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DEPT. OF WATER RESOURCES,

RIVER DEVELOPMENT& GANGA REJUVENATION

CENTRAL GROUND WATER BOARD

GROUND WATER QUALITY IN SHALLOW AQUIFER OF UTTAR PRADESH

(AAP 2023-24)

By

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CHEMICAL QUALITY OF GROUND WATER OF U.P.

(based on NHS data 2022-23)

CONTENT

1. INTRODUCTION

The availability of fresh water for human consumption, irrigation, agricultural development and other activities is associated with the growing needs of modern living conditions but is decreasing day by day due to increase in population, urbanization, industrialization and erratic behavior of rains. To meet the requirement of fresh water, the dependency on ground water is increasing in comparison to surface water because during summer season most of the surface water bodies do not have sufficient water, while ground water is easily accessible throughout the year.

The quality of groundwater is affected in three ways i.e. physical, chemical and bacteriological, although the procedure is very slow and complex to understand. The quality of ground water in the phreatic aquifer depends on the nature of rocks, contact time, circulation and temperature. It is also dependent on the solubility of the minerals present in the rocks. To some extent the atmospheric precipitation (rain water) is also contributory factor for affecting the quality of ground water as during the rain fall most of the gases such as CO_2, SO_2 and NO_2 present in the atmosphere gets dissolved in the rain water during the course of downward travel and percolate down through the earth surface dissolving mainly calcium and magnesium present in the soil forming calcium bicarbonate. The pH plays an important role in the geochemical reactions as low pH tends to help faster dissolution of the minerals. The quality of ground water is also influenced by the excessive use of fertilizers and pesticides for agricultural production and also industrial activity.

Ground water due to its long standing with minerals and rocks is generally more mineralized than surface water. This was found to be confirmed largely for water in phreatic zones. The chemical quality of ground water in phreatic zones is also affected by anthropogenic sources at the ground surface, whether it is domestic, agriculture or industrial in nature.

2. METHODOLOGY

To evaluate the drinking water quality of ground water, 919 water samples were collected from Ground Water Monitoring Stations (GWMS) during the A.A.P. 2022-23. Generally the monitoring stations are open dug wells tapping phreatic aquifer. Ground water samples were collected from hand pumps where dug wells are not in use. All the samples were analyzed for the determination of pH, EC, CO_3, HCO_3, Cl, F, NO_3, SO_4, PO_4, SiO_2, T.H., Ca, Mg, Na & K. These water samples were analyzed as per standard methods (APHA 2017). Following standard methods (Table1) have been adopted for the chemical analysis of different constituents in water samples.

TABLE 1–: Methods used for Chemical Analysis of Ground Water Samples (2022-23)

Sl. No.	Constituents	Method Used
1.	pH	pH Meter
2.	EC	EC Meter
3.	Carbonate	Titrimetric method
4.	Bi-carbonate	-do-
5.	Chloride	Mohr's method
6.	Fluoride	Spectrophotometric method
7.	Nitrate	-do-
8.	Sulphate	-do-
9.	Phosphate	-do-
10.	Silica	-do-
11.	Total Hardness	Titrimetric method
12.	Calcium	-do-
13.	Magnesium	Evaluation from TH and Ca
14.	Sodium	Flame emission photometric method
15.	Potassium	-do-

3. WATER QUALITY NORMS & CRITERIA

Water quality standards and guidelines have been laid down by WHO (1984), Govt. of India, National High Tech Mission (1986) and BIS (2012) and many other organizations. These guidelines are exhaustive and it becomes very difficult to analyse ground water samples for all the constituents. The water quality is judged by a common man mainly by ENT (Eyes, nose and tongue) tests before using it for domestic purposes. They are-

E (Eyes) : Appearance - turbidity, particles, oily layer, color etc.

N (Nose) : Odor - no smell, rotten egg smell, fishy smell etc.

T (Tongue) : Taste - salinity, pH, temperature, soluble iron chloride etc.

The guidelines/standards laid down by BIS (2012) with regard to some constituents for domestic and potable purposes have been tabulated below in the Table:

TABLE 2: Indian Standard for Drinking Water Specifications (BIS 2012)

S. No.	**Substance/ Characteristics**	**Desirable limit**	**Undesirable effect outside desirable limit**	**Permissible limit in absence of alternate source**
1	*2*	*3*	*4*	*5*
1.	Colour (Hazen Units)	5	Above 5, consumer acceptance decreases	25
2.	Turbidity (NTU)	5	Above 5, consumer acceptance decreases	10
3.	pH value	6.5-8.5	Beyond this range water will effect mucous membrane.	No relaxation
4.	Dissolved solids mg/l max	500	Beyond this palatability decreases and may cause gastro intestinal irritation	2000
5.	Alkalinity mg/l max	200	Unpleasant taste	600
6.	Total hardness (as $CaCO_3$) mg/l max	300	Encrustation in water supply structure and adverse effect on domestic use.	600
7.	Chloride (as CI) mg/l max	250	Beyond this limit taste corrosion and palatability are effected	1000
8.	Calcium (as Ca) mg/l max	75	Encrustation in water supply structure and adverse effect on domestic use.	200

S. No.	Substance/ Characteristics	Desirable limit	Undesirable effect outside desirable limit	Permissible limit in absence of alternate source
1	*2*	*3*	*4*	*5*
9.	Magnesium (as Mg) mg/l max	30	Encrustation in water supply structure and adverse effect on domestic use.	100
10.	Sulphate (as SO_4) mg/l max	200	Beyond this limit gastrointestinal irritation occurs when Magnesium of sodium is present	400
11.	Nitrate (as NO_3) mg/l max	45	Beyond this methaemoglobinaemia takes place	45
12.	Fluoride (as F) mg/l max	1.0	Fluoride may be kept as low as possible. High fluoride may cause fluorosis	1.5

4. CHEMICAL QUALITY OF GROUND WATER IN UTTAR PRADESH

The chemical quality of ground water depends on various factors like source of water such as rainfall, erosion, dry fall out, weathering of rocks and as a result of chemical reactions taking place on and below the surface. Thus, the chemical quality of water is dependent on geological and hydro geological conditions prevailing in the area, climate, topography, nature of soil, physicochemical characteristics of rocks, nature of plantation and finally the activities of man resulting in environmental pollution. The pollution of ground water may lead to abandonment of wells, so in order to deal with this problem it becomes necessary to assess its suitability for drinking and irrigation purpose before corrective measures are undertaken.

4.1 SUITABILITY OF GROUND WATER FOR POTABLE PURPOSES

The suitability of ground water for drinking purposes has been assessed according to the guidelines laid down by BIS (2012), Table –2 for various analysed parameters. The chemical analysis results for 911nos. of samples collected from GW monitoring Stations spread in entire Uttar Pradesh have been tabulated in Annexure A.

The minimum, maximum and average values of various constituents determined during chemical analysis have been summarized in following Table-3 below -

TABLE 3 –: Hydro-Chemical Data of Ground Water in Uttar Pradesh (an overview) (2022-23)

S. No.	Constituents	Minimum	Maximum	Average
1.	pH	7.05	8.84	7.94
2.	EC µS/cm at 25 ºC	235	23920	1014
3.	CO_3 mg/l	Nil	84	1.67
4.	HCO_3 mg/l	97.62	854	333
5.	Cl mg/l	3.5	7161	96
6.	F mg/l	Nd	9.0	0.57
7.	NO_3 mg/l	Nd	850	17
8.	SO_4 mg/l	Nd	2483	75
9.	PO_4 mg/l	Nd	0.78	.003
10.	TH (as $CaCO_3$) mg/l	50	8607	289
11.	Ca mg/l	0	1002	47
12.	Mg mg/l	0	1483	41
13.	Na mg/l	1.9	2122	98
14.	K mg/l	0	796	8.96

Hydrogen Ion Concentration (pH):

The pH value of ground water in the state of U.P. varies from 7.05 to 8.84 and is generally well within the permissible limit and the water is slightly alkaline in nature. The average pH value has been found to be 7.94.

Carbonate & Bicarbonate (CO_3 & HCO_3) :

The Carbonate has been observed to be nil in most of the cases however it has been found up to 84 mg/l & Bicarbonate has been observed in the range of 98 to 854 mg/l with average value of 333mg /l.

Electrical Conductivity (EC):

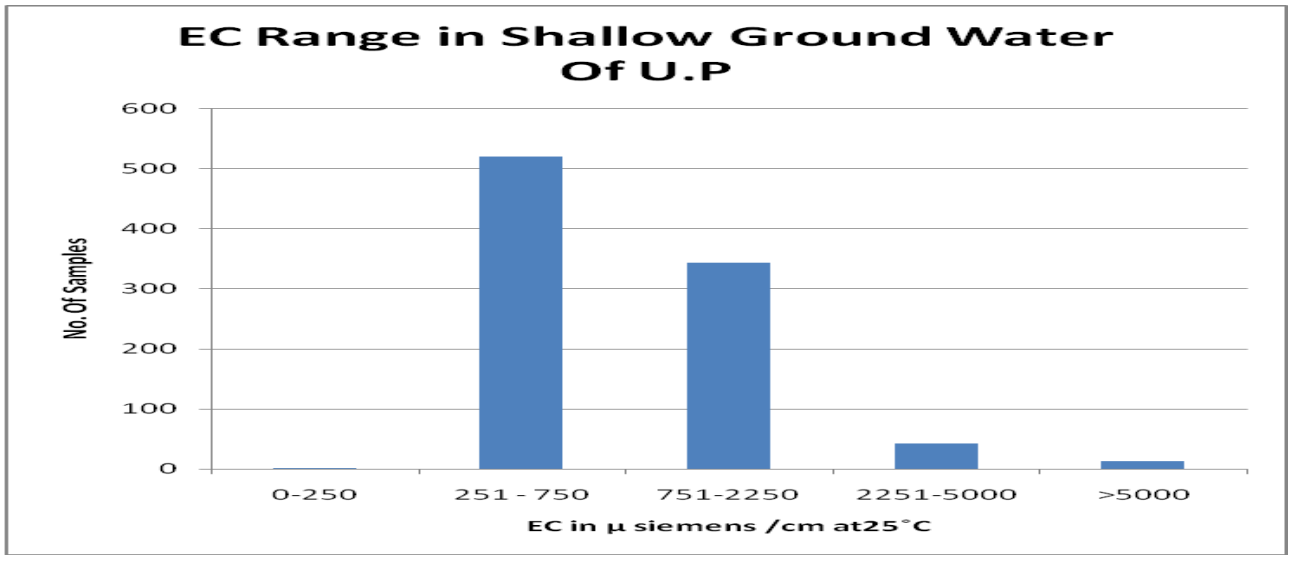
The Electrical Conductivity is a reflection of the concentration of various chemical constituents in ground water and gives the overall quality of ground water for its various uses like drinking, irrigation and other purposes. In the study area EC ranges from 235 to 23920µSiemens/cm at 25ºC with average value of 1014µSiemens/cm at 25ºC. In94% of water samples EC values up to a maximum of 2250 µS/cm at 25ºC was observed. In 4.6 % of samples EC ranges between 2251 to 5000 µS/cm whereas only 1.4 % samples are found to have EC value more than 5000 µS/cm at 25ºC. The highest value of EC, 23920µS/cm at 25ºC was observed in ground water from Baroli block (Mathura district). The frequency distribution is shown in the following table:

TABLE 4: Frequency distribution of Electrical Conductivity (2022-23)

EC ranges in µS/cm at 25ºC	**0-250**	**251 - 750**	**751-2250**	**2251-5000**	**>5000**
No. of samples	1	520	343	42	13
%	0.10	56.6	37.3	4.6	1.4

Fig 1.depicts the range of Electrical Conductivity in shallow ground water of U.P

FIGURE-1



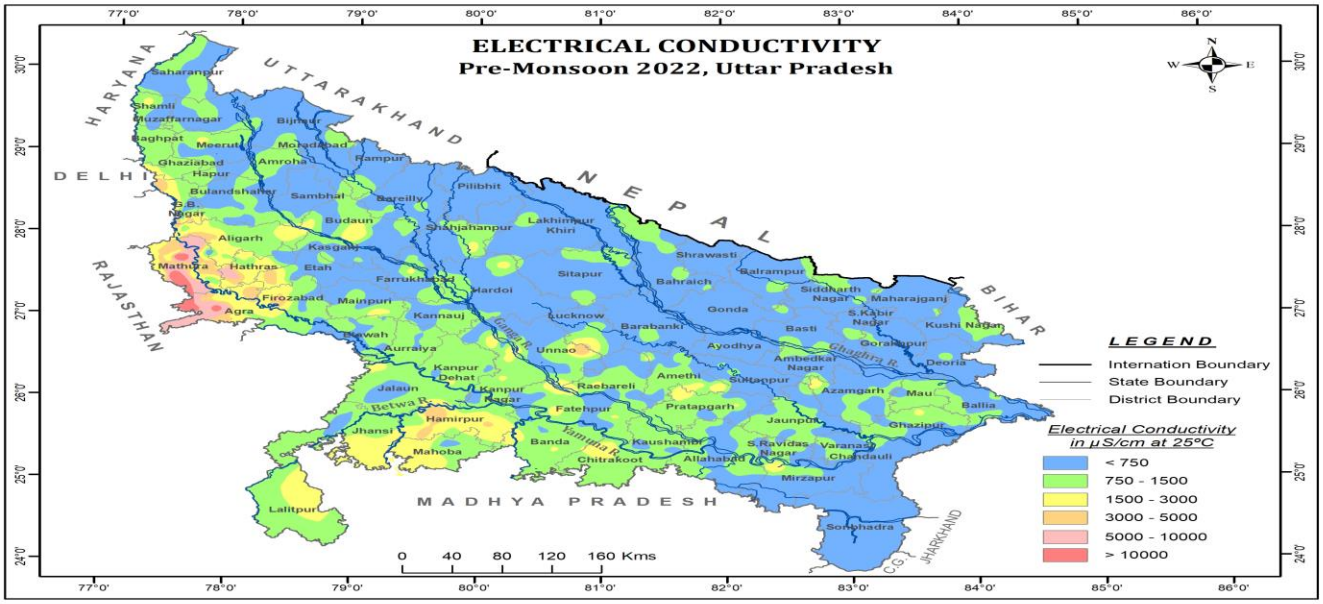
The various partly affected blocks exhibiting high values of E.C. (>2250 µS/cm at 25°C) are tabulated in following table below-

TABLE 5: The partly affected blocks exhibiting high values of E.C. (>2250 µS/cm at 25°C µS/cm) (2022-23)

S. No.	District	Block	E.C µS/cm at 25°C
1	Agra	Fatehabad	2665
2	Agra	Saiyan	3250
3	Agra	Kheragarh	6636
4	Agra	Jagner	5223
5	Agra	Akola	11370
6	Agra	Fatehpur Sikari	12300
7	Agra	Achhnera	4419
8	Agra	Bichpuri	2359
9	Agra	Khandauli	2456
10	Agra	Etmadpur	4512
11	Aligarh	Gonda	3882
12	Aligarh	Khair	3146
13	Aligarh	Nama	2655
14	Amethi	Bhadar	2496
15	Budaun	Ujhani	2297
16	Etah	Jalesar	3367
17	Fatehapur	Malwan	3179
18	Firozabad	Narkhi	2910
19	Firozabad	Firozabad	3838
20	Gautam Buddha Nagar	Bisrakh	3398
21	Gautam Buddha Nagar	Dankaur	2863
22	Gautam Buddha Nagar	Zewar	5035
23	Gautam Buddha Nagar	Zewar	3302
24	Gautam Buddha Nagar	Zewar	2518
25	Hamirpur	Rath	3279
26	Hamirpur	Sarila	4393
27	Hamirpur	Maudaha	3092
28	Hathras	Hassain	2418
29	Hathras	Hathras	2492
30	Hathras	Mursan	4254
31	Hathras	Sadabad	5218
32	Jhansi	Bangra	2668
33	Jhansi	Mauranipur	2650

S. No.	District	Block	E.C µS/cm at 25°C
34	Kanpur Nagar	Kalyanpur	2760
35	Lalitpur	Bar	2500
36	Mahamaya Nagar	Aharai	8250
37	Mahoba	Charkhari	2665
38	Mathura	Chaumuhan	4536
39	Mathura	Farah	7608
40	Mathura	Goverdhan	4463
41	Mathura	Mat	4345
42	Mathura	Nandgaon	2762
43	Mathura	Nohjhil	9756
44	Mathura	Raya	4937
45	Mathura	Bathain Kalan	3610
46	Mathura	Ajijpur	5198
47	Mathura	Karahari	2269
48	Mathura	Ajnokh	3688
49	Mathura	Baroli	23920
50	Mathura	Gaiyara	4173
51	Mathura	Bhagosa	6623
52	Mathura	Lohaban	3370
53	Mathura	Nagla Karan	4404
54	Mathura	Borpa	16740
55	Unnao	Asoha	4255

The map showing Electrical conductivityconcentration in the state of Uttar Pradesh is represented in **Fig-2**



TREND ON ELECTRICAL CONDUCTIVITY

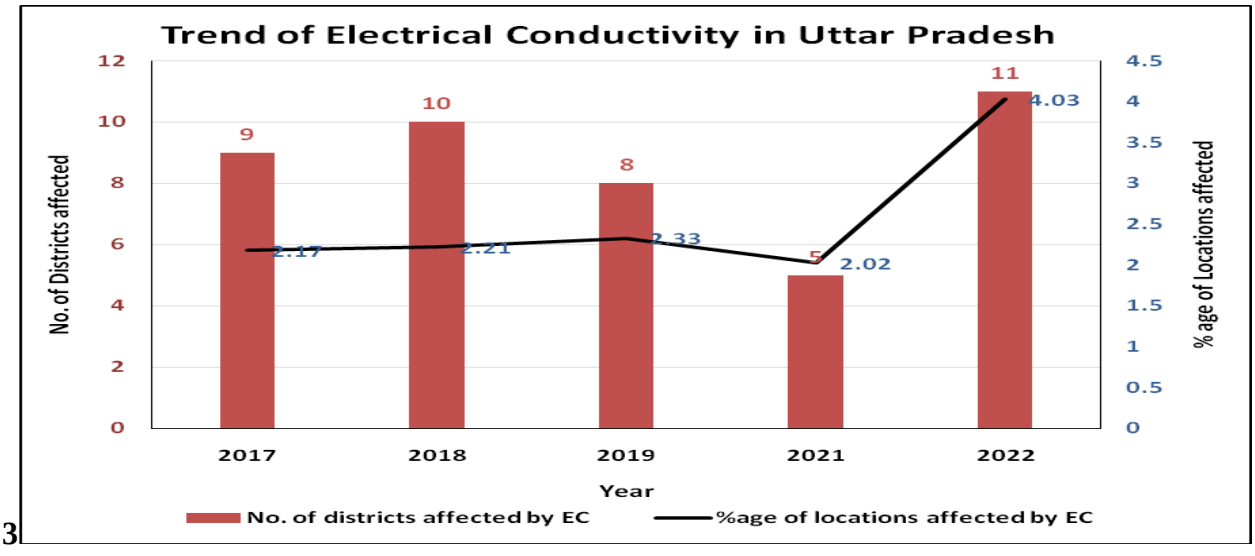
Trend analysis determines whether the measured values of the water quality variables increase or decrease during a time period. The Electrical Conductivity (EC) of groundwater is contributed by all the dissolved ionic constituents. Therefore, it is a measure of the total ionic content of the water. It could be used as a source of inorganic pollution indicator as most of the inorganic compounds are present as ions in water. Hence, EC was taken to assess the trend of ground water quality in India. The wells weret monitored in the year 2020 due to COVID pandemic situation. The percentage of well exceeds the electrical conductivity more than 3000 µS/cm for the period of 2017 to 2022 were compared and presented in the Table 6 and Fig 3 and observed that the percentage of samples exceed the permissible limit of 3000 µS/cm were ranging between 2 - 4 %.

Table 6 Showing trend of Electrical Conductivity from 2017-2022

Year	No. of districts affected by EC	Total of locations affected by EC	Total Number of samples analysed	%age of locations affected by EC
2017	**9**	**18**	**828**	2.17
2018	**10**	**19**	**858**	2.21
2019	**8**	**19**	**817**	2.33
2021	**5**	**17**	**840**	2.02
2022	**11**	**37**	**919**	4.03

Figure-3 showing trend of Electrical Conductivity from 2017-2022

FIG-3 -



3

Chloride (Cl):

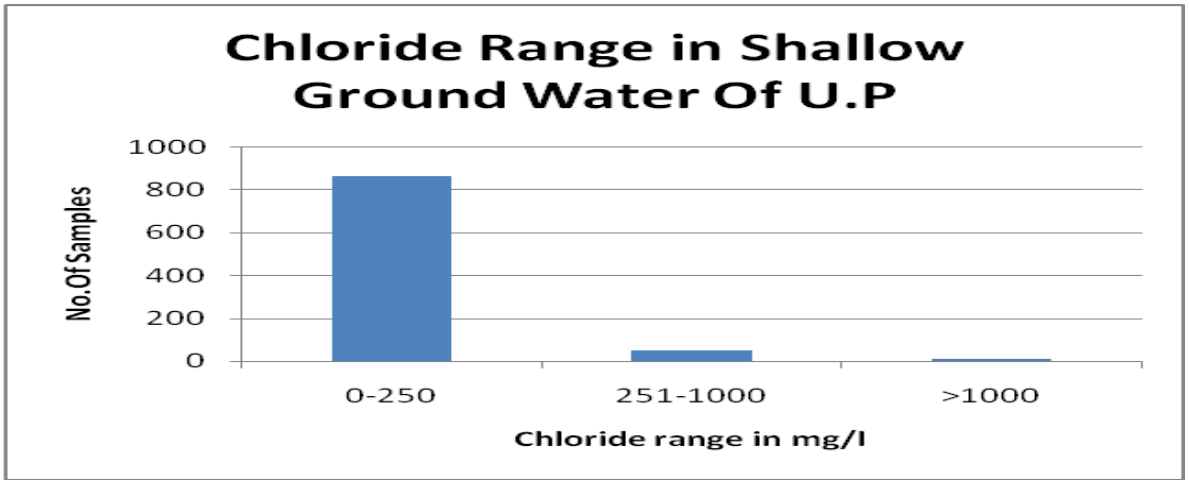
The study reveals that concentration of chloride ion ranges from 3.5 to 7161 mg/l with an average value of 96 mg/l. From Table 7 it is clear that a total of 93.8 % water samples fall within the desirable limit while 99.0% contain chloride within the maximum permissible limit prescribed by BIS (2012). Only 1.0% samples exhibit Chloride values > 1000 mg/l viz.

TABLE 7: Frequency distribution of Chloride (2022-23)

Range of Chloride in mg/l	0-250	251-1000	>1000
No. of samples	862	48	9
%	93.8	5.2	1.0

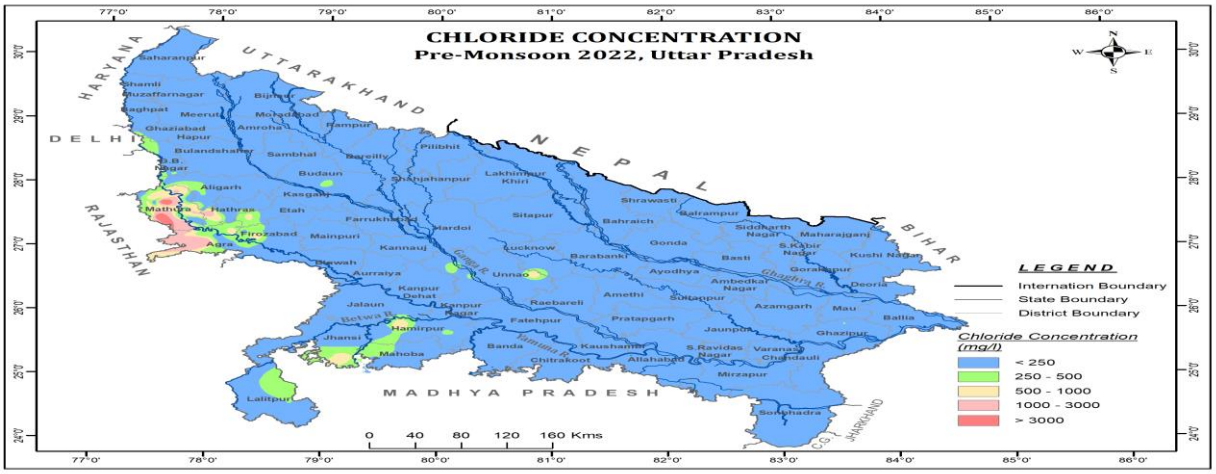
Fig 4.depicts the range of Chloride in shallow ground water

FIGURE -4



The map showing Chloride concentration in the state of Uttar Pradesh is represented in **Fig-5**

Fig-5



The various partly affected blocks exhibiting high values of Cl (>1000 mg/l) are tabulated in following table below-

TABLE 8 : The partly affected blocks exhibiting high values of Cl (>1000 mg/l) (2022-23)

S.No	District	Block	Cl >1000 mg/l
1	Agra	Kheragarh	1234
2	Agra	Akola	2865
3	Agra	Fatehapur	2801
4	Mahamaya Nagar	Aharai	1531
5	Mathura	Farah	1921
6	Mathura	Nihjhil	1056
7	Mathura	Baroli	7161
8	Mathura	Nagla Karan	1092
9	Mathura	Borpa	4750

Nitrate (NO_3) :

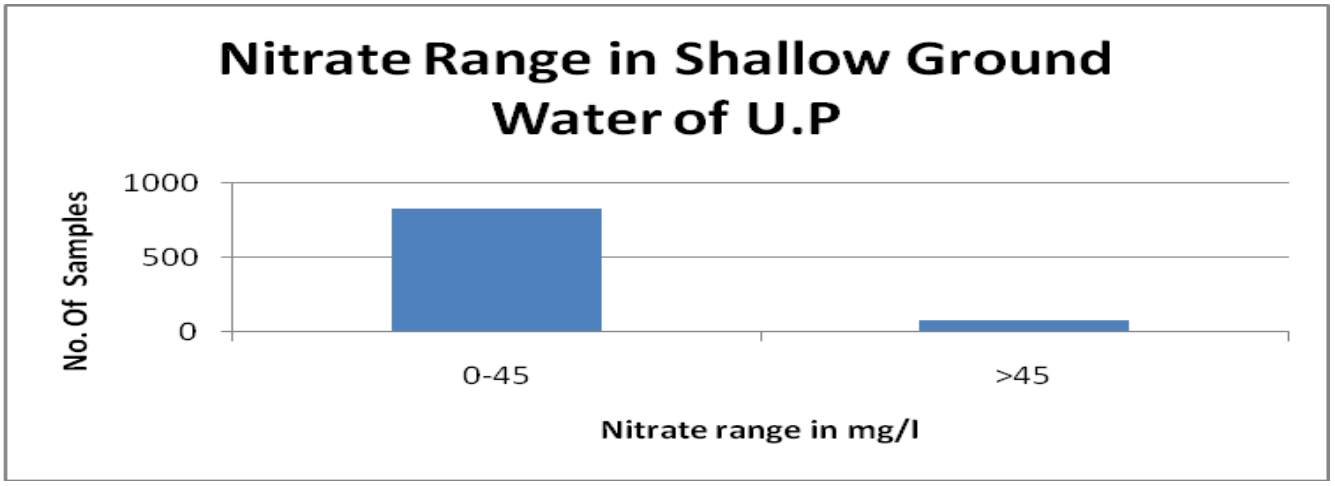
The concentration of Nitrate has been found varying widely. It ranges between not detectable to 850 mg/l with an average value of 16.65mg/l. 90.8% of water samples fall within the permissible limit of 45 mg/l (BIS 2012) and 9.2% samples have higher level of Nitrate concentration with the highest value 850 mg/l recorded at Fatehpur Sikri block (distt. Agra). High Nitrate in found all over the state and does not follow any definite pattern of distribution. The distribution of samples in different concentration ranges are given in following table

TABLE 9: Frequency Distribution of Nitrate (2022-23)

Range of Nitrate in mg/l	**0-45**	**>45**
No. of Samples	835	84
%	90.8	9.2

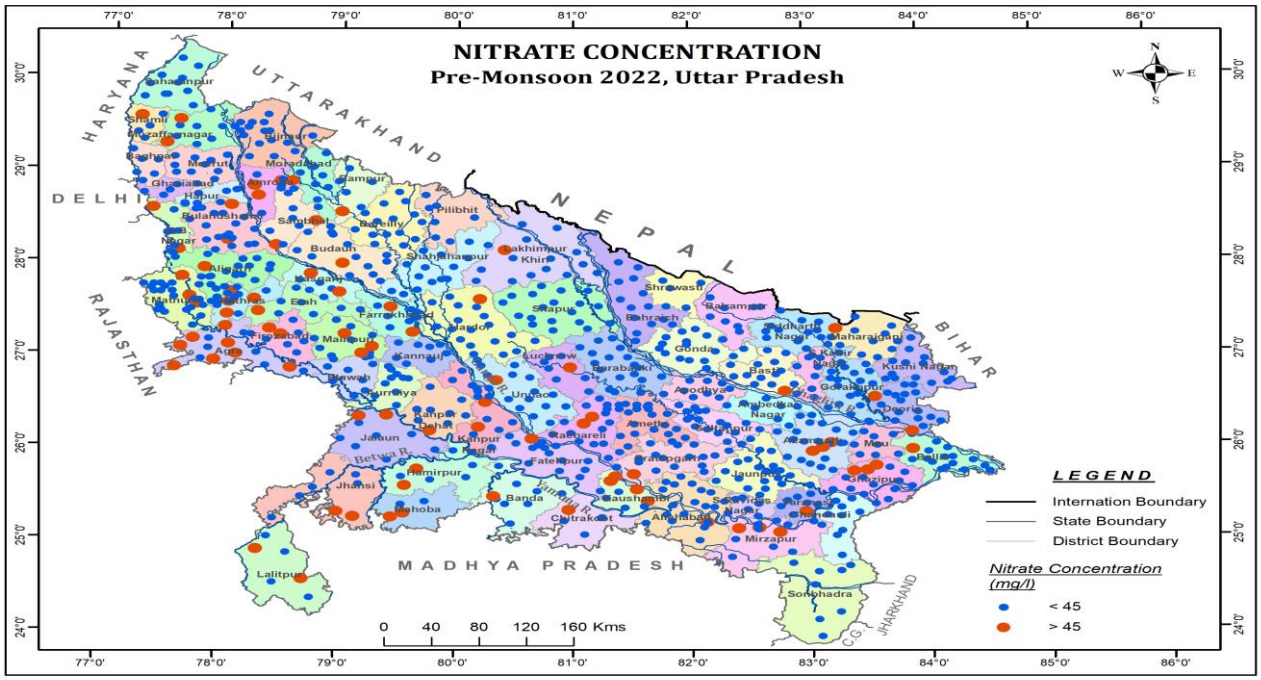
Fig. 6 depicts the nitrate range in shallow ground water of U.P.

Fig-6



The map showing Nitrate concentration in the state of Uttar Pradesh is represented in **Fig-7**

Fig-7



The various partly affected blocks exhibiting high values of nitrate concentration (>45 mg/l) are tabulated below:

TABLE 10: Partly affected **Blocks associated with high values of nitrate (>45 mg/l) (2022-23)**

S.No	District	Block	NO3 >45 mg/l
1	Agra	Bah	120
2	Agra	Shamsabad	79
3	Agra	Saiyan	167
4	Agra	Jagner	425
5	Agra	Barauli Ahir	60
6	Agra	Fatehpur Sikari	850
7	Agra	Achhnera	88
8	Agra	Khandauli	317
9	Aligarh	Khair	227
10	Allahabad	Manda	55
11	Amroha/ J.P. Nagar	Amroha	48
12	Amroha/ J.P. Nagar	Amroha	89
13	Azamgarh	Harriya	69
14	Azamgarh	Mohammadpur	57
15	Azamgarh	Rani Ki Sarai	66
16	Ballia	Negara	61
17	Banda	Banda	72
18	Basti	Kudraha	122
19	Budaun	Ujhani	49

S.No	District	Block	NO3 >45 mg/l
20	Bulandshahr	Mustfabad Daduwa	55
21	Bulandshar	Siyana	69
22	Chitrakoot	Pahari	173
23	Deoria	Bhagalpur	49
24	Etah	Jalesar	50
25	Farukhabad	Shamsabad	220
26	Farukhabad	Kamalganj	189
27	Fatehpur	Malwan	100
28	Firozabad	Narkhi	167
29	Firozabad	Khairgarh(Hathwant)	53
30	G.B.Nagar	Bisrakh	109
31	Gautam Buddha Nagar	Jewar	70
32	Ghazipur	Birno	64
33	Ghazipur	Jakhaniya	58
34	Ghazipur	Mardah	81
35	Gorakhpur	Brahmpur	45
36	Hamirpur	Rath	403
37	Hamirpur	Sarila	103
38	Hardoi	Pihani	49
39	Hathras	Hassain	117
40	Hathras	Hathras	171
41	Hathras	Sadabad	192
42	Hathras	Sasni	64
43	J P Nagar	Gajraula	92
44	J P Nagar	Hasanpur	87
45	Jalaun	Kuthond	96
46	Jalaun	Rampura	82
47	Jhansi	Bangra	114
48	Jhansi	Mauranipur	171
49	Kanpur Dehat	Amraudha	56
50	Kanpur Nagar	Kalyanp Ur	50
51	Kanpur Nagar	Patara	60
52	Kasganj	Soron	128
53	Kasganj	Patiyali	175
54	Kaushambi	Chail	65
55	Kaushambi	Kara	215
56	Kaushambi	Moorat Ganj	240
57	Kaushambi	Sirathu	47
58	Lakhimpur Kheri	Bankeyganj	49
59	Lalitpur	Jakhaura	52
60	Lalitpur	Mehrauni	124
61	Lucknow	Chinhat	69
62	Mahoba	Kabrai	135

S.No	District	Block	NO3 >45 mg/l
63	Mahoba	Jaitpur	80
64	Mainpuri	Mainpuri	51
65	Mainpuri	Kusmura	122
66	Mainpuri	Katra Saman	61
67	Mathura	Mat	325
68	Mathura	Nohjhil	480
69	Mathura	Raya	56
70	Mirzapur	Mirza-Pur Hq	114
71	Mirzapur	Chanbey	145
72	Mirzapur	Pahari	62
73	Muzaffarnagar	Budhana	57
74	Muzaffarnagar	Charthawal	48
75	Pratapgarh	Kunda	49
76	Raibareli	Harichandpur	54
77	Raibareli	Sartawan	70
78	Rampur	Shahabad	80
79	Sambhal	Bania Khera	63
80	Sambhal	Gunnaur	49
81	Shamli	Un	48
82	Siddharth Nagar	Lotan	115
83	Unnao	Safipur	49
84	Varanasi	Kashi Vidya Peeth	50

TREND ON NITRATE

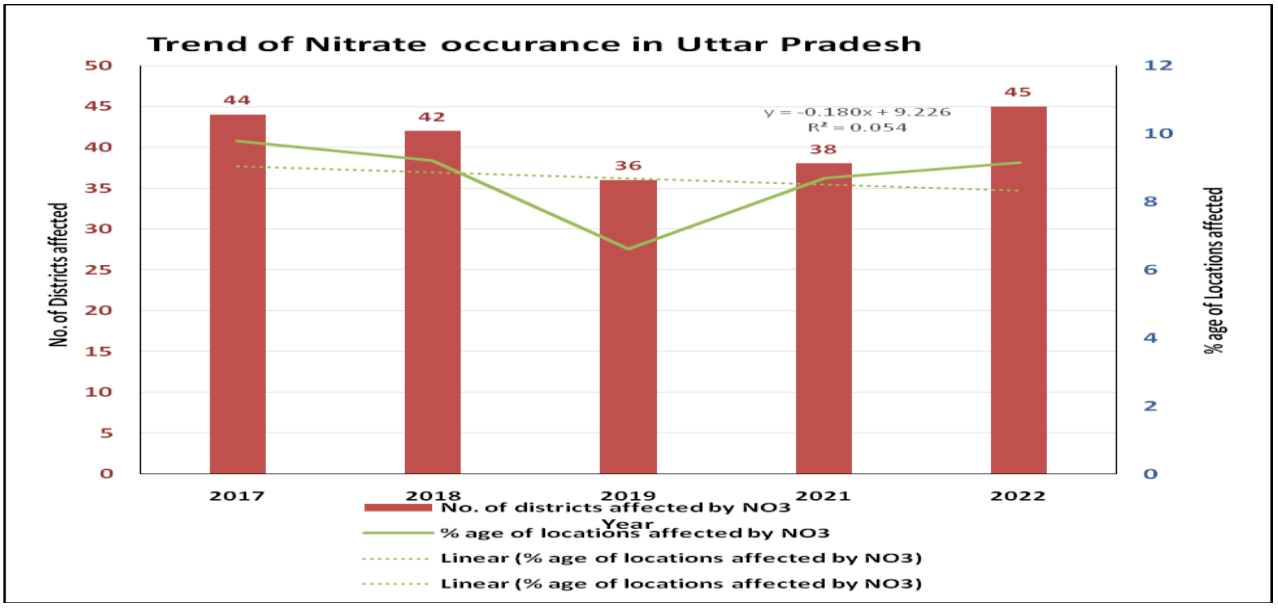
Trend analysis determines whether the measured values of the water quality variables increase or decrease during a time period. Nitrate is one of the major indicators of anthropogenic sources of pollution. Nitrate is the ultimate oxidized product of all nitrogen containing matter and its occurrence in groundwater can be fairly attributed to infiltration of water through soil containing domestic waste, animal waste, fertilizer and industrial pollution. As the lithogenic sources of nitrogen are very rare, its presence in ground water is almost due to anthropogenic activity. Hence, nitrate was taken to assess the trend of ground water quality in Uttar Pradesh due to anthropogenic activity. The percentage of well exceeds the permissible limit of 45mg/L for the period of 2017 to 2022 were compared and presented in the Table 11 and Fig 8 and observed that the percentage of samples exceed the permissible limit of nitrate (> 45 mg/L) were ranging between 6.6 – 9.8 % and no significant trend was noticed. The wells were not monitored in the year 2020 due to COVID pandemic situation. There is hardly any change in the number of nitrate affected district from 2017 to year 2022

Table-11 showing trend of Nitrate from 2017-2022

Year	No. of districts affected by NO3	No. of locations affected by NO3	Total Number of samples analysed	% age of locations affected by NO3
2017	**44**	**81**	**828**	9.8
2018	**42**	**79**	**858**	9.2
2019	**36**	**54**	**817**	6.6
2021	**38**	**73**	**840**	8.7
2022	**45**	**84**	**919**	9.14

Figure-8 showing trend of Nitrate from 2017-2022

FIG-8



Fluoride (F):

Small quantities of Fluoride are beneficial in reducing tooth decay, whereas excess concentration (>1.5 mg/l) is harmful causing staining of tooth enamel and Fluorosis. The value of Fluoride concentration is found to range between not detectable to 9.0 mg/l with 96.1% samples falling within the permissible limit prescribed by BIS (2012). The highest value of 9.0 mg/l, has

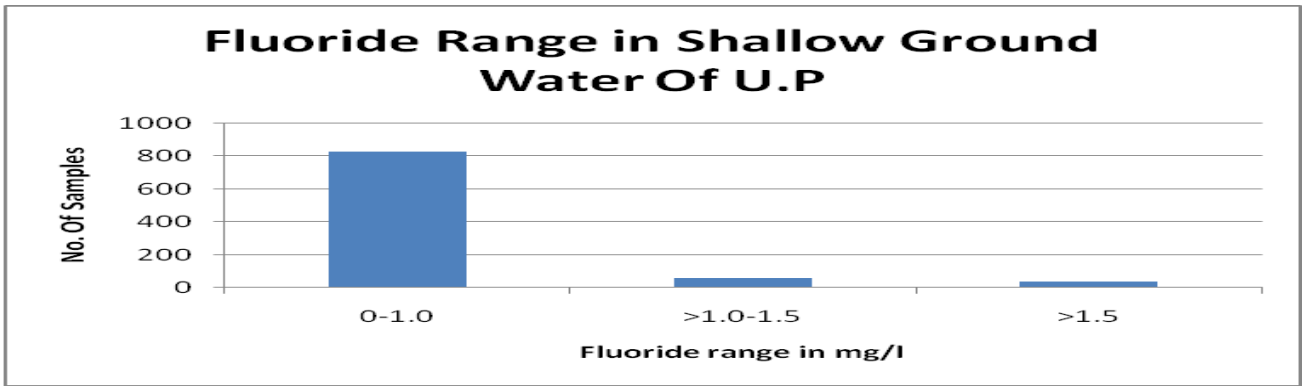
been recorded in Tundla block (distt. Firozabad). The distribution of samples in different Fluoride ranges has been tabulated in following table below:

TABLE 12: Frequency Distribution of Fluoride (2022-23)

Range of Fluoride in mg/l	**0-1.0**	**>1.0-1.5**	**>1.5**
No. of Samples	823	60	36
%	89.6	6.5	3.9

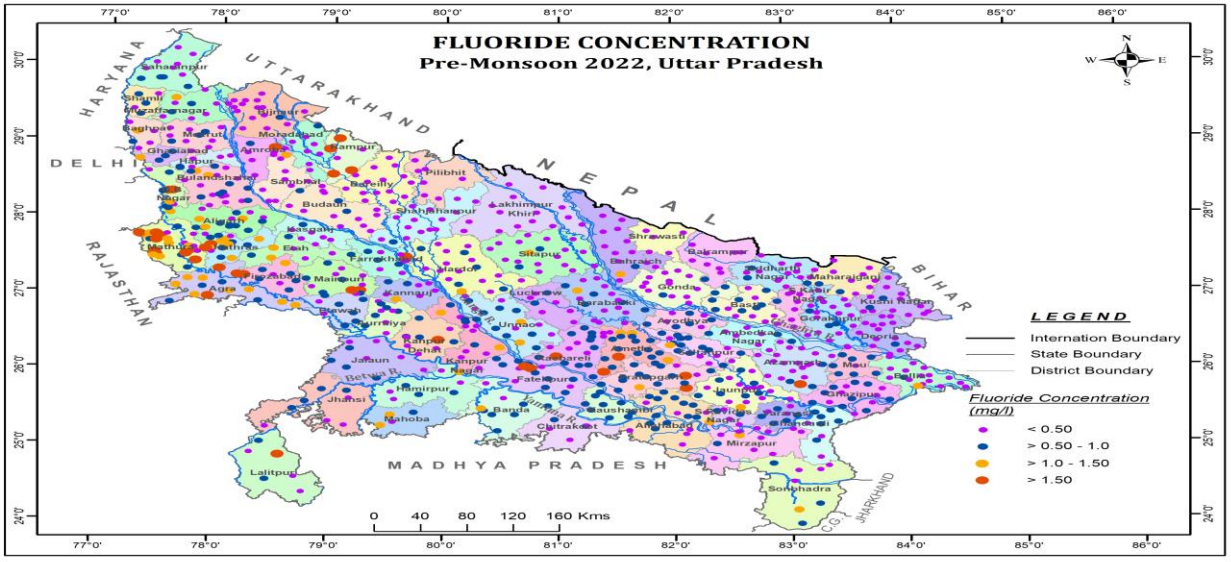
Figure-9 depicts the fluoride range in shallow ground water of U.P.

FIGURE-9



The map showing Fluoride concentration in the state of Uttar Pradesh is represented in **Fig-10**

Fig-10



The various partly affected Blocks exhibiting high values of Fluoride concentration (>1.5 mg/l) are tabulated in following table below

TABLE 13: Partly affected Blocks associated with high values of Fluoride (>1.5 mg/l)

(2022-23)

S.No	District	Block	F ((>1.5 mg/l)
1	Agra	Saiyan	3.3
2	Agra	Khandauli	2.8
3	Agra	Etmadpur	2.9
4	Aligarh	Nama	2.3
5	Azamgarh	Palhana	2.0
6	Farrukhabad	Rajepur(ur)	2.1
7	Fatehpur	Teliyani	2.4
8	Fatehpur	Malwan	3.8
9	Fatehpur	Malwan	3.0
10	Firozabad	Tundla	9.0
11	Gautam buddha nagar	Dankaur	1.7
12	Gautam buddha nagar	Dankaur	2.5
13	J. P. nagar	Amroha	2.0
14	Kanpur dehat	Akberpur	1.5
15	Lalitpur	Bar	2.4
16	Mainpuri	Kishni(ur)	3.2
17	Mainpuri	Katra saman	1.6
18	Mathura	Baldeo	7.4
19	Mathura	Chhata	3.7
20	Mathura	Goverdhan	2.7
21	Mathura	Raya	1.7
22	Mathura	Puthari	2.1
23	Mathura	Ajijpur	1.7
24	Mathura	Umraya	3.1
25	Mathura	Thok bindavani	1.8
26	Mathura	Bhagosa	2.4
27	Mathura	Lohaban	1.9
28	Pratapgarh	Baba bekhernath	1.8

29	Pratapgarh	Gaura	1.7
30	Raibareli	Chhatoh	3.1
S.No	**District**	**Block**	**F ((>1.5 mg/l)**
31	Raibareli	Lalganj	2.6
32	Raibareli	Rohnia	2.2
33	Rampur	Milak	6.0
34	Rampur	Said Nagar	5.0
35	Rampur	Shahabad	4.0
36	Rampur	Swar	3.0

TREND ON FLUORIDE

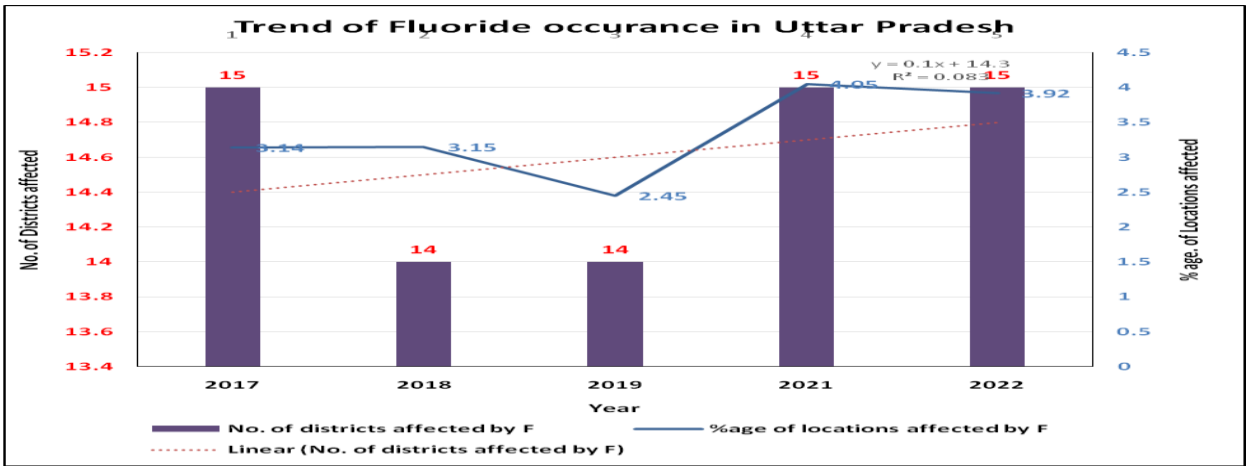
The occurrence of fluoride in groundwater is mainly due to weathering and leaching of fluoride bearing minerals from rocks and sediments. To assess the trend of ground water pollution due to geogenic activity, the percentage of well exceeds the permissible limit of 1.5mg/L for the period of 2017 to 2022 were compared and presented in the Table14 and Fig 11 and observed that the percentage of samples exceed the permissible limit of fluoride 1.5 mg/L were ranging between 2.5 - 4 % and no significant trend was noticed. **The wells were not monitored in the year 2020 due to COVID pandemic situation**. There is not much change in number of fluoride affected district from the year2017- 2022 .

Table14 showing trend of Fluoride from 2017-2022

Year	No. of districts affected by F	No. of locations affected by F	Total Number of samples analysed	%age of locations affected by F
2017	**15**	**26**	828	**3.14**
2018	**14**	**27**	858	**3.15**
2019	**14**	**20**	817	**2.45**
2021	**15**	**34**	840	**4.05**
2022	**15**	**36**	919	**3.92**

Figure-11 showing trend of Fluoride from 2017-2022

FIG-11



Total Hardness (T.H.) :

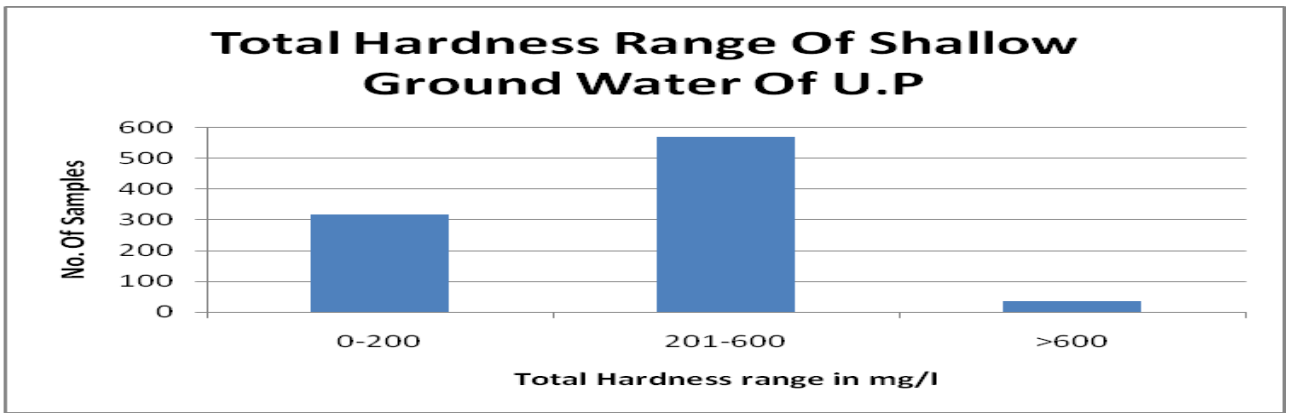
The concentration of total hardness has been found to vary widely. It ranges between 50 to 8607 mg/l with 96.3% of water samples falling within the permissible limit of 600 mg/l (BIS- 2012) and 3.7% samples have higher level of Total Hardness concentration with the highest value 8607 mg/l recorded at Baroli block (distt. Mathura). The distribution of samples in different concentration ranges are given in following table:

TABLE 15 : Frequency Distribution of Total Hardness (2022-23)

Range of T.H. in mg/l	**0-200**	**201-600**	**>600**
No. of Samples	316	569	34
%	34.4	61.9	3.7

Figure-12 depicts the T.H. range in shallow ground water of U.P.

FIGURE-12



The various Blocks exhibiting high values of T.H. concentration (>600 mg/l) are tabulated in table below-

TABLE 16 : Partly affected Blocks exhibiting high values of total hardness (>600 mg/l) (2022-23)

S. No	District	Block	T.H. (>600 mg/l)
1	Agra	Saiyan	1200
2	Agra	Kheragarh	1500
3	Agra	Jagner	1000
4	Agra	Akola	2400
5	Agra	Fatehpur sikari	2700
6	Agra	Etmadpur	620
7	Chitrakoot	Pahari	650
8	Fatehpur	Malwan	740
9	Gautam buddha nagar	Zewar	610.5
10	Ghaziabad	Loni	670
S. No	**District**	**Block**	**T.H. (>600 mg/l)**
11	Hardoi	Pihani	700
12	Hathras	Mursan	630
13	Hathras	Sadabad	690
14	Jalaun	Rampura	680
15	Jhansi	Bangra	615
16	Jhansi	Mauranipur	1110
17	Kanpur Dehat	Amraudha	640
18	Kanpur Nagar	Shivrajp ur	930
19	Lalitpur	Mehrauni	860
20	Mahamaya Nagar	Aharai	1902
21	Mathura	Chaumuhan	850
22	Mathura	Farah	1960
23	Mathura	Goverdhan	690
24	Mathura	Mat	800
25	Mathura	Nohjhil	2190
26	Mathura	Raya	780
27	Mathura	Ajijpur	1001
28	Mathura	Baroli	8607
29	Mathura	Gaiyara	741
30	Mathura	Bhagosa	1071
31	Mathura	Nagla karan	1091
32	Mathura	Borpa	3603
33	Meerut	Daurala	635
34	Unnao	Asoha	1490

Calcium (Ca) :

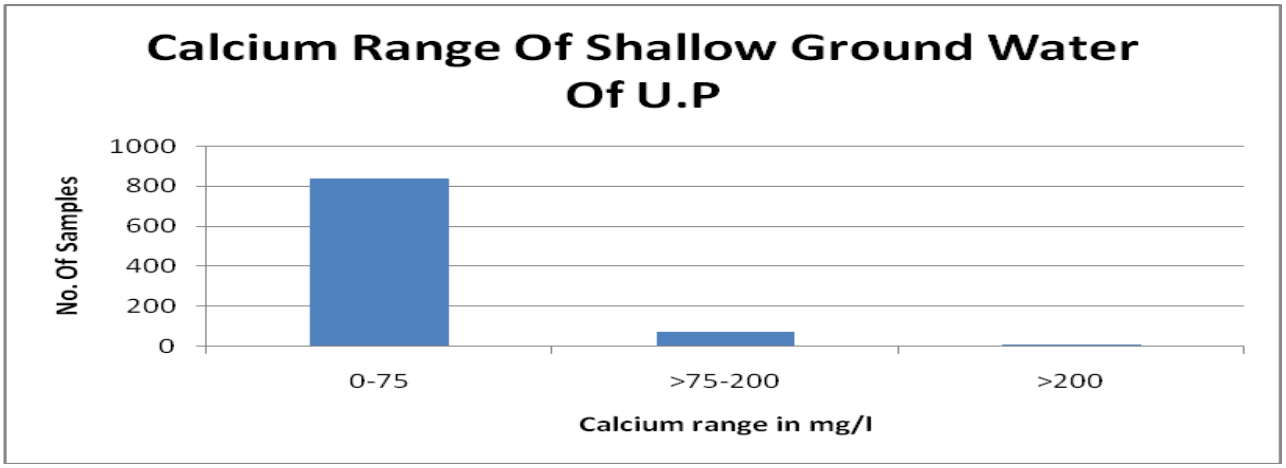
The concentration of Calcium has been found varying widely. It ranges between not detectable to 1002 mg/l with 90.9 % of water samples falling within the desirable limit of 75 mg/l (BIS- 2012) and 8.12% samples have higher level of calcium concentration but within maximum permissible limit of 200 mg/l. Only 0.98% water samples exhibited calcium values >200 mg/l with a maximum value of 508 mg/l recorded at Baroli block (distt. Mathura). The distribution of samples in different concentration ranges are given in following table:

TABLE 17: Frequency Distribution of Calcium (2022-23)

Range of Calcium in mg/l	**0-75**	**>75-200**	**>200**
No. of Samples	835	75	9
%	90.9	8.12	0.98

Figure-13 depicts the Calcium range in shallow ground water of U.P.

FIGURE-13



The various partly affected Blocks exhibiting high values of Calcium concentration (>200 mg/l) are tabulated in following table below:

TABLE 18: Partly affected Blocks exhibiting high values of Calcium (>200 mg/l) (2022-23)

S.No	**District**	**Block**	**Calcium (>200 mg/l)**
1	Agra	Akola	232
2	Agra	Fatehpur sikari	304
3	Jhansi	Mauranipur	344

4	Lalitpur	Mehrauni	344
5	Mahamaya Nagar	Aharai	341
6	Mathura	Farah	252
7	Mathura	Nohjhil	232
8	Mathura	Baroli	1002
9	Mathura	Borpa	601

Magnesium (Mg) :

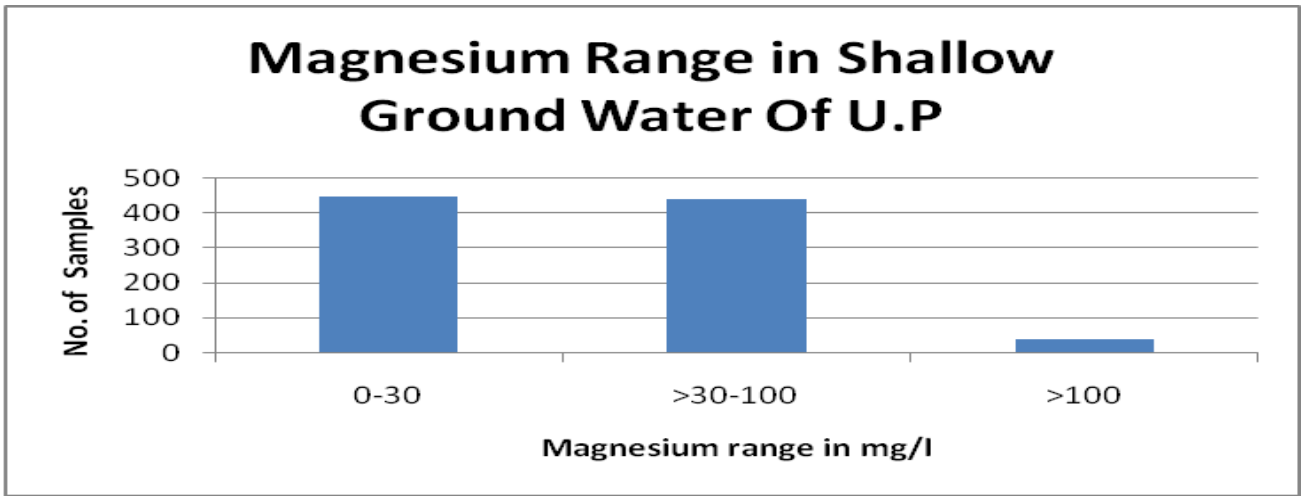
The main sources of magnesium in ground water are (i) rain water, (ii) evaporate deposits & (iii) weathering of magnesium silicate minerals. The source of magnesium in igneous rocks are olivine, pyroxenes, amphiboles, dark coloured micas etc. Among the sedimentary rocks, the sources are chlorite, serpentine biotite, amphiboles, staurolite etc. Mg is one of the constituents responsible for hardness of water. The lower concentration of Mg is not harmful but higher concentration is laxative. The concentration of Magnesium has been found varying widely. It ranges between 0 mg/l to 1483 mg/l with 48.3% of water samples falling within the desirable limit of 30 mg/l (BIS-2012) and 47.7 % samples have higher level of Mg concentration but within maximum permissible limit of 100 mg/l. Only 4.0% water samples exhibited Mg values >100 mg/l with a maximum value of 689 mg/l recorded at Baroli block (distt. Mathura). The distribution of samples in different concentration ranges are given in following table:

TABLE 19 : Frequency Distribution of Magnesium (2022-23)

Range of Magnesium in mg/l	**0-30**	**>30-100**	**>100**
No. of Samples	444	438	37
%	48.3	47.7	4.0

Figure-14 depicts the Magnesium range in shallow ground water of U.P.

FIGURE –14



The various partly affected Blocks exhibiting high values of Magnesium concentration (>100 mg/l) are tabulated in following table below:

TABLE 20: Partly affected Blocks exhibiting high values of Magnesium (>100 mg/l)

(2022-23)

S.No	District	Block	Mg(>100 mg/l)
1	Agra	Saiyan	228
2	Agra	Kheragarh	252
3	Agra	Jagner	190
4	Agra	Akola	437
5	Agra	Fatehpur sikari	466
6	Agra	Achhnera	120
7	Aligarh	Khair	103
8	Fatehpur	Malwan	139
9	Firozabad	Narkhi	108
10	Gautam buddha nagar	Zewar	107
11	Ghaziabad	Loni	139
12	Hardoi	Pihani	118
13	Hathras	Mursan	125
14	Hathras	Sadabad	132
15	Jalaun	Rampura	146
16	Jaunpur	Jaunpur H.Q.	106
17	Kanpur Dehat	Sandalpur	104
18	Kanpur Nagar	Kalyanpur	109

19	Kanpur Nagar	Patara	102
20	Kanpur Nagar	Shivrajpur	124
21	Mahamaya Nagar	Aharai	255
22	Mahoba	Charkhari	106
23	Mathura	Chaumuhan	158
24	Mathura	Farah	319
25	Mathura	Goverdhan	137
26	Mathura	Mat	151
27	Mathura	Nohjhil	386
28	Mathura	Raya	166
29	Mathura	Ajijpur	185
30	Mathura	Baroli	1484
31	Mathura	Gaiyara	114
32	Mathura	Bhagosa	187
33	Mathura	Nagla karan	216
34	Mathura	Borpa	510.7
35	Raibareli	Tiloi	103
36	Saharanpur	Sadauli qudim	115
37	Unnao	Asoha	283

Sodium (Na):

It is found in varying concentrations in all natural waters. It is found in evaporates and sea water in high concentration. It occurs among silicate minerals in feldspar, mica, amphiboles and pyroxenes. The main sources of sodium in ground water are (i) rain water, (ii) evaporate deposits, (iii) weathering of rock minerals present in the soil, (iv) disposal of sewage and industrial wastes containing sodium. The higher concentration of Na in drinking water is harmful especially to those suffering from cardiac, renal diseases pertaining to circulatory system of the human body.

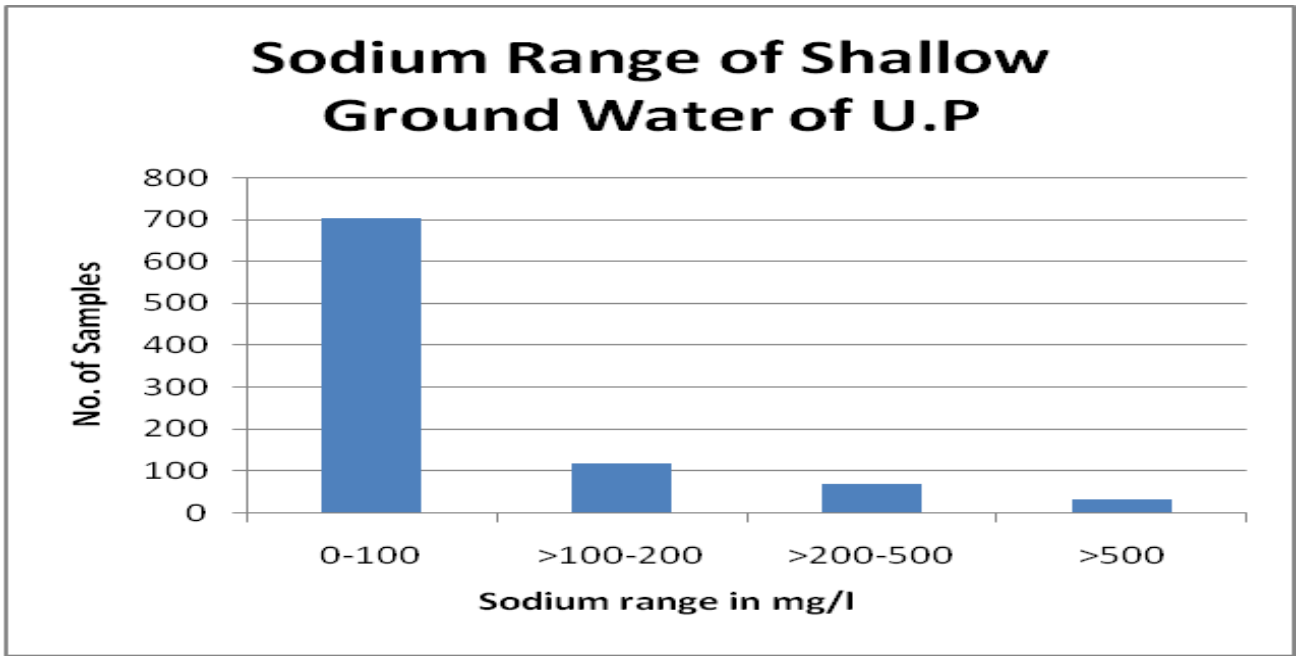
The analysis result of shallow ground water indicate that sodium ranges between 1.87 mg/l to 2122mg/l with an average value of 98.3 mg/l. 76.2 % of water samples exhibit sodium concentration up to 100 mg/l and 3.5% samples were found to be associated with extremely high levels of Na concentration >500 mg/l with a maximum value of 2122 mg/l recorded at Borpa block (distt. Mathura). The distribution of samples in different concentration ranges are given in following table:

TABLE 21 : Frequency Distribution of Sodium (2022-23)

Range of Sodium in mg/l	**0-100**	**>100-200**	**>200-500**	**>500**
No. of Samples	702	118	67	32
%	76.4	12.8	7.3	3.5

Figure-15 depicts the Sodium range in shallow ground water of U.P.

FIGURE – 15



The various partly affected Blocks exhibiting high values of Sodium concentration (>500 mg/l) are tabulated in following table below:

TABLE 22: Partly affected Blocks exhibiting high values of Sodium (>500 mg/l) (2022-23)

S. No.	District	Block	Sodium(>500 mg/l)
1	Agra	Fatehabad	552
2	Agra	Kheragarh	859
3	Agra	Jagner	757
4	Agra	Akola	1528
5	Agra	Fatehpur sikari	1847
6	Agra	Bichpuri	510
7	Agra	Etmadpur	845
8	Aligarh	Gonda	679
9	Aligarh	Nama	585
10	Etah	Jalesar	610
11	Firozabad	Firozabad	608
12	Gautam Buddha Nagar	Zewar	900
13	Hamirpur	Rath	558
14	Hamirpur	Sarila	828
15	Hamirpur	Maudaha	594
16	Hathras	Mursan	667
17	Hathras	Sadabad	849

18	Mahamaya nagar	Aharai	939
19	Mathura	Chaumuhan	635
20	Mathura	Farah	823
21	Mathura	Goverdhan	735
22	Mathura	Mat	558
23	Mathura	Nohjhil	801
24	Mathura	Raya	754
25	Mathura	Ajijpur	703
26	Mathura	Ajnokh	635
27	Mathura	Baroli	2120
28	Mathura	Gaiyara	628
29	Mathura	Bhagosa	1044
30	Mathura	Lohaban	710
31	Mathura	Nagla karan	559
32	Mathura	Borpa	2122

Potassium (K)

Although potassium is more abundant than sodium in sedimentary rocks, its concentration in natural waters is quite low due to greater resistance to weathering of potassium bearing minerals. The main sources of K in natural waters are (i) rain water, (ii) weathering of Potash silicate minerals, (iii) potash fertilizers. K enters into structure of clay and clay bearing minerals during weathering. In illite K ions are incorporated in spaces between crystal layers where these are not removable by further ion exchange reactions (Buckman & Brady, 1960). Usually the concentration of K in water from natural source is small but high concentration of this ion if present, may be attributed to pollution.

Potassium is an essential plant nutrient. It plays an important role in maintenance of cellular organization and in keeping the protoplasm in a proper degree of hydration by stabilizing the emulsions of highly colloidal particles. K deficiency causes water imbalance. The carbohydrate metabolism is also affected by inadequate supplies of potassium.

The analysis result of shallow ground water indicate that Potassium ranges between 0 to 796mg/l with an average value of 8.96 mg/l. 92.9% of water samples exhibit Potassium concentration up to 10 mg/l and 3.5% samples were found to be associated with extremely high levels of K concentration >30 mg/l with a maximum value of 742 mg/l recorded at Achhnera block (distt. Agra). The distribution of samples in different concentration ranges are given in following table:

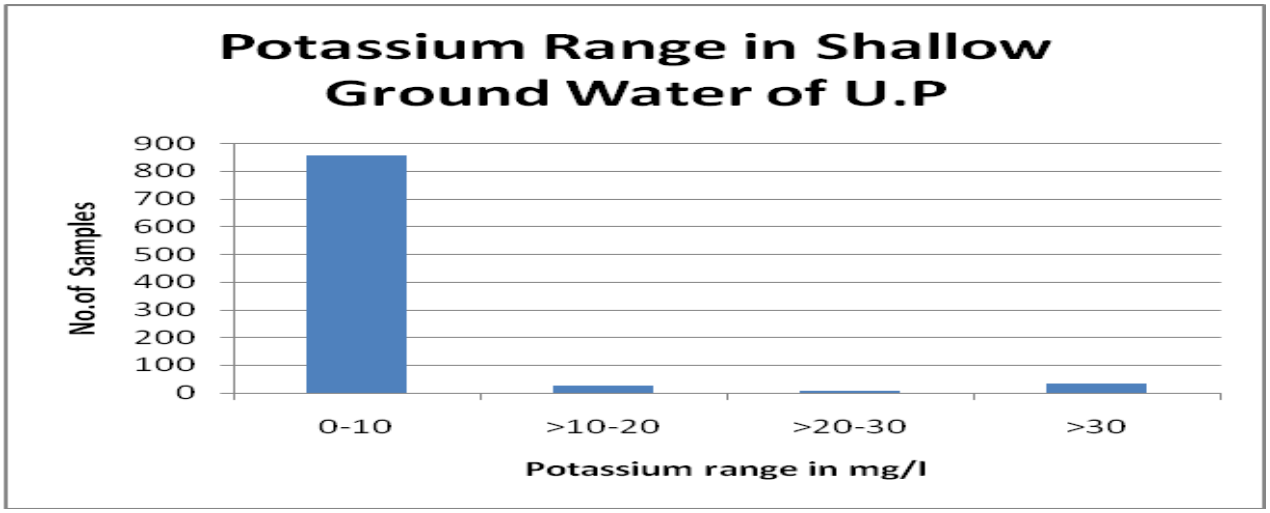
TABLE-23: Frequency Distribution of Potassium (2022-23)

Range of Potassium in mg/l	**0-10**	**>10-20**	**>20-30**	**>30**

No. of Samples	855	26	7	32
%	93.0	2.8	0.80	3.4

Figure-16 depicts the Potassium range in shallow ground water of U.P.

FIGURE-16



The various partly affected Blocks exhibiting high values of Potassium concentration (>30 mg/l) are tabulated in following table below:

TABLE 24: Partly affected Blocks exhibiting high values of Potassium (>30 mg/l) (2022-23)

S. No.	District	Block	Potassium (mg/l)
1	Agra	Achhnera	796
2	Aligarh	Khair	100
3	Amethi	Jamo	41
4	Amroha/ j.p. nagar	Amroha	72
5	Bahraich	Chittaura	44
6	Bahraich	Mihipurwa	32
7	Ballia	Maniyar	34
8	Bulandshahr	Amarpur	36
9	Fatehpur	Hathgaon	33
10	Firozabad	Aron	165
11	Gautam buddha nagar	Bisrakh	34
12	Hathras	Hassain	168
13	Hathras	Hathras	52
14	Jhansi	Gursarai	57

15	Kanpur nagar	Bidhnoo	50
16	Kanpur nagar	Kalyanp ur	80
17	Kaushambi	Chail	102
18	Mahamaya nagar	Nagla jahru	38
19	Mathura	Mat	96
20	Mathura	Nohjhil	695
21	Mathura	Bathain kalan	99
22	Mathura	Karahari	79
23	Meerut	Daurala	56
24	Muzaffarnagar	Charthawal	31
25	Pratapgarh	Pratapgarh sadar	56
26	Pratapgarh	Rampur-sangramgarg	310
27	Pratapgarh	Sandwa -chandrika	50
28	Pratapgarh	Sangaipur	420
29	Sambhal	Gunnaur	53
30	Shahjahanpur	Nigohi	34
31	Shamli	Un	34
32	Siddharth Nagar	Uskabazar	48

Piper Diagram:

The Hill-piper Diagram is a widely used trilinear diagram to represent the chemical composition of natural waters. It aids in understanding the sources of the dissolved constituent salts in the ground water and further classification of water samples from various lithological environment. It demonstrates the chemical character of water samples using the dominant cation and anion of the ground water samples. The Hydrochemical facies are delineated by plotting percentage reacting value of major ions on tri-linear diagrams know as Piper Diagram.In Uttar Pradesh, cation chemistry is dominated by calcium followed by sodium and Potassium. In anion side bicarbonate is dominating anion followed by chloride and sulphate.

The facies mapping shows (Fig.17) that Ca-HCO_3 is the dominant hydrogeochemical facies followed by mixed chemical character of hydrogeochemical facies. The piper plot of Uttar Pradesh exhibits that the groundwater is mostly Ca- HCO3 type in nature.

Figure -17 Shows the piper plot of Uttar Pradesh (2022-23)

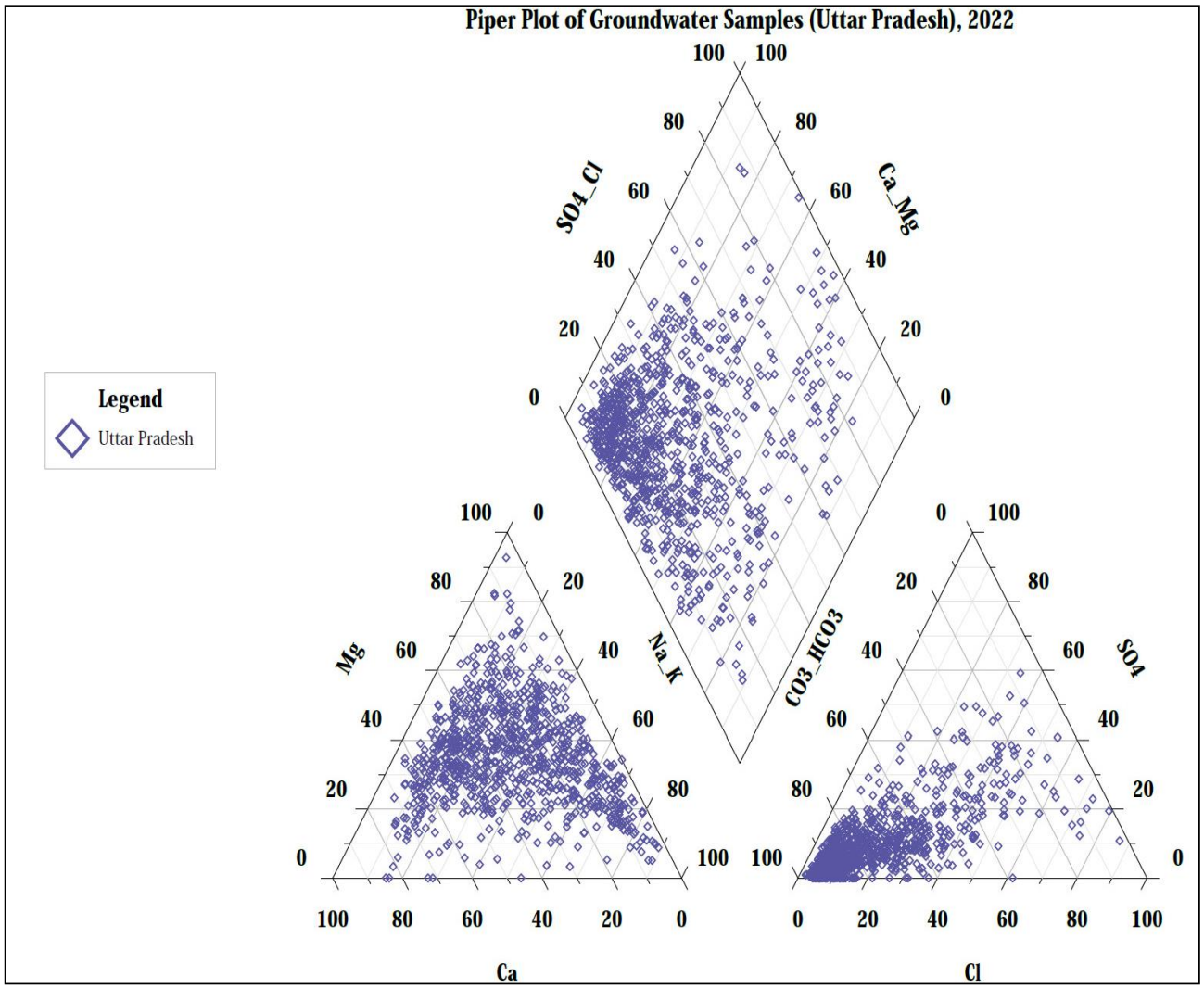
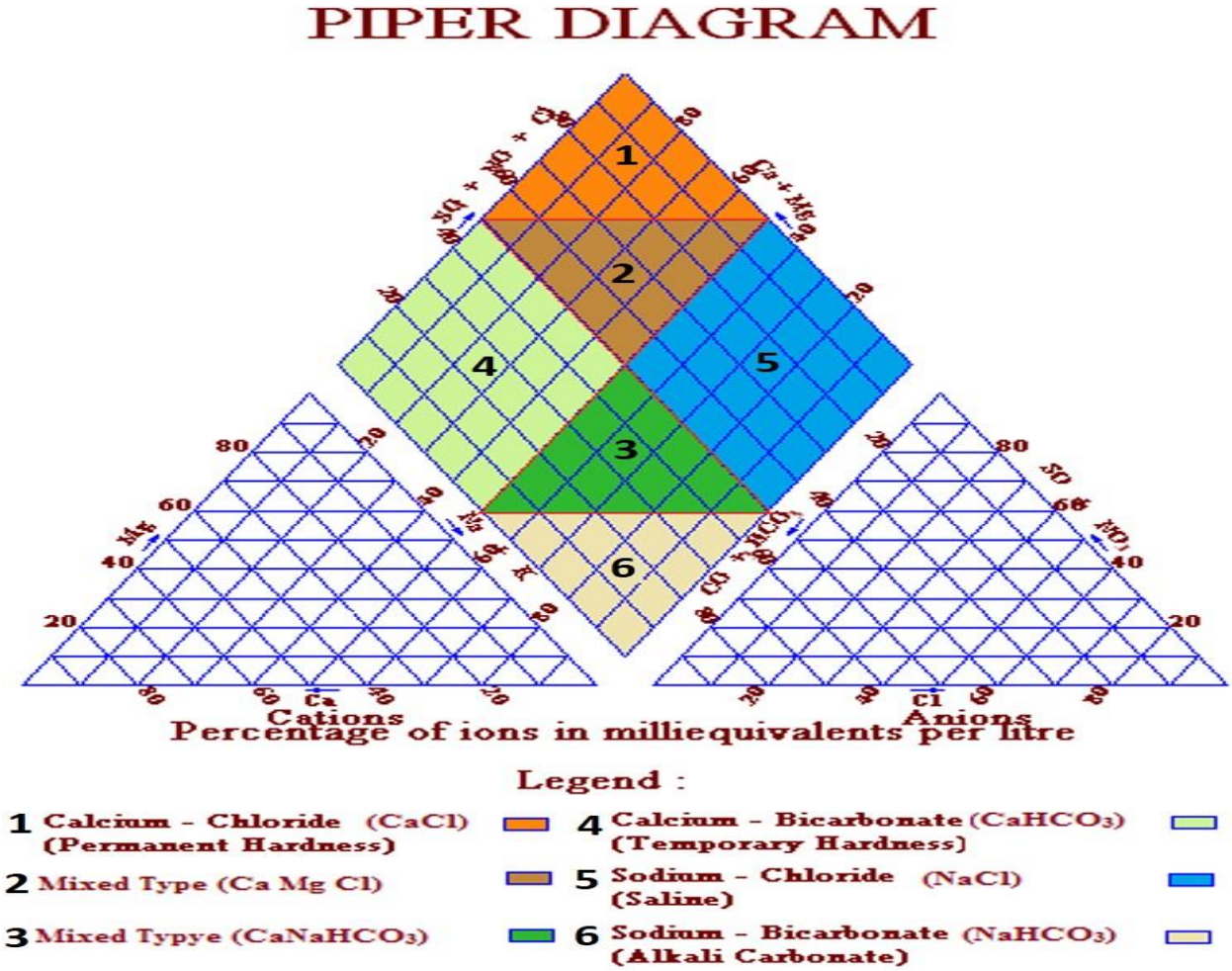


Figure 18 shows the type of water in Piper Diagram (2022-23)



4.2 SUITABILITY OF GROUND WATER FOR IRRIGATION PURPOSE

The chemical quality of water is an important factor to be considered in evaluating its usefulness for irrigation purposes. Plants grown by irrigation absorb and transpire the water but leave nearly all the salts behind in the soil, where they accumulate and eventually prevent plant growth. Excessive concentrations of solute interfere with the osmotic process by which plant root membranes are able to assimilate water and nutrients. $CaCO_3$ has low solubility, it may precipitate harmlessly but the bulk of residual solutes present a disposal problem that must be solved effectively to maintain productivity of the irrigated soil. In areas where natural drainage is inadequate, the irrigation water infiltrating the root zone will cause water table to rise excessively. The crop productivity depends on the quality of the water used for irrigation. Water suitability for irrigation needs to be evaluated on the basis of hazards it can create in the soil, affecting yield & quality of crops.

In addition to problems caused by excessive concentration of dissolved solids (TDS), certain constituents in irrigation water are especially undesirable and some may be damaging even when present in small concentrations viz. Sodium Adsorption Ratio (SAR) & Residual Sodium Carbonate (RSC) (Annexure-A). The potential hazards to crop growth are salinity, sodicity, alkalinity & toxicity.

Electrical Conductivity (EC):

The Electrical Conductivity is a reflection of the concentration of various chemical constituents in ground water and gives the overall quality of ground water for its various uses like irrigation**.** The Electrical Conductivity data reveals that the majority of the samples belong to C1, C2 class as per USSL classification.

TABLE 25: Frequency distribution of Electrical Conductivity (2022-23)

EC ranges in µS/cm at 25ºC	**0-250 (C1)**	**251 – 750 (C2)**	**751-2250 (C3)**	**>2250 (C4)**
No. of samples	1	520	343	55
Percentage	0.10	56.6	37.3	6.0

Total Dissolved Solids (TDS):

The total load of dissolved solids in water is determined theoretically by taking into account the EC of that particular water body.

Thus**,** **TDS = EC * .65 mg/l** where EC is in µS/cm at 25º C

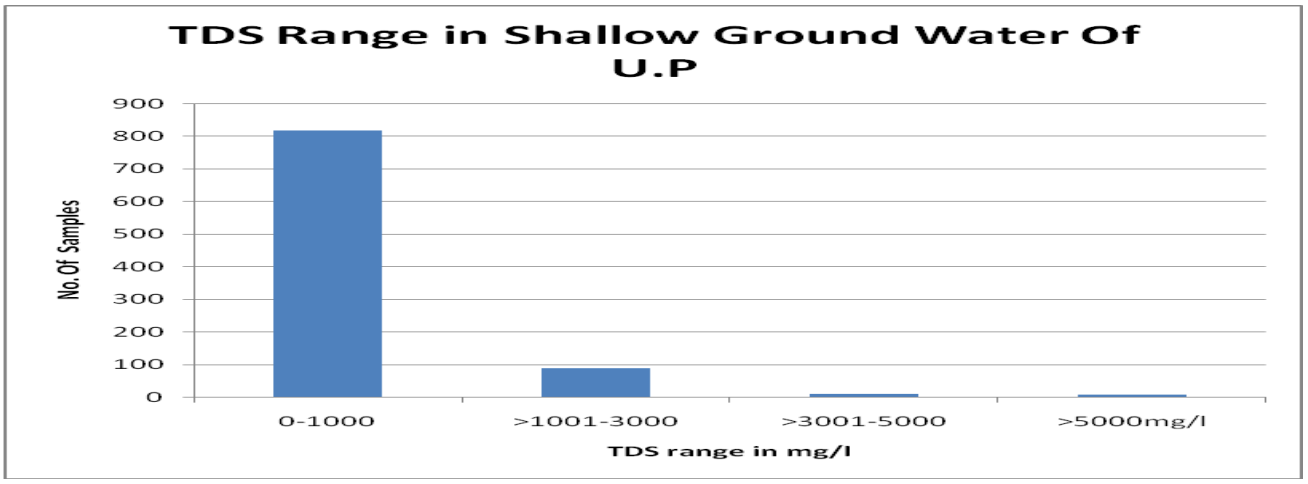
TDS is responsible for the mineralization of water and gives its degree of salinity. The perusal of the analysis data of U.P. shows that the Total Dissolved Solids in the area ranges from a minimum of 153 mg/l to a maximum of 15548 mg/l at Baroli block (distt. Mathura) with an average value of 673mg/l.

Table 25 : Frequency Distribution of T.D.S. in NH Stations of U.P. (2022-23)

Salinity as per T.D.S range	**No. of Samples**	**Percentage**
Fresh, non saline (0-1000 mg/l)	817	88.9
Slightly saline (1001-3000 mg/l)	88	9.60
Moderately saline (3001-5000 mg/l)	8	0.86
Highly saline (>5000 mg/l)	6	0.64

Figure-19 depicts the T.D.S. range in shallow ground water of U.P (2022-23)

FIGURE-19



Alkalinity Hazard or Residual Sodium Carbonate (RSC) :

When carbonate or bicarbonate concentration in irrigation water is relatively higher than the alkaline earth metals, there is tendency for calcium and magnesium ions to precipitate as carbonates in the soil, thereby reducing the level of calcium and magnesium ions and increasing the relative levels of sodium in the soil. The highly soluble sodium carbonate (black alkali) known as residual sodium carbonate (RSC) is defined as –

RSC = (HCO_3 + CO_3) – (Ca + Mg)

Where concentrations are expressed in meq/l.

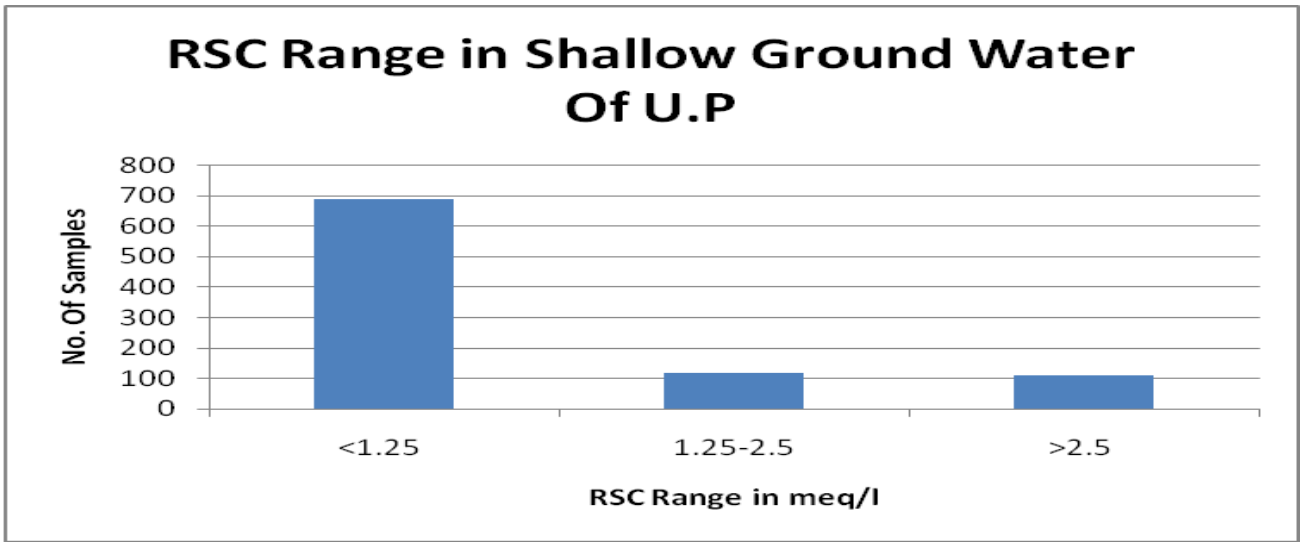
The perusal of the analyzed data of U.P. shows that the Residual Sodium Carbonate in the area ranges from a minimum of -169.1 meq /l to a maximum of 9.99 meq /l with an average value of 0.44meq/l.

Table 26 : Frequency Distribution of R.S.C. in NH Stations of U.P. (2022-23)

RSC range (meq/l)	No. of samples	Percentage
<1.25 (Very safe water)	693	75.4
1.25-2.5 (Marginally safe water)	116	12.6
>2.5 (Unsuitable water)	110	12.0

Figure-20 depicts the R.S.C. range in shallow ground water of U.P

FIGURE-20



Sodium Adsorption Ratio:

Sodium Adsorption Ratio (SAR) is an estimate of the degree to which Sodium will be absorbed by soil from water. Sodium in irrigation, waters adversely affects soil structure and permissibility by replacing Ca and Mg ions.

$$SAR = \frac{Na^{+}}{\left[Ca^{+2} + Mg^{+2}/2\right]^{1/2}}$$

Where: Na^{+}, Ca^{+2} and Mg^{+2} are expressed in meq/l

Table 27– Shows quality of Water on the basis of SAR values (2022-23)

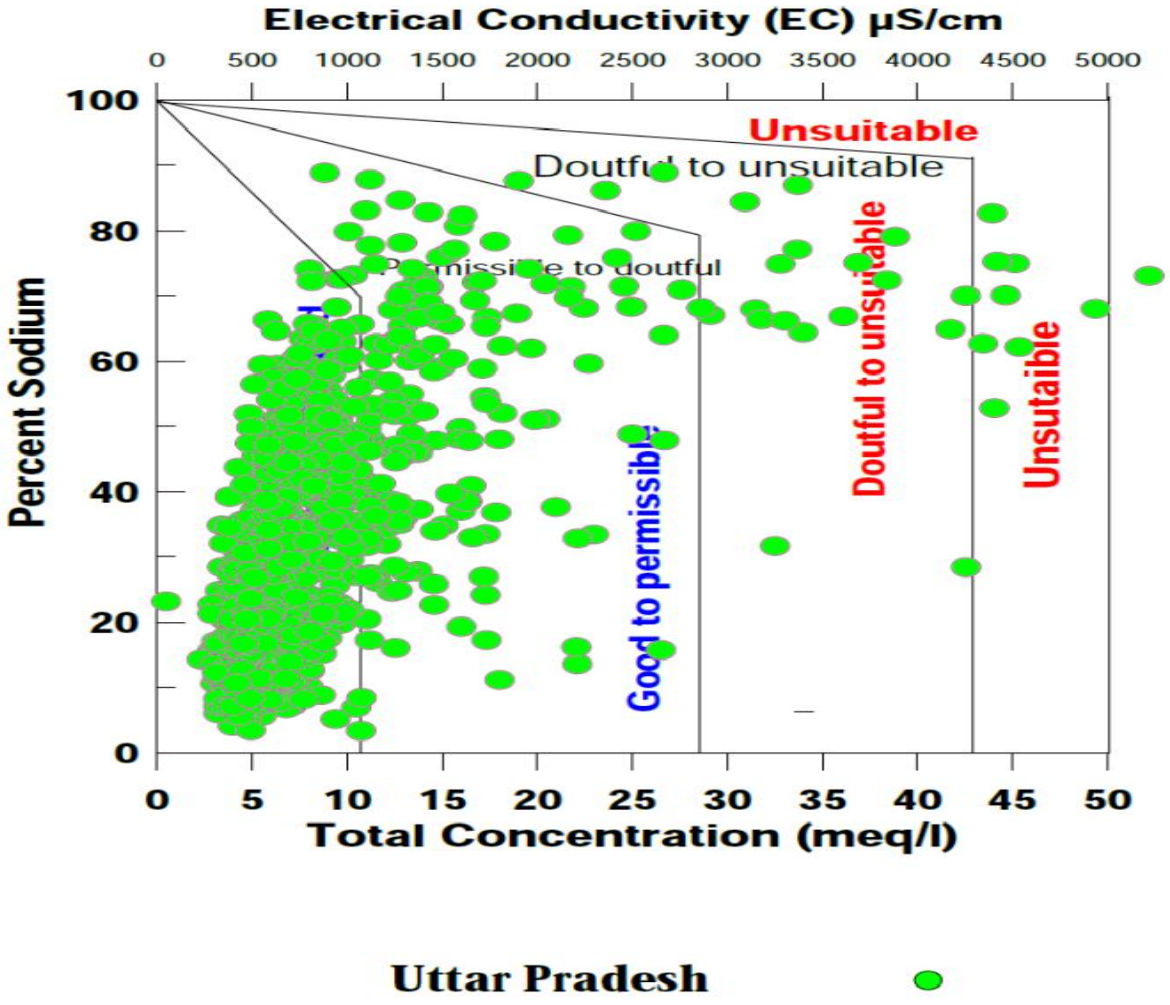
S. No.	Range of SAR	No. of Samples	% of Samples	Quality of Water
1.	<10	888	96.6	Low Na hazard (good quality)
2.	>10-18	27	3.0	MediumNa hazard (medium quality)
3.	>18-26	4	0.40	High Na hazard (bad quality)
4.	>26	0	0	V. High Na hazard (V. bad quality)

Table 27 - shows that the quality of water samples as per SAR is good as 96.6% wells have SAR value below 10.

Wilcox diagram

Electrical Conductivity and sodium concentration are very important in classifying irrigation water. The Wilcox diagram (Wilcox 1948) relating EC and %Na(fig. 21), shows that most of thewater samples are plotted in excellent to good and good to permissible categories indicating their suitability for irrigation.
Wilcox diagram of Uttar Pradesh is presented in Fig-21.

Fig -21 Wilcox diagram of Uttar Pradesh



5.0 Heavy metal

In the context of management of water resources, the identification of heavy metals is one of the most important aspects because of their influence on the quality of groundwater and subsequent health effects on all living creatures as groundwater is the principal natural water resource for both drinking and agricultural purposes. Water functions as a medium of transport for pollutants and they can be damaging to both the environment and human beings. Virtually any activity whereby chemicals or wastes are released to the environment, either intentionally or accidentaly, can be a cause to pollute groundwater. Usually in natural environments, the concentration of the metals is very low and is mostly derived from the minerals and the weathering of geological formations and types of soils of that area .Overexploitation of groundwater resources may also lead to degradation of groundwater quality.

Heavy metals enter in groundwater from variety of sources; it can either be natural or anthropogenic (Reza & Singh, 2010). It is widely accepted that anthropogenic activity makes a significant contribution to the total aquatic burden of toxic metals by both point and non-point sources of contamination. Easily identifiable point-sources of metal pollution include mining, landfill leachate, foundries, pharmaceutical industries and smelters, and other metal-based industrial operations, whereas non-point source contamination usually arises from agricultural-runoff, fertilizers, atmospheric deposition industrial, and urban/domestic effluents that reach the sea by way of waterways, surface runoff, and precipitation (Biswas et. al. ,2017). Once ground water gets contaminated, it is difficult and expensive to clean up.

As the concentrations of heavy metals increases in environment and the capacityof soils for retaining decreases, heavy metals start leaching into groundwater through soilsolution resulting in contamination of all sources of drinking water e.g. surface waters, ground water and sea water. (Bryan & Langston,1992). Generally, heavy metals cannot be removed from soil solution and when they enter into the soil, they are taken up by plant's roots along with other nutrients through osmosis ensuing poor crop production. When these crops or their products are consumed by animals or humans, they get entry into food chain. Heavy metals can bio-accumulate over a period of time and the concentrations become apparent and unmanageable. At a toxic level on the food chain, bio-accumulation of heavy metal within target organ or tissue of organisms can ultimately threaten health.

The term "Heavy metals" is used to describe more than dozens elements that are metals or metalloids or transition metals, basic metals, lanthanides, and actinides .Being metals ions, heavy

metal cannot be degraded or destroyed, therefore their stability make them as the persistent toxic substances in environment. Examples of heavy metals include mercury (Hg), cadmium (Cd), arsenic (As), chromium (Cr), thallium (Tl), lead (Pb), Copper (Cu), Zinc (Zn), Cobalt (Co), Nickel (Ni), and Iron (Fe) etc. These metals are classified in to three categories: Toxic metals Precious metals (such as Pd, Pt, Ag, Au, Ru etc.) and Radionuclides (such as U, Th, Ra, Am, etc.).

Unlike organic pollutants, heavy metals, being non-biodegradable, pose a different kind of challenge for remediation. The environmental behaviour of heavy metals critically depends on their specific chemical forms in which they are present and on their binding state which influences their bioavailability, mobility, and toxicity to organisms. The metal's solubility in water and soil depend on pH, metal concentration, organic carbon, ion exchange and oxidation state of mineral components as well as the redox potential of the system.

As mentioned earlier heavy metals are dangerous because these tend to bioaccumulate. Bioaccumulation means an increase in the concentration of a chemical in an organism over time, compared to its concentration in the environment. Though some of these heavy metals are essential for the growth, development and health of living organisms, whereas others are non-essential as they have been proved toxic and perdurable(Underwood,1956).. Metals like Cu and Zn are essential as micronutrients for the life processes in animals and plants, while many other metals such as Cd and Pb have no known physiological activities(Suthar & Singh 2008). At a trace level, heavy metals like Iron, Manganese, Copper, Zinc play an important role in the metabolism of the human body. However, levels higher than prescribed limit can lead to poisoning. Metals such as Chromium (Cr), Copper (Cu), Zinc (Zn), and Lead (Pb) are generally more persistent than organic contaminants. They can be mobile in soil-solution phase and leach into aquifers.

Because of their high degree of toxicity, Arsenic, Chromium and Lead rank among the priority metals that are of public health significance. These metallic elements are considered systemic toxicants that are known to induce multiple organ damage, even at lower levels of exposure. They are also classified as human carcinogens (known or probable) according to the U.S. Environmental Protection Agency, and the International Agency for Research on Cancer. Some of the above elements are present naturally (e.g. arsenic) but the major sources of other elements (e.g. lead) in the environment are from pollution from industries and other human activities.

Adverse health effects, such as lung and skin cancer, prostatic proliferative lesions, peripheral neuropathy, kidney dysfunction, dermal lesions, and peripheral vascular disease, have been attributed to trace metal pollution. Metals like Lead, Cadmium, Arsenic, Silver, Mercury etc. cause conditions such as heart diseases, liver injury, hypophosphatemia, neurological and cardiovascular disease and sensory disturbances. However, metal toxicity mainly depends on the metal speciation, dose and bioavailability, as well as on the rout of exposure(food, drinking water and air), accumulation, age, gender, genetics and nutritional status of exposed individuals or organisms .

5.1 EFFECT OF WATER POLLUTION ON HUMAN HEALTH

Water pollution directly impacts human health. The effects can be short term or long term. Sometimes the use of contaminated water can also be fatal. In addition to this many diseases occur when drinking water comes in contact with contaminated water: which in turn may be life threatening. The contaminated water discharged from various industrial units such as various metal processing units, paper mills, chlor- alkali units, galvanizing or electroplating units, metal extraction units, utensil manufacturing, battery manufacturing or recycling, chemical industries etc contains large quantities of metals in dissolved form, semi soluble or as insoluble chemical compounds or mixtures as effluents. These effluents reach the river and ground water when the water from drains is discharged in the river water. From there it reaches our body through food chain or directly through drinking water. They then adversely affect different parts of our body. Sometimes they accumulate inthe body and slowly show their adverse effects.

5.2 COLLECTION OF SAMPLES AND ANALYSIS

Central Ground Water Board, as a part of its national programme, has established Groundwater monitoring network stations in the state of Uttar Pradesh for periodic monitoring of groundwater levels and to study its quality variation in time and space. A total number of 937 water samples from Groundwater monitoring network stations in 2022 were collected for Heavy metal analysis after 1:1Ultrapure Nitric acid treatment. The analysis for heavy metals was carried out on ICP-MS (Thermo Fischer model i cap Q) for 8 heavy metals viz. Chromium, Manganese, Iron , Copper, Zinc, Lead,Arsenic and Uranium. Monitoring of groundwater quality is an effort to obtain information on chemical quality through representative sampling in different hydro

geological units. Groundwater is commonly tapped from phreatic aquifers through Hand pumps in major part of the state.

5.3 RESULTS AND DISCUSSION

In the present investigations an attempt has been made to evaluate the Uranium and other trace metal concentrations in drinking water samples collected from Uttar Pradesh, India. The purpose of the study was mainly to investigate the Uranium and other trace metal concentrations in drinking water samples being utilized by inhabitants of the study region and their health risk assessment from health hazard point of view. The concentration of the metals given in Annexure I have been interpreted as per the standards prescribed for drinking water (Bureau of Indian Standards (BIS) IS10500:2012. The general description of various metal concentration in ground water and their effect on Human health is described as under:-

IRON

Iron is the most abundant element in the earth's crust and the most abundant heavy metal; it is present in the environment mainly as Fe^{2+} or Fe^{3+}.It is a common constituent of rocks and soil. It is derived from the weathering of igneous rocks and sulphide ores of sedimentary and metamorphic rocks. Iron ores like haematite, magnetite, and hydroxides may be leached from ferruginous sandstone and other rocks containing these constituents. Chemically, the most common oxidation states of iron are iron (II) and iron (III). Iron forms compounds in a wide range of oxidation states, −2 to +7. Iron also forms many coordination compounds; some of them, such as ferrocene, ferrioxalate, and Prussian blue, have substantial industrial, medical, or research applications.

Iron deficiency is the most common nutritional deficiency in the world. Most casesof iron-deficiency anaemia are mild, but if not treated can cause problems like fast or irregular heartbeat, complications during pregnancy, and delayed growth in infants and children. The behaviour of Iron in aqueous solution is controlled by redox reactions, complex formation, metabolism of organisms, exchange of iron between solution and solid phases. In ground water Fe^{++} is the dominant species which is oxidised to Fe^{+++} when water is under aerobic conditions. Iron is required for life. The average adult human contains about 0.005% body weight of iron.

Iron an essential element in human nutrition, is an integral component of cytochromes, porphyrins and metalloenzymes. Estimates of the minimum daily requirement for iron depend on

age, sex, physiological status, and iron bioavailability and range from about 10 to 50 mg/day. Iron-containing proteins participate in transport, storage and use of oxygen. Examples of iron-containing proteins in higher organisms include haemoglobin, cytochrome and catalase. The ingestion of large quantities of iron results in haemochromatosis. It is a condition in which normal regulatory mechanisms do not operate effectively which leads to tissue damage as a result of the accumulation of iron. Humans experience iron toxicity when the iron exceeds 20 milligrams for every kilogram of body mass; 60 milligrams per kilogram is considered a lethal dose.

Iron is an objectionable constituent in water supplies domestic or industrial purposes. Iron in higher concentration above 1.0mg/l, appreciably affects the taste of water and stains laundered clothes and plumbing fixtures and in the presence of Aluminium causes dirty water problems. Higher concentration of iron in drinking water may affect the metabolic system of human beings. It becomes toxic when administered parentally and the affected persons frequently develop pigmentation of skin, enlargement of liver, diabetes mellitus and heart failure. These effects are caused by a toxic accumulation of Iron in the body tissues.

937 water samples from Groundwater monitoring network stations in 2022 were analysed for Iron . Iron was found to be in the range of nd – 58.62 mg/l. High values above the permissible limit of 1.0mg/l were observed at 266 locations (Table 28). The high concentration of Iron in these areas may be geogenic .The highest concentration of 58.63mg/l Iron was observed at BDO office, Naugarh Block, Chandauli district.

Table -28 Hotspot with respect to Iron (Fe >1.0mg/l) (2022-23)

S.No	District	Block	Location	Fe(mg/l)
1	Agra	Fatehpur sikari	In front of kaila Devi temple, near 13 Gate no. Fathepur Sikri	2.750
2	Agra	Achhnera	In front of Govt. Primary school , Achhenera	1.089
3	Ambedkar nagar	Bhiti	Block hq	1.552
4	Ambedkar nagar	Tanda	Block hq	9.219
5	Amethi	Singhpur	Block HQ	1.096
6	Amethi	Gauriganj	Block HQ	2.350
7	Amroha/ J.P. Nagar	Amroha	Tohfapur	1.067
8	Auraiya	Airwa Katra	Sarai Kachhwaha	1.741

9	Auraiya	Sahar	Indapamau	1.522
10	Ayodhya	Amaniganj	Block HQ	1.115
11	Ayodhya	Bikapur	Block HQ	1.409
12	Ayodhya	Masodha	Block HQ	5.719
13	Ayodhya	Maya Bazar	Block HQ	1.736
S.No	**District**	**Block**	**Location**	**Fe(mg/l)**
14	Ayodhya	Mawai	Block HQ	5.779
15	Azamgarh	Ahiraula	Block HQ	3.062
16	Azamgarh	Azmatgarh	Block HQ	1.625
17	Azamgarh	Bilariyaganj	Block HQ	1.734
18	Azamgarh	Jahanganj	Block HQ	5.172
19	Azamgarh	Koyalsa	Block HQ	1.221
20	Azamgarh	Lalganj	Block HQ	1.110
21	Azamgarh	Mirzapur	Block HQ	1.178
22	Azamgarh	Tarwa	Block HQ	2.598
23	Baghpat	Baghpat	Block office	1.543
24	Baghpat	Baraut	Block office	1.636
25	Baghpat	Khekra	Block office	1.165
26	Bahraich	Balha	Block Office	5.458
27	Bahraich	Bisheshwarganj	Block Office	3.403
28	Bahraich	Chittaura	Block Office	16.21
29	Bahraich	Fakharpur	Block Office	2.307
30	Bahraich	Huzurpur	Block Office	2.591
31	Bahraich	Jarwal	Block Office	2.291
32	Bahraich	Kaisarganj	Block Office	1.577
33	Bahraich	Mahasi	Block Office	2.967
34	Bahraich	Mihipurwa	Block Office	6.886
35	Bahraich	Nawabganj	Block Office	2.055
36	Bahraich	Prayagpur	Block Office	2.078
37	Bahraich	Risiya	Block Office	5.175
38	Ballia	Bairya	Block Office	2.587
39	Ballia	Belhari	Block Office	4.466
40	Ballia	Dubahar	Block Office	2.367

41	Ballia	Muralichhapara	Block Office	5.775
42	Ballia	Nawanagar	Block Office	1.394
43	Ballia	Reoti	Block Office	2.015
44	Balrampur	Balrampur	Block Office	8.641
45	Balrampur	Gaisadi	Block Office	1.040
S.No	**District**	**Block**	**Location**	**Fe(mg/l)**
46	Balrampur	Gaidas Buzurg	Block Office	2.615
47	Balrampur	Harraiya Satgharwa	Block Office	1.006
48	Balrampur	Sriduttganj	Block Office	6.767
49	Balrampur	Utraula	Block Office	6.247
50	Barabanki	Bani Kodar	Block-office	1.790
51	Barabanki	Dewa	Block-office	1.144
52	Barabanki	Fatehpur	Block-office	1.974
53	Barabanki	Harak	Block-office	5.846
54	Barabanki	Ram Nagar	Block-office	2.355
55	Bareilly	Alampur Jafrabad	Block Office	1.960
56	Bareilly	Bhadpura	Block Office	2.335
57	Bareilly	Bhutah	Block Office	1.695
58	Bareilly	Faridpur	Block Office	6.190
59	Bareilly	Fatehganj	Block Office	1.174
60	Bareilly	Meerganj	Block Office	2.446
61	Basti	Dubauliya	Block Office	2.677
62	Basti	Harraiya	Block Office	7.965
63	Basti	Kapatanganj	Block Office	2.196
64	Basti	Kudraha	Block Office	1.046
65	Basti	Parasrampur	Block Office	1.060
66	Basti	Saltaua	Block Office	2.168
67	Basti	Saunghat	Block Office	2.458
68	Basti	Vikramjot	Block Office	3.098
69	Bijnor	Afzalgarh	Block Office	1.322
70	Bijnor	Alhepur (Dhampur)	Block Office	3.859
71	Bijnor	Jaleelpur	Block Office	4.201
72	Bijnor	Najibabad	Block Office	2.989

73	Bijnor	Noorpur	Block Office	9.660
74	Bijnor	Kiratpur	Ashrafpur/ Dudhli	2.906
75	Bijnor	Kiratpur	Islampur Vishnoi	1.573
76	Bijnor	Mohammadpur Deomal	Islampur Hadu/ Dass	1.649
77	Budaun	Dhigawaan	Block Office	1.059
S.No	**District**	**Block**	**Location**	**Fe(mg/l)**
78	Budaun	Dataganj	Block Office	7.791
79	Budaun	Miaon	Block Office	3.612
80	Budaun	Samrer	Block Office	1.003
81	Budaun	Wajirganj	Block Office	2.078
82	Bulandshahr	Amarpur	Amarpur	2.362
83	Bulandshar	B.B.Nagar	Block office premises	2.959
84	Chandauli	Naugarh	BDO, Naugarh	58.631
85	Chandauli	Sakal-diha	BDO, Sakaldiha	1.553
86	Deoria	Barhaj	Barhaj	5.651
87	Deoria	Bhaluwani	Bhaluwani	1.515
88	Deoria	Bhatani	Bhatani	3.236
89	Deoria	Bhatparani	Bhatparani	2.107
90	Deoria	Desahi Deoria	Desahi Deoria	1.660
91	Deoria	Gauri Bazar	Gauri Bazar	1.085
92	Deoria	Rudrapur	Rudrapur	1.339
93	Deoria	Bhaluwani	Garer chak, near house of Shivnath Chaurasia	1.391
94	Etah	Marhara	BDO office	1.668
95	Farrukhabad	Shamsabad	BDO office	1.048
96	Farrukhabad	Mohammdabad	BDO office	9.510
97	Farrukhabad	Amritpur(ur)	Near iti, amritpur	2.543
98	Farrukhabad	Kanakpur(ur)	in premises, lal bahadur inter college, kanakpur	5.032
99	Fatehpur	Malwan	Guneer	2.609
100	Fatehpur	Malwan	Kotiya	1.062
101	Fatehpur	Deomai	Block office	1.926
102	Fatehpur	Khajuha	Block office	2.706

103	Firozabad	Aron	in bdo office	3.041
104	G.b.nagar	Bisrakh	Outside block office premises	2.449
105	Ghaziabad	Bhojpur	Block office	6.697
106	Ghazipur	Muhammadabad	Block office	4.674
S.No	**District**	**Block**	**Location**	**Fe(mg/l)**
107	Ghazipur	Jakhania	Block office	1.052
108	Gonda	Belsar	Block Office	3.474
109	Gonda	Colonelganj	Block Office	5.132
110	Gonda	Haldharmaij	Block Office	1.631
111	Gonda	Itiyathok	Block Office	3.042
112	Gonda	Jhanjhari	Block Office	1.215
113	Gonda	Katra Bazar	Block Office	2.256
114	Gonda	Mujehna	Block Office	3.167
115	Gonda	Paraspur	Block Office	1.011
116	Gorakhpur	Bansgaon	Bansgaon	7.420
117	Gorakhpur	Barahalganj	Barahalganj	5.630
118	Gorakhpur	Bharohia	Bharohia	2.878
119	Gorakhpur	Khajani	Khajani	6.830
120	Gorakhpur	Sahjanwa	Sahjanwa	1.757
121	Gorakhpur	Sardar Nagar	Sardar Nagar	1.184
122	Gorakhpur	Uruwa	Uruwa	1.295
123	Hardoi	Ahirori	Block Office	2.561
124	Hardoi	Behdar Khurd	Block Office	1.639
125	Hardoi	Harpalpur	Block Office	1.106
126	J p nagar	Joya	Block office	4.147
127	Jalaun	Rampura	BDO	1.518
128	Jaunpur	Jaunpur H.Q.	T.D. Collage Road, Olandganj, Jaunpur	1.120
129	Jaunpur	Dobhi	BDO, Bhobi, Chandwak	3.691
130	Jaunpur	Karanja Kalan	BDO, Karanjakanal	1.126
131	Jaunpur	Ram Nagar	BDO, Ramnagar	5.308
132	Jaunpur	Sirkoni	BDO, Sirkoni	1.457
133	Jaunpur	Sikrara	BDO, Office	4.854

134	Kannauj	Jalalbad	Jalalbad Block Office	5.655
135	Kannauj	Kannauj	Kannauj Block Office	12.81
136	Kanpur dehat	Malasa	Malasa block office	2.267
137	Kanpur nagar	Shivrajpur	Shivrajpur	1.368
S.No	**District**	**Block**	**Location**	**Fe(mg/l)**
138	Kanpur nagar	Chaubeypur	Katari bajidpur	2.460
139	Kasganj	Sahawar	in bdo office	1.655
140	Kushinagar	Dudhai	Dudhai	2.540
141	Kushinagar	Fazil Nagar	Fazil Nagar	1.307
142	Kushinagar	Kaptanganj	Kaptanganj	6.117
143	Kushinagar	Kasiya	Kasiya	1.926
144	Kushinagar	Khadda	Khadda	3.876
145	Kushinagar	Nebuwa Naurangia	Nebuwa Naurangia	2.230
146	Kushinagar	Padrauna	Padrauna	16.29
147	Kushinagar	Ram Kola	Ram kola	1.382
148	Kushinagar	Sewarhi	Sewarhi	3.087
149	Kushinagar	Sukrauli	Sukrauli	1.097
150	Kushinagar	Vishunpurwa	Vishunpurwa	2.093
151	Lakhimpur kheri	Behjam	Block office	5.997
152	Lakhimpur kheri	Bijua	Block office	1.014
153	Lakhimpur kheri	Dhaurahra	Block office	1.437
154	Lakhimpur kheri	Gola	Block office	3.841
155	Lakhimpur kheri	Ishanagar	Block office	2.778
156	Lakhimpur kheri	Mohammadi	Block office	4.585
157	Lakhimpur kheri	Mitauli	Block office	10.145
158	Lakhimpur kheri	Nakaha	Block office	9.958
159	Lakhimpur kheri	Nighasan	Block office	3.558
160	Lakhimpur kheri	Palia kalan	Block office	1.763
161	Lakhimpur kheri	Phool behar	Block office	6.302
162	Lakhimpur kheri	Ramaiya behar	Block office	3.638
163	Lucknow	Bakshi Ka Talab	Block HQ	2.596
164	Lucknow	Malihabad	Block HQ	2.201

165	Lucknow	Mohanlal Ganj	Block HQ	3.853
166	Maharaj ganj	Maharaj ganj	Gaunaria babu (near Pond of Satyendra Pradhan on Maharajganj to Partwal road)	1.650
167	Maharajganj	Brijmanganj	Brijmanganj	1.961
S.No	**District**	**Block**	**Location**	**Fe(mg/l)**
168	Maharajganj	Dhani	Dhani	6.028
169	Maharajganj	Ghughuli	Ghughuli	1.592
170	Maharajganj	Maharajganj	Maharajganj	4.662
171	Maharajganj	Nautanwa	Nautanwa	2.761
172	Maharajganj	Pharenda	Pharenda	1.991
173	Maharajganj	Siswa	Siswa	4.943
174	Mainpuri	Jageer	in bdo office	1.652
175	Mathura	Nohjhil	Block office premises	2.500
176	Mathura	Raya	Block office premises	2.425
177	Mathura	Karahari	Karahari	6.316
178	Mathura	Nagla Karan	Nagla Karan	7.966
179	Maunath bhanjan	Kopaganj	Block office premises	4.478
180	Meerut	Daurala	Block office	1.716
181	Meerut	Machhra	Block office	6.478
182	Meerut	Rohta	Block office	12.09
183	Mirzapur	Haliya	BDO, Haliya	3.006
184	Mirzapur	Kon	BDO, Kon	1.643
185	Mirzapur	Lalganj	BDO, Lalganj	1.018
186	Mirzapur	Rajgarh	BSNL Office, 100m away from BDO Rajgarh, Dabra	1.961
187	Moradabad	Bhagatpur Tanda	Block Office	3.198
188	Moradabad	Bilari	Block Office	3.352
189	Moradabad	Chhajlet	Block Office	2.163
190	Moradabad	Moondhapandey	Block Office	1.308
191	Moradabad	Moradabad	Block Office	3.375
192	Muzaffarnagar	Charthawal	Block office	1.456

193	Muzaffarnagar	Muzaffar Nagar	Block office	3.715
194	Muzaffarnagar	Shahpur	Block office	5.516
195	Pilibhit	Amaria	Block Office	1.569
196	Pilibhit	Bar Khera	Block Office	1.133
197	Pilibhit	Bilsanda	Block Office	2.279
S.No	**District**	**Block**	**Location**	**Fe(mg/l)**
198	Pilibhit	Bilaspur	Block Office	2.639
199	Pilibhit	Lalauli Khera	Block Office	1.577
200	Pratapgarh	Aspur-deosara	BDO, Office	3.501
201	Pratapgarh	Sangaipur	Ateha village	1.521
202	Prayagraj	Baheria	BDO, Office	4.223
203	Prayagraj	Jasra	BDO, Office	1.118
204	Prayagraj	Koraon	BDO, Office	1.367
205	Prayagraj	Saidabad	BDO, Office	1.144
206	Prayagraj	Shankar garh	BDO, Office	1.064
207	Raibareli	Dinshahgaura	Block HQ	1.475
208	Raibareli	Kheron	Block HQ	10.61
209	Raibareli	Lalganj	Block HQ	2.633
210	Raibareli	Rohnia	Block HQ	1.022
211	Raibareli	Salon	Block HQ	1.264
212	Raibareli	Sheogarh	Block HQ	3.219
213	Rampur	Bilaspur	Block Office	1.995
214	Rampur	Chamraua	Opposite Prathma Bank near block office	11.76
215	Rampur	Milak	Block Office	3.137
216	Rampur	Swar	Block Office	2.855
217	Saharanpur	Baliakheri	Block office	1.261
218	Saharanpur	Nanauta	Block office	2.315
219	Saharanpur	Puwarka	Block office	2.150
220	Sambhal	Rajpura	Block Office	1.031
221	Sant kabir nagar	Bagholi	Bagholi	4.704
222	Sant kabir nagar	Belhar kalan	Belhar kalan	2.204
223	Sant kabir nagar	Khalilabad	Khalilabad	1.907

224	Sant kabir nagar	Mehdawal	Mehdawal	1.631
225	Sant kabir nagar	Nnath nagar	Nnath nagar	1.171
226	Sant kabir nagar	Semariyawan	Semariyawan	3.956
227	Shahjahanpur	Banda	Block Office	4.676
228	Shahjahanpur	Dadraul	Block Office	2.562
S.No	**District**	**Block**	**Location**	**Fe(mg/l)**
229	Shahjahanpur	Jaitpur	Block Office	3.826
230	Shahjahanpur	Kalan	Block Office	2.589
231	Shahjahanpur	Kanth	Block Office	1.151
232	Shahjahanpur	Khutar	Block Office	3.645
233	Shahjahanpur	Madanapur	Block Office	4.349
234	Shahjahanpur	Puyawan	Block Office	2.839
235	Shahjahanpur	Tilhar	Block Office	3.899
236	Shamli	Kairana	Block office	3.730
237	Shamli	Kandhala	Block office	2.023
238	Shrawasti	Sirsiya	Block Office	3.749
239	Siddharth nagar	Jogiya	Block office	2.802
240	Siddharth nagar	Khesraha	Block office	1.574
241	Siddharth nagar	Naugarh	Block office	2.476
242	Siddharth nagar	Shoharatgarh	Block office	2.647
243	Siddharth nagar	Uskabazar	Block office	12.35
244	Sitapur	Godalamau	In front of block office.	2.305
245	Sitapur	Pisawan	In front of block office.	6.428
246	Sitapur	Moholi	Block office	2.179
247	Sitapur	Laharpur	Block office	6.437
248	Sitapur	Behta	In front of block office	7.456
249	Sitapur	Rewsa	Block office	2.790
250	Sitapur	Rampur mathura	Block office	1.029
251	Sitapur	Biswan	Block office	1.694
252	Sonbhadra	Chopan	In front of BDO, Chopan	1.731
253	Sonbhadra	Dudhhi	BDO, Dudhhi	1.762
254	Sonbhadra	Myorpur	BDO, Myorpur	14.38

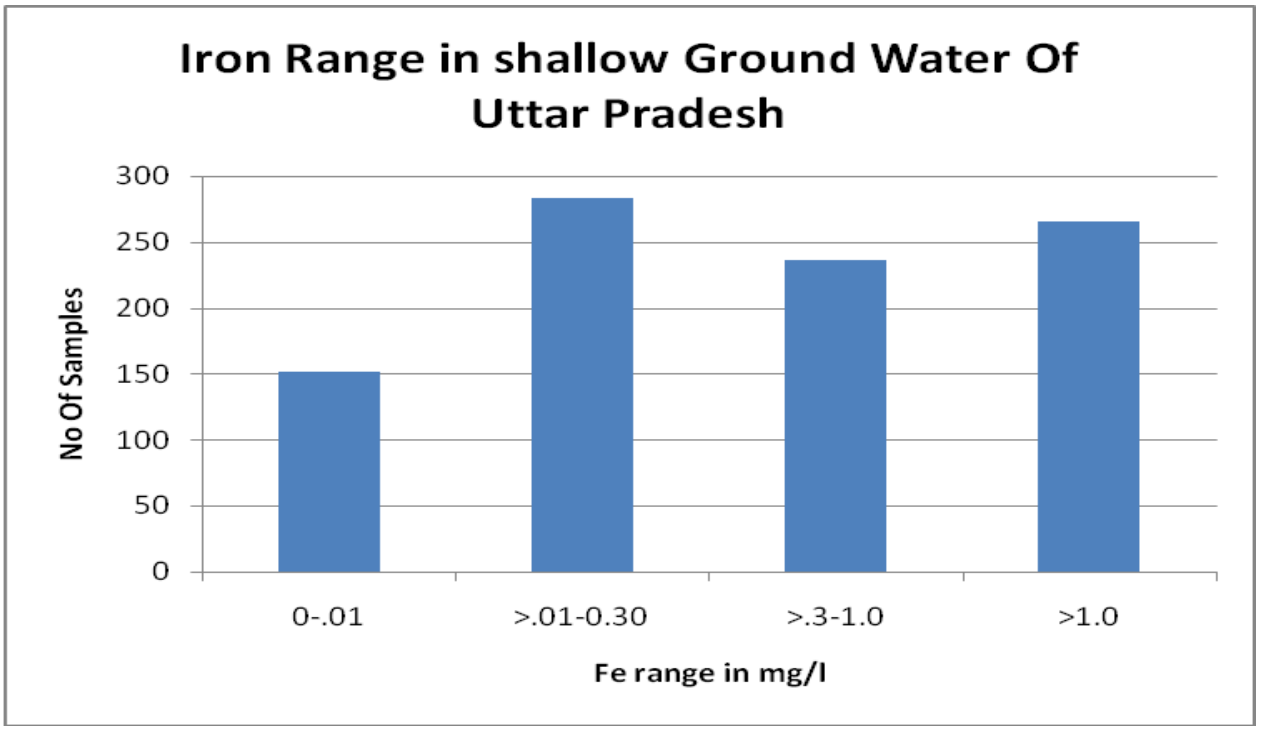
255	Sonbhadra	Robertsganj	BDO, Robertsganj, Chhapka	28.49
256	Sultanpur	Jaisinghpur	Block HQ	1.226
257	Sultanpur	Lambhua	Block HQ	1.687
258	Unnao	Auras	Block office	1.104
S.No	**District**	**Block**	**Location**	**Fe(mg/l)**
259	Unnao	Miyaganj	Block office	1.530
260	Unnao	Hasanganj	Block office	4.316
261	Unnao	Asoha	100 m from block office	2.393
262	Unnao	Bichhiya	Block office	5.290
263	Unnao	Hilauli	Block office	6.186
264	Unnao	Sumerpur	Block office	6.849
265	Unnao	Sikandarpur Karan	In front of block office	1.408
266	Varanasi	Arajiline	BDO, Arajiline	3.654

The frequency distribution is of Iron is shown in the following table:

TABLE 29: FREQUENCY DISTRIBUTION OF IRON (2022-23)

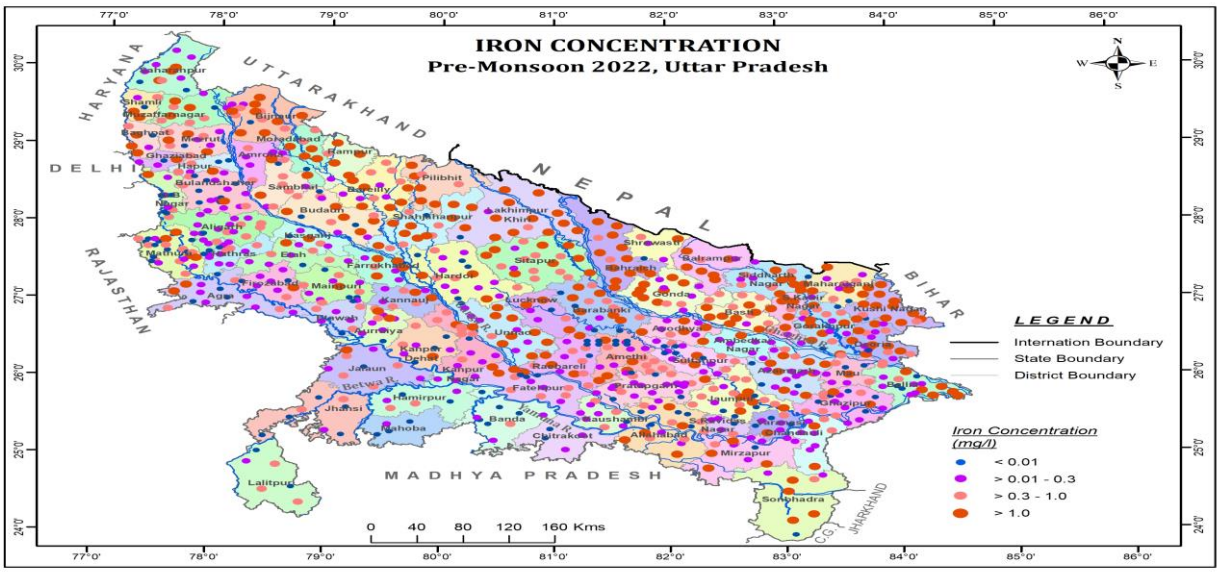
Range of Iron in ppm	< .01	>.01 - .30	>0.3 - 1.0	>1.0
No. of Samples	152	283	236	266

Figure 22 depicts the range of Iron in shallow ground water of Uttar Pradesh



The map showing Iron concentration in the state of Uttar Pradesh is represented in **Fig23.**

Fig-23



MANGANESE

Manganese is a mineral that naturally occurs in rocks and soil and may also be present due to underground pollution sources. Naturally occurring manganese is composed of one stable

isotope, ^{55}Mn. The most common oxidation states of manganese are +2, +3, +4, +6, and +7, though all oxidation states from −3 to +7 have been observed. The most stable oxidation state for manganese is +2, which has a pale pink color, Manganese comprises about 0.1% of the Earth's crust, the 12th most abundant of the crust's elements.

Manganese is one out of three toxic essential trace elements, which means that it is not only necessary for humans to survive, but it is also toxic when too high concentrations are present in a human body. Manganese is an essential human dietary element. It is present as a coenzyme in several biological processes, which include macronutrient metabolism, bone formation, and free radical defense systems. It is a critical component in dozens of proteins and enzymes. The human body contains about12 mg of manganese, mostly in the bones.

Manganese is seldom found alone in a water supply. It is frequently found in iron- bearing waters but is more rare than iron. Chemically it can be considered a close relative of iron since it occurs in much the same forms as iron. When manganese is present in water, it is as annoying as iron, perhaps even more so. In low concentrations it produces extremely objectionable stains on everything with which it comes in contact. Deposits collect in pipelines, and tap water may contain black sediment and turbidity due to precipitated manganese. When fabrics are washed in manganese-bearing water, dark brown or black stains are formed due to the oxidation of the manganese.

Manganese can be consumed from our diet and in our drinking water. High exposure to manganese has been associated with toxicity to the nervous system, producing a syndrome that resembles Parkinsonism. Manganese can also cause lung embolism and bronchitis. A syndrome that is caused by manganese has symptoms such as schizophrenia, dullness, weak muscles, headaches and insomnia. Excessive exposure or intake may lead to a condition known as manganism, a neurodegenerative disorder that causes dopaminergic neuronal death and symptoms similar to Parkinson's disease.Manganese is unlikely to produce other types of toxicity such as cancer or reproductive damage. Young children appear to absorb more manganese than older age groups but excrete less. This makes it particularly important for pregnant women and children to have clean drinking water.

Due to the fact that dissolved manganese oxidizes slower than iron, it is generally more difficult to be removed from water. Pure elemental manganese metal is grey tinged with pink, brittle and somewhat harder than iron which it resembles. The pure metal is not found in nature. Manganese is present most frequently as a Manganous ion (Mn++) in water. Salts of Manganese

are generally more soluble in acid than in alkaline water. In this way they are similar to iron. The Manganous ion is usually introduced to water through the solubility of Manganous bicarbonate.

Manganese was found to be high i.e above the permissible limit of 0.3mg/l in 65 samplescollected from Groundwater monitoring network stations (Table XXVIII). Very high values i.eabove 1mg/l were observed at Fatehpur Sikri Block,in front of Kali devi temple ,Agra district , (1.09mg/l) and Khekra Block office , Baghpat district (1.18mg/l) ; Chittaura block office, Bahraich district (3.03mg/l);Dataganj block office,Budaun district (1.12mg/l);Karvi block, in HP of inspection Bungalow (1.44mg/l),& Manikpur block office, (1.52mg/l) Chitrakoot district; BDO office Aron ,Firozabad district(3.2mg/l);in H.P.of Gayatri Vidya Mandir, Sumerpur Block, Hamirpur district (2.22mg/l);Talgram block office(1.69mg/l) & Umrada Block office1.32mg/l) Kannauj district and at Babhani BDO, Sonbhadra district(2.66mg/l).Manganese was found to be in the range of nd – 3.22 mg/l.The high concentration of Manganese in these areas may be geogenic.

Table-30 Hotspot with respect to Manganese (Mn >0.30mg/l) (2022-23)

S.No	District	Block	Location	Mn (mg/L)
1	Agra	Fatehpur sikari	In front of kaila Devi temple, near 13 Gate no. fathepur Sikri	1.094
2	Aligarh	Bijauli	Block office	0.348
3	Aligarh	Khair	Block office	0.359
4	Aligarh	Tappal	Block office	0.356
5	Ambedkar Nagar	Jahangirganj	Block HQ	0.387
6	Amethi	Jagdishpur	Block HQ	0.395
7	Baghpat	Khekra	Block office	1.178
8	Bahraich	Chittaura	Block Office	3.028
9	Bahraich	Mihipurwa	Block Office	0.420
10	Ballia	Muralichhapara	Block Office	0.575
11	Bareilly	Bithri Chainpur	Block Office	0.370
12	Bareilly	Meerganj	Block Office	0.307
13	Basti	Kudraha	Block Office	0.306
14	Bijnor	Afzalgarh	Block Office	0.402
15	Bijnor	Noorpur	Block Office	0.303
16	Bijnor	Kiratpur	Ashrafpur/ Dudhli	0.316
17	Bijnor	Kiratpur	Islampur Vishnoi	0.353
18	Bijnor	Mohammadpur Deomal	Islampur Hadu/ Dass	0.306
19	Budaun	Dhigawaan	Block Office	0.497
20	Budaun	Dataganj	Block Office	1.121
21	Budaun	Wajirganj	Block Office	0.313
22	Bulandshahr	Amarpur	Amarpur	0.430
23	Chitrakoot	Ramnagar	Block office	0.548

S.No	District	Block	Location	Mn
24	Chitrakoot	Karwi	HP of inspection Bungalow	1.442
25	Chitrakoot	Manikpur	Block office	1.523
26	Farrukhabad	Mohammdabad	in BDO office	0.731
27	Farrukhabad	Amritpur(ur)	Near iti, Amritpur	0.559
28	Fatehpur	Bahua	Block office	0.412
29	Firozabad	Aron	in BDO office	3.220
30	Gautam buddha nagar	Dankaur	Fatehpur Atta	0.323
31	Gautam buddha nagar	Zewar	Bhagwantpur Chhatanga	0.363
32	Ghazipur	Reotipur	Block Office	0.497
33	Ghazipur	Jakhania	Block Office	0.400
34	Gonda	Belsar	Block Office	0.404
35	Gonda	Colonelganj	Block Office	0.332
36	Hamirpur	Sarila	HP 150m before Block office near temple & water body	0.494
37	Hamirpur	Sumerpur	HP of Gayatri Vidya Mandir	2.216
38	Hardoi	Sandi	Block Office	0.324
39	Hathras	Hathras	Block office	0.981
40	J P Nagar	Gajraula	Block Office	0.712
41	Jhansi	Babina	BDO	0.540
42	Kannauj	Talgram	Block Office	1.695
43	Kannauj	Umrada	Block Office	1.315
44	Kanpur nagar	Bidhnoo	Block office	0.721
45	Kasganj	Amanpur	in BDO office	0.325
46	Kushinagar	Vishunpurwa	Vishunpurwa	0.713
47	Mahamaya nagar	Aharai	Aharai	0.727

S.No	District	Block	Location	Mn
48	Mahoba	Kabrai	Block office	0.462
49	Mahoba	Jaitpur	HP of PHC near Block office	0.784
50	Mahoba	Charkhari	Block office	0.619
51	Mathura	Ajijpur	Ajijpur	0.557
52	Mathura	Borpa	Borpa	0.821
53	Meerut	Daurala	Block office	0.366
54	Meerut	Kharkhoda	Block office	0.520
55	Mirzapur	Kon	BDO, Kon	0.382
56	Raibareli	Kheron	Block HQ	0.404
57	Rampur	Chamraua	Opposite Prathma Bank near block office	0.312
58	Saharanpur	Muzafarabad	Block office	0.314
59	Saharanpur	Nakur	Block office	0.451
60	Shahjahanpur	Sindhhauli	Block Office	0.321
61	Shrawasti	Sirsiya	Block Office	0.347
62	Sitapur	Sidhauli	Block office	0.331
63	Sitapur	Laharpur	Block office	0.355
64	Sitapur	Behta	In front of block office	0.309
65	Sonbhadra	Babhani	BDO, Babhani	2.660

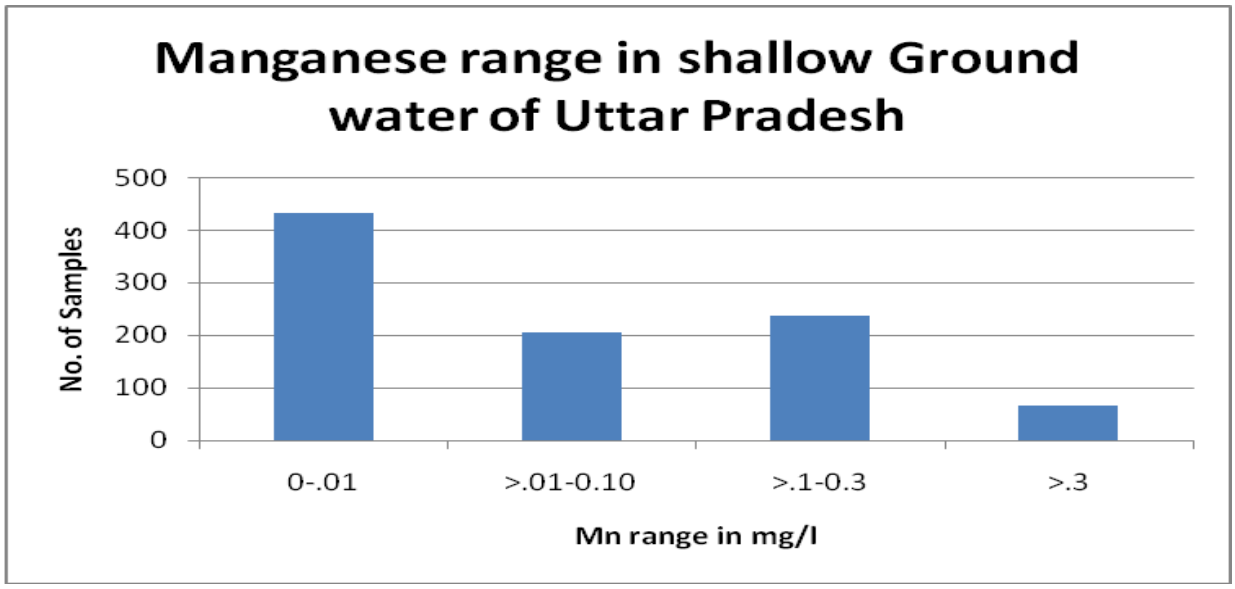
The frequency distribution is of Manganese is shown in the following table:

TABLE 31: FREQUENCY DISTRIBUTION OF MANGANESE (2022-23)

Range of Manganese in ppm	< .01	>.01 - .10	>0.10 - 0.30	>0.30
No. of Samples	432	204	236	65

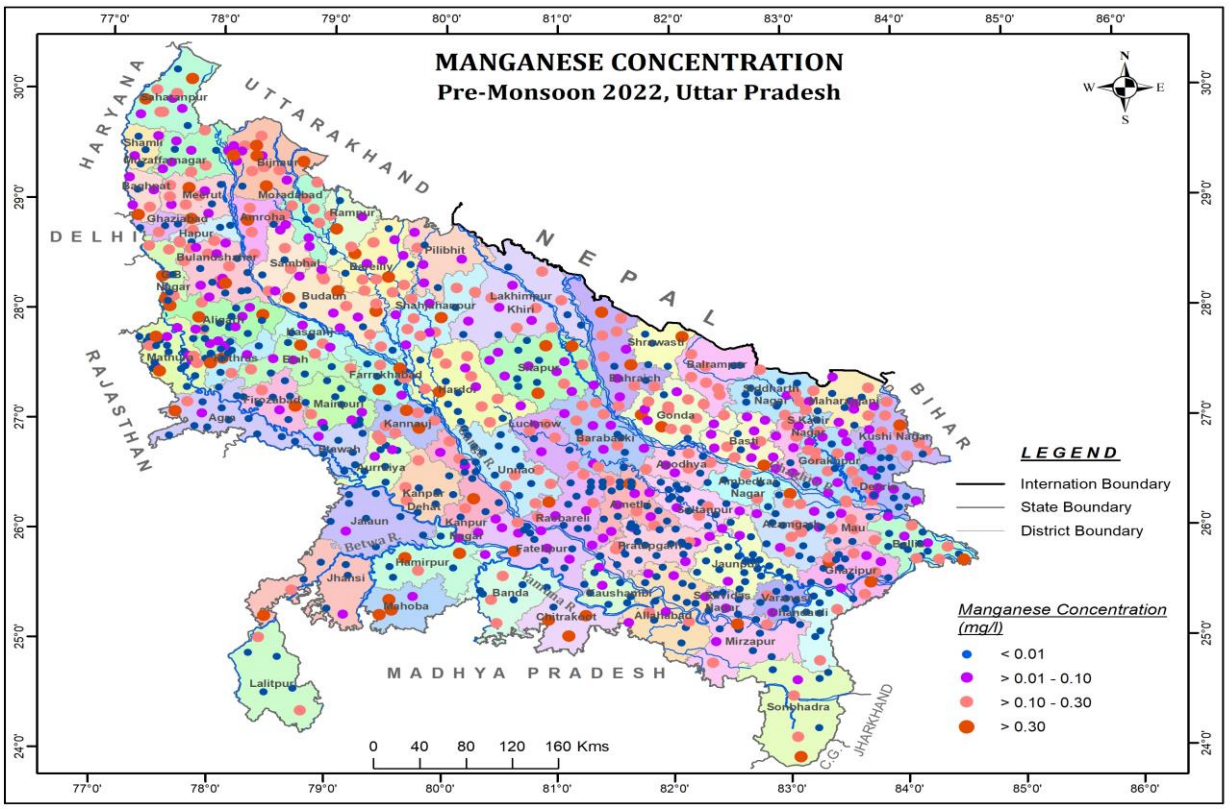
Fig 24 depicts the range of Manganese in shallow ground water of Uttar Pradesh **(2022-23)**

Fig-24



The map showing Manganese concentration in the state of Uttar Pradesh is represented in **Fig25**.

Fig-25



COPPER

Copper is an element commonly found in the nature and widely used by humans. Copper is one of the few metals that can occur in nature in a directly usable metallic form (native metal). There are 29 isotopes of copper. ^{63}Cu and ^{65}Cu are stable, with ^{63}Cucomprising approximately 69% of naturally occurring copper. Because copper is releasedboth naturally and through human activity it is very widespread in the environment. Copper is often found near mines, industrial settings, landfills and waste disposals. Most copper compounds will settle and be bound to either water sediment or soil particles. Soluble copper compounds form the largest threat to human health. Usually water-soluble copper compounds occur in the environment after release through application inagriculture.

Copper is an essential trace element for all organisms and can be used in metabolic pathways. .Copper is essential to all living organisms as a trace dietary mineral because it is a key constituent of the respiratory enzyme complex cytochrome c oxidase. Copper is also required for the proper functioning of many other important enzyme systems. Copper-containing enzymes include ceruloplasmin, SOD, tyrosinase, monoamine oxidase, lysyl oxidase and phenylalanine hydroxylase (Linder & Hazegh- Azam, 1996). Adult humans can tolerate up to 12 mg/day, young children are easily toxicated by copper. In human, copper is found mainly in the liver, muscle, and bone. Because of its role in facilitating iron uptake, copper deficiency can produce anaemia-like symptoms, neutropenia, bone abnormalities, hypopigmentation, impaired growth, increased incidence of infections, osteoporosis, hyperthyroidism, and abnormalities in glucose and cholesterol metabolism. Conversely, Wilson's disease causes an accumulation of copper in body tissues. Ingesting high levels of the metal can cause abdominal pain, vomiting and jaundice (a yellowish tinge to the skin and white of the eyes that may indicate the liver is not functioning correctly) in the short term. Long-term exposure to copper can cause irritation of the nose, mouth and eyes and it causes headaches, stomachaches, dizziness, vomiting and diarrhoea. Intentionally high uptakes of copper may cause liver and kidney damage and even death.

The sources of copper in watercourse are copper mining and smelting, chemical weathering, steel production, electrical industry, agriculture and sewer sludge. Occasionally, increased levels of copper are found in the water supply due to old copper pipes. BIS 10500 (2012) has recommended an acceptable limit of 0.05 mg/l of copper in drinking water; this concentration limit can be extended to

1.5 mg /l of copper in case no alternative source of water with desirable concentration is available. Copper can be removed up to 97-98% with a reverse osmosis water filter. Cartridges using activated carbon can also remove copper from water by using adsorption.

Copper was found to be within the permissible limit of .05 mg/l in all the samples collected from Groundwater monitoring network stations except at one location viz. BDO, Aron, Firozabadad district (3.37mg/l). Copper was found to be in the range of nd to 3.37mg/l.

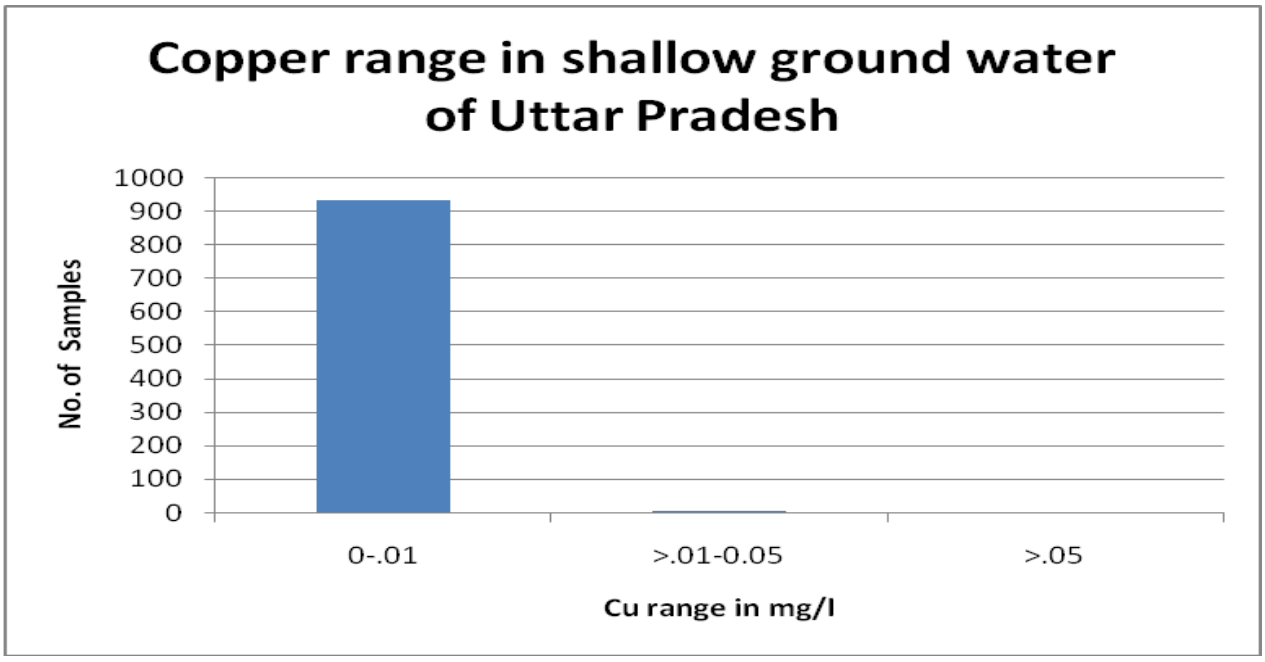
The frequency distribution is of Copper is shown in the following table:

TABLE 32: FREQUENCY DISTRIBUTION OF COPPER (2022-23)

Range of Copper inppm	< .01	>.01-.05	>0.05
No. of Samples	930	6	1

Fig 26 depicts the range of Copper in shallow ground water of Uttar Pradesh

Fig-26



CHROMIUM

Chromium is the 21st most abundant element in Earth's crust . Chromium compounds are found in the environment from the erosion of chromium-containing rocks, and can be redistributed by volcanic eruptions. Naturally occurring chromium is composed of three stable isotopes; ^{52}Cr, ^{53}Cr and ^{54}Cr, with ^{52}Cr being the most abundant (83.789% natural abundance).

Chromium is called as metal with two faces, that it can be either beneficial or toxic to humans and animals depending on its concentrations and oxidation state (Zayed et al. 1998). Cr (III) is considered to be a trace element essential for the proper functioning of living organisms.Nutritionally, at lower concentrations, Cr(III) is an essential component of a balanced human and animal diet for preventing adverse effects in the metabolism of glucose and lipids, e.g., impaired glucose tolerance, increased fasting insulin, increased cholesterol and triglycerides, and hypoglycemic symptoms . Cr (III) at increased concentrations can interfere with several metabolic processes because of its high capability to coordinate various organic compounds resulting in inhibition of some metalloenzyme systems (Zayed et al. 1998).

Hexavalent chromium is highly toxic, mutagenic, and carcinogenic (Lee et al. 2008). In addition, Cr(VI) is highly mobile in most environments, mainly due to its soluble nature . Adverse effects of the hexavalent form on the skin may include ulcerations, dermatitis, and allergic skin reactions. Inhalation of hexavalent chromium compounds can result in ulceration and perforation of the mucous membranes of the nasal septum, irritation of the pharynx and larynx, asthmatic bronchitis, bronchospasms and edema. Respiratory symptoms may include coughing and wheezing, shortness of breath, and nasal itch.

Chromium is widely used in industries, such as electroplating, paint and pigment manufacturing, textile, fertilizer and leather tanning (Ganguli and Tripathi 2002). These industries discharge trivalent and hexavalent chromium with waste effluent to the soil and surface water. Chromium generated by various industries, occurs in different oxidation states but Cr(III) and Cr(VI) are the most significant. The metal industry mainly discharges trivalent chromium. Hexavalent chromium in industrial wastewaters mainly originates from tanning and painting industry. Chromium may be present in domestic waste from various synthetic materials. The element and its compounds can be discharged in surface water through various industries. The level of chromium in air and water is generally low. In drinking water the level of chromium is usually low as well, but at times

contaminated well water may contain the dangerous concentration of Chromium(VI); hexavalent Chromium.

Chromium was found to be in the permissible limit of .05mg/l in all the 937 samples collected from Groundwater monitoring network stations wells except one sample collected from BDO, Aron, Firozabadad district(0.326mg/l). Chromium was found to be in the range of nd to 0.326mg/l.

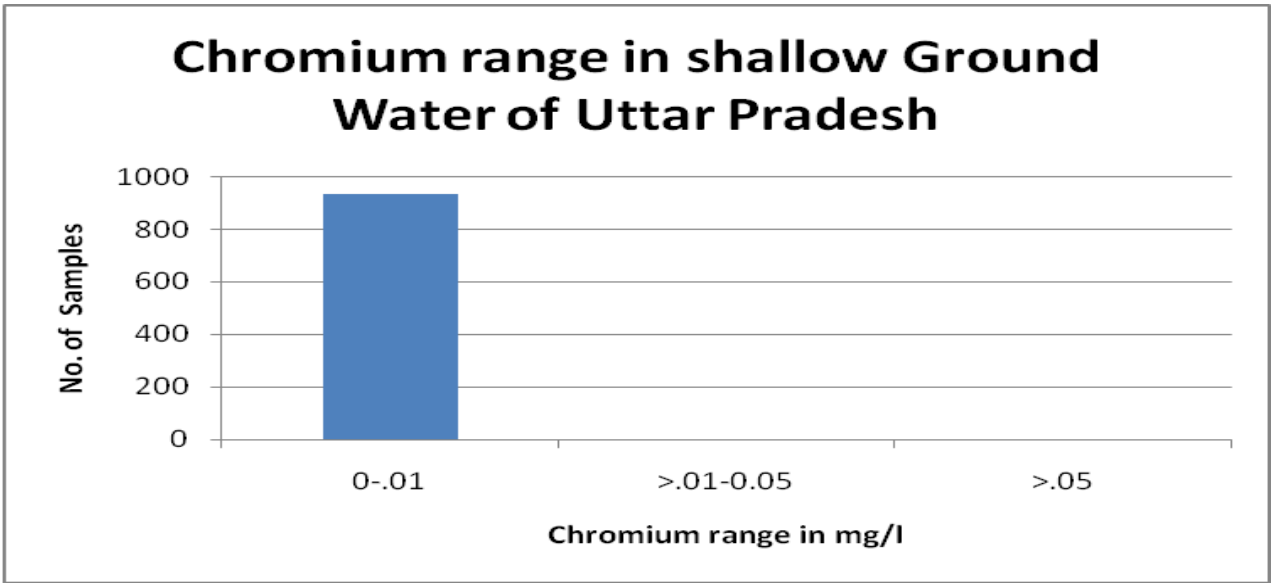
The frequency distribution is of Chromium is shown in the following table:

TABLE 33: FREQUENCY DISTRIBUTION OF CHROMIUM (2022-23)

Range of Chromium in ppm	< .01	>.01-.05	>.05
No. of Samples	933	3	1

Fig 27. depicts the range of Chromium in shallow ground water of Uttar Pradesh

Fig 27



ZINC

Zinc is the 24th most abundant element in Earth's crust and has five stable isotopes with ^{64}Zn being the most abundant isotope (49.17% natural abundance). The other isotopes found in nature are ^{66}Zn (27.73%), ^{67}Zn (4.04%), ^{68}Zn (18.45%), and ^{70}Zn (0.61%).The most common zinc ore is sphalerite (zinc blende), a zinc sulfide mineral. Zinc is a necessary element for all

living things as well as for human beings. Zinc is needed for the proper growth and maintenance of the human body. It is found in several systems and biological reactions, and it is needed for immune function, wound healing, blood clotting, thyroid function, and much more. Zinc containing proteins and enzymes are involved in replication and translation of genetic material. Zinc is an essential element for human diet .4 to 10 mg/day is required depending on age and pregnant women require up to 16 mg/day. Zinc is an essential mineral for prenatal and postnatal development. Food constitutes the most important source of zinc.

It is the second most abundant trace metal in humans after iron and it is the only metal which appears in all enzyme classes. In human, the biological roles of zinc are ubiquitous. It interacts with "a wide range of organic ligands", and has roles in the metabolism of RNA and DNA, signal transduction, and gene expression. It also regulates apoptosis. Zinc is an efficient Lewis acid, making it a useful catalytic agentin hydroxylation and other enzymatic reactions. Two examples of zinc-containing enzymes are carbonic anhydrase and carboxypeptidase, which are vital to the processes of carbon dioxide (CO_2) regulation and digestion of proteins, respectively .Symptoms of mild zinc deficiency are diverse. Clinical outcomes include depressed growth, diarrhoea, impotence and delayed sexual maturation, alopecia , eye and skin lesions, impaired appetite, altered cognition, impaired immune functions, defects in carbohydrate utilization, and reproductive teratogenesis . Zinc deficiency depresses immunity, but excessive zinc also does the same .

Although zinc is an essential requirement for good health, excess zinc can be harmful. Consumption of excess zinc may cause ataxia, lethargy, and copper deficiency. Excessive absorption of zinc suppresses copper and iron absorption. Zinc is considered to be comparatively non-toxic if taken orally but excess amount can cause system dysfunctions that result in impairment of growth and reproduction (Institute of Environmental Conservation and Research INECAR 2000; Nolan 2003). The clinical signs of zinc toxicosis have been reported as vomiting, diarrhoea, bloody urine, icterus (yellow mucus membrane), liver failure, kidney failure and anaemia.

Zinc was found to be within the acceptable limit of 5mg/l in all the samples collected from Groundwater monitoring network stations except 9 samples (Table 34). Zinc was found to be in the range of nd to 10.63mg/l.

Table 34 - Locations having Zinc above 5mg/l (2022-23)

S. No.	District	Block	Location	Zn
1	Aligarh	Iglas	Block office	9.486
2	Basti	Vikramjot	Block Office	6.057
3	Firozabad	Aron	BDO office	7.725
4	Gonda	Wazirganj	Block Office	8.419
5	Kushinagar	Motichak	Motichak	6.516
6	Lalitpur	Madaora	BDO	5.302
7	Mahamaya nagar	Aharai	Aharai	6.134
8	Prayagraj	Shankar garh	BDO, Office	7.088
9	Shahjahanpur	Bhawal Khera	Block Office	10.63

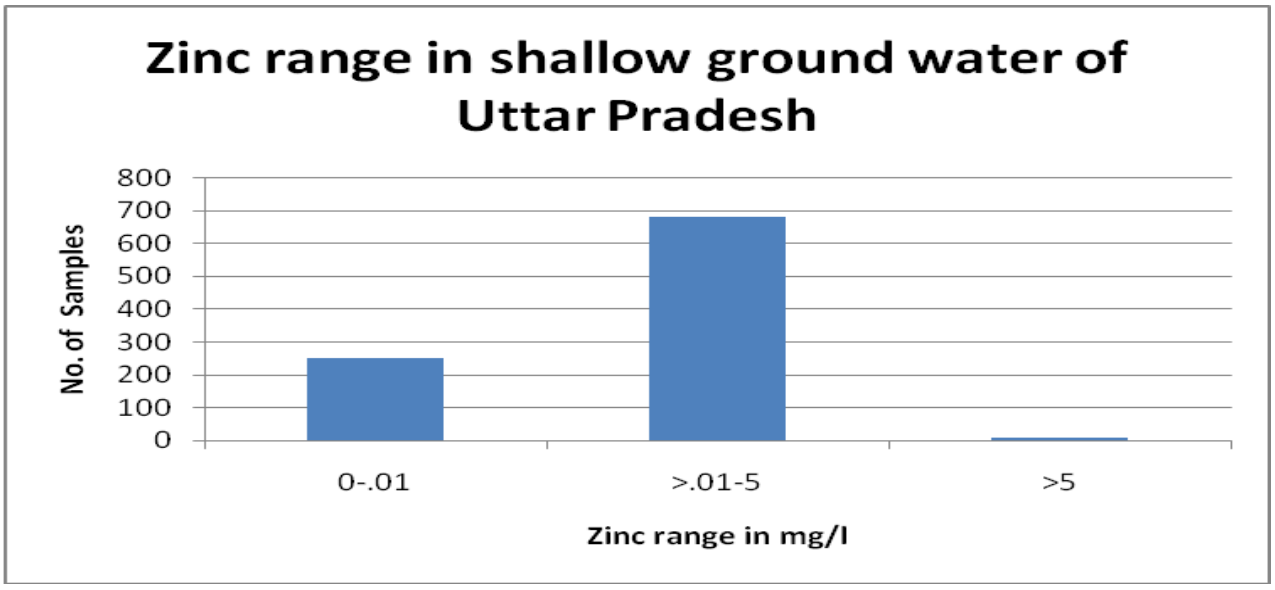
The frequency distribution is of Zinc is shown in the following table:

TABLE 35 : FREQUENCY DISTRIBUTION OF ZINC (2022-23)

Range of Zinc in ppm	< .01	>.01-5.0	>5.0
No. of Samples	248	680	9

Fig -28 depicts the range of Zinc in shallow ground water of Uttar Pradesh

Fig-28



LEAD

Lead is a most common heavy metal and commonly distributed throughout the environment . Lead is the most toxic heavy metal, and the inorganic forms are absorbed through food and water, and inhalation. Lead poisoning causes teratogenic effect, inhibition of the synthesis of haemoglobin, dysfunctions in the kidneys, joints, reproductive systems, cardiovascular system, chronic damage to the central nervous system and peripheral nervous system . And some other effects such as damage to the gastrointestinal tract, urinary tract resulting in bloody urine, neurological disorder and permanent brain damage. Inorganic forms of lead affect central nervous system, peripheral nervous system, gastrointestinal tract and organic forms, mostly affect the central nervous system; Ferner 2001; lead affects children on the brain and results in poor intelligence quotient . Its absorption in the body is increased by calcium and zinc deficiencies. Lead was found to be within the permissible limit of .01mg/l in all the samples collected from Groundwater monitoring network stations except seven samples (Table **36**).Lead was found to be in the range of nd to .026mg/l.

Table-36 Hotspot with respect to Lead (Pb >0.01mg/l) (2022-23)

S.No	District	Block	Location	Pb(mg/l)
1	Baghpat	Binauli	Block office	0.012
2	Ballia	Bairya		0.014
3	Balrampur	Rehra Bazar	Block Office	0.012
4	Firozabad	Aron	BDO office	0.026
5	Kannauj	Kannauj	Block Office	0.011
6	Mirzapur	Jamalpur	BDO, Jamalpur	0.015
7	Mirzapur	Narainpur	In front of Indian Bank, Narayanpur City	0.019

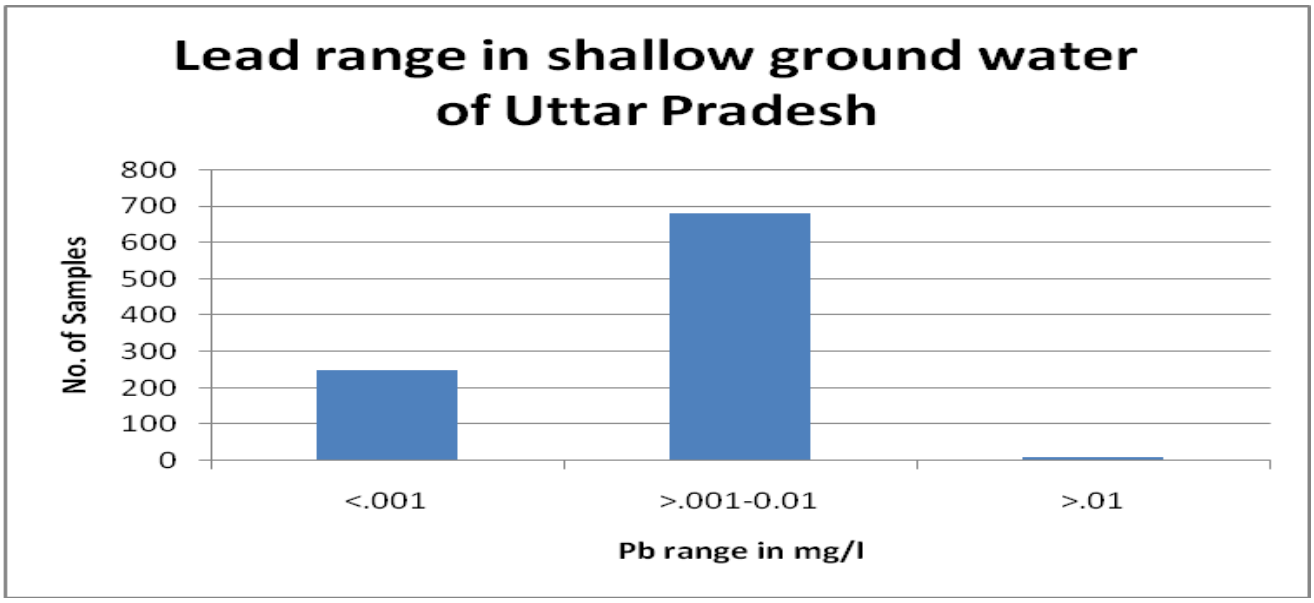
The frequency distribution is of Lead is shown in the following table:

TABLE -37: FREQUENCY DISTRIBUTION OF LEAD (2022-23)

Range of Lead in ppm	< .001	>.001-.01	>.01
No. of Samples	427	503	7

Fig 29. depicts the range of Lead in shallow ground water of Uttar Pradesh

Fig-29



Arsenic

Arsenic is a naturally occurring element that is widely distributed in the Earth's crust. It is found in water, air, food, and soil. There are two general forms of arsenic: Organic& Inorganic.It is present in many different minerals. About one third of the arsenic in the atmosphere comes from natural sources, such as volcanoes, and the rest comes from man-made sources.It is released in the environment through a combination of natural processes such as biological activities, weathering reactions and volcanic emissions as well as through a range of anthropogenic activities . Most environmental arsenic problems are due to natural conditions, but man has a significant impact through mining activity, combustion of fossil fuels, the use of arsenical pesticides, herbicides and crop desiccants and the use of arsenic as an additive in livestock feed, particularly for poultry .In the last few decades, although the use of arsenical products such as pesticides and herbicides has decreased significantly but their use for wood preservation is still common. Arsenic was found to be above the permissible limit of .01mg/l in 63 samples collected from National Groundwater monitoring stations Table (38). Arsenic was found to be in the range of nd to 0.148mg/l.

Table-38 Hotspot with respect to Arsenic (As >0.01mg/l) (2022-23)

S. No.	District	Block	Location	As
1	Ayodhya	Bikapur	Block HQ	0.012
2	Ayodhya	Haringtonganj	Block HQ	0.012
3	Azamgarh	Maharajganj		0.026
4	Bahraich	Chittaura	Block Office	0.054
5	Bahraich	Jarwal	Block Office	0.024
6	Bahraich	Mahasi	Block Office	0.037
7	Bahraich	Mihipurwa	Block Office	0.037
8	Bahraich	Nawabganj	Block Office	0.130
9	Bahraich	Prayagpur	Block Office	0.103
10	Bahraich	Risiya	Block Office	0.039
11	Ballia	Belhari		0.029
12	Ballia	Dubahar		0.021
13	Ballia	Murali Chhapara		0.103
14	Ballia	Reoti		0.148
15	Balrampur	Harraiya Satgharwa	Block Office	0.013
16	Balrampur	Tulsipur	Block Office	0.019
17	Bareilly	Meerganj	Block Office	0.014
18	Basti	Bankati	Block Office	0.013
19	Bijnor	Aku (Nehtaur)	Block Office	0.011
20	Bijnor	Alhepur (Dhampur)	Block Office	0.012
21	Bijnor	Noorpur	Block Office	0.027
22	Bijnor	Mohammadpur Deomal	Barkhurdarpur Buzurg	0.016
23	Bijnor	Kiratpur	Suwaheri Khurd	0.012
24	Bijnor	Kiratpur	Islampur Vishnoi	0.015
25	Bijnor	Mohammadpur Deomal	Islampur Hadu/ Dass	0.019
26	Budaun	Dataganj	Block Office	0.017
27	Bulandshahr	Amarpur	Amarpur	0.020
28	Deoria	Barhaj	Barhaj	0.015
29	Deoria	Bhaluwani	Garer chak, near house of Shivnath Chaurasia	0.027
30	Farrukhabad	Amritpur	Near iti, Amritpur	0.085
31	Firozabad	Aron	BDO office	0.029
32	Gonda	Belsar	Block Office	0.014
33	Gonda	Katra Bazar	Block Office	0.013
34	Gorakhpur	Gagaha	Gag Block Office aha	0.011
35	Hapur	Simbholi	Block office	0.025

S.No	District	Block	Location	As
36	Hardoi	Kacchauana	Block Office	0.093
37	Hardoi	Tadiyawan	Block Office	0.022
38	Kannauj	Talgram	Block Office	0.053
39	Kushinagar	Dudhai	Block Office	0.011
40	Kushinagar	Sewarhi	Block Office	0.020
41	Lakhimpur Kheri	Gola	Block Office	0.011
42	Lakhimpur Kheri	Ishanagar	Block Office	0.033
43	Lakhimpur Kheri	Nakaha	Block Office	0.041
44	Lakhimpur Kheri	Nighasan	Block Office	0.036
45	Maharaj ganj	Maharaj ganj	Munder Kalan	0.012
46	Maharajganj	Ghughuli	Ghughuli	0.024
47	Maharajganj	Nichlaul	Nichlaul	0.011
48	Mirzapur	Kon	BDO, Kon	0.014
49	Moradabad	Bhagatpur Tanda	Block Office	0.011
50	Moradabad	Chhajlet	Block Office	0.018
51	Moradabad	Moondhapandey	Block Office	0.020
52	Muzaffarnagar	Jansath	Block office	0.011
53	Pilibhit	Bar Khera	Block Office	0.017
54	Raibareli	Kheron	Block HQ	0.033
55	Rampur	Milak	Block Office	0.010
56	Sant Kabir Nagar	Poli	Poli	0.024
57	Shahjahanpur	Banda	Block Office	0.010
58	Shahjahanpur	Dadraul	Block Office	0.014
59	Siddharth Nagar	Jogiya	Block Office	0.013
60	Siddharth Nagar	Naugarh	Block Office	0.017
61	Siddharth Nagar	Shoharatgarh	Block Office	0.012
62	Siddharth Nagar	Uskabazar	Block Office	0.026
63	Sitapur	Rampur Mathura	Block office	0.016

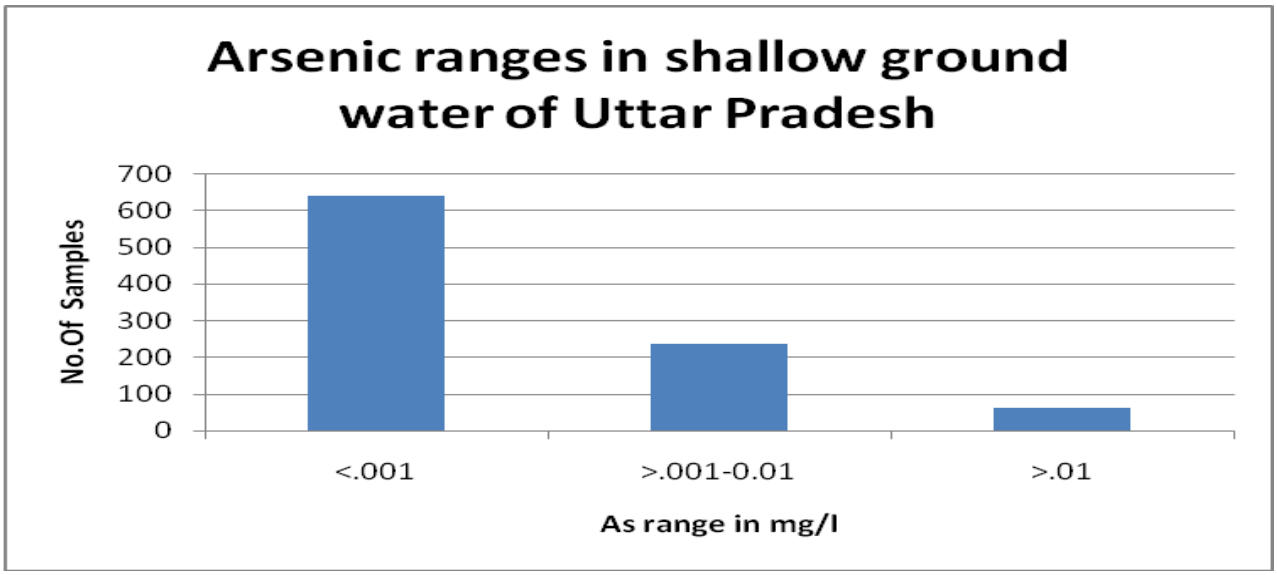
The frequency distribution is of Arsenic is shown in the following table:

TABLE 39: FREQUENCY DISTRIBUTION OF ARSENIC (2022-23)

Range of Arsenic inppm	0-.001	>.001-.01	>.01
No. of Samples	640	234	63

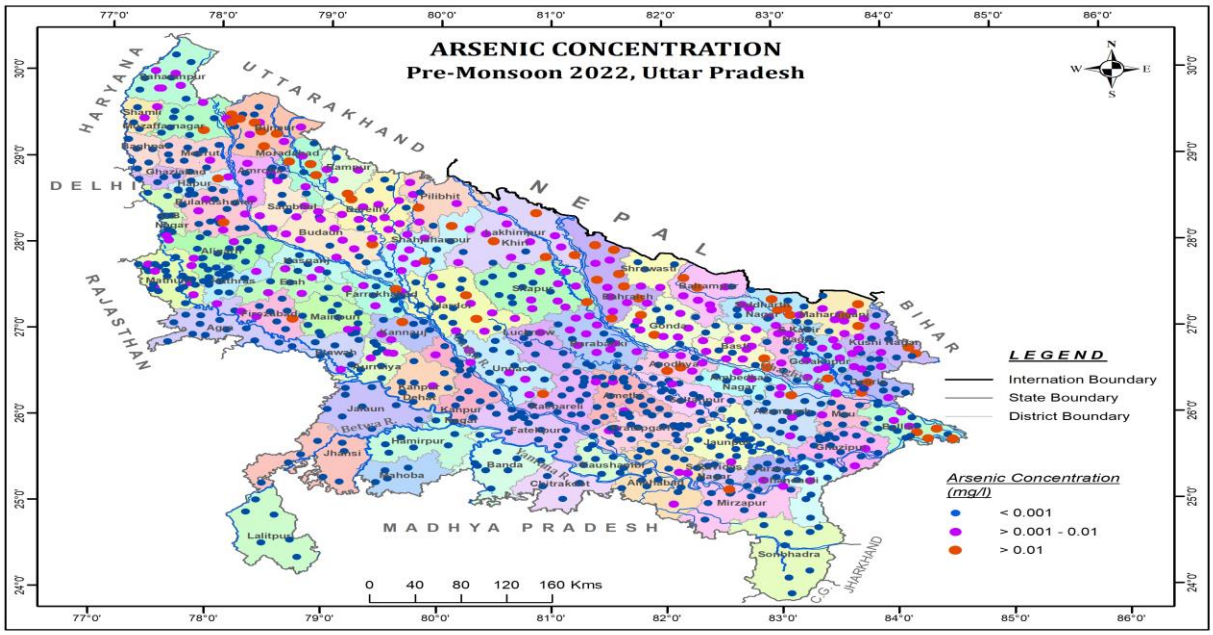
Fig30. depicts the range of Arsenic in shallow ground water of Uttar Pradesh

Fig30



The map showing Arsenic concentration in the state of Uttar Pradesh is represented in **Fig31**.

Fig-31



URANIUM

Uranium is a naturally occurring element that can be found in low levels within all rock, soil, and water. Uranium is the 51st element in order of abundance in the Earth's crust. Uranium occurs naturally in low concentrations of a few parts per million in soil, rock and water, and is commercially extracted from uranium-bearing minerals such as uraninite. In nature, uranium is found as uranium-238 (99.2739–99.2752%), uranium-235 (0.7198–0.7202%), and a very small amount of uranium-234 (0.0050– 0.0059%). Salts of many oxidation states of uranium are water-soluble and may be studied in aqueous solutions .The most common ionic forms are U^{3+} (brown-red), U^{4+}(green), UO_2^{+} (unstable), and UO_2^{2+} (yellow), for U(III), U(IV), U(V), and U(VI), respectively.

Uranium is present in the environment as a result of leaching from natural deposits, release in mill tailings, emissions from the nuclear industry, the combustion of coal and other fuels and the use of phosphate fertilizers that contain uranium. Uranium- 235 is the only naturally occurring fissile isotope, which makes it widely used in nuclear power plants and nuclear weapons. Uranium is used mainly as fuel in nuclear power stations, although some uranium compounds are also used as catalysts and staining pigments.

Intake through drinking-water is normally low; however, in circumstances in which uranium in present in a drinking-water source, the majority of intake can be through drinking-water. The direct evidence of impact of uranium exposure to human health is present as it has been proved that consumption of drinking water contaminated with uranium can cause chronic kidney disease, deformity of bones and liver. Normal functioning of the kidney, brain, liver, heart, and other systems can be affected by uranium exposure, because, besides being weakly radioactive, uranium is a toxic metal. Uranium is also a reproductive toxicant. Radiological effects are generally local because alpha radiation, the primary form of ^{238}U decay, has a very short range, and will not penetrate skin. Alpha radiation from inhaled Uranium has been demonstrated to cause lung cancer in exposed nuclear workers.

Chronic exposure of Uranium radionuclide in drinking water is a potential health risk (Blantz, Pelayo, Gushwa, Myers, & Evan, 1985). Although ubiquitous in the environment, Uranium has no known metabolic function in animals and is currently regarded as non-essential. Uranium accumulated in human results in chemical and radioactive effects. The principal sites of Uranium

deposition in the body are the kidneys, the liver and the bones. The toxicity of Uranium is a function of the route of exposure, particle solubility, contact time, and route of elimination (ATSDR, 1999). The concentrations of radiotoxic elements like Uranium in drinking water are hence kept under vigil by different health organizations. The World Health Organization (WHO, 2004) had earlier recommended a reference level 15 µg/l but now the permissible limit of U in drinking water by WHO is 30 µg/l (WHO, 2011). The reference level is derived from epidemiological studies, based on the assumption of a 60 kg adult consuming 2 litres of drinking water per day and 80% allocation of the Tolerable Daily Intake (TDI) to drinking water. Maximum acceptable level of U in drinking water as per guidelines of India's Atomic Energy Regulatory Board, Department of Atomic Energy, is 60 µg/l (AERB, 2004).

The following techniques may be used for the removal of Uranium:-

1. Combined removal of Uranium and Radium can be achieved using a mixed bed containing 10% strong base anion resin (for removal of Uranium) and strong acid cation resin (for removal of Radium) (Clifford & Zhang, 1994).
2. A domestic-scale reverse osmosis unit removed greater than 99.9% of Uranium from initial concentrations of 69 and 183 µg/litre (Fox & Sorg, 1987).
3. Five nanofiltration membranes were tested for the removal of Uranium (1 mg/litre) from synthetic solutions. In test waters containing bicarbonate and around neutral pH, all the membranes gave removals of 95% or more (Raff & Wilken, 1999).
4. Other techniques that can be used for removal of Uranium include adsorption onto modified GAC (Coleman et al., 2003), bone charcoal and apatite (Bostick et al., 2000) and chitosan (Gerente et al., 1999). Zero valent iron can also be used for Uranium removal (Abdelouas et al., 1999; Farrell et al., 1999; Morrison et al., 2003).

Uranium was found to be above the permissible limit of 30 ppb in118 samples collected from Groundwater monitoring network stations (Table-40). Uranium was found to be in the range of nd to 0.211mg/l. It seems that the plausible source of high Uranium observed in this region may be of geogenic in nature.

Table –40 Hotspot with respect to Uranium (U >30ppb) (2022-23)

S.No	District	Block	Location	U
1.	Agra	Saiyan	In chc, saiyan	0.057
2.	Agra	Kheragarh	In chc, khairagarh	0.039
3.	Agra	Achhnera	In front of govt. Primary school , achhenera	0.032
4.	Aligarh	Atrauli	Block office	0.033
5.	Aligarh	Bijauli	Block office	0.050
6.	Aligarh	Gonda	Block office	0.050
7.	Aligarh	Khair	Block office	0.080
8.	Aligarh	Tappal	Block office	0.032
9.	Aligarh	Sapera bhanpur	Sapera bhanpur	0.052
10.	Aligarh	Bhaiyan	Bhaiyan	0.041
11.	Aligarh	Nama	Nama	0.105
12.	Amethi	Amethi	Block HQ	0.035
13.	Amethi	Bhadar	Block HQ	0.065
14.	Amethi	Gauriganj	Block HQ	0.047
15.	Auraiya	Bidhuna	Block Office	0.039
16.	Auraiya	Sahar	Block Office	0.031
17.	Auraiya	Bidhuana	Purwa Pitaram	0.036
18.	Auraiya	Airwa Katra	Sarai Kachhwaha	0.052
19.	Azamgarh	Lalganj		0.067
20.	Azamgarh	Mohammadpur		0.038
21.	Azamgarh	Palhana		0.066
22.	Azamgarh	Pawai		0.038
23.	Bareilly	Bithri Chainpur	Block Office	0.032
24.	Bijnor	Mohammadpur Deomal	Block Office	0.211
25.	Budaun	Wajirganj	Block Office	0.051
26.	Bulandshar	Danpur	Block Office	0.040
27.	Bulandshar	Jahangirabad	Block Office	0.082
28.	Etah	Sheetalpur	BDO office	0.088
29.	Etah	Jalesar	BDO office	0.077
30.	Farrukhabad	Rajepur(ur)	BDO office	0.043
31.	Fatehpur	Malwan	Guneer	0.056
32.	Fatehpur	Malwan	Kotiya	0.059

S.No	District	Block	Location	U
33.	Fatehpur	Malwan	Mewli Buzurg	0.057
34.	Fatehpur	Malwan	Malwan	0.083
35.	Fatehpur	Malwan	Block office	0.089
36.	Fatehpur	Teliyani	Block office	0.058
37.	Firozabad	Narkhi	BDO office	0.047
38.	Firozabad	Khairgarh(Hathwant)	BDO office	0.038
39.	Firozabad	Tundla	BDO office	0.042
40.	Firozabad	Madanpur	BDO office	0.034
41.	Gautam Buddha Nagar	Dadri	Block office	0.045
42.	Gautam Buddha Nagar	Jewar	Block office	0.052
43.	Gautam Buddha Nagar	Dankaur	Block office	0.051
44.	Gautam Buddha Nagar	Jewar	Choroli	0.055
45.	Ghaziabad	Razapur	Block office	0.031
46.	Ghaziabad	Dhaulana	Dhaulana	0.055
47.	Ghazipur	Jakhaniya		0.042
48.	Ghazipur	Mardah		0.039
49.	Ghazipur	Jakhania		0.037
50.	Hapur	Dholana	Block office	0.055
51.	Hardoi	Mallawan	Block Office	0.043
52.	Hardoi	Sandi	Block Office	0.035
53.	Hathras	Hassain	Block Office	0.098
54.	Hathras	Hathras	Block Office	0.035
55.	Hathras	Mursan	Block Office	0.047
56.	Hathras	Sadabad	Block Office	0.056
57.	Hathras	Sahpau	Block Office	0.053
58.	Hathras	Sasni	Block Office	0.052
59.	Jaunpur	Rampur	BDO, Rampur	0.033
60.	Jaunpur	Machhali shahar	BDO, Office	0.035
61.	Kanpur dehat	Akberpur	Akberpur block office	0.082
62.	Kanpur nagar	Kalyanpur	Kalyanpur block office	0.041
63.	Kanpur nagar	Kalyanpur	Ishwariganj	0.042
64.	Kanpur nagar	Chaubeypur	Pachor	0.042
65.	Mahamaya nagar	Jirauli	Jirauli	0.065
66.	Mahamaya nagar	Lutsan	Lutsan	0.042

S.No	District	Block	Location	U
67.	Mahamaya nagar	Gijrauli	Gijrauli	0.041
68.	Mainpuri	Kishni(ur)	BDO office	0.063
69.	Mainpuri	Karhal	BDO office	0.034
70.	Mainpuri	Kusmura	Kusmura chauraha, in front of pal medical store, kusmura	0.061
71.	Mainpuri	Khadsariya	Near aganbadi kendra, khadsariya	0.032
72.	Mainpuri	Katra saman	Near katra saman chauraha, shiv temple	0.126
73.	Mathura	Chaumuhan	Block office	0.038
74.	Mathura	Goverdhan	Block office	0.114
75.	Mathura	Mathura	Collectrate office premises	0.034
76.	Mathura	Nohjhil	Block office	0.034
77.	Mathura	Raya	Block office	0.040
78.	Mathura	Ajijpur	Ajijpur	0.056
79.	Mathura	Panigaon Khader	Panigaon Khader	0.034
80.	Mathura	Thok Bindavani	Thok Bindavani	0.103
81.	Mathura	Bhagosa	Bhagosa	0.052
82.	Mathura	Lohaban	Lohaban	0.038
83.	Mathura	Anore	Anore	0.033
84.	Maunath bhanjan	Ratanpura		0.054
85.	Meerut	Meerut	Block office	0.032
86.	Meerut	Sardhana	Block office	0.053
87.	Pratapgarh	Baba bekhernath	BDO Office	0.037
88.	Pratapgarh	Babaganj	BDO, Office	0.039
89.	Pratapgarh	Kunda	BDO Office	0.032
90.	Pratapgarh	Lakshmanpur	BDO Office	0.031
91.	Pratapgarh	Lalganj	BDO Office	0.037
92.	Pratapgarh	Pratapgarh sadar	BDO Office	0.050
93.	Pratapgarh	Rampur-sangramgarg	BDO Office	0.035
94.	Pratapgarh	Baba Belkharnath Dham	Sinti Kalsa village	0.053
95.	Pratapgarh	Baba Belkharnath Dham	Sarkhelpur village	0.048
96.	Pratapgarh	Baba Belkharnath Dham	Rakhaha village	0.039
97.	Pratapgarh	Babaganj	Kashipur Chauraha village	0.033
98.	Pratapgarh	Sangaipur	Ateha village	0.042

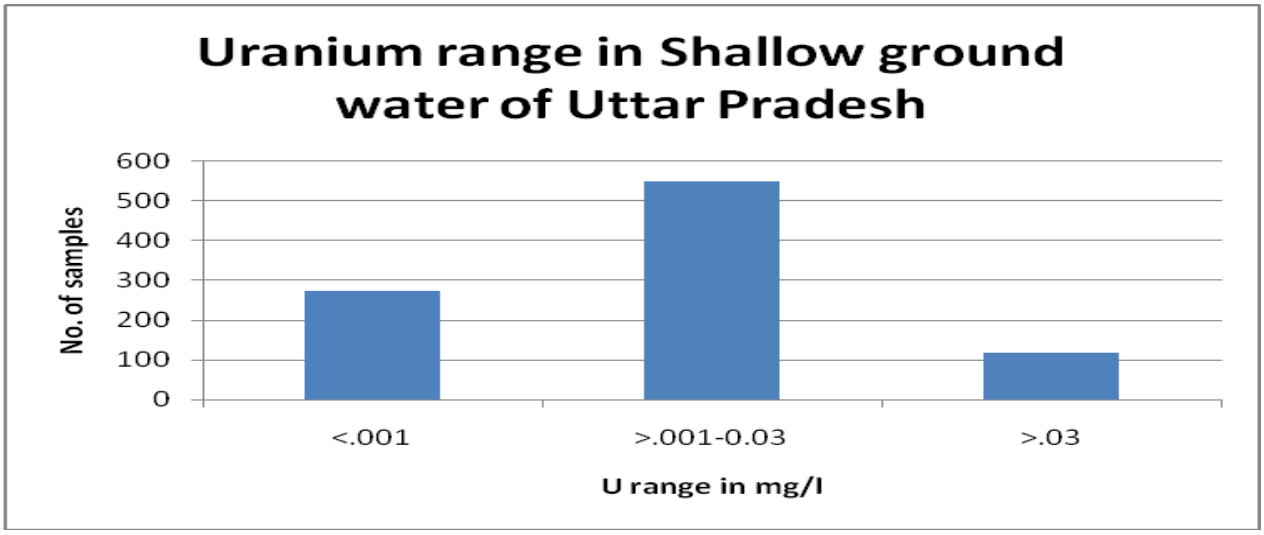
S.No	District	Block	Location	U
99.	Pratapgarh	Sangaipur	Nandu Tiwari Kapurva village	0.043
100.	Pratapgarh	Sangaipur	Bhundhaha village	0.059
101.	Prayagraj	Kaurihar	BDO, Office	0.039
102.	Prayagraj	Phoolpur	BDO, Office	0.050
103.	Prayagraj	Pratappur	BDO, Office	0.035
104.	Raibareli	Chhatoh	Block HQ	0.040
105.	Raibareli	Harichandpur	Block HQ	0.033
106.	Raibareli	Lalganj	Block HQ	0.045
107.	Raibareli	Maharajganj	Block HQ	0.033
108.	Raibareli	Rahi	Block HQ	0.051
109.	Raibareli	Sartawan	Block HQ	0.049
110.	Raibareli	Unchahar	Block HQ	0.040
111.	Saharanpur	Gangoh	Block office	0.040
112.	Sant Ravidas Nagar	Gyanpur	Reseve Police Line, Gyanpur	0.032
113.	Shahjahanpur	Kalan	Block Office	0.031
114.	Sultanpur	Dostpur	Block HQ	0.032
115.	Unnao	Bichhiya	Block office	0.051
116.	Unnao	Sumerpur	Block office	0.031
117.	Unnao	Nawabganj	Block office	0.032
118.	Varanasi	Kashi Vidya Peeth	Beside BDO, Kashi Vidya Peeth, Shivdaspur	0.042

The frequency distribution is of Uranium is shown in the following table:

TABLE 41: FREQUENCY DISTRIBUTION OF URANIUM (2022-23)

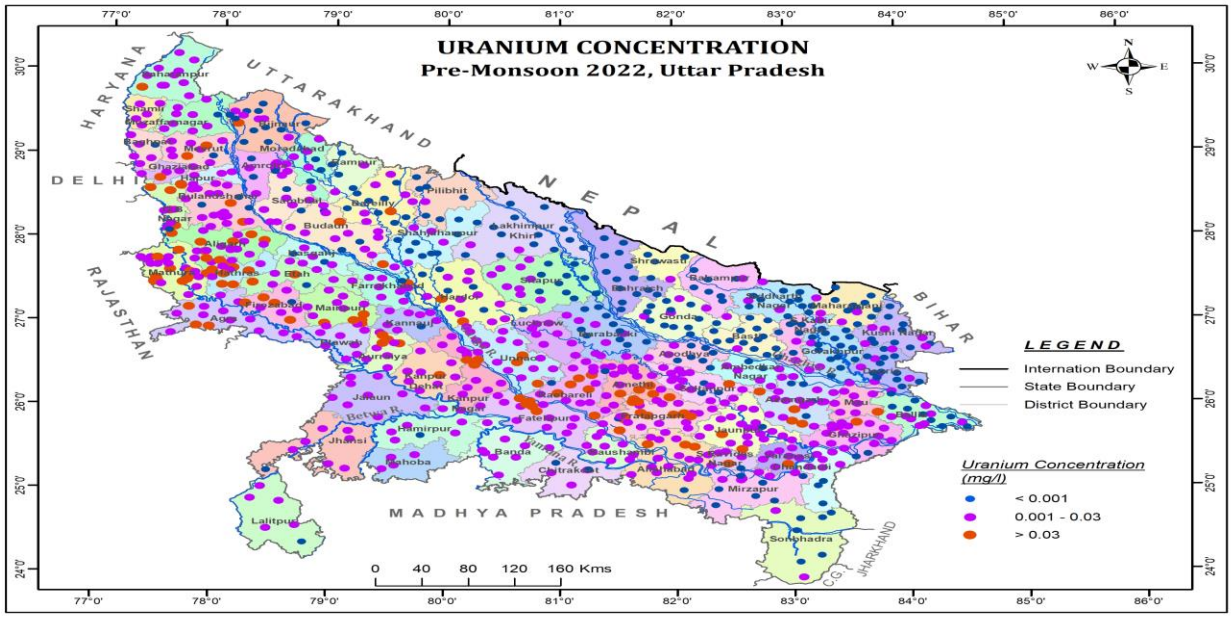
Range of Uranium in ppb	0-0.001	>.001-.03	>.03
No. of Samples	273	546	118

Fig 32. depicts the range of Uranium in shallow ground water of Uttar Pradesh



The map showing Uranium concentration in the state of Uttar Pradesh is represented in **Fig33.**

Fig-33



7. CONCLUSION

In general the evaluation of the ground water quality of the study area for drinking purposes with respect to standards prescribed by BIS (2012) reveals that-

1. Considering the parameters responsible for suitability of ground water of Uttar Pradesh it is observed that it is generally fit for drinking purposes as per analysed chemical parameters viz. Electrical conductivity, Nitrate & Fluoride and is also suitable for irrigation purposes as per Electrical conductivity, Residual Sodium Carbonate, Sodium Adsorption Ratio except at few places where corrective measures are to be taken before drinking and agricultural usage.

2. Iron concentration has been found to be above the acceptable limit of 1.0 mg/l in 28.4% locations. The high concentration of Iron in these areas may be geogenic.

3. Manganese concentration has been found to be above the acceptable limit of 0.3mg/l in 6.9% locations in 40 districts in the samples under study. The high concentration of Manganese in these areas may be geogenic.

4. Uranium concentration has been found to be above the acceptable limit of 30ppb at 120 (12.8%) locations including Uranium hotspots. It seems that the plausible source of high Uranium observed in this region may be of geogenic in nature.

5. Arsenic in the study area was found to be above the permissible limit at 63 locations in 31 districts.

6. In general no toxicity has been observed due to metals Copper, Chromium, Zinc and lead.

Thus from the analytical results it has been observed that majority of water samples collected from observation wells of Central Ground Water Board in a major part of the state fall under desirable or permissible category as per available analysed chemical parameter data (as per BIS 2012) and hence are suitable for drinking purposes. However, a small percentage of well waters are found to have concentrations of some constituents beyond the permissible limits with respect to few Heavy metals, Electrical conductivity, Nitrate & Fluoride. Such waters are not fit for human consumption and are likely to be harmful to health on continuous use.

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