

Physicochemical parameters of Groundwater of Bhagalpur District, Bihar

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Abstract : Physico-chemical parameters of groundwater of district Bhagalpur, state Bihar have been measured by taking the samples from well and tube-well in pre- and post-monsoon seasons with a view to examine the ionic environment in groundwater and evaluate their nutritive value as well as effect if any. All the sixteen community development block head quarters were selected as sampling sites. The parameters measured were aerial temperature, water temperature, pH, turbidity, conductivity, total solid, total hardness, chloride, sulphate, nitrate, magnesium and calcium. The result obtained have been discussed with respect to Indian Standard Specification for Drinking Water IS-10500-1983 as well as with the other foreign standards.

(Keywords : Groundwater, Physico-chemical parameters of groundwater, water quality standards.)

Introduction

The physicochemical parameter of water is of prime importance to assess its quality for different purposes. Chemical analysis of the samples of groundwater has been made with a view to examine the ionic environment in groundwater and evaluate their nutritive value as well as effects if any. The result obtained have been discussed with respect to Indian Standard Specification for Drinking Water IS-10500-1983-3 as well as with the other foreign standards. Chemical quality of water in aquifer is a function of mineral composition of the rocks through which the water percolates in the recharge area and where in the flow system of the water occurs. The quality of groundwater is the resultant of all the processes and reactions that have acted on the

water from the moment it condenses in the atmosphere to the time it is discharged by a well.

Rain water contains very little amount of dissolved mineral matters which is almost negligible. As soon as rain water touches the earth, it starts to react with the minerals of soils and rocks coming in its contact. The amount and character of the mineral matters dissolved by water depend on the physical structure and chemical composition of the rocks and soils with which they have been in contact, the pressure, the temperature, the duration of contact and the chemical matters already present in the solution. The solvent action of water is improved by the presence of carbon dioxide derived from atmosphere and the soils through which it runs.

Among the liquids, water is the most universal solvent. It has the highest surface tension, the highest dielectric constant and the greatest heat of vaporization. The effectiveness of water in rock weathering is increased by the ability of this cohesive liquid to wet mineral surfaces and penetrate into small openings.

Variations of temperature, pressure, hydrogen ion concentrations (pH), redox potential (E) and the relative concentrations of other substances in solution control the solubility of a given element in water. All the minerals have surfaces having unbalanced electrical charges and these surfaces attract water because it is a polar compound.

Water quality standards: The availability of safe and reliable source of water is an essential prerequisite for the establishment of a stable community. To meet these requirements, the concept of water quality criteria was evolved which is based on the acceptable levels of concentration of various constituents which indicate physical, chemical and biological characteristics of water and form the basis for judgment in several environmental protection Agency and State programs that are associated with water quality considerations. In order to achieve the level of satisfaction for the desired water quality for different uses, various agencies have developed standards/criteria viz. European Community Standards (EC standard), WHO standards. Water Quality, Institute of Hydrological Sciences and Water Resources (WQIHSWR) Tehran applicable in their countries.

In India, desirable limit for concentration of various water quality parameters are given in the Indian Standard Specification for Drinking Water IS - 10500 - 19831.

Central Pollution Control Board (CPCB) has also developed the standards for Inland Surface Water (CPCB Standards 16:229, 1982)2. Giving due consideration to classification scheme (A to E Class of water) by CPCB and various other classifications as mentioned above, a general classification as Excellent, Acceptable, Slightly Polluted, Polluted and Heavily Polluted water was proposed by Sargaonkar and Deshpande (2002)3.

Aim of the present work:

The main aim of the present work is a systematic and scientific study of the toxic level of some trace elements4 in the selected pockets of groundwater in different localities of Bhagalpur district so as to data generated may be used for an appropriate, environmentally sound planning of representative area. It is also aimed to integrate and interpret meaningfully all the available/collected and generated scientific data related to the study area and propose a strategy for future

utilization of groundwater resource efficiently.

For this the sampling of water was done from different sites in the container and their physico-chemical characteristics and concentration of some selected trace elements have been determined by standard analytical techniques in the field as well as in the laboratories. In addition, the samples of soil sediments have also been collected and concentrations of selected trace elements in these samples have also been determined. Present paper reports the physico-chemical characteristics of groundwater of Bhagalpur district.

Experimental

Materials and methods:

Chemicals and glasswares used in analysis: All the Chemicals used were of AnalR grade. Double distilled water was used. All the glass wares used in analysis were of Pyrex, Corning and Borrosil.

Sampling site: The district Bhagalpur5 is located in the eastern part of the state in Ganga river basin and extends between the 25.07' N - 25.30' N Latitude and 86.37' E - 87.30' E Longitude at the height of 141 feet above sea level falling in the Survey of India toposheet no. 72 K and O. The districts forms a part of the mid-Gangetic alluvium plain covering an area of 2570 square km. It is bounded by the district Munger in the west, Sahebganj and Katihar in the east, Madhepura and Purndea in the north and Banka in the south. Bhagalpur Sadar, Kahalgaon and Naugachhia are the three sub-divisions of the district with a total of sixteen community development blocks namely Pirpainti, Kahalgaon, Sanhaula, Sabour, Nathnagar, Jagdishpur, Sultanganj purushottam (thana road), Sakhund, Bihpur, Naugachhia, Gopalpur, Kharik, Narayanpur, Gauradih, Ismailpur and Rangrachowk. All the block head quarters are chosen as sampling sites.

Sampling Season: Samples were collected for two seasons namely pre-monsoon (May-June) and post-monsoon (October-November) seasons.

Groundwater sampling:

For the laboratory analytical investigations, ground water samples were collected in one liter polythene bottles. The bottles were properly cleaned by 1:10 HCl and after that by distilled water and again it is rinsed by double distilled water and dried completely before being carried to the site of collection. At the time of water sample collection, first or all the bottle was rinsed by water sample and then collected sample, stored in cool place and protected from sunlight before being transported to the laboratory for analysis.

Due care has been taken to collect the water samples only from those wells which were regularly used. The water samples were collected from the mid-length of the water column so as to avoid the collection of floating foreign matters and the bottom materials. With each sample, a record was made of well site number, depth to water level and date and time of collection.

Laboratory Techniques for Chemical Analysis:

It is difficult to use all samples collected in the field for analysis work. To avoid the unnecessary duplication of samples of similar area and of similar horizon, the representative samples were selected from different geological horizons and different areas.

The procedures for the chemical analysis are based on (a) the Techniques of water resources investigation of U. S. G. S. Book 5, A16 (b) Indian Standard Methods of Sampling and Test (Physical and Chemical) for water⁷, and (c) Standard Methods for Examination of the Water and Wastewater, prepared by American Public Health Association⁸.

For analytical work, mainly three standard analytical procedures have been adopted. They are Titrimetry, Colorimetric Spectrophotometry and Atomic Absorption Spectrophotometry.

Result and Discussion: Analytical results of physicochemical parameters in the groundwater of the study area have been tabulated in the Table-4.4 to 4.10.

Thirteen sites have been selected for groundwater sampling and from each sites two samples, one from well and one from tube well, were collected. Thus in all, twenty six samples were collected for analysis.

Physicochemical characteristics of water :

Following twelve parameters have been studied for the water samples.

- (i) Aerial temperature
- (ii) Water temperature
- (iii) pH
- (iv) turbidity
- (v) conductivity
- (vi) total solid
- (vii) total hardness
- (viii) chloride
- (ix) sulphate
- (x) nitrate
- (xi) magnesium and
- (xii) calcium

Aerial temperature: Aerial temperatures have been recorded at different sampling sites which ranges between 36°C to 39°C for pre-monsoon (May-June) season and from 28°C to 32°C for post-monsoon (October-November).

Water temperature: Water temperature have also been recorded at the sampling site for all the samples and it ranges between 33°C to 36°C for the samples collected in pre-monsoon seasons and 25°C to 28°C for the samples collected in post-monsoon seasons for well water. The average minimum and maximum water temperature was 30°C to 31.5°C for well waters. For tube well water it ranges between 32°C to 35°C and 24°C to 27°C for pre and post monsoon seasons respectively. The average temperature is 28.5°C to 30.5°C for tube well water. The overall average water temperature of well and tube-well for pre- and post-monsoon seasons ranges between 29.25°C to 31.00°C

The ambient and water temperature show a close proximity at all the sampling stations. Seasonal variations, however, had a profound effect on water temperature. The water temperature is 3°C to 7°C lesser than the air temperature in pre-monsoon and 3°C to 8°C lesser in post-monsoon. Water temperature governs the composition and activities of biological species to a large extent. It has an effect on most chemical reactions that occur in natural water system and has pronounced effect on the solubility of gases.

pH: The pH values of well water are in between 7.0 to 7.8 for both pre- and post-monsoon seasons. The average minimum and maximum pH are also 7.0 to 7.8. For tube-well water it lies between 7.0 to 7.6 for both the seasons. The average pH for tube-well water also ranges between 7.0 to 7.6. The overall average of pH values for well and tube-well water for both the seasons are in between 7.0 to 7.7.

Thus all the samples show alkaline nature of water. Similar reports have been made by Ray *et al.*⁹ Pahwa and Mehrotra¹⁰ and Singh¹¹ in river water. Olania *et al.*¹² reported highly alkaline underground water in Jaipur and Andhra Pradesh respectively. CGWB has also reported the higher pH values (above 8.0) for the groundwater of Araria District. Recently, similar reports have been made by A. K. Yadav *et al.*¹³.

The acceptable value of pH as prescribed by USPH is 6.5 to 8.5. The minimum and maximum limit of pH for drinking water, prescribed by both USPH and WHO, are 6.5 and 9.2 respectively. Thus the pH values are within the acceptable limits. Though being slightly alkaline in nature, the pH range of samples are within the acceptable limits and hence the water of the study area is fit for different purposes from the pH point of view.

Turbidity: Turbidity is the state of water in which the suspended particles make the water turbid and opaque. It depends upon the amount of

suspended particles, soil particles, discharged effluents, decomposed organic matter, total dissolved solids as well as microscopic organisms which interfere with the penetration of light. Besides other impacts, the turbidity has a marked effect on microbial population. The number of bacteria and fungi increases with the rise in turbidity while plankton population shows a fall. It was measured in N. T.U. (Nephelo-Turbidity-Unit).

The value of turbidity for well water ranges between 36 to 46 and 32 to 42 for pre and post monsoon seasons respectively. The average minimum and maximum are 34 and 44. For tube well water it ranges between 28 to 36 and 26 to 34 for both the seasons respectively. The average minimum and maximum are 27 and 35. The minimum and maximum for overall average of well and tube-well waters for pre- and post-monsoon seasons are 30.5 to 39.0. The maximum allowable limit as prescribed by WHO is 25. Thus all the values are more than the prescribed allowable limit.

Conductivity: The conductivity value of well water ranges between 463 to 840 and 461 to 780 for pre- and post monsoon seasons respectively. The average minimum and maximum are 470 and 810. For tube well water it ranges between 407 to 820 and 453 to 787 for pre-and post monsoon seasons respectively. The average calculated value ranges between 431.0 to 803.5. The overall average of conductivity values are in between 455.0 to 806.75. All these values are in micromho cm⁻¹ unit.

Total Solid: It is the sum of dissolved solids and suspended solids in water. As per WHO standard, the maximum allowable limit of total solid is 1500 ppm. For the present study its value for well water ranges from 140 to 560 and 120 to 522 for pre-and post monsoon seasons respectively. The average minimum and maximum are 130 and 541. For tube well water it is from 111 to 540 and 109 to 532 for both the seasons respectively. The average minimum and maximum are 110 and 536. The

overall averages are in between 120 and 538.5. All these values are well within the maximum allowable limit of 1500 ppm.

Total Hardness: The value of hardness in the well water of study area ranges from 130 ppm to 260 ppm and 101 ppm to 253 ppm for pre and post-monsoon seasons respectively. The averages minimum and maximum are 120 ppm to 255 ppm. For tube well water it ranges from 110 ppm to 243 ppm and 100 ppm to 221 ppm for pre- and post-monsoon seasons respectively. The average values are 105 ppm to 232 ppm. The minimum and maximum for overall average are 115.0 and 243.5.

There is not much variation in the hardness values but the data shows that the ground water of the study area fall in the range of moderately hard to hard water. Although excess of hardness causes no health hazards but it increases soap consumption and higher fuel consumption in cooling towers. Higher consumption of soap and detergents again impart the pollution to surface and groundwater as it finally reaches to that through surface runoff. Sometimes it also show laxative properties to unaccustomed person and makes skin rough after bathing with soap. Its beneficial effects have also been studied. It is believed that hardness save life by lowering the risk of cardio vascular disease.

Chloride: Chloride is relatively free from effects of exchange of ion, absorption, and biological activities. It is very difficult to remove the dissolved chloride from the water on account of its high solubility. Hence the chloride concentration in natural water continues to rise, particularly in arid regions, because carbonates and sulphates precipitate out depending upon their saturation points and intensity of evaporation. The concentration of chloride in natural waters is therefore, highly variable over wide ranges. Practically, all natural water contains chloride in varying concentration. Their presence can be expressed from their origin as pure sodium chloride crystals in natural deposits of igneous

and sedimentary rocks. Chloride can also show an increase if there are chances of domestic waste water pollution specially caused by release of NaCl taken in food around 10g/day when there is a corresponding rise in the nitrate content as well. Considering non bio-degradable nature of chloride, this has also been considered as an important parameter. The recommended maximum concentration for chloride in drinking water is 250g/L primarily for reasons of taste.

In the present study, the value of chloride in the well water ranges from 46 ppm to 70 ppm and 42 ppm to 65 ppm for pre- monsoon and post-monsoon seasons respectively. The average value is 44.5 ppm to 67.5 ppm. In tube well water it is from 45 ppm to 69 ppm and 44 ppm to 65 ppm for pre-monsoon and post-monsoon seasons respectively. The average value for tube well water is 44.5 ppm to 67ppm. The minimum and maximum for overall average are 115.0 and 243.5. All these values are within the permissible limit.

Sulphate: Sulphur is the minor constituent to the earth's crust. In water and sedimentary rocks, it occurs in the form of sulphate, and also, in reduces form, as metallic sulphides, both in igneous as well as sedimentary rocks. Sulphate ion is chemically stable in aerated water where salts of low solubility are formed. Due to recycling of salts, the concentration of sulphate ions increases in ground water.

It has been commonly observed that sulphate content in rain water increases landwards for which a number of theories have been put forwards¹⁴. In the area of low rainfall the solutes, which are brought by rainfall remain in the soil and are not fully leached. The water either of surface or of sub-surface area are likely to have comparatively high dissolved salts of which sulphate may, at places, become the dominant anion. Pyrite in sedimentary rocks also happens to be a source of ferrous iron and sulphate in groundwater, sulphate also comes into the

groundwater from the minerals of feldspathoid group.

The acceptable limit of sulphate is 200 ppm and maximum allowable limit is 400 ppm. The concentration of sulphate in the well water is 29 ppm to 43 ppm and 25 ppm to 33 ppm for pre-monsoon and post-monsoon seasons respectively. The average value is 27.5 ppm to 38 ppm. In tube well water the value ranges between 22 ppm to 35 ppm and 20 ppm to 30 ppm for pre-monsoon and post-monsoon seasons respectively. The average value is 21 ppm to 32.5 ppm. The minimum and maximum for overall average are 115.0 and 243.5. As obvious from the values of sulphate given in the tables, all the values are well within the acceptable limit of 200 ppm.

Nitrate nitrogen (NO_3/N): The principal source of nitrate is the rainwater itself. It also occurs naturally in some groundwater and enters the mammalian body through drinking water. Although its presence in drinking water is not known to be harmful to children and adults, but it can be hazardous in case of babies up to the age of six months. If baby is fed with milk made from water containing more than 10 mg/litre of nitrate nitrogen the possibility of methaemoglobinaemia exists since nitrate absorbed in the blood prevents oxygen transport.

Nitrate content of aquatic system are important because they have a great bearing on the growth of living bodies in the system, for example, higher amount of this ions is responsible for eutrofication of aquatic body. Atmospheric nitrogen plays an important role in causing the nitrate concentration by pouring this ion through rainfall. Higher denitrifying bacterial activities at increased temperature and utilization of nitrate by dense algal population are considered by earlier worker¹⁵.

Nitrogen, like oxygen, dissolves from the atmosphere in equilibrium with water at the surface. But unlike oxygen, nitrogen gas itself is

quite inert chemically. Nevertheless, nitrogen may exist in a number of different valence state in the natural environment depending on the prevailing redox condition.

Disturbance of the ecology of the watershed alter their nitrogen content. When a watershed is deforested, summer vegetation fails to take up nitrate- nitrogen nutrient and the highly leachable forms of nitrogen are carried away by the waters and lost to the ecosystem.

In well water the value of nitrate ranges from 12 to 22 ppm for pre-monsoon and 11 to 18 ppm for post-monsoon. The average is 11.5 to 20 ppm. In tube well water it ranges between 11 to 18 ppm and 10 to 14 ppm for pre- and post monsoon seasons respectively. The average is 10.5 to 15.0 ppm. The minimum and maximum for overall average are 11 and 17.50. The value of nitrate is well within the permissible limit. The maximum allowable limit of nitrate prescribed by USPH and WHO is 45 ppm. Thus all the values are much less than the limit except the two only.

Magnesium: In well water the value of magnesium ranges between 28 ppm to 44 ppm for pre-monsoon and 26 ppm to 41 ppm for post-monsoon respectively. The average value ranges from 27 ppm to 42 ppm. In tube well water its value ranges between 26 ppm to 40 ppm for pre-monsoon and 24 ppm to 36 ppm for post-monsoon. The average is 25 ppm to 38 ppm. The minimum and maximum for overall average are 26 and 40. The acceptable limit prescribed by USPH is 30 ppm and maximum limit prescribed by USPH and WHO is 150 ppm. Thus almost all the values are well within the maximum limits and mostly around the acceptable limit of 30 ppm.

Calcium:

In well water the value of Ca was found to be 32 ppm to 44 ppm for pre-monsoon and 30 ppm to 37 ppm for post-monsoon seasons. The average is 31.5 ppm to 40.5 ppm. In tube well water the value was found to be 30 ppm to 40 ppm for

Table-1
Physicochemical characteristics of ground water (well-water) of Bhagalpur District
(Bihar) for pre-monsoon season (May-June, 2012)

Sl. No.	Sampling site	Sample No.	Aerial Water temp. in °C	Water temp. in °C	pH	Turbidity	Conductivity	Total Solid	Total Hardness as CaCO ₃	Cl ⁻ in ppm	SO ₄ ²⁻ in ppm	NO ₃ ⁻ in ppm	Mg in ppm	Ca in ppm
1	Pirpanti	W ₁	37	34	7.1	40	580	450	150	49	30	12	28	32
2	Kahalgao	W ₂	39	36	7.5	40	840	390	241	60	37	20	43	38
3	Sanhaua	W ₃	38	35	7.6	42	625	440	228	70	35	16	32	36
4	Sabour	W ₄	37	34	7.3	44	660	260	253	50	36	20	40	36
5	Nathnagar	W ₅	38	35	7.4	44	740	480	257	50	35	14	42	40
6	Jagdishpur	W ₆	37	34	7.8	40	625	410	160	55	34	15	34	32
7	Sultanganj	W ₇	39	36	7.2	46	550	420	260	46	43	22	44	44
8	Sahkund	W ₈	37	34	7.3	40	600	440	133	49	37	12	36	38
9	Bihpur	W ₉	38	35	7.3	42	525	250	141	51	34	16	37	34
10	Naugacchia	W ₁₀	37	34	7.0	40	525	140	170	49	30	15	35	34
11	Gopalpur	W ₁₁	38	35	7.1	42	600	350	180	47	37	14	38	36
12	Kharik	W ₁₂	37	34	7.2	40	463	420	130	52	35	18	40	38
13	Narayanpur	W ₁₃	39	36	7.1	36	630	560	139	53	31	15	35	37
14	Gauradih	W ₁₄	38	35	7.2	38	525	440	130	51	29	14	42	33
15	Ismailpur	W ₁₅	37	34	7.7	42	620	470	190	60	35	16	36	35
16	Rangrachowk	W ₁₆	36	33	7.6	40	480	410	160	49	42	18	38	33

Table-2
Physicochemical characteristics of ground water (well-water) of Bhagalpur District (Bihar)
for post-monsoon season (October-November, 2012)

Sl. No.	Sampling site	Sample No.	Aerial temp. in °C	Water temp. in °C	pH	Turbidity	Conductivity	Total Solid	Total Hardness as CaCO ₃	Cl in ppm	SO ₄ ²⁻ in ppm	NO ₃ ⁻ in ppm	Mg in ppm	Ca in ppm
1	Pirpanti	W ₁	30	28	7.1	36	500	419	140	47	25	11	26	31
2	Kahalgao	W ₂	31	27	7.5	34	780	356	211	58	33	16	41	35
3	Sanhaua	W ₃	30	27	7.6	38	573	442	193	65	30	12	28	29
4	Sabour	W ₄	31	26	7.3	40	590	226	211	48	30	15	34	33
5	Nahnagar	W ₅	30	27	7.4	42	611	460	253	47	31	14	38	37
6	Jagdishpur	W ₆	32	26	7.8	36	601	398	110	46	28	12	30	29
7	Sultanganj	W ₇	30	26	7.2	42	478	412	210	44	33	18	39	37
8	Sakkund	W ₈	32	28	7.3	36	582	410	120	48	32	12	31	31
9	Bihpur	W ₉	28	25	7.3	36	498	200	101	50	27	13	33	30
10	Nangacchia	W ₁₀	31	28	7.0	34	483	120	150	49	25	14	32	32
11	Gopalpur	W ₁₁	32	28	7.1	36	539	300	160	42	26	13	33	35
12	Kharik	W ₁₂	30	27	7.2	34	500	412	120	47	27	14	35	35
13	Narayanpur	W ₁₃	31	26	7.1	32	580	522	111	47	28	13	28	32
14	Gauradih	W ₁₄	32	28	7.2	33	583	412	110	49	29	11	40	30
15	Ismailpur	W ₁₅	30	27	7.7	32	689	430	170	50	25	13	34	30
16	Rangrachowk	W ₁₆	31	28	7.6	35	461	398	160	51	31	15	33	32

Table-3
Average value of physicochemical characteristics of ground water (well-water) for
pre and post-monsoon season of (2012) Bhagalpur District (Bihar)

Sl. No.	Sampling site	Sample No.	Aerial temp. in °C	Water temp. in °C	pH	Turbidity	Conductivity	Total Solid	Total Hardness as CaCO ₃	Cl in ppm	SO ₄ ²⁻ in ppm	NO ₃ ⁻ in ppm	Mg in ppm	Ca in ppm
1	Pirpanti	W ₁	33.5	31.0	7.1	38.0	540.0	434.5	145.0	48.0	27.5	11.5	27	31.5
2	Kahalgaoon	W ₂	35.0	31.5	7.5	37.0	810.0	373.0	226.0	59.0	35	18.0	42	36.5
3	Sanhaula	W ₃	34.0	31.0	7.6	40.0	599.0	441.0	210.5	67.5	32.5	14.0	30	32.5
4	Sabour	W ₄	34.0	30.0	7.3	42.0	625.0	243.0	232.0	49.0	33	17.5	37	34.5
5	Nathnagar	W ₅	34.0	31.0	7.4	43.0	675.5	470.0	255.0	48.5	33	14.0	40	38.5
6	Jagdishpur	W ₆	34.5	30.0	7.8	38.0	613.0	404.0	135.0	50.5	31	13.5	32	30.5
7	Sultanganj	W ₇	34.5	31.0	7.2	44.0	514.0	416.0	235.0	45.0	38	20.0	41.5	40.5
8	Sahkund	W ₈	34.5	31.0	7.3	38.0	591.0	425.0	126.5	48.5	34.5	12.0	35.5	34.5
9	Bihpur	W ₉	33.0	30.0	7.3	39.0	511.5	225.0	121.0	50.5	30.5	14.5	35	32.0
10	Naugacchia	W ₁₀	34.0	31.0	7.0	37.0	504.0	130.0	160.0	49.0	27.5	14.5	33.5	33.0
11	Gopalpur	W ₁₁	35.0	31.5	7.1	39.0	519.5	325.0	170.0	44.5	31.5	13.5	35.5	35.5
12	Kharik	W ₁₂	33.5	30.5	7.2	37.0	481.5	416.0	125.0	49.5	31	16.0	37.5	36.5
13	Narayanpur	W ₁₃	35.0	31.0	7.1	34.0	555.0	541.0	125.0	50.0	29.5	14.0	31.5	34.5
14	Gauradith	W ₁₄	35.0	31.5	7.2	35.5	504.0	426.0	120.0	50.0	29	12.5	41	31.5
15	Ismailpur	W ₁₅	33.5	30.5	7.7	37.0	604.5	450.0	180.0	55.0	30	14.5	35	32.5
16	Rangrachowk	W ₁₆	33.5	30.5	7.6	37.5	470.5	404.0	160.0	55.0	36.5	16.5	35.5	32.5

Table-4
Physicochemical characteristics of ground water (tube well-water) of Bhagalpur District (Bihar)
for pre-monsoon season (May-June, 2012)

Sl. No.	Sampling site	Sample No.	Aerial temp. in °C	Water temp. in °C	pH	Turbidity	Conductivity	Total Solid	Total Hardness as CaCO ₃	Cl ⁻ in ppm	SO ₄ ²⁻ in ppm	NO ₃ ⁻ in ppm	Mg in ppm	Ca in ppm
1	Pirpanti	TW ₁	37	33	7.0	32	560	440	120	48	22	11	26	30
2	Kahalgao	TW ₂	39	35	7.4	32	820	337	223	58	30	16	40	36
3	Sanhaua	TW ₃	38	34	7.5	34	600	420	219	69	30	14	29	35
4	Sabour	TW ₄	37	33	7.3	36	580	240	207	50	30	16	36	34
5	Nathnagar	TW ₅	38	34	7.4	36	680	431	243	48	29	12	39	36
6	Jagdishpur	TW ₆	37	33	7.6	32	603	400	140	53	28	13	32	30
7	Sultanganj	TW ₇	39	35	7.2	36	500	398	212	45	35	18	39	40
8	Sahkund	TW ₈	37	33	7.2	32	573	430	120	48	30	11	34	34
9	Bihpur	TW ₉	38	33	7.2	34	520	240	113	49	28	13	33	32
10	Naugacchia	TW ₁₀	37	33	7.0	31	409	111	159	48	22	12	32	32
11	Gopalpur	TW ₁₁	38	34	7.1	35	573	329	147	46	29	12	35	35
12	Kharik	TW ₁₂	37	33	7.2	30	501	410	110	50	27	16	36	35
13	Narayanpur	TW ₁₃	39	34	7.1	28	580	540	127	52	26	14	30	33
14	Gauradih	TW ₁₄	38	34	7.2	30	520	412	120	52	22	14	40	32
15	Ismailpur	TW ₁₅	37	34	7.6	33	591	410	180	58	28	12	35	34
16	Rangrachowk	TW ₁₆	36	32	7.6	31	407	391	140	48	32	16	36	32

Table-5
Physicochemical characteristics of ground (tube well-water) of Bhagalpur District (Bihar) water
for post monsoon season (October-November, 2012)

Sl. No.	Sampling site	Sample No.	Aerial temp. in °C	Water temp. in °C	pH	Turbidity	Conductivity	Total Solid	Total Hardness as CaCO ₃	Cl in ppm	SO ₄ ²⁻ in ppm	NO ₃ ⁻ in ppm	Mg in ppm	Ca in ppm
1	Pirpanti	TW ₁	30	27	7.0	30	540	420	100	47	20	10	24	28
2	Kahalgau	TW ₂	31	26	7.4	30	787	311	198	56	30	12	36	34
3	Sanhaula	TW ₃	30	26	7.5	32	594	403	217	65	28	13	24	35
4	Sabour	TW ₄	31	26	7.3	34	570	212	203	50	26	14	30	32
5	Nathmagar	TW ₅	30	25	7.4	34	665	429	221	56	29	14	32	32
6	Jagdishpur	TW ₆	32	26	7.6	30	599	397	137	52	25	14	28	32
7	Sultanganj	TW ₇	30	26	7.2	32	495	389	210	44	30	12	35	32
8	Sahkund	TW ₈	32	27	7.2	30	664	420	120	46	30	13	27	32
9	Bihpur	TW ₉	28	24	7.2	31	510	229	106	48	24	14	26	34
10	Naugacchia	TW ₁₀	31	27	7.0	28	453	109	154	48	23	12	30	33
11	Gopalpur	TW ₁₁	32	27	7.1	32	520	323	143	46	24	14	31	32
12	Kharik	TW ₁₂	30	26	7.2	28	473	400	100	47	25	12	30	31
13	Narayanpur	TW ₁₃	31	26	7.1	26	560	532	121	51	24	12	25	34
14	Gauradith	TW ₁₄	32	27	7.2	30	510	410	100	52	27	12	32	35
15	Ismailpur	TW ₁₅	30	26	7.6	32	520	407	180	51	23	12	30	32
16	Rangrachowk	TW ₁₆	31	27	7.6	30	498	376	130	47	29	12	29	32

Table-6
Average value of physicochemical characteristic of ground water (tube well-water))
for pre- and post-monsoon season (2012) of Bhagalpur District (Bihar)

Sl. No.	Sampling site	Sample No.	Aerial temp. °C	Water temp. °C	pH	Turbidity	Conductivity	Total Solid	Total Hardness as CaCO ₃	Cl in ppm	SO ₄ ²⁻ in ppm	NO ₃ ⁻ in ppm	Mg in ppm	Ca in ppm
1	Pirpanti	TW ₁	33.5	30.0	7.0	31.0	550.0	430.0	110.0	47.5	21	10.5	25	29.0
2	Kahalgao	TW ₂	35.0	30.5	7.4	31.0	803.5	324.0	200.5	57.0	30	14.0	38	35.0
3	Sanhaula	TW ₃	34.0	30.0	7.5	33.0	597.0	411.5	218.0	67.0	29	13.5	26.5	35.0
4	Sabour	TW ₄	34.0	29.5	7.3	35.0	575.0	226.0	205.0	50.0	28	15.0	33	33.0
5	Nahnagar	TW ₅	34.0	29.5	7.4	35.0	572.5	430.0	232.0	47.0	29	13.0	35.5	34.0
6	Jagdishpur	TW ₆	34.5	29.5	7.6	31.0	601.0	398.5	138.5	52.5	26.5	13.5	30	31.0
7	Sultanganj	TW ₇	34.5	30.5	7.2	34.0	497.5	393.5	211	44.5	32.5	15.0	37	36.0
8	Sahkund	TW ₈	34.5	30.0	7.2	31.0	618.5	425.0	120.0	47.0	30	12.0	30.5	33.0
9	Bihpur	TW ₉	33.0	28.5	7.2	32.5	515.0	234.5	109.5	48.5	26	13.5	29.5	33.0
10	Naugachhia	TW ₁₀	34.0	30.0	7.0	29.5	431.0	110.0	156.5	48.0	22.5	12.0	31	32.5
11	Gopalpur	TW ₁₁	35.0	30.5	7.1	33.5	646.5	326.0	145.0	46.0	26.5	13.0	33	33.5
12	Kharik	TW ₁₂	33.5	29.5	7.2	29.0	487.0	405.0	105.0	48.5	26	14.0	33	33.0
13	Narayanpur	TW ₁₃	35.0	30.0	7.1	27.0	670.0	536.0	124.0	51.5	25	13.0	27.5	33.5
14	Gauradih	TW ₁₄	35.0	30.5	7.2	30.0	615.0	411.0	110.0	52.0	24.5	13.0	36	33.5
15	Ismailpur	TW ₁₅	33.5	30.0	7.6	32.5	655.5	408.5	180.0	57.0	26.5	12.0	32.5	33.0
16	Rangrachowk	TW ₁₆	33.5	29.5	7.6	30.5	452.5	383.5	135.0	47.5	30.5	14.0	32.5	32.0

Table-7
Physico-chemical characteristics
(Average of well-water (W) and tube well-water (TW) for pre-monsoon and post monsoon season, 2012
of Bhagalpur district, Bihar)

Sl. No.	Sampling site	Sample No.	Aerial temp. in °C	Water temp. in °C	pH	Turbidity	Conductivity	Total Solid	Total Hardness as CaCO ₃	Cl in ppm	SO ₄ ²⁻ in ppm	NO ₃ ⁻ in ppm	Mg in ppm	Ca in ppm
1	Pirpanti	W ₁ & TW ₁	33.50	30.50	7.05	34.50	520.00	432.25	127.50	47.75	24.25	11.00	26.00	30.25
2	Kahalgao	W ₂ & TW ₂	35.00	31.00	7.45	34.00	806.75	348.50	213.25	58.00	32.50	16.00	40.00	35.75
3	Sanhaula	W ₃ & TW ₃	34.00	30.50	7.55	36.50	598.00	426.25	214.25	67.25	30.75	13.75	28.25	33.75
4	Sabour	W ₄ & TW ₄	34.00	29.75	7.3	38.50	600.00	234.50	218.50	49.50	30.50	16.25	35.00	33.75
5	Nathnagar	W ₅ & TW ₅	34.00	29.75	7.4	39.00	674.00	450.00	243.50	47.75	31.00	13.50	37.75	36.25
6	Jagdishpur	W ₆ & TW ₆	34.50	29.75	7.7	34.50	607.00	401.25	136.75	51.50	28.75	13.50	31.00	30.75
7	Sultanganj	W ₇ & TW ₇	34.50	30.75	7.2	39.00	505.75	404.75	223.00	44.75	35.25	17.50	39.25	38.25
8	Sahkund	W ₈ & TW ₈	34.50	30.50	7.25	34.50	604.75	425.00	123.25	47.75	32.25	12.00	32.00	33.75
9	Bihrpur	W ₉ & TW ₉	33.00	29.25	7.25	35.75	488.25	229.75	115.25	49.50	28.25	14.00	32.25	32.50
10	Naugacchia	W ₁₀ & TW ₁₀	34.00	30.50	7.0	33.25	455.00	120.00	158.25	48.50	25.00	13.25	33.25	32.75
11	Gopalpur	W ₁₁ & TW ₁₁	35.00	31.00	7.1	36.25	533.00	325.50	157.50	45.25	29.00	13.25	34.25	35.50
12	Kharik	W ₁₂ & TW ₁₂	33.50	30.00	7.2	33.00	484.25	410.00	115.00	49.00	28.50	15.00	35.25	34.75
13	Narayanpur	W ₁₃ & TW ₁₃	35.00	30.50	7.1	30.50	562.50	538.50	124.50	50.75	27.25	13.50	29.50	34.00
14	Gauradih	W ₁₄ & TW ₁₄	35.00	30.75	7.2	32.75	509.50	418.50	115.00	51.00	26.75	12.75	38.50	32.50
15	Ismaipur	W ₁₅ & TW ₁₅	33.50	30.25	7.65	34.75	580.00	429.25	180.00	56.00	28.25	13.25	33.75	32.75
16	Rangachowk	W ₁₆ & TW ₁₆	33.50	30.00	7.60	34.00	461.50	397.75	147.50	51.25	33.50	15.25	34.00	32.25

pre- monsoon and 28 ppm to 35 ppm for post monsoon. The average is 29 ppm to 36 ppm. The minimum and maximum for overall average are 30.25 and 38.25. The acceptable limit of Ca is 75 ppm as prescribed by USPH. The maximum

allowable limit is 200 ppm as prescribed by USPH and WHO. Thus all the values are well within the acceptable range of 75 ppm.

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