatpur, 3 km away from River Ganga, block - Bangarmau, Unnao. The desirable limit of nitrates in drinking water is 45 mg/l (BIS 10500-1991).

Sulphate occurs naturally in water as result of leaching from gypsum and other common minerals. The values of sulphate are found in the range of 2.7- 1843. 10% samples exceeded the desirable limit but are well within the permissible limit while 6% samples exceed the permissible limit for drinking water standards. The concentration of Sulphate was observed minimum at Morawa Tiraha, near roadways bus stop, Hilloli Block and maximum near Auto stand in village Pariar under block Sikandarpur Sirosi.

Calcium concentration occurs in water mainly due to the presence of limestone, gypsum, dolomite and gypsiferrous minerals. Permissible limit in drinking water for calcium is 75 mg/l (BIS 10500-1991). Calcium concentration ranges from 12.5 - 461 mg/l observed in water sample locations at Village Teji Kheda, Near Prahalad House, Block - Asoha, and Near Auto Stand, Village – Pariar, Block Sikandarpur Sirosi respectively.

Magnesium occurs in water mainly due to the presence of olivine, biotite, augite and talc minerals. Permissible limit of magnesium is 30 mg/l (BIS 10500-1991). In this study it ranges from 11.2 mg/l -106 mg/l. Minimum concentration observed at Koluha gaarha (infront of Sh. Buddan Sahu House), Uchalganj and the maximum at near auto stand of Pariar village of Sikandarpur Sirosi block & Lamboi village of Fatehpur Chauras block.

In this study the Sodium concentration ranges from 13.6-1135 mg/l. Minimum concentration was observed at village Chandpur hassanganj block and maximum value was observed near auto stand, village Pariar under Sikanderpur block.

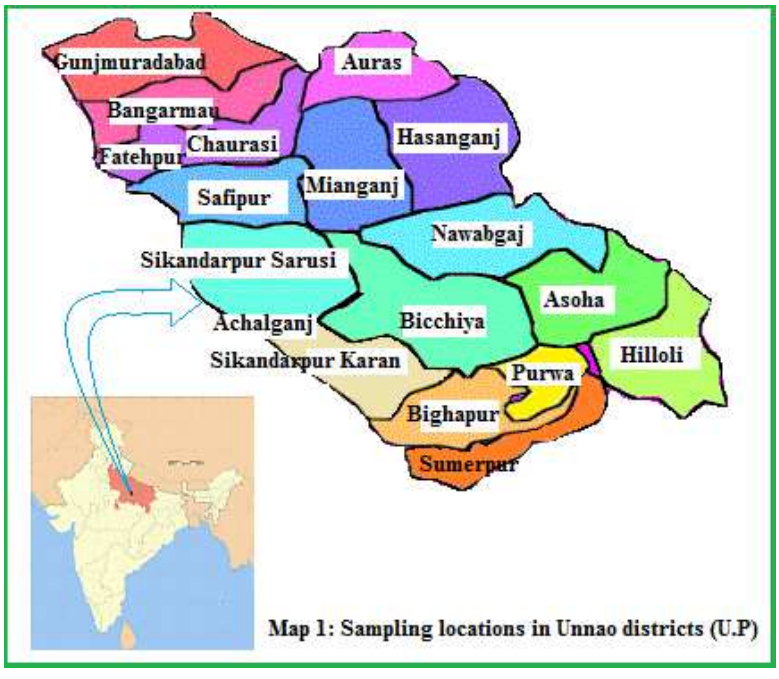
Potassium was found in the range 0.23-1405 mg/l. Maximum was observed near Rameshwar temple, village Bhadni under Safipur block and minimum value was observed near auto stand, village Pariar under Sikanderpur block.

Total Chromium concentration in groundwater was 0.175 mg/l. found at village Talhi in Nawabganj block among all the 16 block of study area where as at other locations it was below detectible limit.

Evaluation of Water Quality Index:

Using the average values of different water quality parameters for the samples as listed in Table 2, WHO standard values, ideal values and weightage factors as listed in Table 3, the computed values of WQI are listed in Table 5. These values of WQI were compared with standard values of WQI (as listed in Table 4) and accordingly quality of water was categorized as listed in Table 5. The computed values of WQI, ranged from 14.0-43.00 is further categorised in two groups as per the quality classification in two groups.

1. Good category- Total 6 blocks fall in this category as per WQI calculation.
2. Excellent category- Total 10 blocks fall in this class as per the WQI computation.



Map 1: Sampling locations in Unnao districts (U.P)

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Table 1: Details of the Groundwater sampling locations in Unnao district (U.P.)

S. No.	Location	Latitude	Longitude
1.	Banthar (Unnao, U.P), Industrial Area (Inside Powerhouse campus)	N -26^0 29' 27.2''	E - 080^0 27' 29.7''
2.	SAB Inter College Campus, Achalganj , Unnao	N -26^0 26'32.8''	E - 080^0 32'25.3''
3.	Koluhagaarha (Infront of Sh. Buddan Sahu House), Unnao	N -26^0 22' 13.0''	E - 080^0 33' 01.7''
4.	Karmi Gadhewa, Unnao Block - Bighapur	N -26^0 16'30.1''	E - 080^0 36'00.9''
5.	Pandit Dev Krishna Inter College Campus, Sagwar Block Bighapur, Unnao.	N -26^0 13'14.2''	E - 080^0 40'42.5''
6.	Uuchgaon ,Block Sumerpur, Unnao	N -26^0 10'22.1''	E - 080^{0}41'39.1''
7.	In front of Chandrika Devi Temple , Block Sumerpur, Unnao.	N -26^0 08'28.8''	E - 080^0 39'48.9''
8.	Prathmik Swathya Kender, Campus, Block – Sumerpur , Unnao.	N -26^0 16'48.4''	E - 080^0 48'24.2''
9.	Near Zero Milestone, In front of the Lord Shiv Temple, Block Bighapur, Unnao.	N -26^0 21'08.5''	E - 080^0 33'21.5''
10.	Village TejiKheda, Near Prahalad House, Block Asoha, Unnao.	N -26^0 47' 09.9''	E - 080^0 56' 49.8''
11.	Karyalaya Khand Vikas Adhikari, Block Asoha, Unnao.	N -26^0 05' 09.8''	E - 080^0 49' 52.7''
12.	Village: Kaalkheda , Opposite to Aryavart Gramin Bank , Block – Asoha, Unnao.	N -26^0 35' 10.2''	E - 080^0 49' 52.6''
13.	Village Kudra, Oppsite Primary School, Block Hilloi, Unnao.	N -26^0 23' 50.4''	E - 080^0 53' 12.5''
14.	Near Navalkishor Sweet House (Chauraha) , Block Hilloli , Unnao.	N -26^0 28' 12.2''	E - 080^0 50' 12.2''
15.	Morawa Tiraha, Near Roadways Bus Stop, Block – Hilloli, Unnao.	N -26^0 27' 24.0''	E - 080^0 56'26.8''
16.	Village Chandighari, NearLohpurush Sardar Patel Inter College, Block Purva, Unnao.	N -26^0 26' 04.6''	E - 080^0 52' 36.2''
17.	Near Primary Health Center, Purva - Block, Unnao.	N -26^0 27' 05.3''	E - 080^0 46' 01.1''
18.	Village Langarpur, Near Primary School. Block Purwa, Unnao.	N -26^0 29'39.2''	E - 080^0 43' 32.3''
19.	Near Girja Shankar Home, Village: Ghoor khet, Block Bichia, Unnao.	N -26^0 29' 33.9''	E - 080^0 43'32.1''
20.	Primary Health Center, Block Bichia, Unnao.	N -26^0 32' 17.4''	E - 080^0 37' 31.6''
21.	Village Taargaon, Near Bank of India, Block Bichia, Unnao.	N – 26^0 32' 17.6''	E – 080^0 37' 31.4''
22.	Village: Maswasi, 40 meters away from city Jail drain , Block-Sikandarpur- Karn,Unnao	N – 26^0 31'55.3''	E- 080^0 36'08.2''
23.	Karyalaya Khand Vikas Adhikari, Block Sikandarpur Sirosi, Unnao.	N - 26^0 32'09.3''	E - 080^0 27'08.9''
24.	Near Bus Stand , Village Thana, Block Sikandarpur Sirosi, Unnao.	N - 26^0 36' 24.7''	E - 080^0 27' 13.7''
25.	Village: Bhadni, Near Rameshwar Temple , Bhadni Nala, Block Safipur , Unnao.	N - 26^0 39'43.1''	E - 080^0 26'11.3''
26.	Near Auto Stand, Village Pariar, Block Sikandar Pur Sirosi.	N - 26^0 37' 52.4''	E - 080^0 19' 07.9''
27.	Near Tehsil , Block Safipur, Unnao.	N - 26^0 44'22.6''	E - 080^0 20'58.8''
28.	Near Prathmik Vidyalaya (Dr. Ambedkar Gram) , Village Papri, Block Safipur	N - 26^0 44'22.7''	E - 080^0 20'58.5''
29.	Block Fatehpur Chaurasi, Unnao.	N - 26^0 47'43.9''	E - 080^0 60'1''
30.	Village Lamboi, Block Fatehpur Chaurasi, Unnao.	N - 26^{0}49'09.5''	E - 080^0 15'44.5''
31.	Village Patti Hamid (Kunjwa), Block Fatehpur Charasi, Unnao.	N - 26^0 48'46.1''	E - 080^0 19'18.9''
32.	Village Gauriyakalan , 1.5 Km away from Sai River , Block Bangarmau, Unnao	N – 26 ^{0} 54' 48.6''	E – 080^0 22' 33.2''
33.	Village Benta Bhijawar, 2 Km away from Sai River, Block Ganjmuradabad, Unnao	N – 26 ^{0} 58' 12.9''	E – 080^0 18'55.2''
34.	Village Fatehpur Khalsa, In front of Primary Health Center, Block Ganjmuradabad, Unnao.	N – 26 ^{0} 57' 29.8''	E – 080^0 11' 11.0''
35.	Village Jasrapur, Block Ganjmuradabad, Unnao	N - 26^0 55' 34.0''	E - 080^0 06'36.6''
36.	Village Jagatpur, 3 Km away from River Ganga, Block Bangarmau, Unnao	N - 26^0 53'03.8''	E - 007^0 57'9''
37.	Bus Stand, Block Banngarmau, Unnnao	N - 26^0 53'14.1''	E - 080^0 12'48.9''
38.	Near Juma Masjid , Block Mianganj, Unnao	N - 26^0 48'09.5''	E - 080^0 28'50.6''
39.	Village Mallhimau Near , Babwa Talab, Block – Mianganj, Unnao	N - 26^0 50'36.4''	E - 080^0 27'59.3''
40.	Village Ajmat Nagar, Block Mianganj, Unnao.	N - 26^0 43'56.6''	E - 080^0 27'49.2'
41.	Primary Health Center, Block Nawabganj, Unnao	N - 26^0 37'18.5''	E - 080^0 40'32.4''
42.	Village Dalwar,Block Nawabganj, Unnao	N - 26^0 39'18.3''	E - 080^0 32'44.8''
43.	Village Chandpur Jaliyani, Block Hasanganj, Unnao.	N - 26^0 42'14.6''	E - 080^0 36'38.6''
44.	Block Hasanganj, (Chowk), Unnao (U.P.)	N - 26^0 46'24.5''	E - 080^0 38'25.8''
45.	Village Dhaurra, Block Hasanganj, Unnao.	N - 26^0 49'32.8''	E - 080^0 39'55.8''
46.	Village Narsa, Block Aurash, Unnao.	N - 26^0 52'51.6''	E - 080^0 36'05.9''
47.	Near Block Aurash Chowk, Unnao (U.P.)	N - 26^0 54'48.8''	E - 080^0 30'07.7''
48.	Village Talhi, Block Aurash, Unnao	N - 26^0 56'34.9''	E - 080^0 28'00.5''
49.	Kasba Sohramau, Block Nawabganj, Unnao	N - 26^0 38' 30.8''	E - 080^0 45' 49.7''

50.	City Centre, Unnao.	N- 26°33'18.2"	E 080" 30'19.7"
51.	Kannya Primay School, Makur Village, Nawabganj Unnao	N - 26^0 37'18.9''	E - 080^0 40'33.9''
52.	House of Sh Maan Singh, Makur Village, Nawabganj Unnao	N - 26^0 37'19''	E - 080^0 41'42''
53.	Junior & Primary School, Makur Village, Nawabganj Unnao	N - 26^0 37'25.3''	E - 080^0 41'49.3''
54.	In front of post office, Nawabganj Makur, village	N - 26^0 39'29.7''	E - 080^0 40'52.3''
55.	Makur ka Mazra, Marks Nagar, village	N - 26^0 37'32.5''	E - 080^0 40'49''
56.	Kendriya Vidyalaya staff Quarter, Dahi Chowki	N - 26^0 39'22''	E - 080^0 40'46.8''

Table 2: Groundwater quality* of different block in Unnao district during the study period.

Parameter / Sampling Location	pH	EC	TH	TDS	Cl^-	F^-	SO_4^{2-}	NO_3^-	Ca^{2+}	Mg^{2+}	Na^+	K^+	Total Cr
Achalganj	7.43	1008	314	461	51	0.00	68	3.0	32	15	54	14	0.0
Bighapur	7.49	725	262	311	25	0.00	51	1.6	51	33	40	5.0	0.0
Sumerpur	7.41	986	292	448	19	0.00	45	7.0	86	20	90	14	0.0
Asoha	7.66	1659	284	869	179	0.40	6.4	4.0	58	58	93	6.0	0.0
Hilloli	7.43	693	272	325	17	0.19	5.0	0.34	45	34	46	5.0	0.0
Purwa	7.30	1125	368	377	26	0.40	36	0.6	72	72	53	84	0.0
Bicchia	7.33	1464	341	749	90	0.56	30	0.46	56	49	81	6.0	0.0
Safipur	7.13	1124	602	1737	222	0.33	212	0.53	113	78	57	15	0.0
Secunderpur	7.26	2114	136	1607	668	0.26	643	0.60	278	177	546	2.0	0.0
Aurus	7.47	726	248	864	7.0	0.27	28	0.07	36	39	56	7.0	0.0
Fatapur Ch	7.50	1140	613	657	77	0.27	170	0.27	82	99	116	6.0	0.0
Bangarmau	7.30	925	299	405	32	0.15	33	3.8	38	49	44	4.0	0.0
Gaunmuradabad	7.23	611	284	388	25	0.18	15	3.5	44	43	42	4.0	0.0
Mianganj	7.40	612	243	372	78	0.21	25	3.0	41	30	30	5.0	0.0
Hasanganj	7.13	674	263	236	12	0.26	23	4.0	37	34	49	4.0	0.0
Nawabganj	7.4	2531	537	1786	284	0.78	213.9	17.0	253	284	311.9	182	0.175

All the values are expressed in mg/l except pH and EC. (EC-µmhocm^{-1})
** Values are average of three locations except Total chromium at Nawabganj*

Table 3: Variables Considered for Computation of Water Quality Index based on studied parameters.

Parameters	Mean Value in ppm (v_i)	Highest permitted value (WHO) (s_i)	Unit weightage (W_i)	W_i X Q_i
pH	7.35	8.5	0.117	10.2
EC	1532	1400	0.0007	0.08
TH	318	500	0.002	0.12
TDS	655	500	0.002	0.26
Cl^-	116	250	0.004	0.19
F^-	0.25	1.5	0.67	11.1
SO_4^{2-}	89	400	0.0025	0.04
NO_3^-	2.5	10	0.10	0.1
Ca^{2+}	82	75	0.01	1.5
Mg^{2+}	54	30	0.03	6.0
Na^+	90	200	0.005	0.23
K^+	6.6	10	0.1	6.6
Σ			1.0432	36.4

$WQI = \Sigma^n_{i=1}(QiWi)/\Sigma^n_{i=1}W_i = 34.89$

Table 4: Classification based on the WQI.

S. No.	Water Quality Index	Category of groundwater Quality
1.	0-25	Excellent
2.	26-50	Good
3.	51-75	Poor
4.	76-100	Very Poor
5.	100 and above	Unsuitable for drinking (U.S. F.)

Table 5: Water Quality Index Values for Studied Groundwater in Unnao district.

S. No.	Sampling Location	Water Quality Index	Status
1.	Achalganj	15	Excellent
2.	Bighapur	14	Excellent
3.	Sumerpur	17	Excellent

4.	Asoha	32	Good
5.	Hilloli	18	Excellent
6.	Purwa	28	Good
7.	Bicchia	40	Good
8.	Safipur	27	Good
9.	Secunderpur	28	Good
10.	Aurus	22	Excellent
11.	Fatapur Chaurasi	23	Excellent
12.	Bangarmau	20	Excellent
13.	Gaunmuradabad	21	Excellent
14.	Mianganj	21	Excellent
15.	Hasanganj	24	Excellent
16.	Nawabganj	43	Good

Conclusion:

Studies indicate that groundwater quality of studied area does not reflect any significant abnormality in terms of its suitability for human consumption baring few locations, which has been further evaluated using statistical tool i.e. Water Quality Index. As per Water Quality Index classification they have been categorised as Excellent at 10 blocks i.e. Achalganj, Bighapur, Sumerpur, Hilloli, Fatapur Chaurasi Bangarmau Gaunmuradabad Mianganj and Hasanganj and Good at 6 blocks *i.e.* Asoha, Purwa, Bicchia, Safipur, Secunderpur and Nawabganj. Bichia and Nawabganj these blocks are nearer to the industrial clusters which are dominated by industries such as tanneries, textiles, and chemicals *etc.* which are water intensive, may be the reason of deterioration of the available water quality. Groundwater of these locations is approaching towards the poor Water Quality Index having score of 40 and 43 at Bichia and Nawabganj respectively. Considering the data generated during the above study, significant efforts are required to be made towards the prevention of further groundwater quality deterioration at these locations due to poor environmental management in the area concerned.

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