Bangladesh Water Development Board

Changes of Ground Water Quality in Dinajpur, Pabna and Jessore Sub-division of Ground Water Hydrology-II, BWDB's Ground Water Network

Year: 2002 and 2012 to 2016

September 2021

Ground Water Processing Branch
BWDB, 72 Green Road, Dhaka.

Bangladesh Water Development Board

An assessment of changes of ground water quality in Dinajpur, Pabna and Jessore Sub-division of Ground Water Hydrology Division-II, BWDB's ground water network using available data during the year 2002 and 2012 to 2016

September 2021

Prepared & Published by:

Ground Water Processing Branch
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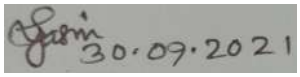
Acknowledgement

I would like to express my satisfaction to perform such an interesting assignment regarding "An assessment of changes of ground water quality in Dinajpur, Pabna and Jessore Sub-division of Ground Water Hydrology division-II, BWDB's ground water network using available data during the year 2002 and 2012 to 2016" to evaluate the changes of quality parameters over years. It's my pleasure to acknowledge the support and help of B. M. Abdul Momin, Deputy Director (Add. Charge), Ground Water Processing Branch, BWDB, Dhaka under whose valuable guidance this report is being prepared. I would like to express my sincere appreciation and gratitude to him for his overall guidance and continuous suggestion to prepare this report.

I acknowledge my deep gratitude to Md. Mushfiquer Rahaman, System Analyst, Processing and Flood Forecasting Circle, BWDB, Dhaka for his extensive support and help in doing all the data related works.

I would also like to mention the support of Md. Shahadat Ali, Deputy Director (Current Charge), Ground Water Hydrology Division-2, BWDB, Dhaka in doing water quality data related activities.

Finally, I like to extend my sincere thanks to my colleagues for their co-operation during the preparation of this report.



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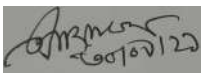
Executive Summary

Ground water quality is a vital issue in Bangladesh due to extreme value of some parameters. The present work deals with the assessment of changes of ground water quality using available data (pH, TDS, Ca_2^+, Mg_2^+, Na^+, K^+, Fe, Mn, NO_3^-, Cl^-, F^-, Si, CO_2 and B) in BWDB database server of 2002 and 2012 to 2016 in Dinajpur, Pabna and Jessore sub-division of BWDB's ground water network.

The analysis of pH, TDS and Na^+ show most of the values lie within their allowable limit for drinking purpose, with some exceptions in Charghat, Narail Sadar and Shatkhira Sadar. High concentrations of Ca_2^+ are mainly found in Natore Sadar, Shibganj, Charghat, Narail Sadar, Chatmohar, Sujanagar and Singra. Mg_2^+ concentrations found high mainly in Bheramara, Sundarganj, Narail Sadar and Kushtia Sadar. Worse conditions of K^+ are found in Khulna Sadar, Nageshwari, Bheramara and Boda.

The analysis of Fe (Iron) shows its high concentrations in most of the wells, except Sujanagar. Most of the Mn (Manganese) values exceed its allowable limit, with highest value found in Kushtia Sadar. From Cl^-, F^-, NO_3^- and B analysis, it is found that most of the values lie within their maximum allowable limit with a few exceptions. High concentrations of Si (Silicon) are mainly found in Manda, Patnitala, Chatmohar Joypurhat Sadar, Charghat, Sujanagar and Singr. CO_2 analysis reveals its higher concentrations in Natore Sadar, Bera, Singra, Pabna Sadar, Nageshwari and Charghat.



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Acronyms

1.	BWDB	Bangladesh Water Development Board
2.	WHO	World Health Organization
3.	pH	potential of Hydrogen (Hydrogen ion concentration)
4.	TDS	Total Dissolved Solids
5.	ppm	parts per million
6.	mg/l	milligram per liter
7.	mol/L	moles per litre
8.	IS	Indian Standard

Name of Chemical Elements and their Symbols

SL No.	Name of Chemical Elements	Symbol of Chemical Elements
1	Calcium	Ca_2^+
2	Magnesium	Mg_2^+
3	Potassium	K^+
4	Iron	Fe
5	Manganese	Mn
6	Sodium	Na^+
7	Chloride	Cl^-
8	Fluoride	F^-
9	Nitrate	NO_3^-
10	Silicon	Si
11	Carbon Dioxide	CO_2
12	Boron	B

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1. Introduction

Water quality is a measure of its condition relative to the requirements of one or more biotic species and or to any human need or purpose. Ground water quality is the vital issue in Bangladesh due to extreme value of some parameters. Though the abundance of ground water is not the problem but concern is in the quality. The present work deals with the assessment of changes of ground water quality using available data of water quality parameters of 2002 and 2012 to 2016 in Dinajpur, Pabna and Jessore sub-division of BWDB's ground water network (reporting area showing in figure 1(i)). Data of 34 ground water quality wells are analyzed out of total 54 wells due to data availability, whose locations are given in figure 1(ii).

The present work is to find out the ground water quality changes in the reported area using available data (pH, TDS, Ca_2^+, Mg_2^+, Na^+, K^+, Fe, Mn, NO_3^-, Cl^-, F^-, Si, CO_2 and B) of 2002 and 2012 to 2016. According to the drinking water quality standards the ground water of the reported area in most cases, is suitable for public health. It is also good for domestic and irrigation uses as well.

The findings of this assessment will help to understand long term annual changes of ground water quality in the reported area.

2. Objectives

Objectives of the present work are -

- To analyze available ground water quality data of the reported area.
- To find out abnormalities in available ground water quality data.
- To assess the chemical properties of ground water.
- To compare the analytical results with national and international standards for water use specially in drinking purposes.
- To evaluate the change of quality parameters over years.

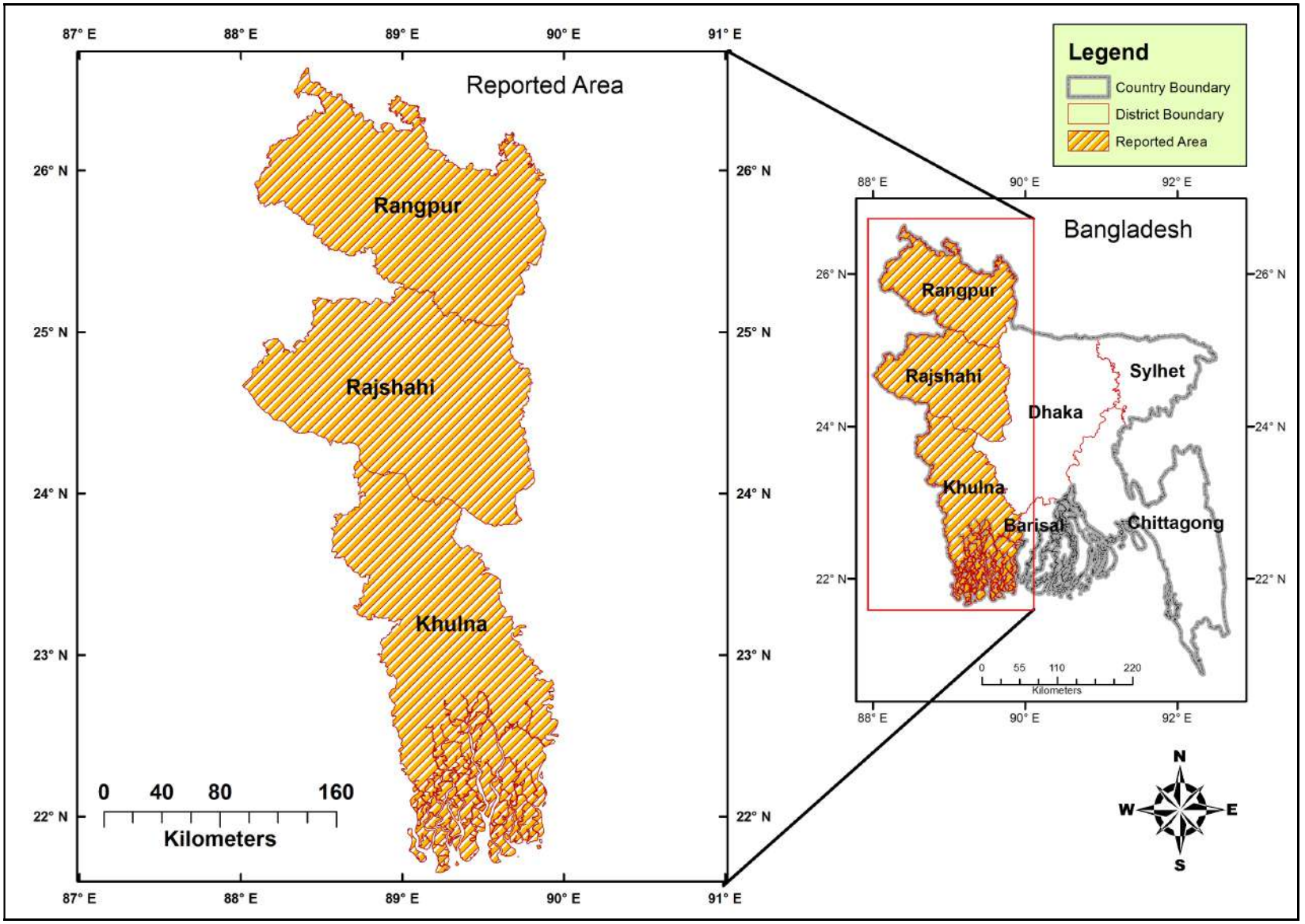


Figure 1(i): Map of the reported area.

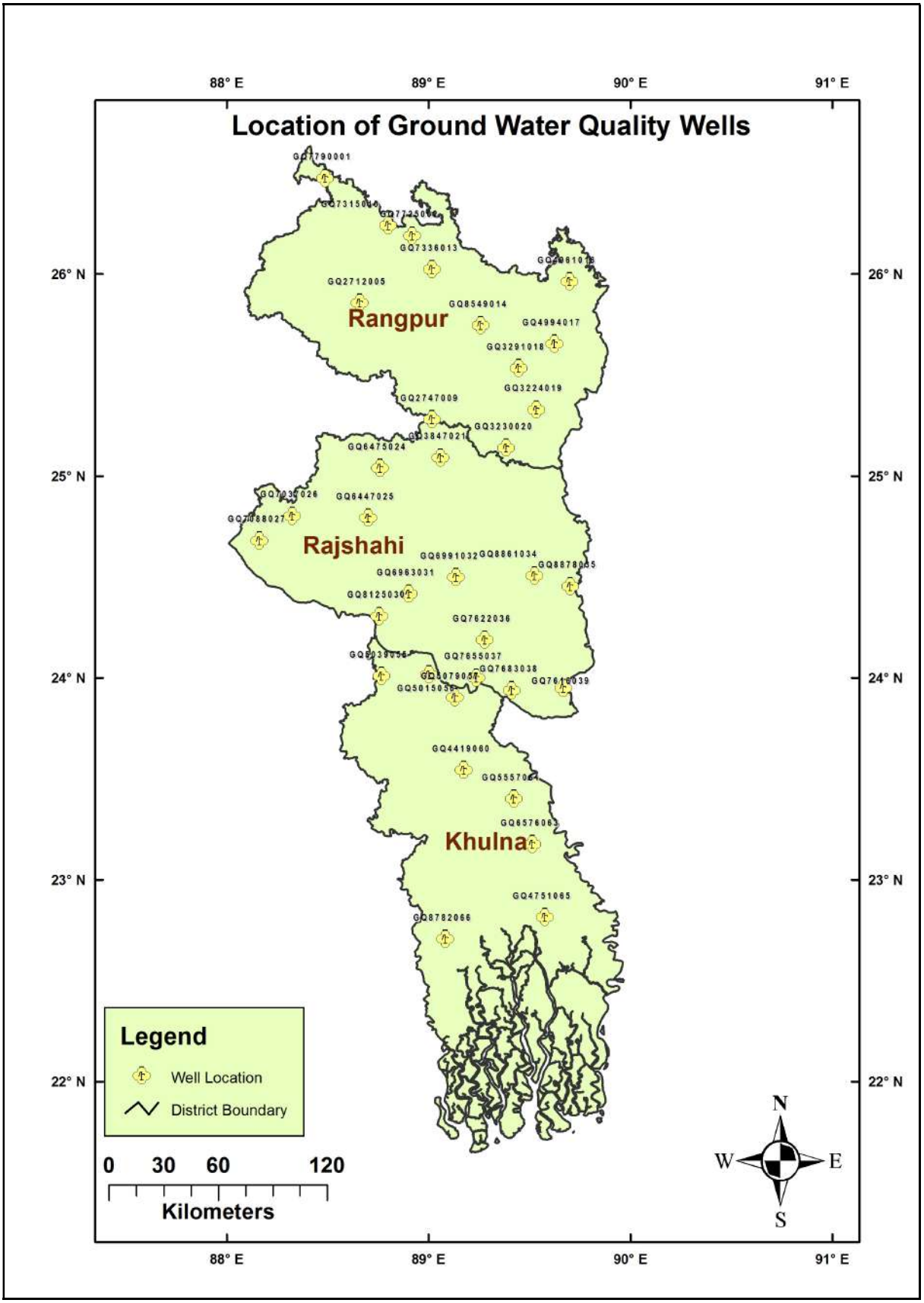


Figure 1(ii): Location map of 34 Water Quality Wells.

3. Scenes of Ground water Quality changes

Since many compounds can dissolve in water and others can be suspended in water, there is a potential for contamination with toxic compounds which led to change its quality. One of the good things about ground water as a source of water is that, it is not as easily contaminated as surface water.

Ground water quality may be changes by following two ways-

A. Natural Contamination:

Ground water can become naturally contaminated because of its very close connection to the materials of its aquifer. In most aquifers, the geological materials that make up the aquifer are relatively inert, or are made up of minerals that dissolve very slowly into the ground water. Over time, however, all ground water gradually has more and more material dissolved within it as it remains in contact with the aquifer. In some areas, that rock or sediment includes some minerals that could potentially contaminate the water with elements that might make the water less than ideal for human consumption or agricultural use. Examples include copper, arsenic, mercury, fluorine, sodium, and boron. In some cases, contamination may occur because the aquifer material has particularly high levels of the element in question. In other cases, the aquifer material is just normal rock or sediment, but some particular feature of the water or the aquifer allows the contaminant to build up to significant levels.

B. Anthropogenic Contamination:

Ground water can be contaminated by pollution at the surface (or at depth), and there are many different anthropogenic (human-caused) sources of contamination. The vulnerability of aquifers to pollution depends on several factors, including the depth to the water table, the permeability of the material between the surface and the aquifer, the permeability of the aquifer, the slope of the surface, and the amount of precipitation.

The important sources of anthropogenic ground water contamination include the following:

(a) Chemicals and animal waste related to agriculture, and chemicals applied to golf courses and domestic gardens

(b) Landfills

(c) Industrial operations

(d) Mines, quarries, and other rock excavations

(e) Leaking fuel storage tanks (especially those at gas stations)

(f) Septic systems

(g) Runoff from roads (e.g., winter salting) or chemical spills of materials being transported etc.

4. Ground water Quality of the Reported Area:

For the assessment of ground water quality of the reported area, the following water quality parameters are analyzed:

4.1. pH:

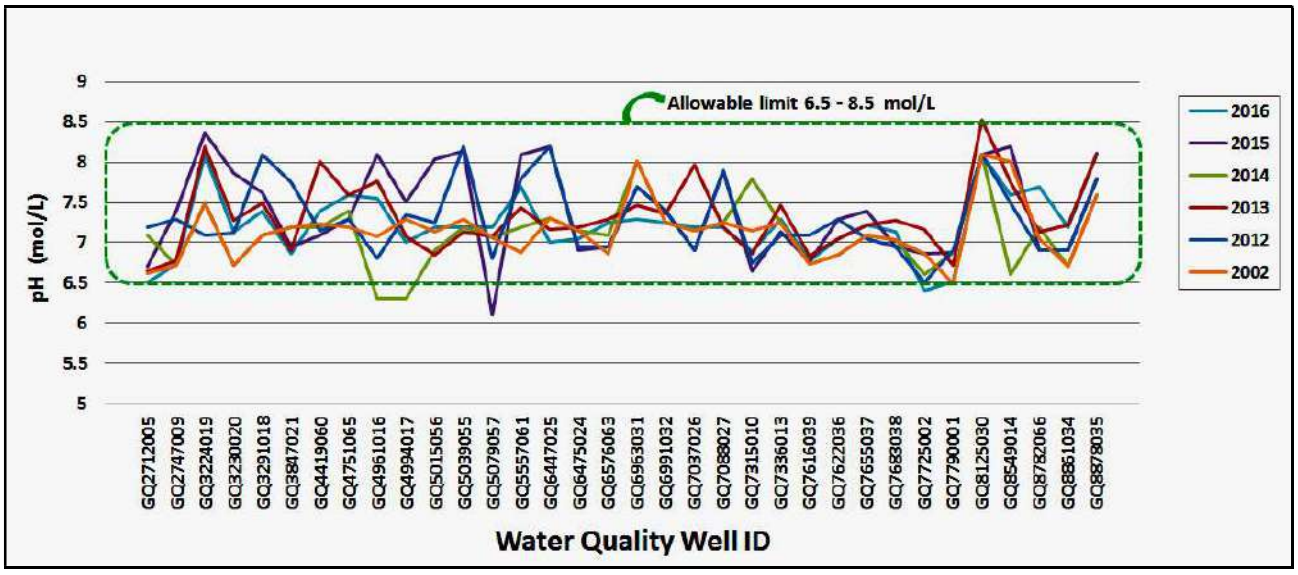
pH is the negative logarithm of the hydrogen ion concentration of a solution and it is thus a measure of whether the liquid is acid or alkaline. The pH scale ranges from 0 (very acid) to 14 (very alkaline). The acceptable range of pH in ground water for drinking purpose in Bangladesh extends from 6.5 to 8.5 mol/L. In general, a water with a pH < 7 is considered acidic and with a pH > 7 is considered basic and with a pH = 7 is considered neutral. Available pH data (2002 and 2012 to 2016) of ground water of the reported area are given in table 4.1.

Sl No.	Station Name	WELL ID	2002	2012	2013	2014	2015	2016	Allowable limit (mol/L)	
									Bangladesh Standard	WHO Standard
1	Birganj	GQ2712005	6.62	7.20	6.65	7.10	6.70	6.50	6.5 - 8.5	6.5 - 8.5
2	Hakimpur	GQ2747009	6.72	7.30	6.78	6.72	7.40	6.74	6.5 - 8.5	6.5 - 8.5
3	Gaibandha	GQ3224019	7.50	7.10	8.20	7.50	8.37	8.10	6.5 - 8.5	6.5 - 8.5
4	Gobindaganj	GQ3230020	6.72	7.12	7.28	6.72	7.86	7.13	6.5 - 8.5	6.5 - 8.5
5	Sundarganj	GQ3291018	7.10	8.10	7.50	7.10	7.62	7.40	6.5 - 8.5	6.5 - 8.5
6	Joypurhat Sadar	GQ3847021	7.20	7.75	6.91	7.20	6.95	6.86	6.5 - 8.5	6.5 - 8.5
7	Jhenaidah Sadar	GQ4419060	7.23	7.15	8.01	7.20	7.10	7.40	6.5 - 8.5	6.5 - 8.5
8	Khulna Sadar	GQ4751065	7.20	7.30	7.59	7.40	7.30	7.60	6.5 - 8.5	6.5 - 8.5
9	Nageshwari	GQ4961016	7.08	6.80	7.77	6.30	8.10	7.55	6.5 - 8.5	6.5 - 8.5
10	Ulipur	GQ4994017	7.30	7.35	7.08	6.30	7.51	7.00	6.5 - 8.5	6.5 - 8.5
11	Bheramara	GQ5015056	7.14	7.25	6.85	6.90	8.04	7.20	6.5 - 8.5	6.5 - 8.5
12	Daulatpur	GQ5039055	7.30	8.20	7.14	7.20	8.14	7.20	6.5 - 8.5	6.5 - 8.5
13	Kushtia Sadar	GQ5079057	7.06	6.80	7.08	7.06	6.11	7.20	6.5 - 8.5	6.5 - 8.5
14	Magura Sadar	GQ5557061	6.88	7.80	7.43	7.20	8.10	7.70	6.5 - 8.5	6.5 - 8.5
15	Manda	GQ6447025	7.31	8.20	7.17	7.31	8.20	7.00	6.5 - 8.5	6.5 - 8.5
16	Patnitala	GQ6475024	7.15	6.95	7.20	7.15	6.90	7.05	6.5 - 8.5	6.5 - 8.5
17	Narail Sadar	GQ6576063	6.87	6.95	7.29	7.10	6.95	7.25	6.5 - 8.5	6.5 - 8.5
18	Natore Sadar	GQ6963031	8.01	7.70	7.46	8.01	7.70	7.30	6.5 - 8.5	6.5 - 8.5
19	Singra	GQ6991032	7.25	7.40	7.37	7.25	7.40	7.25	6.5 - 8.5	6.5 - 8.5
20	Gomastapur	GQ7037026	7.15	6.90	7.96	7.15	6.90	7.20	6.5 - 8.5	6.5 - 8.5
21	Shibganj	GQ7088027	7.25	7.90	7.20	7.25	7.90	7.20	6.5 - 8.5	6.5 - 8.5
22	Domar	GQ7315010	7.15	6.75	6.87	7.79	6.65	6.89	6.5 - 8.5	6.5 - 8.5
23	Jaldhaka	GQ7336013	7.25	7.10	7.47	7.25	7.13	7.30	6.5 - 8.5	6.5 - 8.5
24	Bera	GQ7616039	6.74	7.10	6.84	6.74	6.76	6.78	6.5 - 8.5	6.5 - 8.5
25	Chatmohar	GQ7622036	6.85	7.30	7.05	6.85	7.30	7.05	6.5 - 8.5	6.5 - 8.5
26	Pabna Sadar	GQ7655037	7.10	7.05	7.22	7.10	7.40	7.22	6.5 - 8.5	6.5 - 8.5

Sl No.	Station Name	WELL ID	2002	2012	2013	2014	2015	2016	Allowable limit (mol/L)	
									Bangladesh Standard	WHO Standard
27	Sujanagar	GQ7683038	7.04	6.95	7.28	7.04	6.95	7.14	6.5 - 8.5	6.5 - 8.5
28	Boda	GQ7725002	6.87	6.50	7.16	6.60	6.87	6.40	6.5 - 8.5	6.5 - 8.5
29	Tentulia	GQ7790001	6.49	6.90	6.72	6.88	6.88	6.52	6.5 - 8.5	6.5 - 8.5
30	Charghat	GQ8125030	8.10	8.10	8.52	8.10	8.10	8.10	6.5 - 8.5	6.5 - 8.5
31	Rangpur Sadar	GQ8549014	8.01	7.50	7.75	6.60	8.20	7.60	6.5 - 8.5	6.5 - 8.5
32	Satkhira Sadar	GQ8782066	7.05	6.90	7.13	7.20	6.90	7.70	6.5 - 8.5	6.5 - 8.5
33	Raiganj	GQ8861034	6.70	6.90	7.22	6.70	6.90	7.20	6.5 - 8.5	6.5 - 8.5
34	Sirajganj Sadar	GQ8878035	7.60	7.80	8.11	7.60	7.80	8.11	6.5 - 8.5	6.5 - 8.5

Table 4.1: pH values of ground water in 2002 and 2012 to 2016.

Most of the pH values lie within the allowable limit for Bangladesh standard, according to the Department of Public Health Engineering (DPHE) of Bangladesh, which are clearly shown in graph 4.1(a) and figures 4.1(i) to 4.1(iv). In some areas few values cross the allowable limit, which are shown in those figures with red color.



Graph 4.1(a): Variation in pH condition of ground water in 2002 and 2012 to 2016.

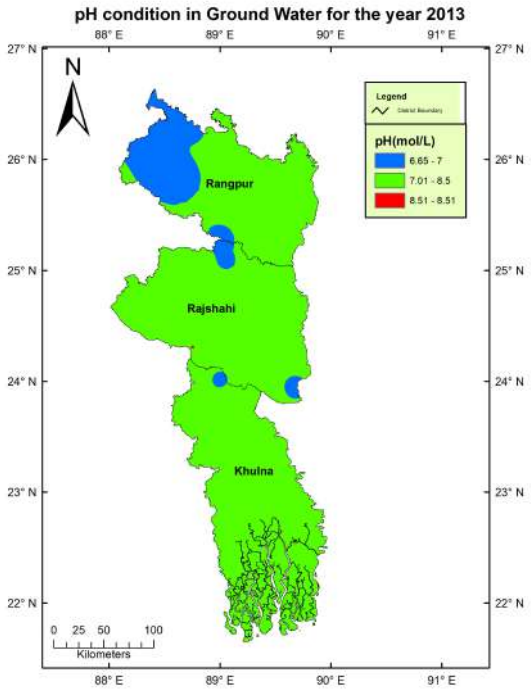


Figure 4.1(i): pH condition in 2013

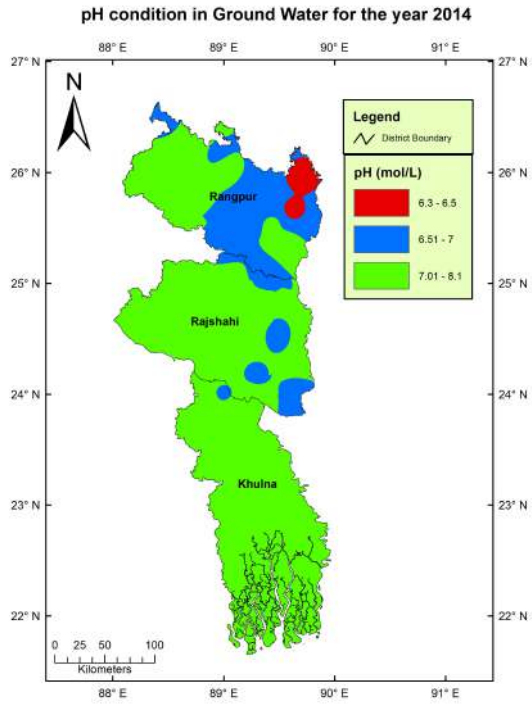


Figure 4.1(ii): pH condition in 2014

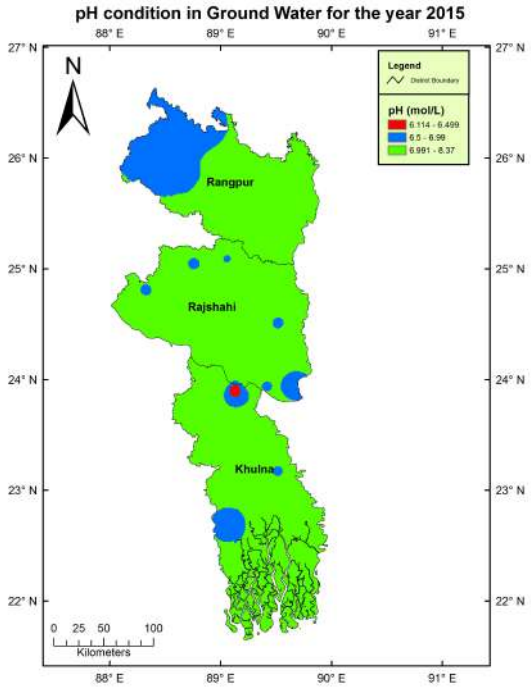


Figure 4.1(iii): pH condition in 2015

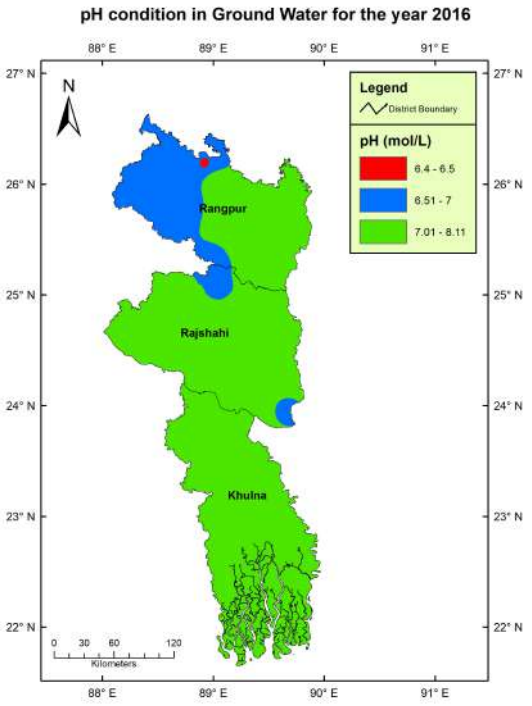


Figure 4.1(iv): pH condition in 2016

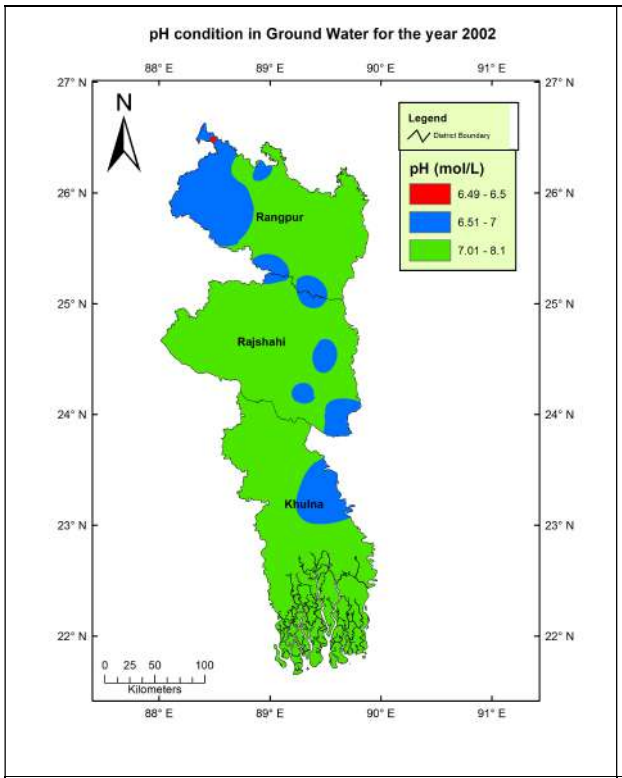


Figure 4.1(v): pH condition in 2002

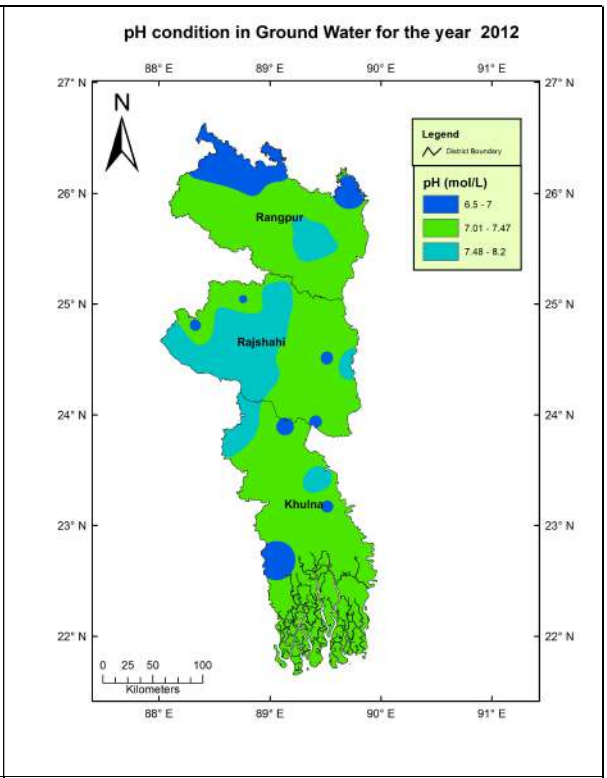
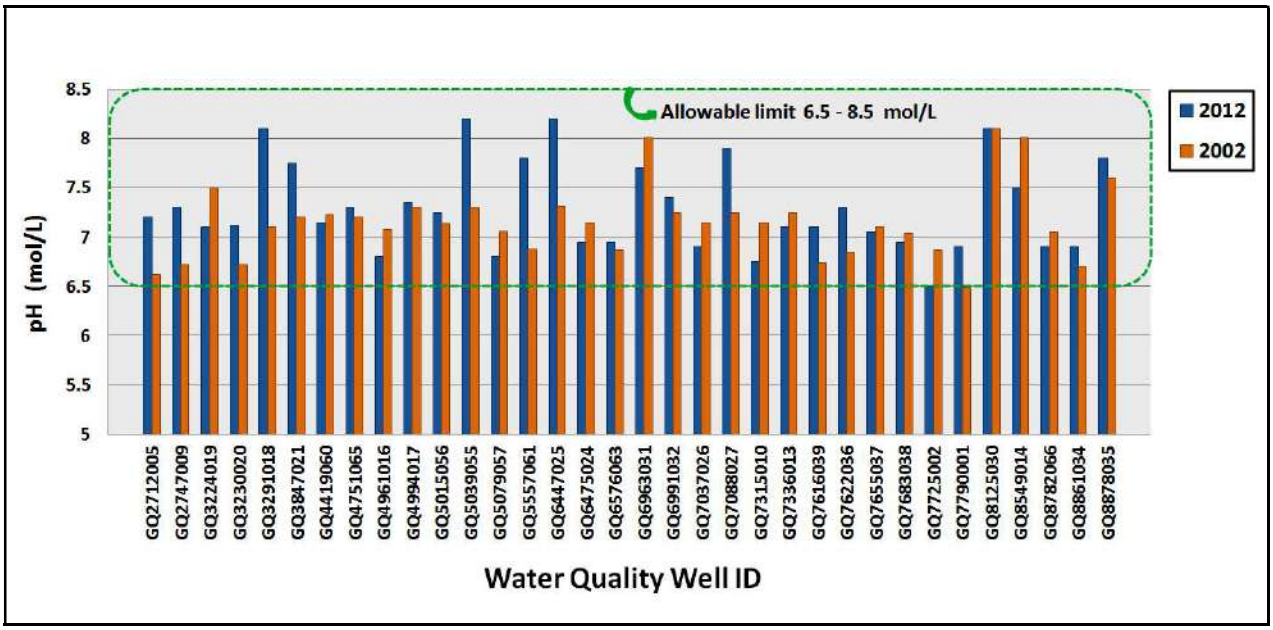


Figure 4.1(vi): pH condition in 2012

Variations in pH condition of ground water in 2002 and 2012 are shown in figures 4.1(v) and 4.1(vi). The same difference is also shown in graph 4.1(b).



Graph 4.1(b): Variation in pH condition of ground water in 2002 and 2012.

4.2. Total dissolved solids (TDS):

TDS is a measure of the dissolved combined content of all inorganic and organic substances present in a liquid in molecular, ionized, or micro-granular (colloidal sol) suspended form. Total dissolved solids are normally discussed only for freshwater systems, as salinity includes some of the ions constituting the definition of TDS. Although TDS is not generally considered a primary pollutant (e.g. it is not deemed to be associated with health effects), it is used as an indication of aesthetic characteristics of drinking water and as an aggregate indicator of the presence of a broad array of chemical contaminants.

Water can be classified as follows based on TDS:

Sl No.	TDS (ppm)	Water Type
1	up to 500	Fresh water
2	500 - 30,000	Brackish water
3	30,000 - 40,000	Saline water
4	greater than 40,000	Hypersaline

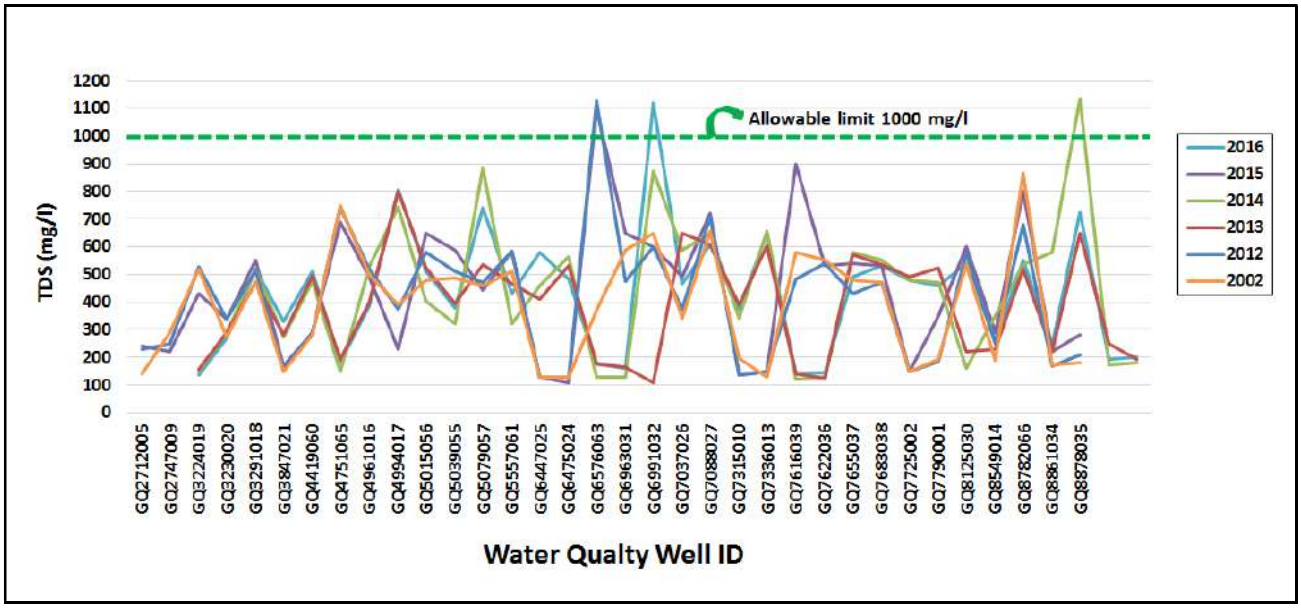
Available TDS data (2002 and 2012 to 2016) of ground water of the reported area are given in table 4.2.

Sl No.	Name of station	WELL ID	2002	2012	2013	2014	2015	2016	Allowable limit (mg/l)	
									Bangladesh Standard	WHO Standard
1	Birganj	GQ2712005	140	230	158	148	240	137	1000	1000
2	Hakimpur	GQ2747009	290	250	288	290	220	270	1000	1000
3	Gaibandha	GQ3224019	518	528	470	518	430	520	1000	1000
4	Gobindaganj	GQ3230020	273	338	283	273	338	330	1000	1000
5	Sundarganj	GQ3291018	475	515	495	475	552	510	1000	1000
6	Joypurhat Sadar	GQ3847021	149	152	192	149	170	180	1000	1000
7	Jhenaidah Sadar	GQ4419060	281	290	398	527	290	387	1000	1000
8	Khulna Sadar	GQ4751065	748	740	800	746	690	807	1000	1000
9	Nageshwari	GQ4961016	500	520	525	403	490	510	1000	1000
10	Ulipur	GQ4994017	390	375	395	324	230	380	1000	1000
11	Bheramara	GQ5015056	480	580	534	885	650	743	1000	1000
12	Daulatpur	GQ5039055	487	510	468	324	590	429	1000	1000
13	Kushtia Sadar	GQ5079057	460	470	412	460	442	580	1000	1000
14	Magura Sadar	GQ5557061	513	583	530	562	583	485	1000	1000
15	Manda	GQ6447025	129	128	178	129	131	175	1000	1000
16	Patnitala	GQ6475024	130	130	165	130	110	160	1000	1000
17	Narail Sadar	GQ6576063	370	1130	109	875	1100	1120	1000	1000
18	Natore Sadar	GQ6963031	590	475	650	590	650	466	1000	1000

Sl No.	Name of station	WELL ID	2002	2012	2013	2014	2015	2016	Allowable limit (mg/l)	
									Bangladesh Standard	WHO Standard
19	Singra	GQ6991032	647	600	607	647	601	607	1000	1000
20	Gomastapur	GQ7037026	344	375	391	344	490	375	1000	1000
21	Shibganj	GQ7088027	656	710	606	656	720	650	1000	1000
22	Domar	GQ7315010	198	137	142	121	135	142	1000	1000
23	Jaldhaka	GQ7336013	130	150	123	130	150	144	1000	1000
24	Bera	GQ7616039	582	485	571	582	900	490	1000	1000
25	Chatmohar	GQ7622036	550	540	535	550	530	530	1000	1000
26	Pabna Sadar	GQ7655037	480	430	490	480	540	478	1000	1000
27	Sujanagar	GQ7683038	470	470	525	470	530	460	1000	1000
28	Boda	GQ7725002	147	150	221	161	147	540	1000	1000
29	Tentulia	GQ7790001	195	185	228	351	351	260	1000	1000
30	Charghat	GQ8125030	536	575	520	536	602	553	1000	1000
31	Rangpur Sadar	GQ8549014	190	250	220	580	291	245	1000	1000
32	Satkhira Sadar	GQ8782066	865	680	650	1138	800	724	1000	1000
33	Raiganj	GQ8861034	172	170	250	172	220	195	1000	1000
34	Sirajganj Sadar	GQ8878035	182	210	195	182	280	200	1000	1000

Table 4.2: TDS values of ground water in 2002 and 2012 to 2016.

Most of the TDS values lie in the allowable limit for Bangladesh and WHO standard, which are clearly shown in graph 4.2(a) and figures 4.2(i) to 4.2(iv). Areas, where values cross the allowable limit, are shown in those figures with red color.



Graph 4.2(a): Variation in TDS condition of ground water in 2002 and 2012 to 2016.

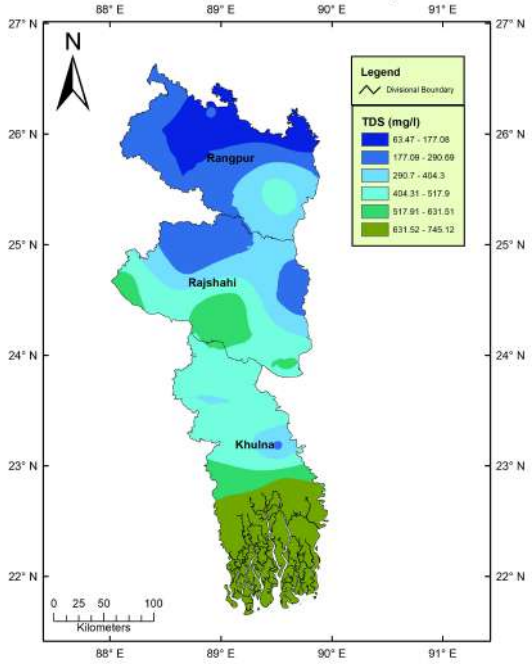


Figure 4.2(i): TDS condition in 2013

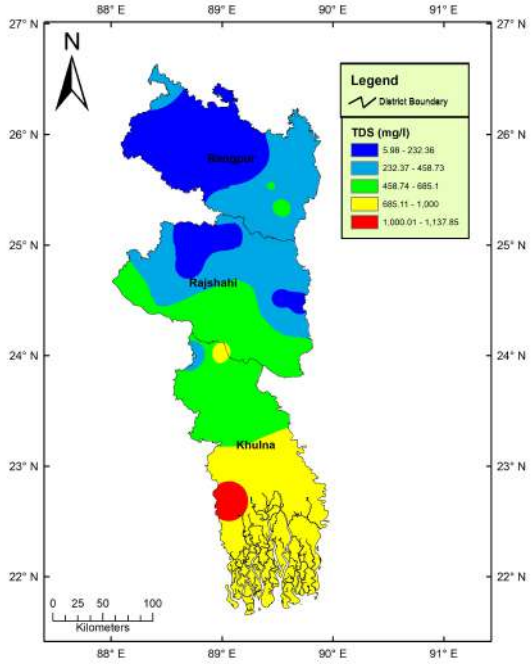


Figure 4.2(ii): TDS condition in 2014

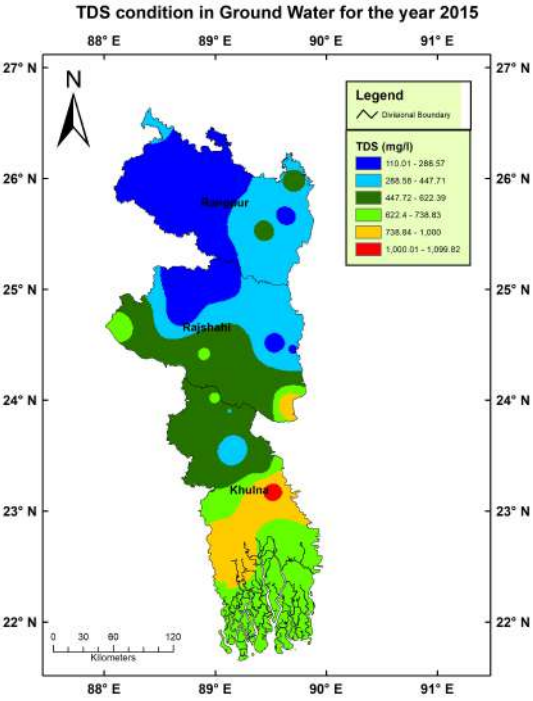


Figure 4.2(iii): TDS condition in 2015

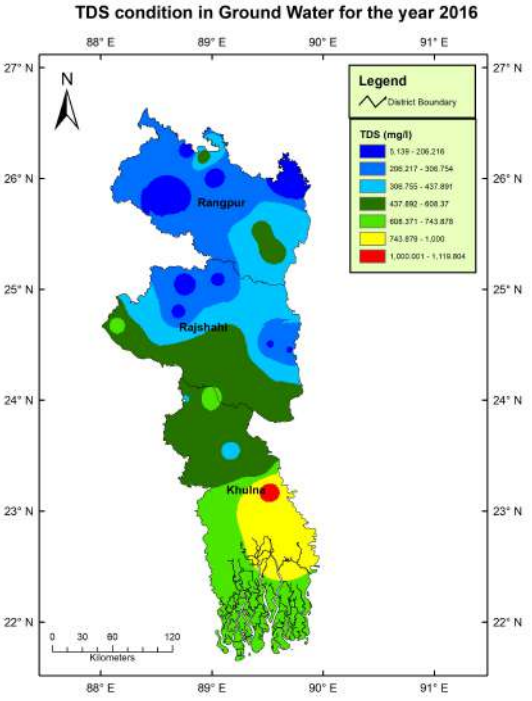


Figure 4.2(iv): TDS condition in 2016

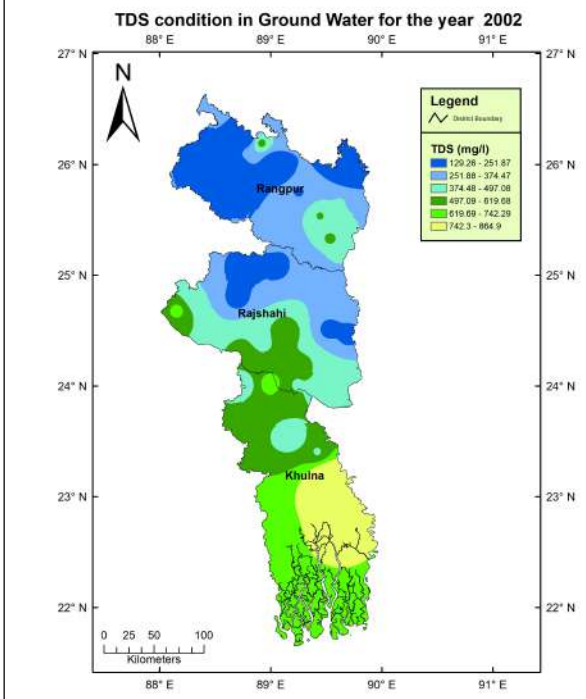


Figure 4.2(v): TDS condition in 2002

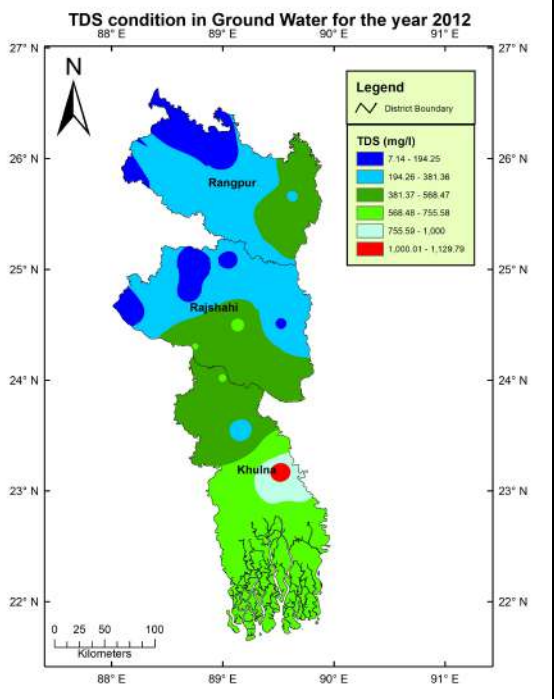
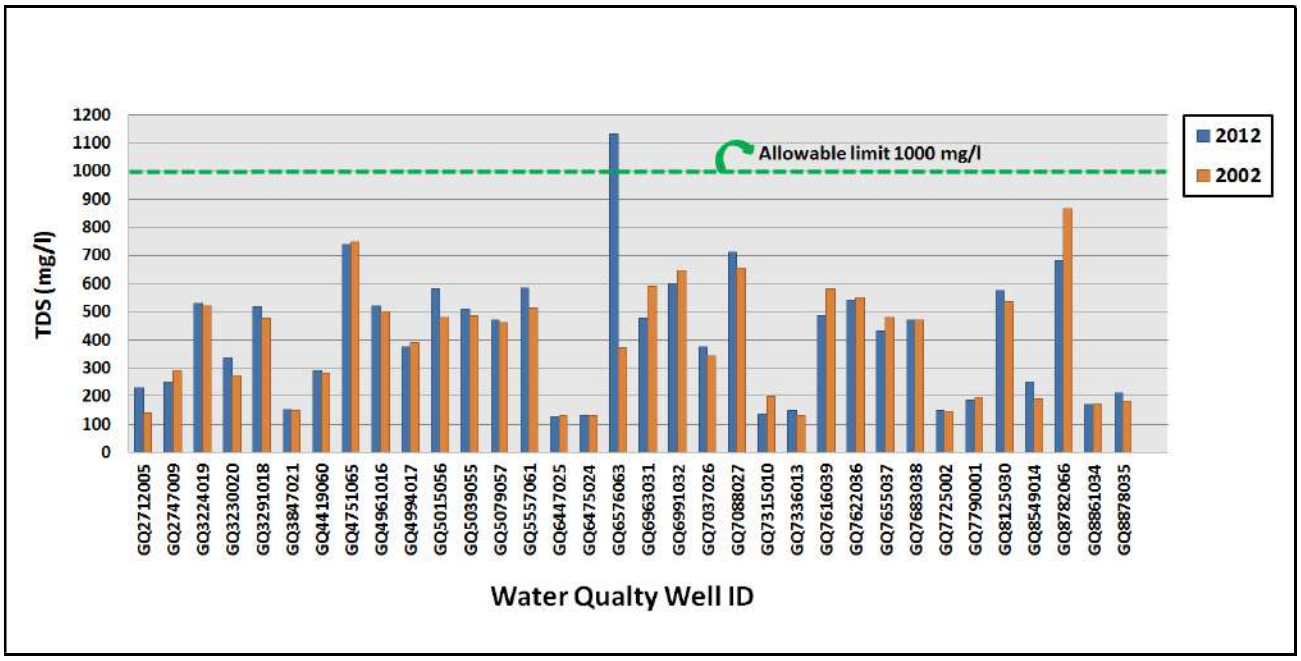


Figure 4.2(vi): TDS condition in 2012

Variations in TDS condition of ground water in 2002 and 2012 are shown in figures 4.2(v) and 4.2(vi). The same difference is also shown in graph 4.2(b).



Graph No. 4.2(b): Variation in TDS condition of ground water in 2002 and 2012.

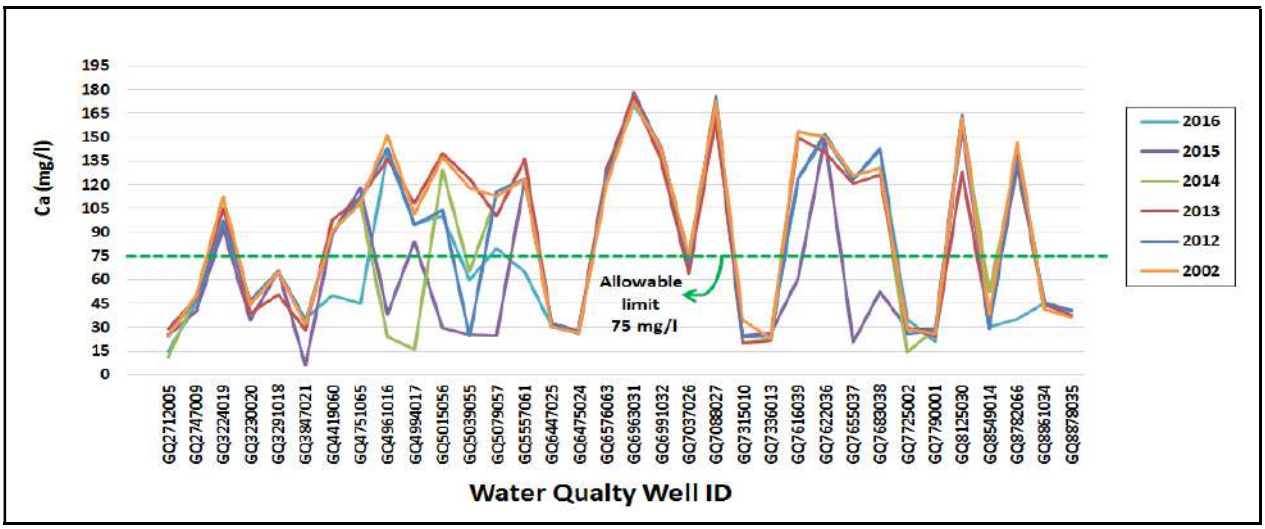
4.3. Calcium (Ca_2^+):

This element is the most important and abundant in the human body and an adequate intake is essential for normal growth and health. It is a primary constituent of water hardness. The maximum daily requirement of Ca_2^+ is 1 to 2 grams for the normal human growth. Available Ca_2^+ data (2002 and 2012 to 2016) of ground water of the reported area are given in table 4.3.

Sl No.	Name of station	WELL ID	2002	2012	2013	2014	2015	2016	Allowable limit (mg/l)
									Bangladesh Standard
1	Birganj	GQ2712005	24.40	25.60	28.80	11.20	24.80	15.00	75
2	Hakimpur	GQ2747009	50.00	48.00	48.00	50.00	40.00	45.00	75
3	Gaibandha	GQ3224019	112.00	96.40	105.20	112.00	92.00	97.00	75
4	Gobindaganj	GQ3230020	44.80	47.20	39.20	44.80	34.80	46.00	75
5	Sundarganj	GQ3291018	65.20	65.60	50.80	65.20	65.60	65.00	75
6	Joypurhat Sadar	GQ3847021	32.40	34.00	28.40	32.40	6.30	35.00	75
7	Jhenaidah Sadar	GQ4419060	90.80	90.00	98.00	90.80	88.85	50.00	75
8	Khulna Sadar	GQ4751065	108.40	112.00	112.00	108.40	118.22	45.00	75
9	Nageshwari	GQ4961016	150.80	143.20	136.00	24.00	38.40	140.00	75
10	Ulipur	GQ4994017	101.20	94.80	108.40	16.00	84.00	95.00	75
11	Bheramara	GQ5015056	137.20	104.00	140.00	129.60	29.60	100.00	75
12	Daulatpur	GQ5039055	118.00	24.80	124.00	65.60	25.20	60.00	75
13	Kushtia Sadar	GQ5079057	112.40	116.00	100.00	112.40	24.80	80.00	75
14	Magura Sadar	GQ5557061	123.60	124.00	136.00	123.60	123.25	65.00	75
15	Manda	GQ6447025	30.40	32.00	32.40	30.40	32.84	31.00	75
16	Patnitala	GQ6475024	26.80	27.20	28.00	26.80	27.65	26.00	75
17	Narail Sadar	GQ6576063	120.40	125.00	130.00	126.40	123.63	126.00	75
18	Natore Sadar	GQ6963031	172.00	172.00	176.00	172.00	178.00	170.00	75
19	Singra	GQ6991032	143.60	144.00	136.40	143.60	142.40	145.00	75
20	Gomastapur	GQ7037026	74.80	71.20	64.00	74.80	71.20	70.00	75
21	Shibganj	GQ7088027	172.40	176.00	164.00	172.40	162.00	174.00	75
22	Domar	GQ7315010	34.40	24.00	20.00	20.40	25.00	24.00	75
23	Jaldhaka	GQ7336013	22.80	24.80	21.60	22.80	26.80	25.00	75
24	Bera	GQ7616039	153.60	124.00	150.00	153.26	60.80	124.00	75
25	Chatmohar	GQ7622036	150.40	152.00	140.40	150.40	149.60	150.00	75
26	Pabna Sadar	GQ7655037	125.60	123.00	120.80	125.60	20.40	123.00	75
27	Sujanagar	GQ7683038	130.40	142.80	126.00	130.40	52.40	142.00	75
28	Boda	GQ7725002	28.80	26.00	30.00	14.40	28.80	35.00	75
29	Tentulia	GQ7790001	26.00	28.00	24.00	28.80	28.80	21.00	75
30	Charghat	GQ8125030	162.00	164.00	128.00	162.00	156.00	163.00	75
31	Rangpur Sadar	GQ8549014	38.40	29.20	32.40	52.80	34.00	30.00	75
32	Satkhira Sadar	GQ8782066	146.40	137.00	132.00	135.20	142.44	35.00	75
33	Raiganj	GQ8861034	41.20	46.00	44.80	41.20	44.00	45.00	75
34	Sirajganj Sadar	GQ8878035	36.40	40.80	38.00	36.40	40.80	40.00	75

Table 4.3: Ca_2^+ values of ground water in 2002 and 2012 to 2016.

Many Ca_2^+ values exceed its allowable limit 75 mg/l for Bangladesh Standard, which is shown in graph 4.3(a). Areas, where Ca_2^+ values cross the allowable limit, are shown in figures 4.3(i) to 4.3(iv) with yellow, orange and red color.



Graph 4.3(a): Variation in Ca_2^+ condition of the ground water in 2002 and 2012 to 2016

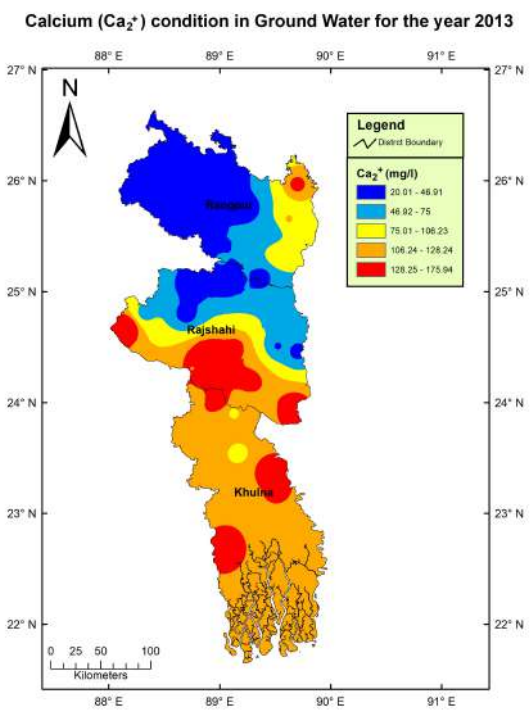


Figure 4.3(i): Ca_2^+ condition in 2013

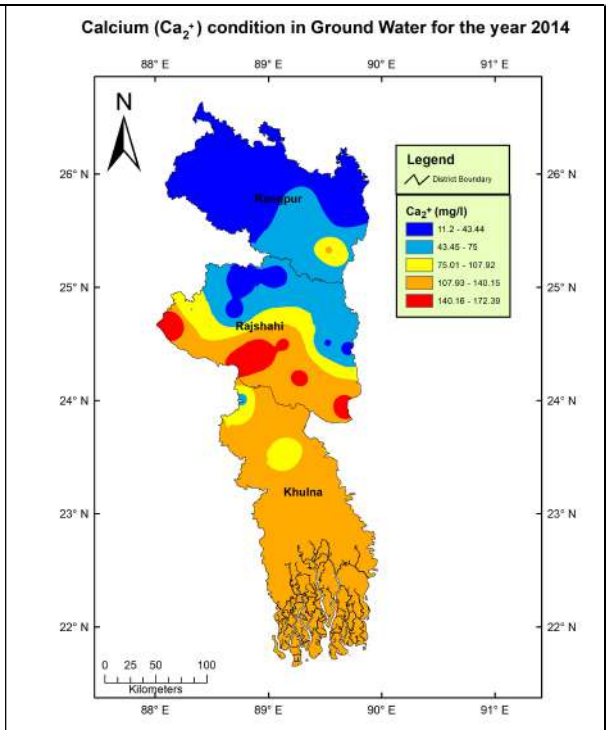


Figure 4.3(ii): Ca_2^+ condition in 2014

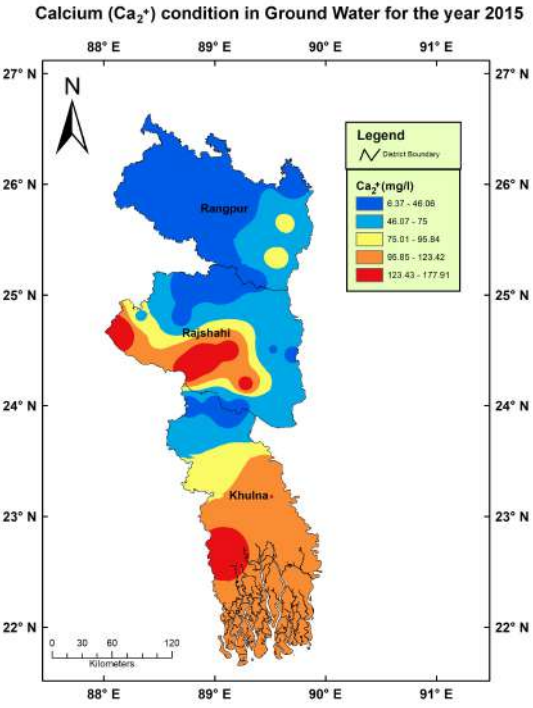


Figure 4.3(iii): Ca_2^+ condition in 2015

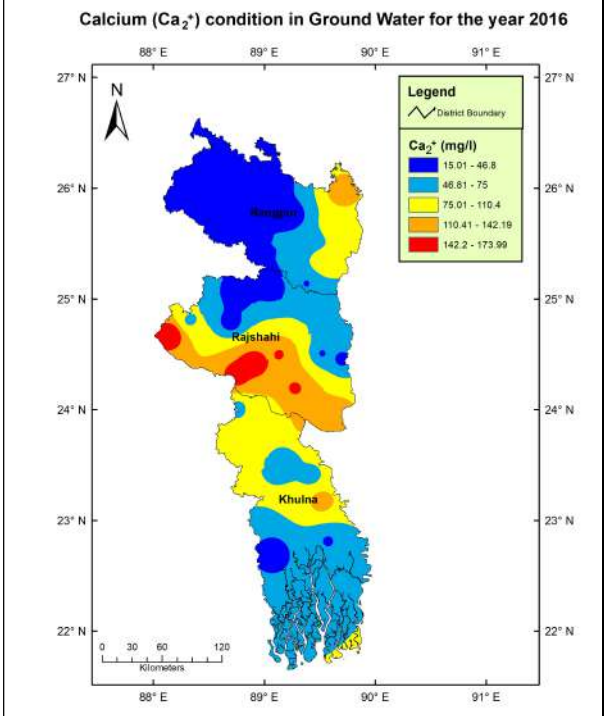


Figure 4.3(iv): Ca_2^+ condition in 2016

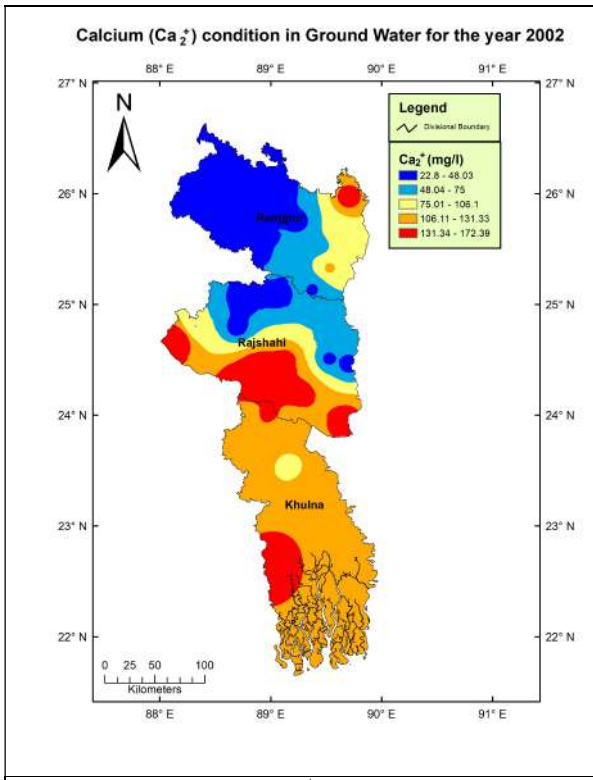


Figure 4.3(v): Ca_2^+ condition in 2002

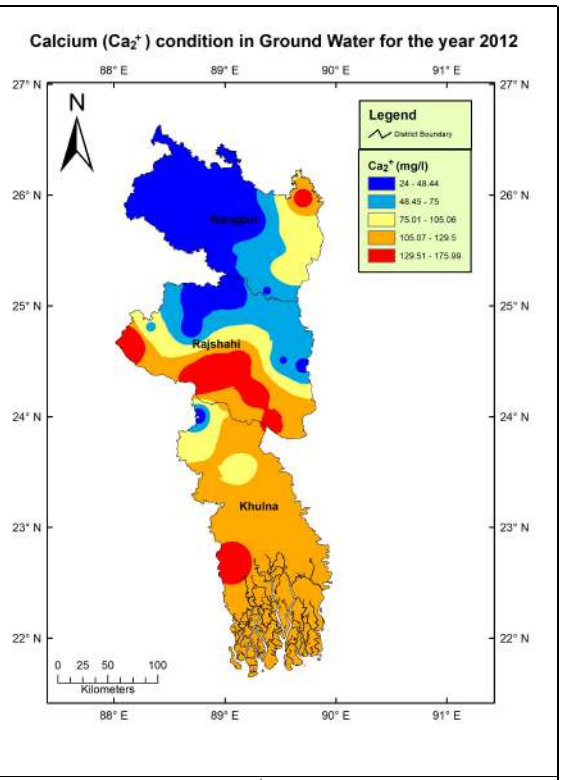
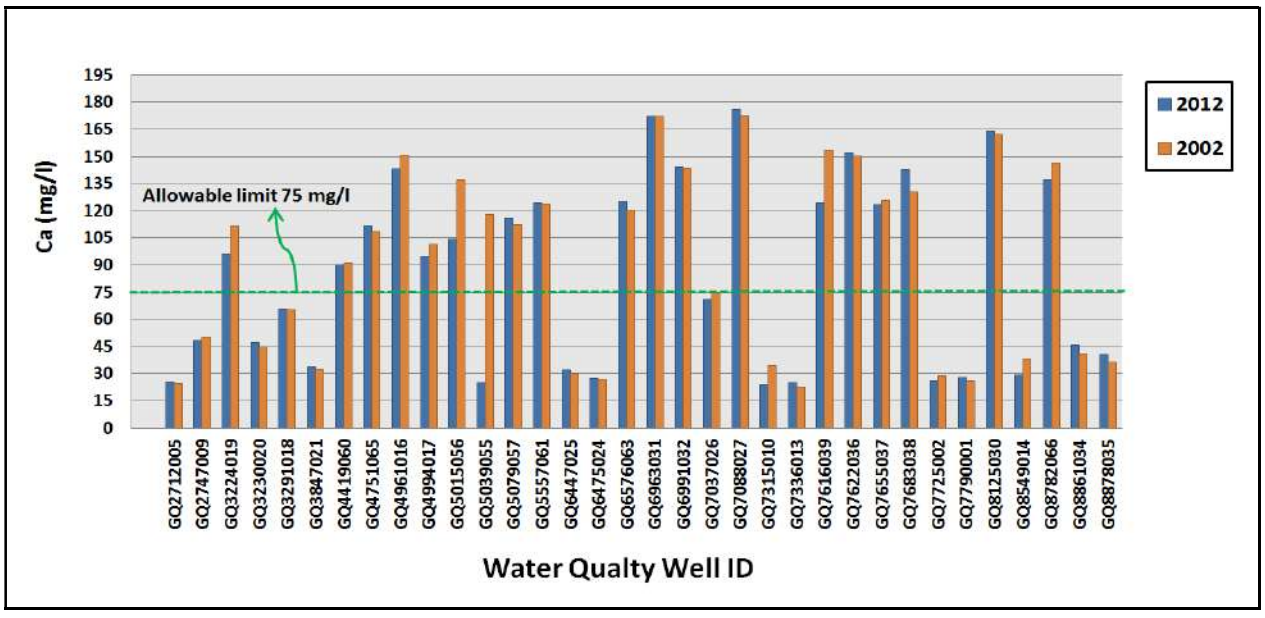


Figure 4.3(vi): Ca_2^+ condition in 2012

Variations in Ca_2^+ condition of ground water in 2002 and 2012 are shown in figures 4.3(v) and 4.3(vi). The same difference is also shown in graph 4.3(b).



Graph 4.3(b): Variation in Ca_2^+ condition of ground water in 2002 and 2012.

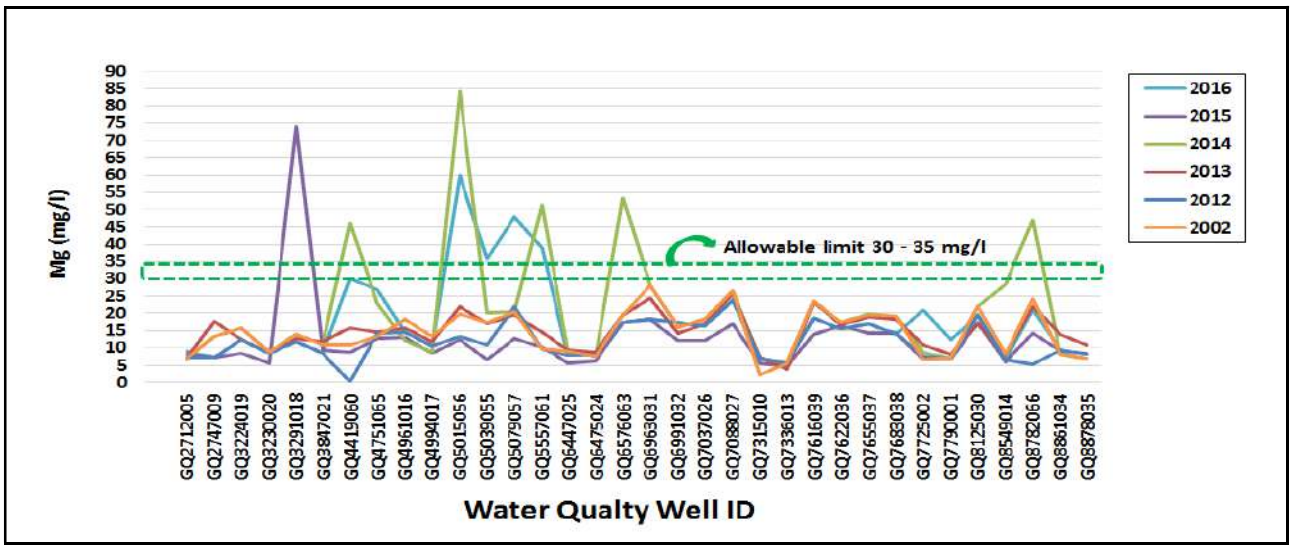
4.4. Magnesium (Mg_2^+):

Like Calcium, Magnesium is abundant and a major dietary requirement for humans (0.3-0.5 g/day). It is the second major constituent of hardness parameter and it generally comprises 15-20 percent of the total hardness expressed as $CaCO_3$. Table 4.4 shows the available Mg_2^+ data of ground water of the reported area in 2002 and 2012 to 2016.

Sl No.	Name of station	WELL ID	2002	2012	2013	2014	2015	2016	Allowable limit (mg/l)
									Bangladesh Standard
1	Birganj	GQ2712005	6.82	7.15	6.82	6.72	8.03	9.00	30-35
2	Hakimpur	GQ2747009	13.40	7.30	17.54	13.40	7.30	7.20	30-35
3	Gaibandha	GQ3224019	15.83	12.55	12.42	15.83	8.52	12.50	30-35
4	Gobindaganj	GQ3230020	8.77	8.45	8.50	8.77	5.60	8.40	30-35
5	Sundarganj	GQ3291018	13.88	11.75	12.91	13.88	74.00	11.70	30-35
6	Joypurhat Sadar	GQ3847021	10.96	8.50	11.97	10.96	9.25	8.50	30-35
7	Jhenaidah Sadar	GQ4419060	10.96	0.45	15.84	46.00	8.67	30.00	30-35
8	Khulna Sadar	GQ4751065	13.43	14.35	14.62	22.80	12.91	27.00	30-35
9	Nageshwari	GQ4961016	18.27	14.56	15.83	12.00	13.15	14.50	30-35
10	Ulipur	GQ4994017	13.40	10.55	11.94	8.64	8.52	10.50	30-35
11	Bheramara	GQ5015056	19.97	13.50	21.92	84.24	12.42	60.00	30-35
12	Daulatpur	GQ5039055	17.50	11.00	17.05	20.16	6.45	36.00	30-35
13	Kushtia Sadar	GQ5079057	20.40	22.15	19.49	20.40	12.91	48.00	30-35
14	Magura Sadar	GQ5557061	9.74	9.80	14.62	51.12	10.23	39.00	30-35
15	Manda	GQ6447025	9.01	7.80	9.50	9.01	5.60	7.75	30-35
16	Patnitala	GQ6475024	7.55	8.25	8.77	7.55	6.33	8.25	30-35
17	Narail Sadar	GQ6576063	19.49	17.29	19.49	53.52	17.29	17.30	30-35
18	Natore Sadar	GQ6963031	28.01	18.25	24.36	28.01	18.45	18.20	30-35
19	Singra	GQ6991032	16.08	17.45	14.37	16.08	12.18	17.45	30-35
20	Gomastapur	GQ7037026	18.27	16.56	17.05	18.27	12.13	16.50	30-35
21	Shibganj	GQ7088027	26.55	23.75	25.58	26.55	17.05	23.70	30-35
22	Domar	GQ7315010	2.28	6.90	7.31	7.06	5.60	6.85	30-35
23	Jaldhaka	GQ7336013	5.60	5.83	3.90	5.60	4.87	5.80	30-35
24	Bera	GQ7616039	23.63	18.65	23.12	23.63	14.13	18.60	30-35
25	Chatmohar	GQ7622036	17.29	15.55	16.81	17.29	16.45	15.50	30-35
26	Pabna Sadar	GQ7655037	19.48	17.05	19.00	19.84	14.37	17.00	30-35
27	Sujanagar	GQ7683038	19.24	14.37	18.27	19.24	14.45	14.00	30-35
28	Boda	GQ7725002	6.58	7.50	10.96	8.64	6.58	21.00	30-35
29	Tentulia	GQ7790001	7.31	6.90	8.28	6.82	6.82	12.50	30-35
30	Charghat	GQ8125030	21.92	19.45	17.05	21.92	17.45	19.40	30-35
31	Rangpur Sadar	GQ8549014	8.28	6.75	8.28	28.32	6.09	6.75	30-35
32	Satkhira Sadar	GQ8782066	24.12	5.44	22.14	46.80	14.37	21.00	30-35
33	Raiganj	GQ8861034	8.28	9.25	14.13	8.28	9.15	9.25	30-35
34	Sirajganj Sadar	GQ8878035	7.06	8.25	10.96	7.06	8.57	8.20	30-35

Table 4.4: Mg_2^+ values of ground water in 2002 and 2012 to 2016.

Many Mg_2^+ values exceed its allowable limit (30 – 35 mg/l) for Bangladesh Standard, which is shown in graph 4.4(a). Areas, where Mg_2^+ values cross the allowable limit, are shown in figures 4.4(i) to 4.4(iv) with yellow, brown and red color.



Graph 4.4(a): Variation in Mg_2^+ condition of the ground water in 2002 and 2012 to 2016.

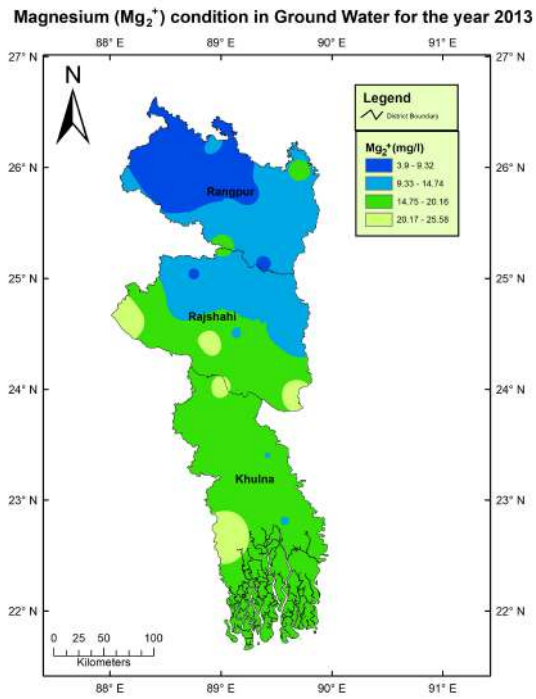


Figure 4.4(i): Mg_2^+ condition in 2013

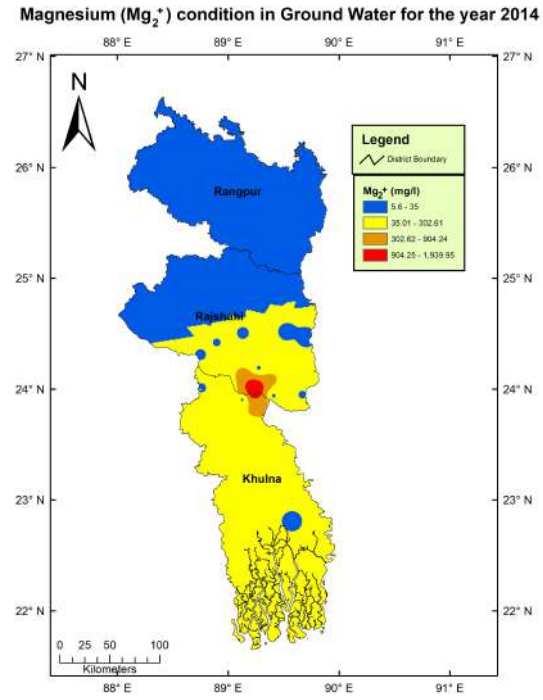


Figure 4.4(ii)**:** Mg_2^+ condition in 2014

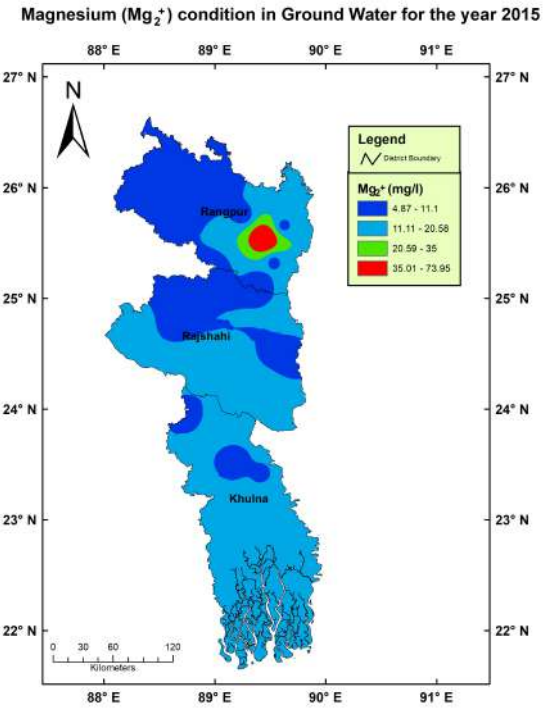


Figure 4.4(iii): Mg_2^+ condition in 2015

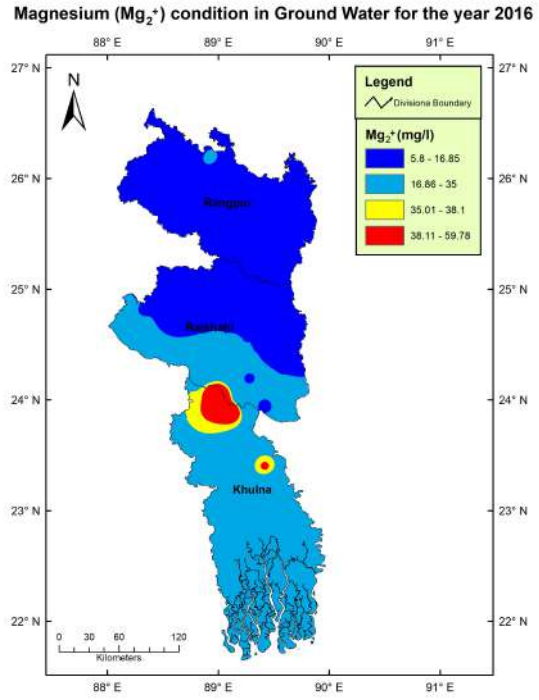


Figure 4.4(iv): Mg_2^+ condition in 2016

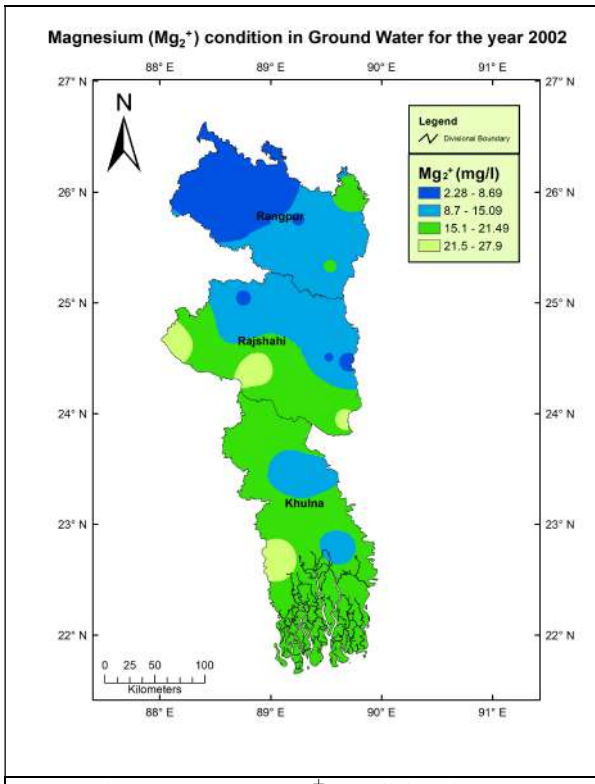


Figure 4.4(v): Mg_2^+ condition in 2002

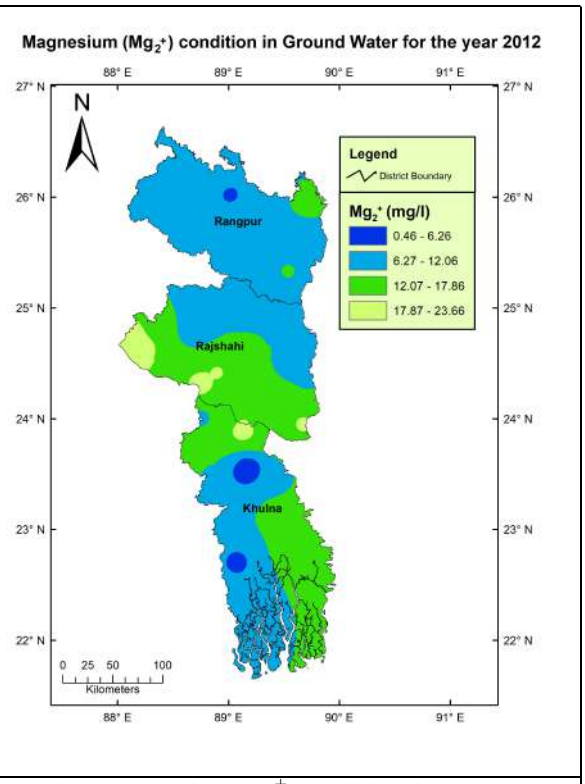
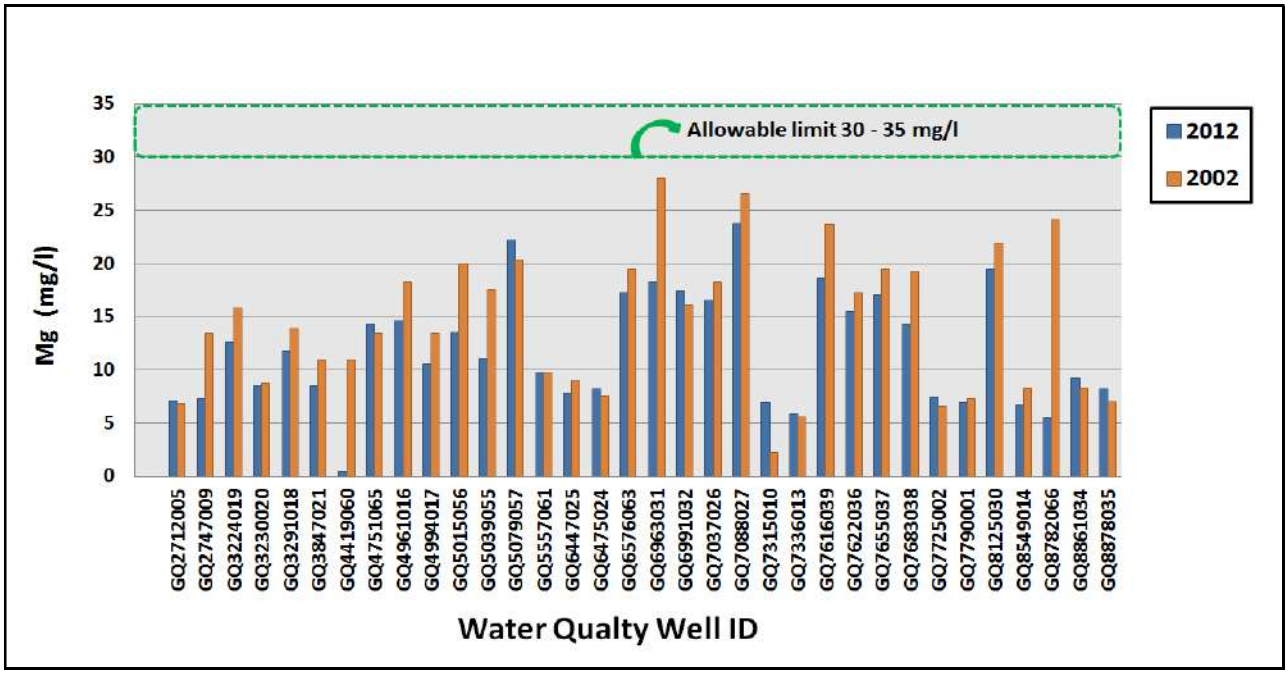


Figure 4.4(vi): Mg_2^+ condition in 2012

Variations in Mg_2^+ condition of ground water in 2002 and 2012 are shown in figures 4.4(v) and 4.4(vi). The same difference is also shown in graph 4.4(b).



Graph 4.4(b): Variation in Mg_2^+ condition of ground water in 2002 and 2012.

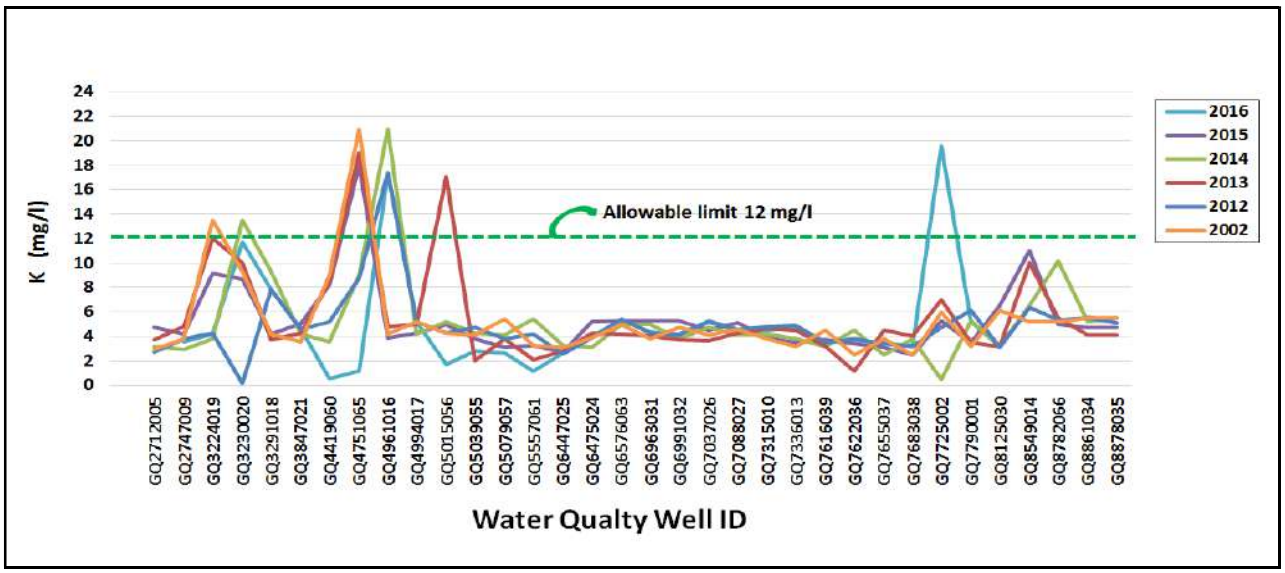
4.5. Potassium (K^+):

Potassium is an essential element in humans and is seldom, if ever, found in drinking water at levels that could be a concern for healthy humans. Table 4.5 shows the available K^+ data of ground water of the reported area in 2002 and 2012 to 2016.

Sl No.	Name of station	WELL ID	2002	2012	2013	2014	2015	2016	Allowable limit (mg/l) Bangladesh Standard
1	Birganj	GQ2712005	2.95	2.75	3.70	3.20	4.75		12
2	Hakimpur	GQ2747009	3.84	3.80	4.80	2.95	4.21	3.60	12
3	Gaibandha	GQ3224019	13.50	4.30	12.00	3.84	9.20	4.20	12
4	Gobindaganj	GQ3230020	9.30	0.15	10.00	13.50	8.70	11.71	12
5	Sundarganj	GQ3291018	4.20	7.84	3.75	9.30	4.20	7.82	12
6	Joypurhat Sadar	GQ3847021	3.60	4.60	4.25	4.20	5.05	4.63	12
7	Jhenaidah Sadar	GQ4419060	9.00	5.22	8.50	3.60	8.23	0.52	12
8	Khulna Sadar	GQ4751065	21.00	8.74	19.00	9.00	18.00	1.13	12
9	Nageshwari	GQ4961016	4.20	17.40	4.80	21.00	3.85	17.30	12
10	Ulipur	GQ4994017	5.20	5.20	5.00	4.20	4.25	5.22	12
11	Bheramara	GQ5015056	4.30	4.25	17.05	5.20	5.00	1.73	12
12	Daulatpur	GQ5039055	4.15	4.75	2.00	4.30	3.80	2.78	12
13	Kushtia Sadar	GQ5079057	5.40	3.80	3.80	4.15	3.08	2.65	12
14	Magura Sadar	GQ5557061	3.25	4.21	2.10	5.40	3.25	1.16	12
15	Manda	GQ6447025	3.10	2.60	2.80	3.25	2.75	2.62	12
16	Patnitala	GQ6475024	3.90	3.90	4.25	3.10	5.23	3.93	12
17	Narail Sadar	GQ6576063	5.00	5.45	4.20	5.00	5.25	5.38	12
18	Natore Sadar	GQ6963031	3.80	4.30	4.00	5.00	5.25	4.33	12
19	Singra	GQ6991032	4.70	4.10	3.70	3.80	5.25	4.16	12
20	Gomastapur	GQ7037026	4.10	5.20	3.65	4.70	4.50	5.25	12
21	Shibganj	GQ7088027	4.60	4.50	4.30	4.10	5.10	4.56	12
22	Domar	GQ7315010	3.79	4.80	4.65	4.20	3.90	4.50	12
23	Jaldhaka	GQ7336013	3.16	4.88	4.50	3.79	3.50	4.70	12
24	Bera	GQ7616039	4.50	3.48	3.20	3.16	3.75	3.50	12
25	Chatmohar	GQ7622036	2.51	3.78	1.20	4.50	3.41	3.72	12
26	Pabna Sadar	GQ7655037	3.80	3.41	4.50	2.51	3.10	3.45	12
27	Sujanagar	GQ7683038	2.50	3.20	4.00	3.80	2.50	3.23	12
28	Boda	GQ7725002	6.00	4.75	7.00	0.50	5.25	19.60	12
29	Tentulia	GQ7790001	3.20	6.10	3.50	5.25	3.50	5.20	12
30	Charghat	GQ8125030	6.10	3.10	3.20	3.20	6.50	3.16	12
31	Rangpur Sadar	GQ8549014	5.20	6.34	10.00	6.50	11.05	6.37	12
32	Satkhira Sadar	GQ8782066	5.20	5.35	5.50	10.15	5.00		12
33	Raiganj	GQ8861034	5.50	5.50	4.13	5.20	4.75	5.56	12
34	Sirajganj Sadar	GQ8878035	5.50	5.10	4.13	5.50	4.75	5.13	12

Table 4.5: K^+ values of ground water in 2002 and 2012 to 2016.

K^+ values of some wells exceed the allowable limit (12 mg/l) for drinking purpose, which can be seen in the graph 4.5(a). Areas, where K^+ values cross the allowable limit, are shown in figures 4.5(i) to 4.5(iv) with yellow and red color.



Graph 4.5(a): Variation in K^+ condition of ground water in 2002 and 2012 to 2016.

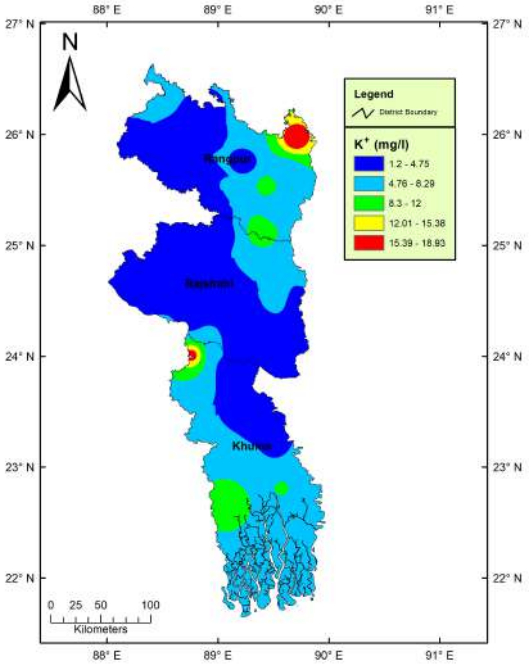


Figure 4.5(i): K^+ condition in 2013

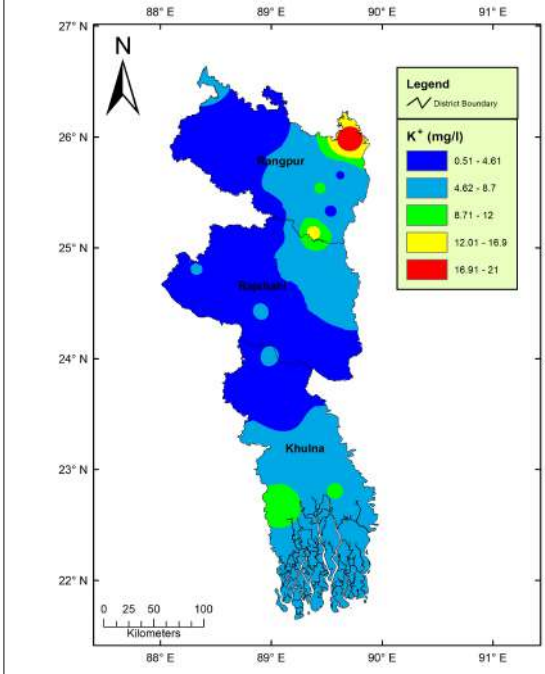


Figure 4.5(ii): K^+ condition in 2014

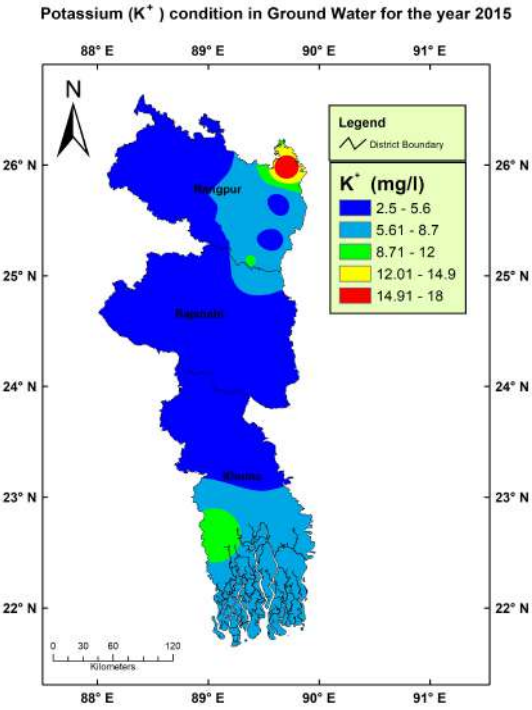


Figure 4.5(iii): K^+ condition in 2015

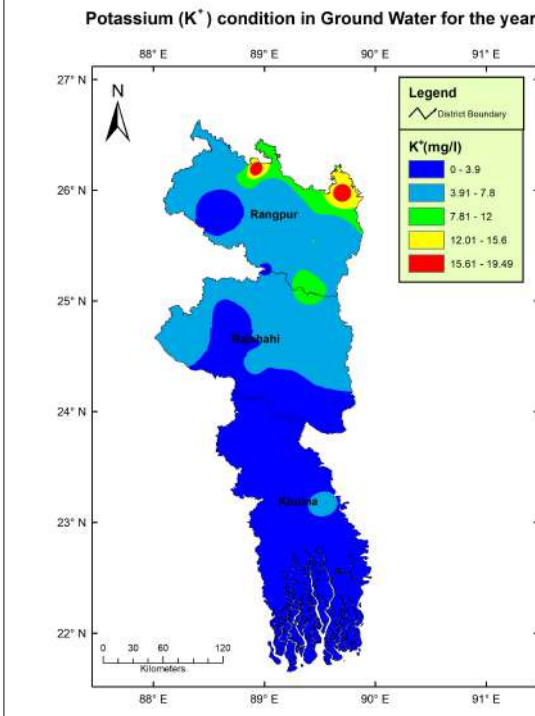


Figure 4.5(iv): K^+ condition in 2016

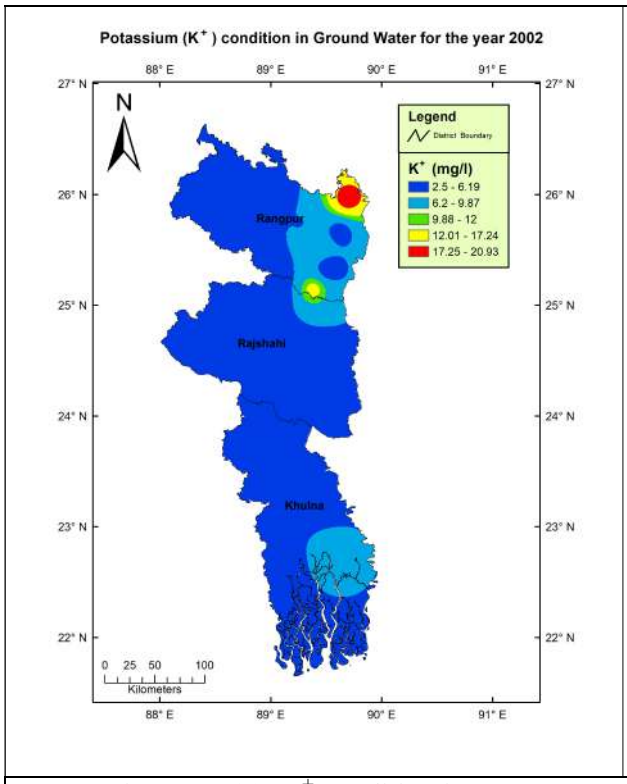


Figure 4.5(v): K^+ condition in 2002

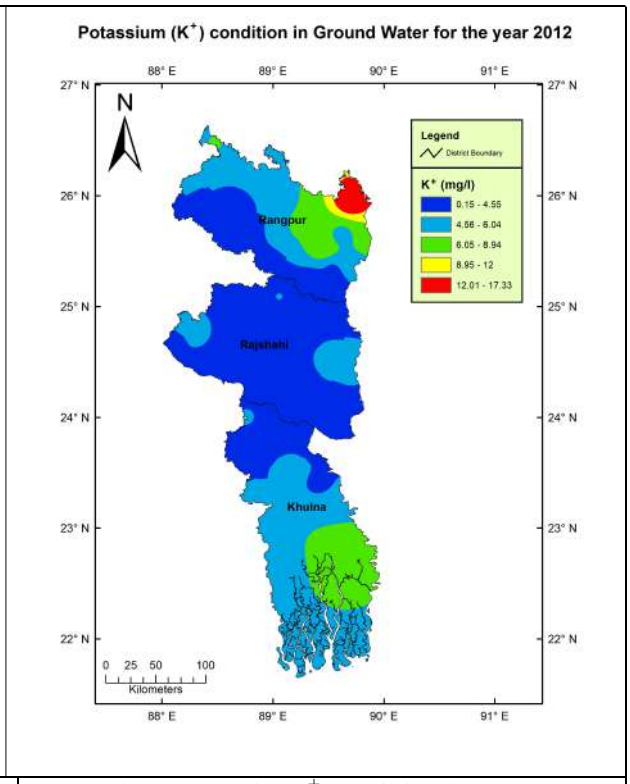
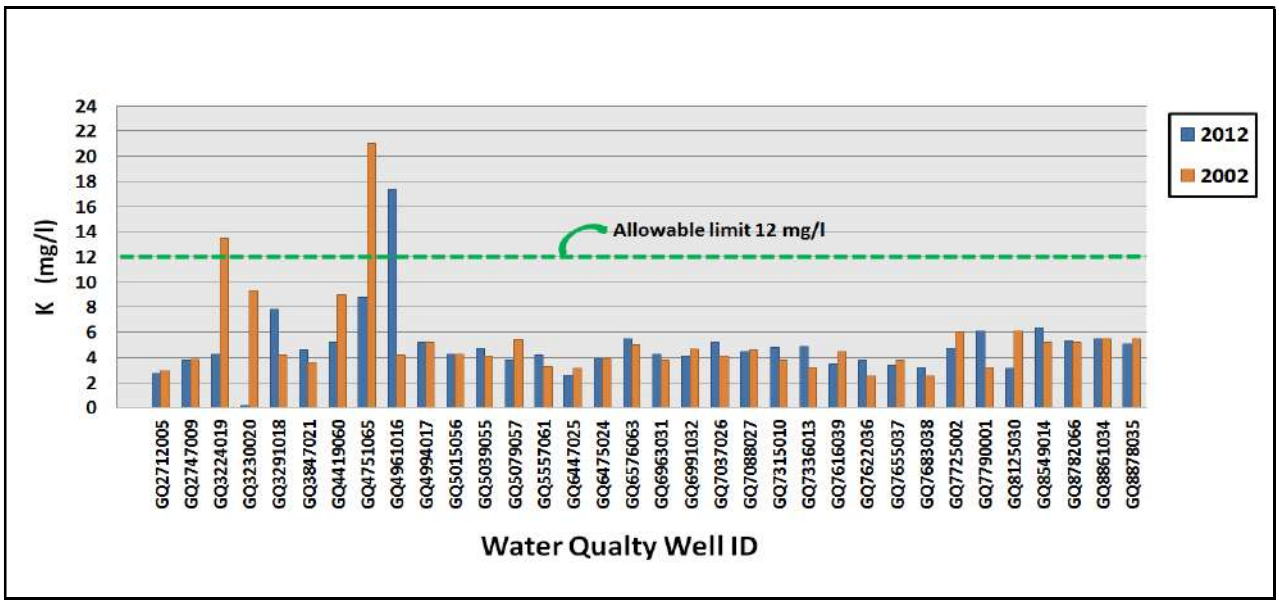


Figure 4.5(vi): K^+ condition in 2012

Differences in K^+ condition of ground water in 2002 and 2012 are shown in figures 4.5(v) and 4.5(vi). The same difference is also shown in graph 4.5(b).



Graph 4.5(b): Variation in K^+ condition of ground water in 2002 and 2012.

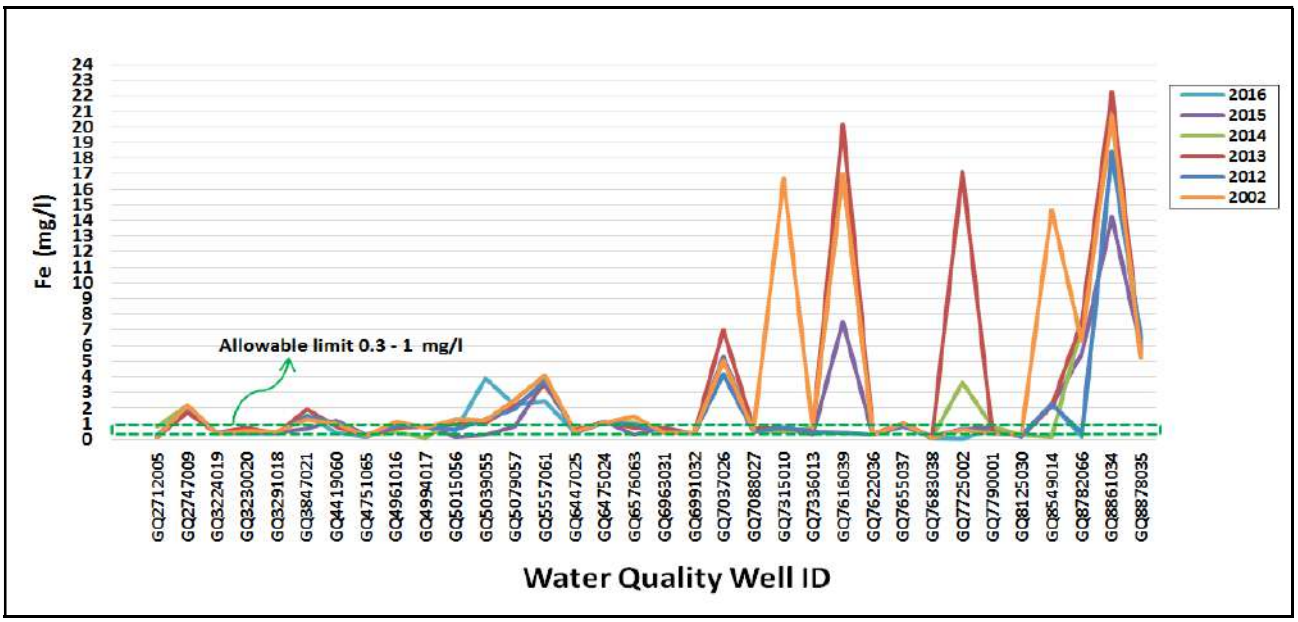
4.6. Iron (Fe):

Iron is present in significant amounts in soils and rocks, principally in insoluble forms. However, many complex reactions which occur naturally in ground formations can give rise to more soluble forms of iron which will therefore be present in water passing through such formations. Appreciable amount of iron may therefore be present in ground water. Table 4.6 shows the available Fe data of ground water of the reported area in 2002 and 2012 to 2016.

Sl No.	Name of station	WELL ID	2002	2012	2013	2014	2015	2016	Allowable limit (mg/l)
									Bangladesh Standard
1	Birganj	GQ2712005	0.14	0.18	0.18	0.82	0.19	0.26	0.3-1.0
2	Hakimpur	GQ2747009	2.20	2.10	1.75	2.20	1.75	2.11	0.3-1.0
3	Gaibandha	GQ3224019	0.35	0.40	0.41	0.35	0.45	0.40	0.3-1.0
4	Gobindaganj	GQ3230020	0.55	0.45	0.75	0.55	0.35	0.43	0.3-1.0
5	Sundarganj	GQ3291018	0.50	0.40	0.38	0.50	0.40	0.40	0.3-1.0
6	Joypurhat Sadar	GQ3847021	1.25	1.50	1.95	1.25	0.70	1.51	0.3-1.0
7	Jhenaidah Sadar	GQ4419060	1.02	1.10	0.84	1.02	1.20	0.39	0.3-1.0
8	Khulna Sadar	GQ4751065	0.25	0.27	0.22	0.25	0.27	0.15	0.3-1.0
9	Nageshwari	GQ4961016	1.15	0.90	0.75	0.48	0.80	0.91	0.3-1.0
10	Ulipur	GQ4994017	0.75	0.80	0.81	0.12	0.80	0.80	0.3-1.0
11	Bheramara	GQ5015056	1.30	0.60	0.95	1.30	0.18	0.58	0.3-1.0
12	Daulatpur	GQ5039055	1.20	1.30	1.10	1.20	0.30	3.93	0.3-1.0
13	Kushtia Sadar	GQ5079057	2.50	1.90	2.10	2.50	0.80	2.22	0.3-1.0
14	Magura Sadar	GQ5557061	4.10	3.75	3.48	4.10	3.70	2.47	0.3-1.0
15	Manda	GQ6447025	0.50	0.45	0.61	0.50	0.55	0.43	0.3-1.0
16	Patnitala	GQ6475024	1.10	1.10	1.10	1.10	1.15	1.08	0.3-1.0
17	Narail Sadar	GQ6576063	1.50	0.95	0.75	1.10	0.30	0.88	0.3-1.0
18	Natore Sadar	GQ6963031	0.40	0.50	0.70	0.40	0.72	0.53	0.3-1.0
19	Singra	GQ6991032	0.45	0.40	0.38	0.45	0.35	0.41	0.3-1.0
20	Gomastapur	GQ7037026	5.00	4.15	7.00	5.00	5.26	4.16	0.3-1.0
21	Shibganj	GQ7088027	0.55	0.50	0.71	0.55	0.57	0.47	0.3-1.0
22	Domar	GQ7315010	16.75	0.75	0.65	0.50	0.78	0.72	0.3-1.0
23	Jaldhaka	GQ7336013	0.75	0.50	0.53	0.75	0.30	0.50	0.3-1.0
24	Bera	GQ7616039	17.00	0.40	20.15	17.00	7.50	0.43	0.3-1.0
25	Chatmohar	GQ7622036	0.30	0.29	0.35	0.30	0.29	0.26	0.3-1.0
26	Pabna Sadar	GQ7655037	1.00	0.90	1.01	1.00	0.80	0.87	0.3-1.0
27	Sujanagar	GQ7683038	0.10	0.10	0.14	0.10	0.20	0.12	0.3-1.0
28	Boda	GQ7725002	0.60	0.65	17.13	3.63	0.60	0.04	0.3-1.0
29	Tentulia	GQ7790001	0.38	0.40	0.39	0.80	0.80	0.70	0.3-1.0
30	Charghat	GQ8125030	0.30	0.20	0.21	0.30	0.15	0.21	0.3-1.0
31	Rangpur Sadar	GQ8549014	14.70	2.25	2.14	0.18	2.10	2.26	0.3-1.0
32	Satkhira Sadar	GQ8782066	6.25	0.40	7.55	7.20	5.50	0.13	0.3-1.0
33	Raiganj	GQ8861034	20.75	18.45	22.25	20.75	14.25	18.20	0.3-1.0
34	Sirajganj Sadar	GQ8878035	5.25	6.50	5.45	5.25	5.80	6.22	0.3-1.0

Table 4.6: Fe values of ground water in 2002 and 2012 to 2016.

Many of the Fe values exceed its maximum allowable limit (0.3 – 1.00 mg/l), which is shown in graph 4.6(a). These exceeding conditions are shown in figures 4.6(i) to 4.6(iv) with yellow, orange and red colors.



Graph 4.6(a): Variation in Fe condition of ground water in 2002 and 2012 to 2016.

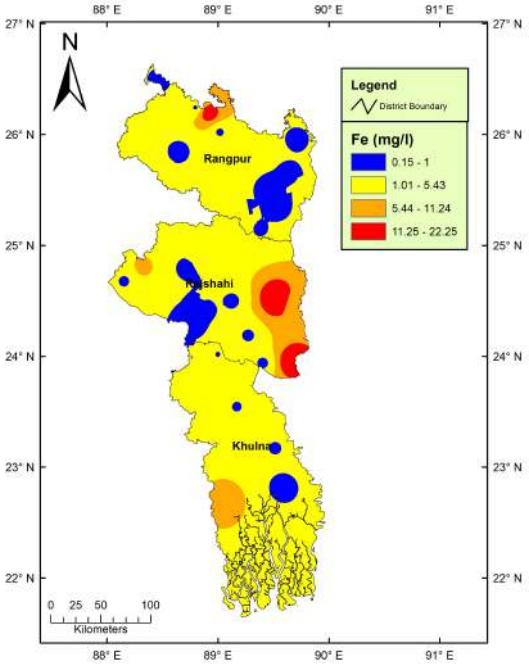


Figure 4.6(i): Fe condition in 2013

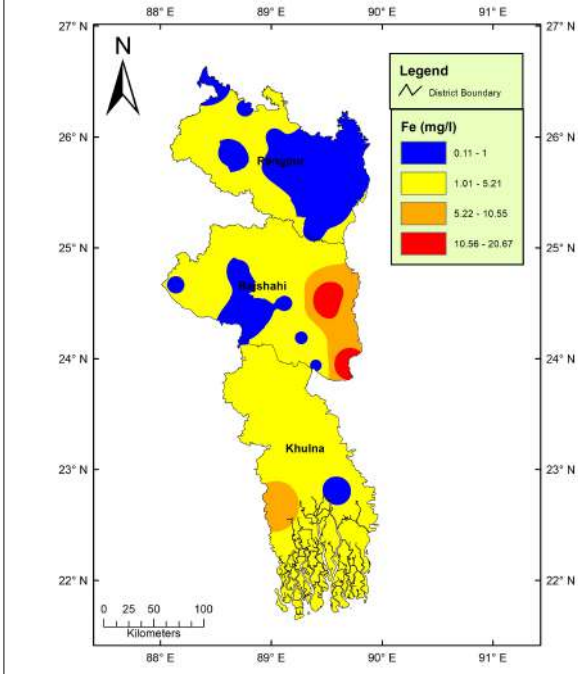


Figure 4.6(ii): Fe condition in 2014

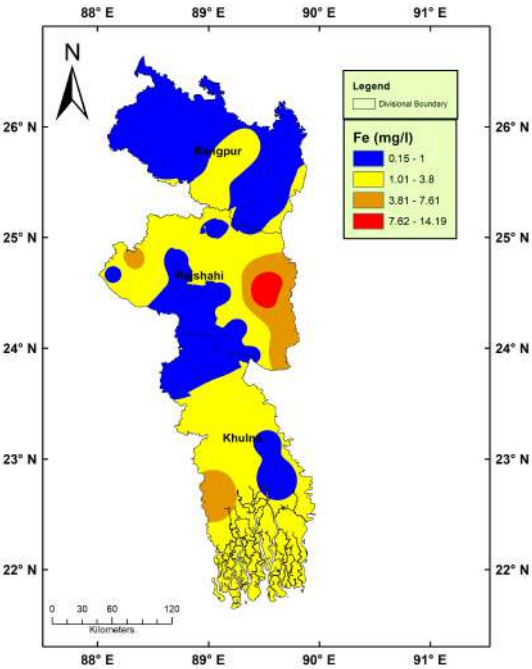


Figure 4.6(iii): Fe condition in 2015

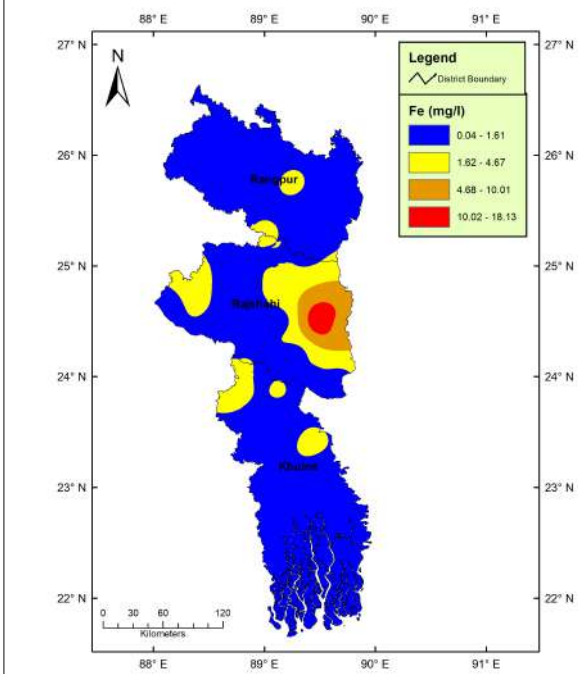


Figure 4.6(iv): Fe condition in 2016

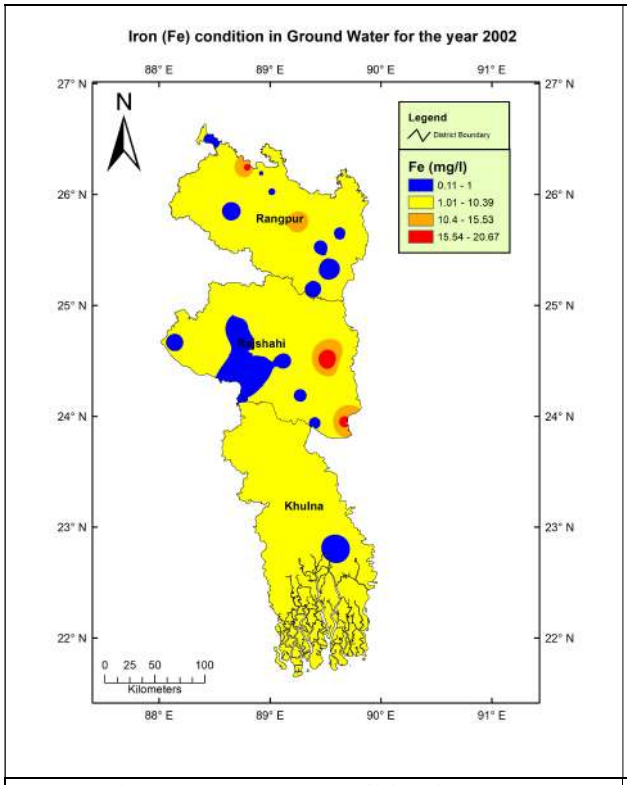


Figure 4.6(v): Fe condition in 2002

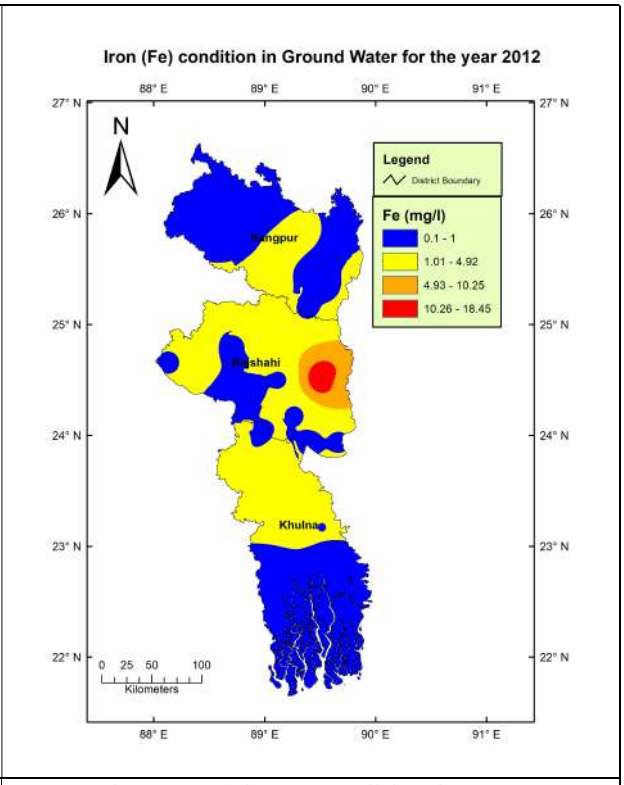
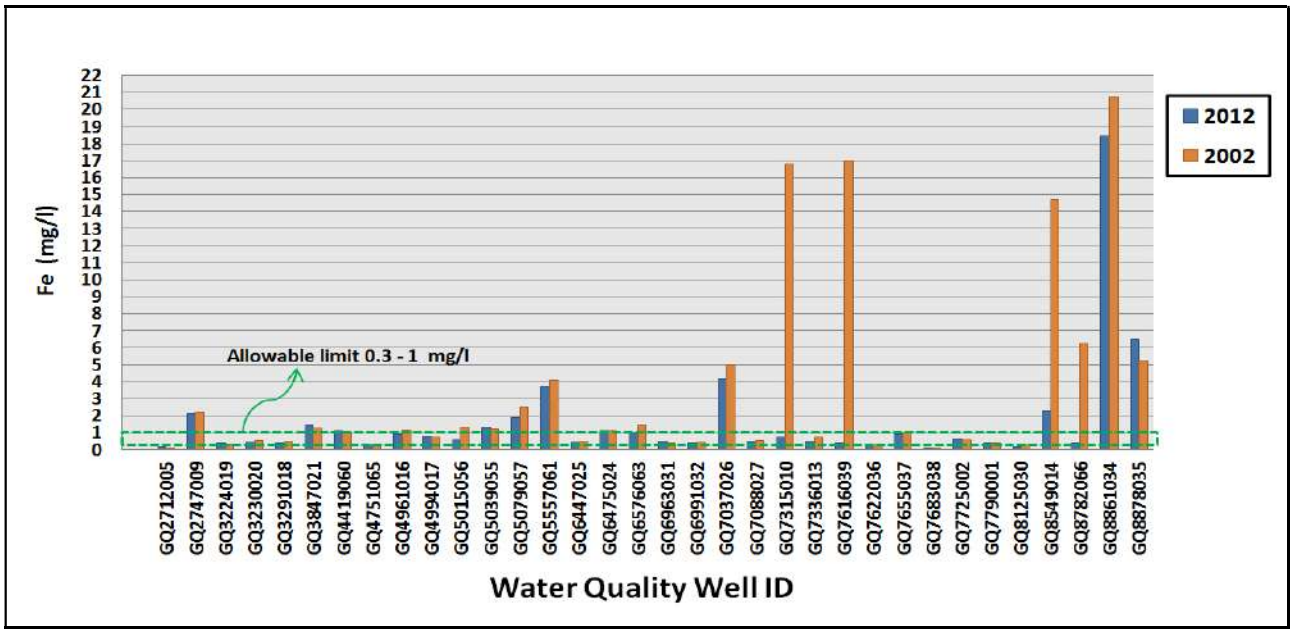


Figure 4.6(vi): Fe condition in 2012

Variations in Fe condition of ground water in 2002 and 2012 are shown in figures 4.6(v) and 4.6(vi). The same difference is also shown in graph 4.6(b).



Graph 4.6(b): Variation in Fe condition of ground water in 2002 and 2012.

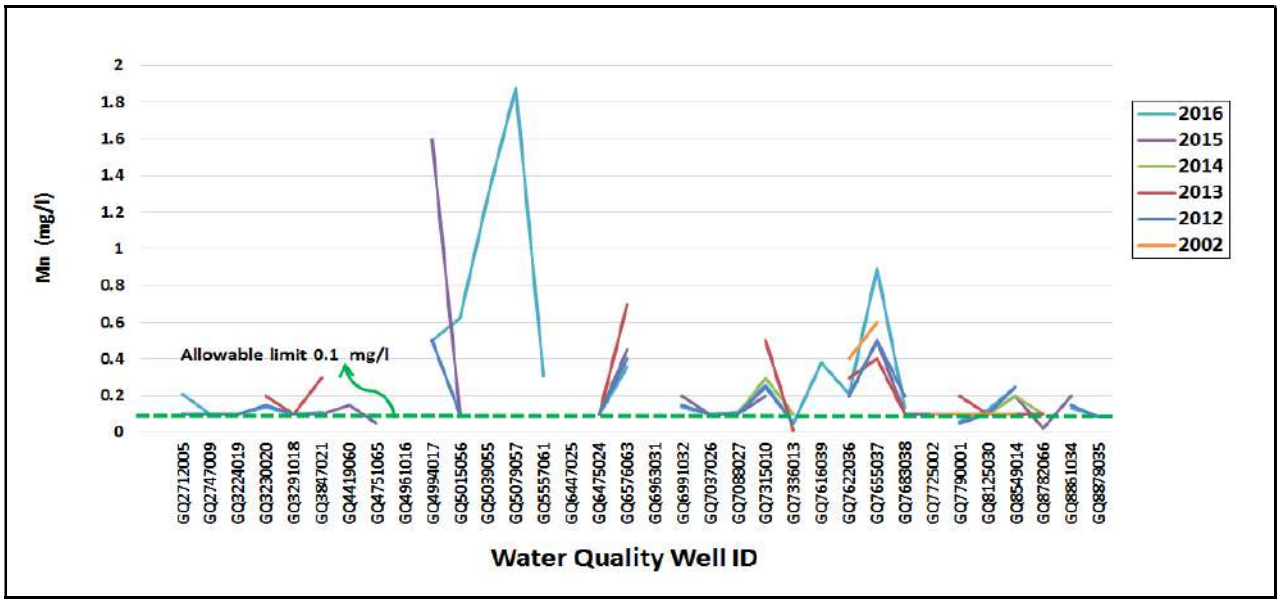
4.7. Manganese (Mn):

As with iron, manganese is found widely in soils and is a constituent of many ground water. The general remarks for iron apply to Mn but the staining problems with this metal may be even more severe, hence the quite stringent limits. A second effect of the presence of manganese much above the limits is an unacceptable taste problem. Available Mn data of ground water of the reported area in 2002 and 2012 to 2016, are given in table 4.7.

Sl No.	Name of station	WELL ID	2002	2012	2013	2014	2015	2016	Allowable limit (mg/l) Bangladesh Standard
1	Birganj	GQ2712005		0.10			0.05	0.21	0.1
2	Hakimpur	GQ2747009	0.10	0.10	0.20	0.10		0.10	0.1
3	Gaibandha	GQ3224019		0.10				0.10	0.1
4	Gobindaganj	GQ3230020	0.20	0.15	0.20	0.20		0.14	0.1
5	Sundarganj	GQ3291018		0.10	0.10		0.10	0.10	0.1
6	Joypurhat Sadar	GQ3847021	0.20	0.10	0.30	0.20	0.10	0.11	0.1
7	Jhenaidah Sadar	GQ4419060					0.15		0.1
8	Khulna Sadar	GQ4751065					0.05		0.1
9	Nageshwari	GQ4961016							0.1
10	Ulipur	GQ4994017	0.30	0.50	0.20	0.30	1.60	0.50	0.1
11	Bheramara	GQ5015056		0.10			0.10	0.62	0.1
12	Daulatpur	GQ5039055						1.29	0.1
13	Kushtia Sadar	GQ5079057						1.88	0.1
14	Magura Sadar	GQ5557061	0.20	0.30	0.20	0.20	0.47	0.31	0.1
15	Manda	GQ6447025							0.1
16	Patnitala	GQ6475024		0.10	0.10		0.10	0.10	0.1
17	Narail Sadar	GQ6576063	0.20	0.40	0.70	0.50	0.45	0.36	0.1
18	Natore Sadar	GQ6963031							0.1
19	Singra	GQ6991032	0.10	0.15	0.30	0.10	0.20	0.14	0.1
20	Gomastapur	GQ7037026		0.10			0.10	0.10	0.1
21	Shibganj	GQ7088027	0.10	0.10		0.10	0.10	0.11	0.1
22	Domar	GQ7315010		0.25	0.50	0.30	0.20	0.26	0.1
23	Jaldhaka	GQ7336013	0.10	0.05	0.01	0.10		0.05	0.1
24	Bera	GQ7616039						0.38	0.1
25	Chatmohar	GQ7622036	0.40	0.20	0.30	0.40	0.20	0.21	0.1
26	Pabna Sadar	GQ7655037	0.60	0.50	0.40	0.60	0.50	0.89	0.1
27	Sujanagar	GQ7683038		0.20	0.10		0.10	0.13	0.1
28	Boda	GQ7725002	0.10				0.10		0.1
29	Tentulia	GQ7790001	0.10	0.05	0.20	0.10	0.10	0.06	0.1
30	Charghat	GQ8125030	0.10	0.10	0.10	0.10	0.10	0.12	0.1
31	Rangpur Sadar	GQ8549014	0.10	0.25	0.10	0.20	0.20	0.25	0.1
32	Satkhira Sadar	GQ8782066			0.10	0.10	0.02		0.1
33	Raiganj	GQ8861034		0.15			0.20	0.13	0.1
34	Sirajganj Sadar	GQ8878035	0.10	0.08	0.20	0.10		0.09	0.1

Table 4.7: Mn values of ground water in 2002 and 2012 to 2016.

Most of the Mn values exceed the allowable limit (0.10 mg/l) for Bangladesh standard, which is clearly shown in the Graph no. 4.7(a). No data found in 3 wells in Negeshwari, Manda and Natore Sadar, with some scattered data shortages. Areas, where values cross the allowable limit, are shown in figures 4.7(i) to 4.7(iv) with purple, orange and red colors.



Graph 4.7(a): Variation in Mn condition of the ground water in 2002 and 2012 to 2016.

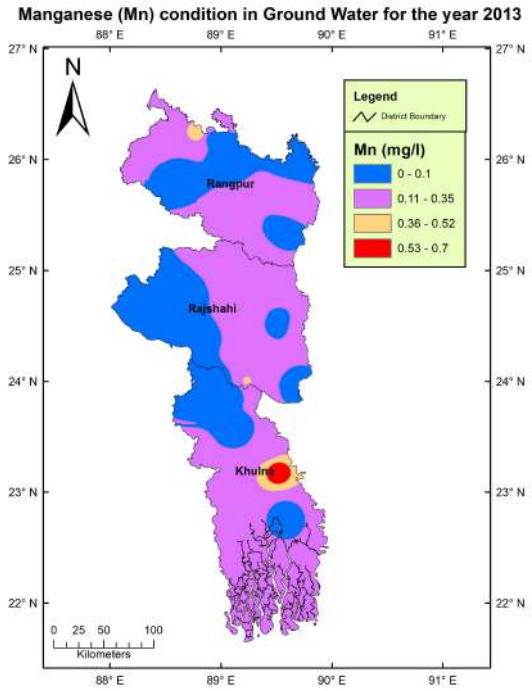


Figure 4.7(i): Mn condition in 2013

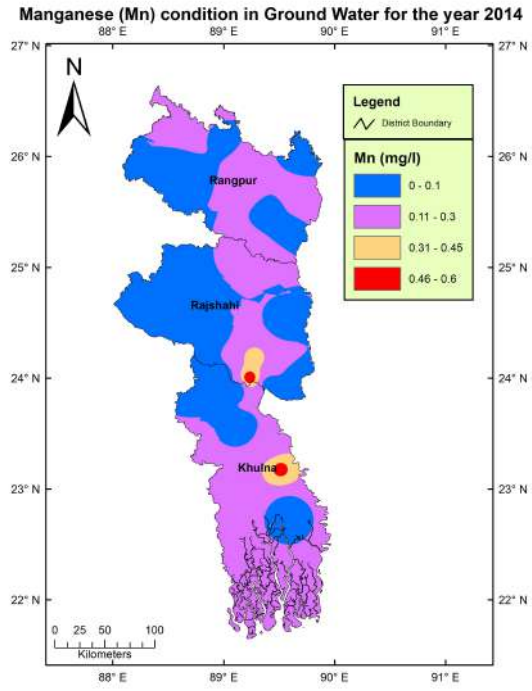


Figure 4.7(ii): Mn condition in 2014

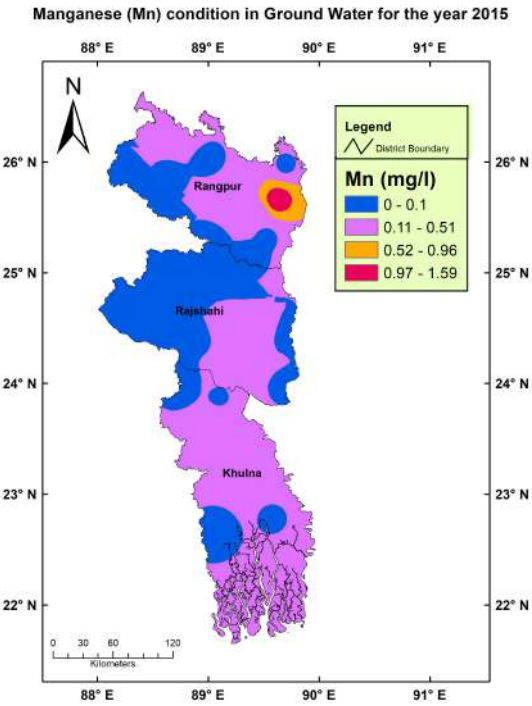


Figure 4.7(iii): Mn condition in 2015

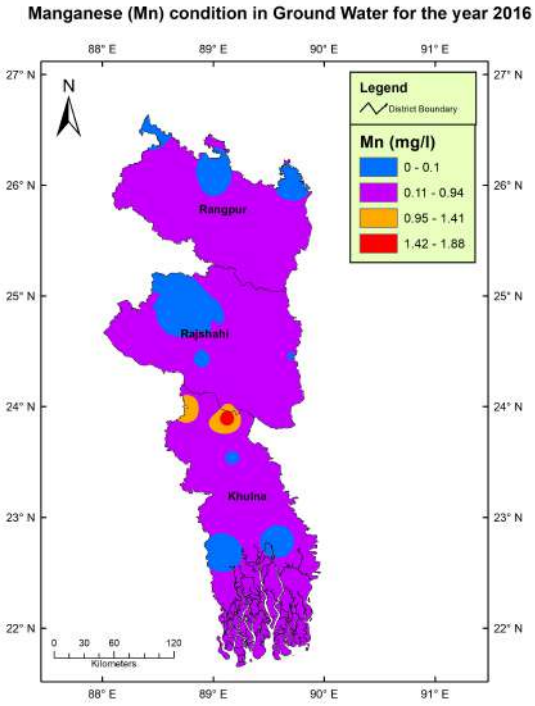


Figure 4.7(iv)**:** Mn condition in 2016

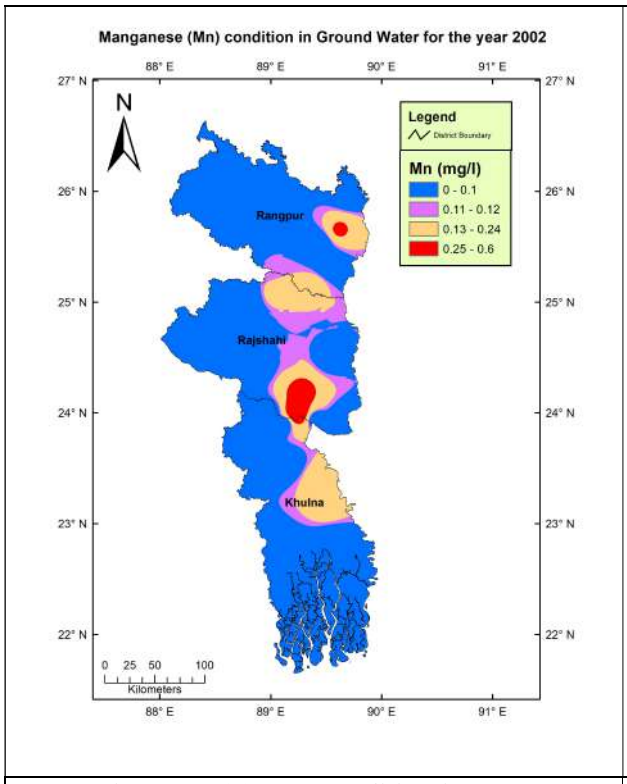


Figure 4.7(v): Mn condition in 2002

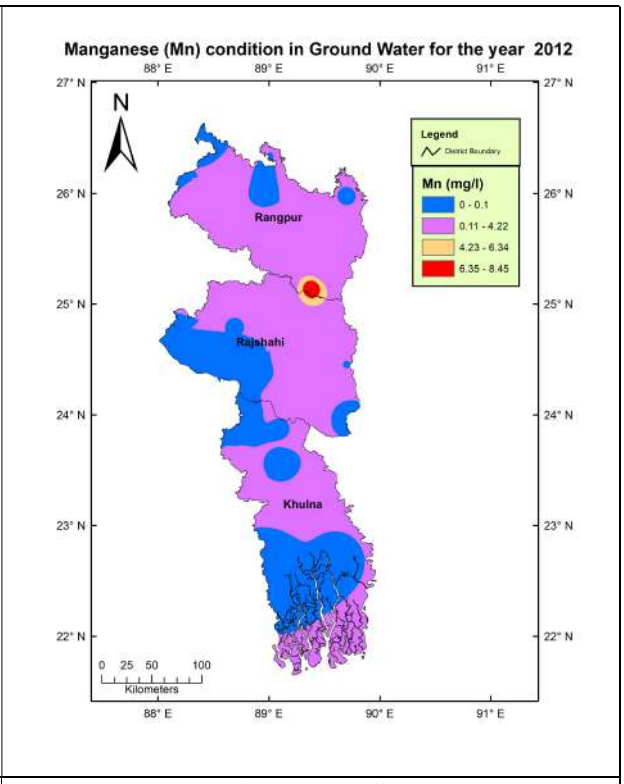
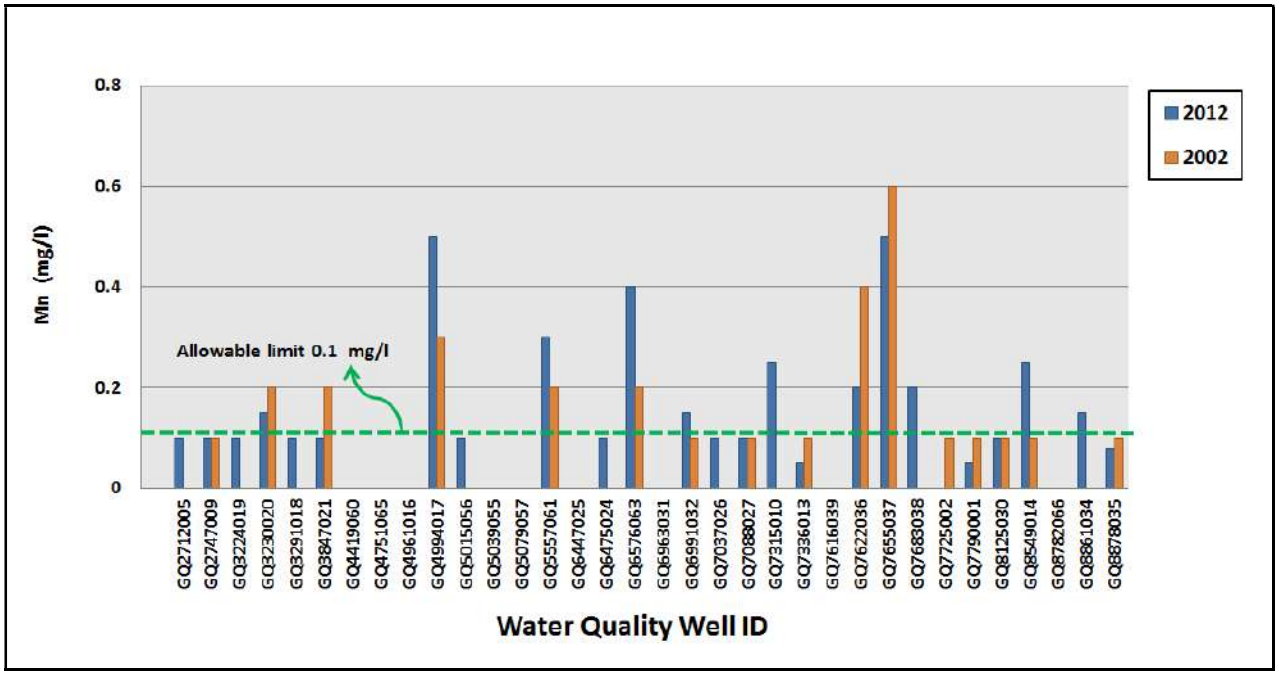


Figure 4.7(vi): Mn condition in 2012

Variations in Mn condition of ground water in 2002 and 2012 are shown in figures 4.7(v) and 4.7(vi). The same difference is also shown in graph 4.7(b).



Graph 4.7(b): Variation in Mn condition of ground water in 2002 and 2012.

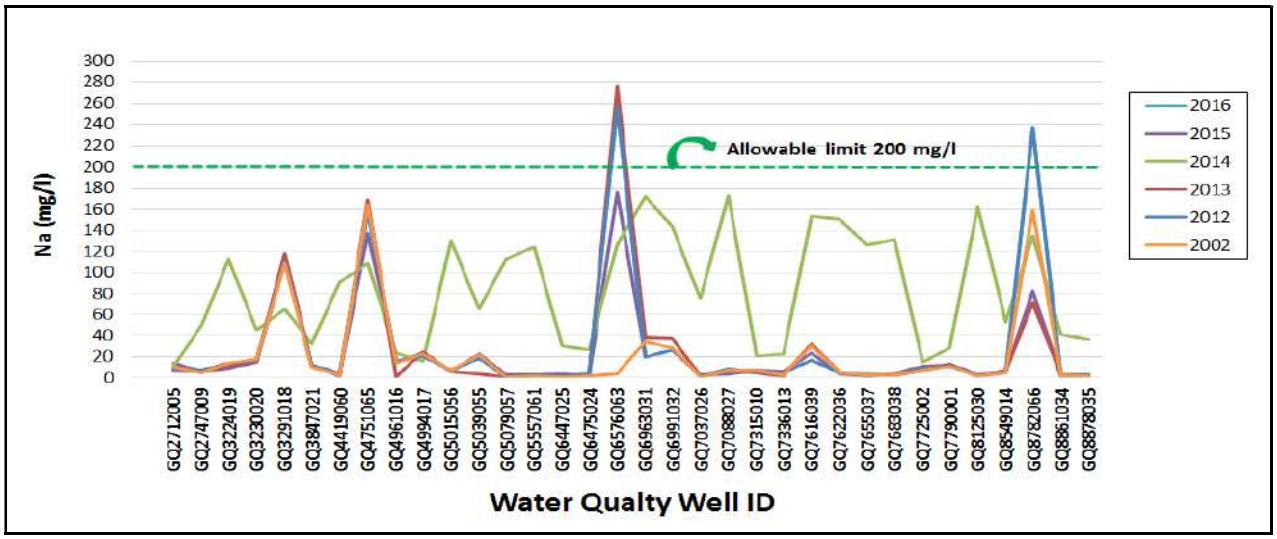
4.8. Sodium (Na^+):

Sodium is always present in most of the natural water. It is also an essential dietary requirement and the normal intake is as common salt (sodium chloride) in food; daily consumption may amount to 5 grams or more. Table 4.8 shows the available Na^+ data of ground water of the reported area in 2002 and 2012 to 2016.

Sl No.	Name of station	WELL_ID	2002	2012	2013	2014	2015	2016	Allowable limit (mg/l)
									Bangladesh Standard
1	Birganj	GQ2712005	9.43	8.08	7.28	11.20	14.00	9.50	200
2	Hakimpur	GQ2747009	5.03	6.57	5.98	50.00	5.52	6.57	200
3	Gaibandha	GQ3224019	13.81	13.85	11.05	112.00	9.10	14.00	200
4	Gobindaganj	GQ3230020	17.68	16.88	16.25	44.80	14.78	17.00	200
5	Sundarganj	GQ3291018	108.55	110.50	117.00	65.20	117.00	111.00	200
6	Joypurhat Sadar	GQ3847021	10.08	11.70	12.03	32.40	12.05	11.50	200
7	Jhenaidah Sadar	GQ4419060	2.73	3.64	2.42	90.80	4.39	3.64	200
8	Khulna Sadar	GQ4751065	163.80	158.00	169.00	108.40	136.50	158.00	200
9	Nageshwari	GQ4961016	13.78	15.78	1.30	24.00	15.06	15.70	200
10	Ulipur	GQ4994017	22.42	20.25	24.05	16.00	23.40	20.25	200
11	Bheramara	GQ5015056	6.83	7.28	5.85	129.60	6.01	7.28	200
12	Daulatpur	GQ5039055	21.45	18.95	3.95	65.60	22.91	18.95	200
13	Kushtia Sadar	GQ5079057	0.78	1.40	0.65	112.40	3.08	1.40	200
14	Magura Sadar	GQ5557061	2.53	2.73	2.47	123.60	3.41	2.73	200
15	Manda	GQ6447025	1.46	2.28	1.79	30.40	4.32	2.28	200
16	Patnitala	GQ6475024	2.47	3.62	2.67	26.80	2.08	3.62	200
17	Narail Sadar	GQ6576063	4.23	256.75	276.25	126.40	175.50	256.75	200
18	Natore Sadar	GQ6963031	34.58	19.99	37.70	172.00	20.80	19.99	200
19	Singra	GQ6991032	28.44	26.65	37.05	143.60		26.65	200
20	Gomastapur	GQ7037026	1.11	1.63	2.28	74.80	3.08	1.63	200
21	Shibganj	GQ7088027	7.14	7.90	6.83	172.40	3.73	7.90	200
22	Domar	GQ7315010	7.35	6.34	5.07	20.40	7.28	6.34	200
23	Jaldhaka	GQ7336013	2.80	4.71	2.28	22.80	5.85	4.71	200
24	Bera	GQ7616039	30.68	16.25	32.50	153.26	23.55	16.25	200
25	Chatmohar	GQ7622036	5.03	4.62	5.20	150.40	3.80	4.62	200
26	Pabna Sadar	GQ7655037	2.73	3.48	2.54	125.60	3.41	3.84	200
27	Sujanagar	GQ7683038	3.41	3.09	3.90	130.40	3.08	3.09	200
28	Boda	GQ7725002	6.63	9.43	11.05	14.40	6.63	10.50	200
29	Tentulia	GQ7790001	10.73	11.09	11.70	28.80	12.39	11.20	200
30	Charghat	GQ8125030	1.95	2.93	1.63	162.00	2.92	2.93	200
31	Rangpur Sadar	GQ8549014	5.00	6.01	6.66	52.80	5.85	6.00	200
32	Satkhira Sadar	GQ8782066	159.25	237.41	71.50	135.20	82.55	237.41	200
33	Raiganj	GQ8861034	2.73	3.35	2.60	41.20	1.95	3.35	200
34	Sirajganj Sadar	GQ8878035	1.95	2.67	2.44	36.40	2.43	2.67	200

Table 4.8: Na^+ values of ground water in 2002 and 2012 to 2016.

Most of the Na^+ values lie within the allowable limit (200 mg/l) for Bangladesh standard, which is clearly shown in the graph 4.8(a). Areas, where values exceed the allowable limit, are shown in figures 4.8(i) to 4.8(iv) with red color.



Graph 4.8(a): Variation in Na^+ condition of the ground water in 2002 and 2012 to 2016.

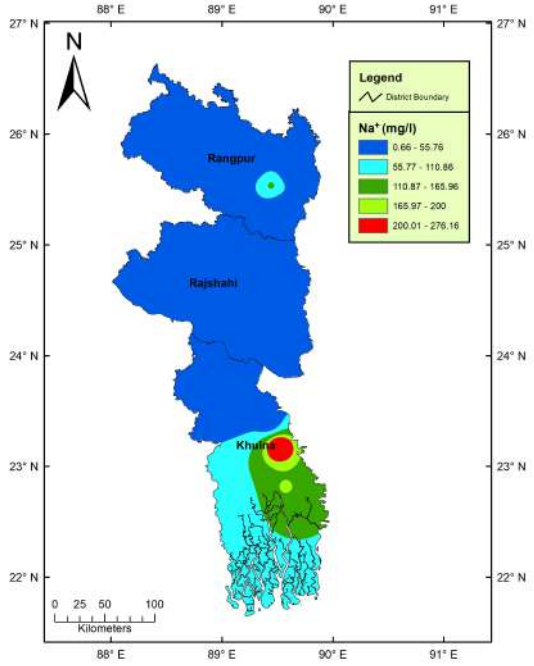


Figure 4.8(i): Na^+ condition in 2013

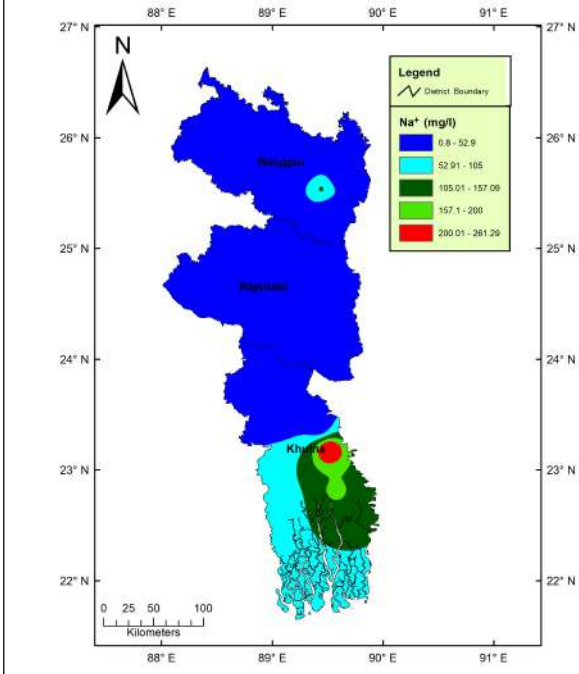


Figure 4.8(ii): Na^+ condition in 2014

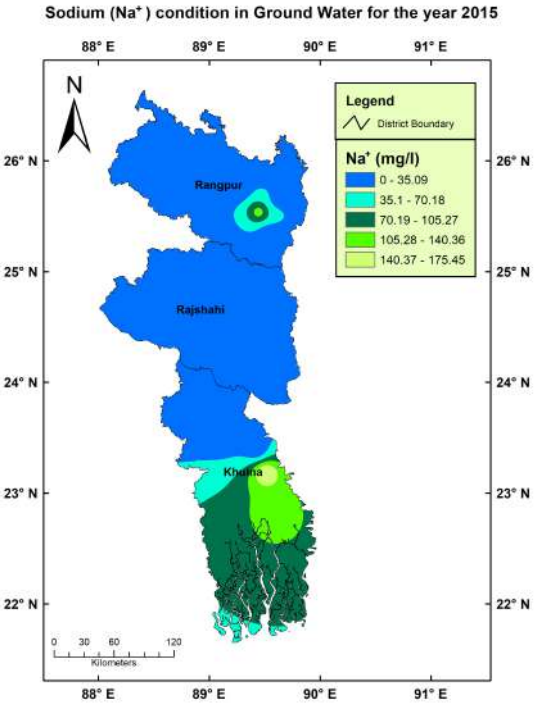


Figure 4.8(iii): Na^+ condition in 2015

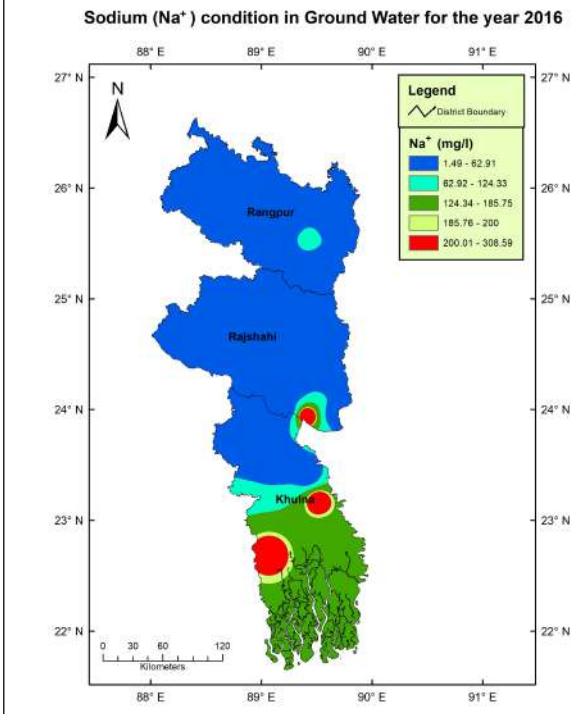


Figure 4.8(iv): Na^+ condition in 2016

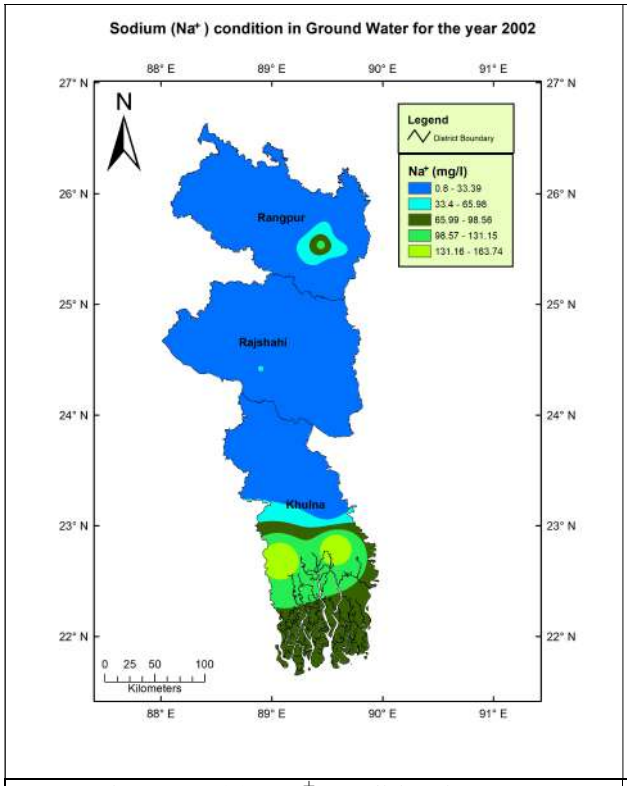


Figure 4.8(v): Na^+ condition in 2002

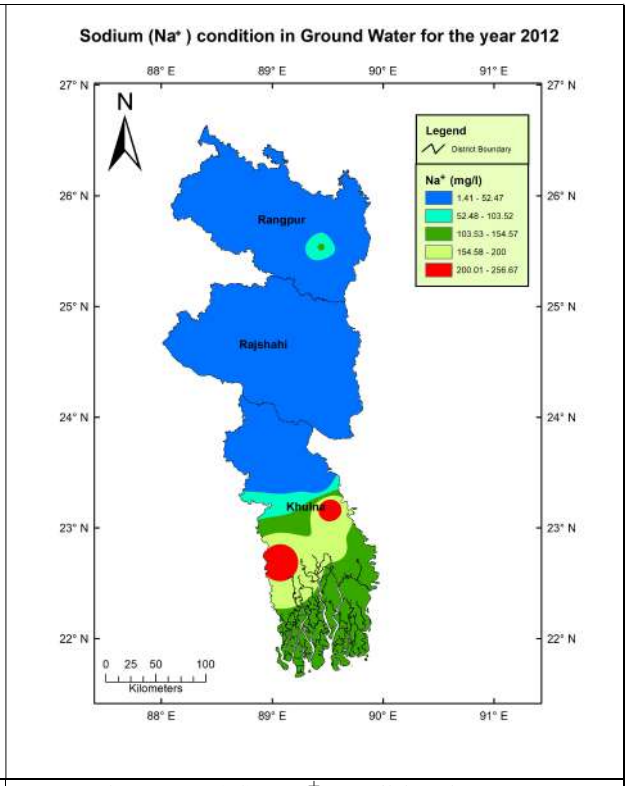
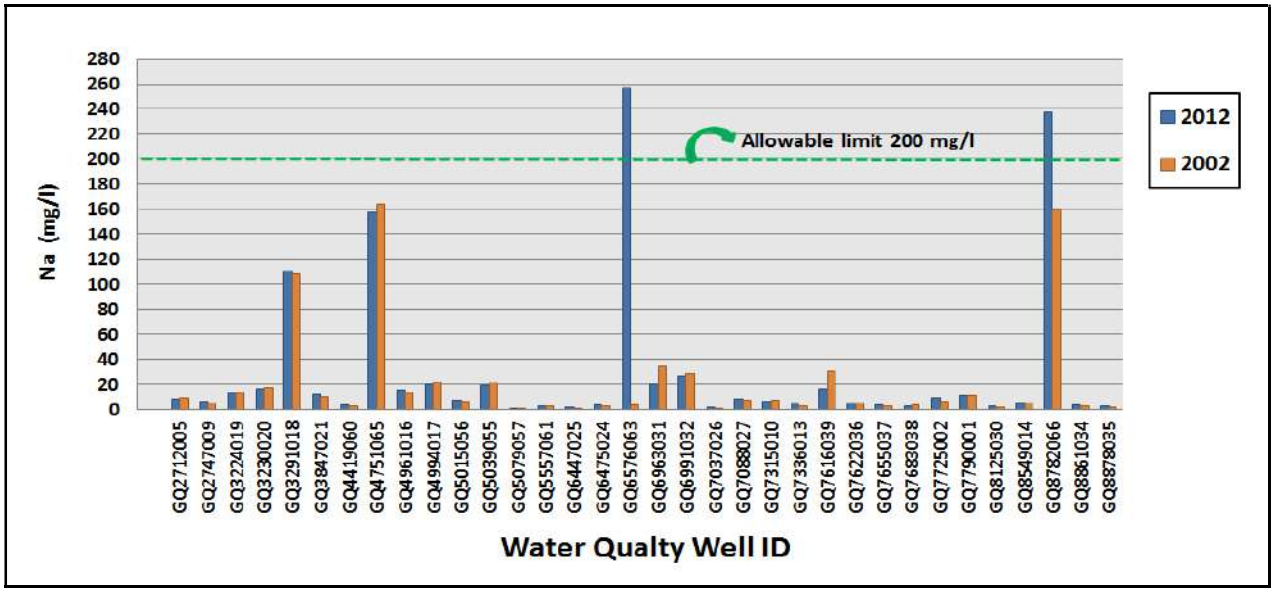


Figure 4.8(vi): Na^+ condition in 2012

Variations in Na^+ condition of ground water in 2002 and 2012 are shown in figures 4.8(v) and 4.8(vi). The same difference is also shown in graph 4.8(b).



Graph 4.8(b): Variation in Na^+ condition of ground water in 2002 and 2012.

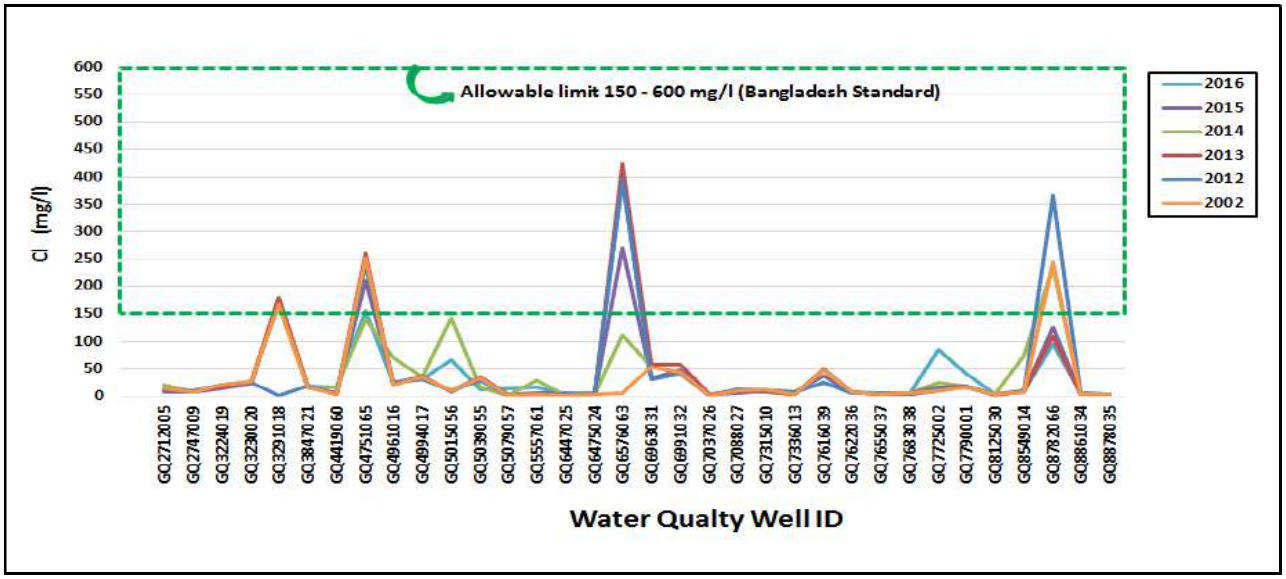
4.9. Chloride (Cl^-):

Chlorine (as chloride) exists in all natural water, the concentrations varying very widely and reaching a maximum in sea water (up to 35,000 mg/l). At levels above 250 mg/l (according to WHO) water will begin to taste salty and will become increasingly objectionable as the concentration rises further. Table 4.9 shows the available Cl^- data of ground water in 2002 and 2012 to 2016 of the reported area.

Sl No.	Name of station	WELL ID	2002	2012	2013	2014	2015	2016	Allowable limit (mg/l)	
									Bangladesh Standard	WHO Standard
1	Birganj	GQ2712005	14.50	12.60	11.20	20.00	9.10	15.00	150-600	250
2	Hakimpur	GQ2747009	7.75	10.10	9.20	7.75	8.50	10.00	150-600	250
3	Gaibandha	GQ3224019	21.25	21.30	17.00	21.52	14.00	21.20	150-600	250
4	Gobindaganj	GQ3230020	27.20	24.75	25.00	27.20	22.75	24.43	150-600	250
5	Sundarganj	GQ3291018	167.00	1.70	180.00	167.00	180.00	172.00	150-600	250
6	Joypurhat Sadar	GQ3847021	15.50	18.00	18.50	15.50	17.25	18.00	150-600	250
7	Jhenaidah Sadar	GQ4419060	4.20	5.60	4.00	16.00	6.77	16.00	150-600	250
8	Khulna Sadar	GQ4751065	252.00	240.00	260.00	140.00	210.08	156.00	150-600	250
9	Nageshwari	GQ4961016	21.20	24.28	20.00	70.00	24.00	24.24	150-600	250
10	Ulipur	GQ4994017	34.50	31.15	37.00	36.00	36.00	30.50	150-600	250
11	Bheramara	GQ5015056	10.50	11.20	9.00	142.00	9.25	67.00	150-600	250
12	Daulatpur	GQ5039055	33.00	29.16	36.00	16.00	35.25	12.00	150-600	250
13	Kushtia Sadar	GQ5079057	1.20	2.15	1.00	1.20	4.75	14.00	150-600	250
14	Magura Sadar	GQ5557061	3.90	4.20	3.80	28.00	5.26	17.00	150-600	250
15	Manda	GQ6447025	2.25	3.50	2.75	2.25	6.80	3.55	150-600	250
16	Patnitala	GQ6475024	3.80	5.57	4.10	3.80	3.25	5.50	150-600	250
17	Narail Sadar	GQ6576063	6.20	395.00	425.00	112.00	270.05	398.00	150-600	250
18	Natore Sadar	GQ6963031	53.20	30.75	58.00	53.20	32.15	30.75	150-600	250
19	Singra	GQ6991032	43.75	41.00	57.90	43.75	48.15	42.00	150-600	250
20	Gomastapur	GQ7037026	1.70	2.50	3.50	1.70	4.45	2.54	150-600	250
21	Shibganj	GQ7088027	11.00	12.15	10.50	11.00	5.79	12.17	150-600	250
22	Domar	GQ7315010	11.30	9.75	7.80	9.50	11.20	9.55	150-600	250
23	Jaldhaka	GQ7336013	4.30	7.25	3.50	4.30	9.00	7.20	150-600	250
24	Bera	GQ7616039	47.20	25.00	50.00	47.20	36.25	24.00	150-600	250
25	Chatmohar	GQ7622036	7.75	7.10	8.00	7.75	5.85	7.13	150-600	250
26	Pabna Sadar	GQ7655037	4.20	5.15	3.90	4.02	5.25	5.17	150-600	250
27	Sujanagar	GQ7683038	5.25	4.75	6.00	5.25	4.75	4.75	150-600	250
28	Boda	GQ7725002	10.20	14.50	17.00	24.00	10.20	85.00	150-600	250
29	Tentulia	GQ7790001	16.50	17.00	18.00	19.00	19.00	42.00	150-600	250
30	Charghat	GQ8125030	3.00	4.50	2.50	3.00	4.55	4.60	150-600	250
31	Rangpur Sadar	GQ8549014	7.70	9.25	10.25	74.00	9.00	9.27	150-600	250
32	Satkhira Sadar	GQ8782066	245.00	365.25	110.00	236.00	127.07	95.00	150-600	250
33	Raiganj	GQ8861034	4.20	5.15	4.00	4.20	3.45	5.16	150-600	250
34	Sirajganj Sadar	GQ8878035	3.00	4.10	3.75	3.00	3.45	4.11	150-600	250

Table 4.9: Cl^- values of ground water in 2002 and 2012 to 2016.

All the Cl^- values lie within its allowable limit 150 – 600 mg/l for Bangladesh standard, which can be seen in graph 4.9(a). The same scenarios are also shown in figures 4.9(i) to 4.9(iv).



Graph 4.9(a): Difference in Cl^- condition of ground water in 2002 and 2012 to 2016.

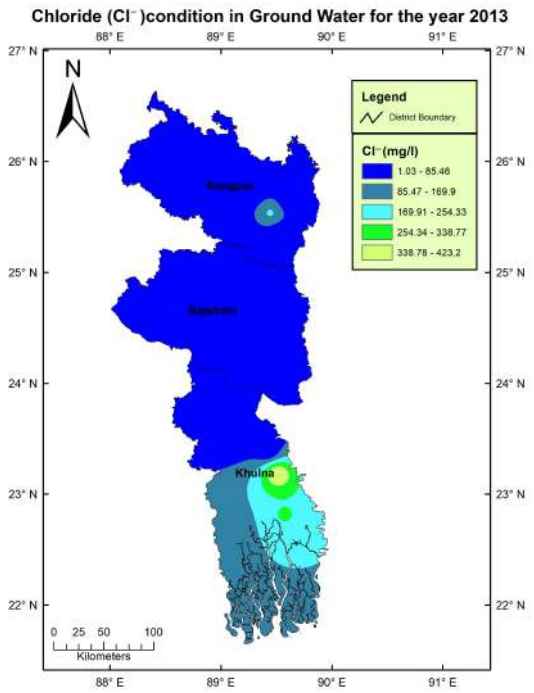


Figure 4.9(i): Cl^- condition in 2013

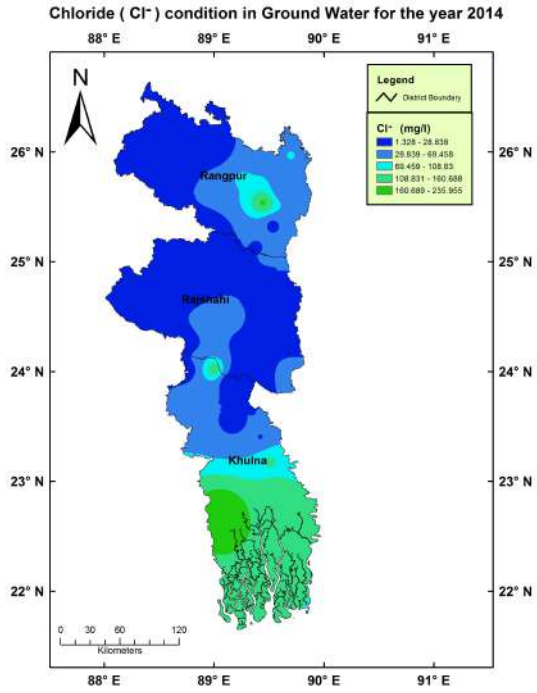


Figure 4.9(ii): Cl^- condition in 2014

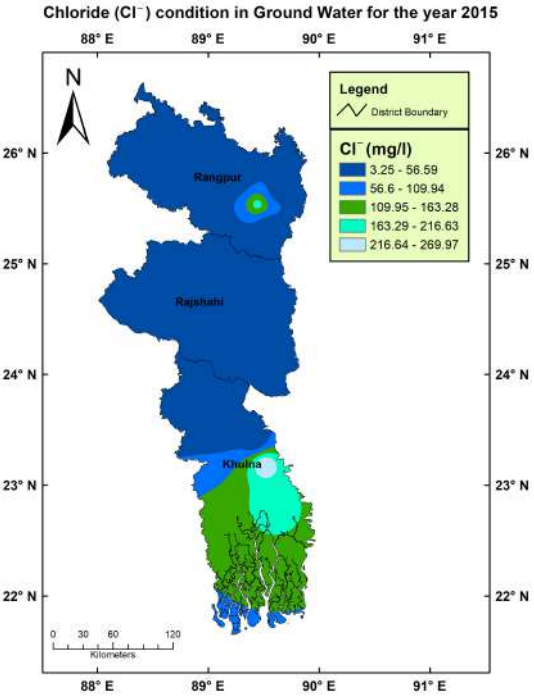


Figure 4.9(iii): Cl^- condition in 2015

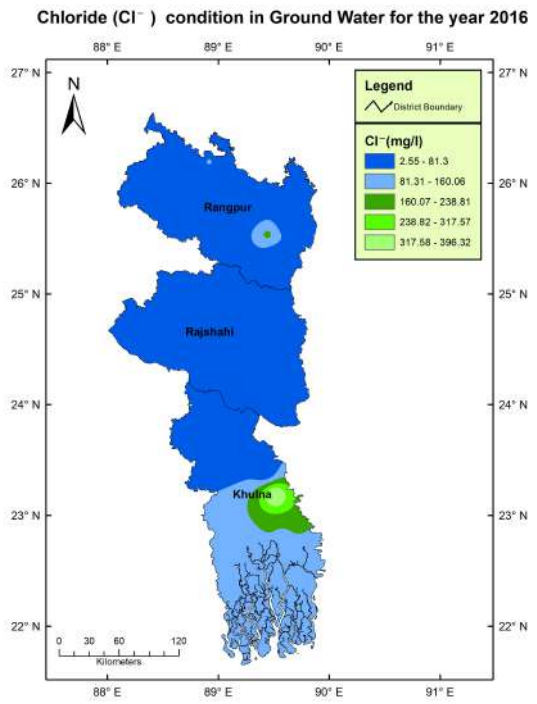


Figure 4.9(iv): Cl^- condition in 2016

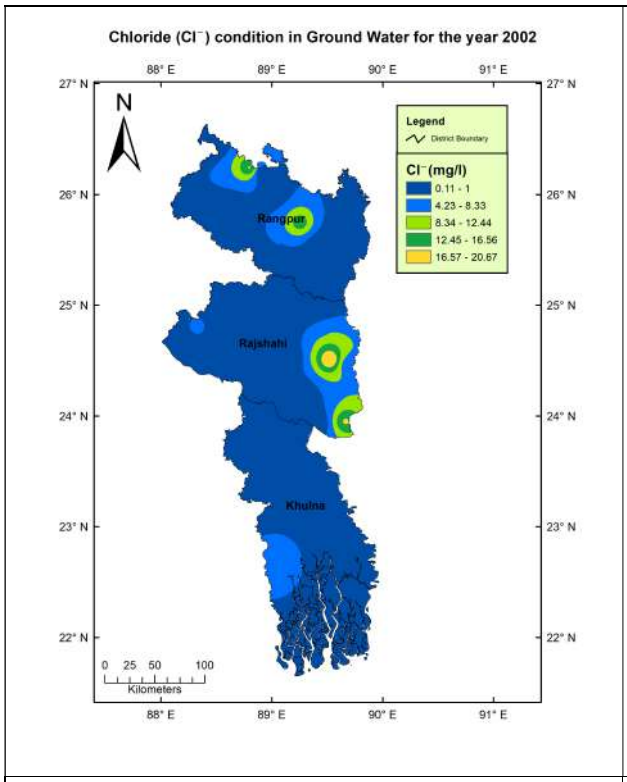


Figure 4.9(v): Cl^- condition in 2002

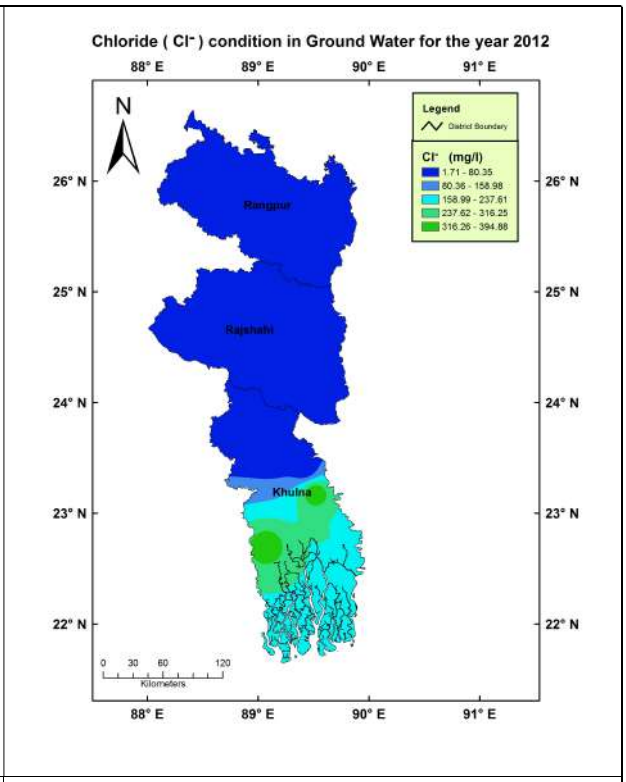
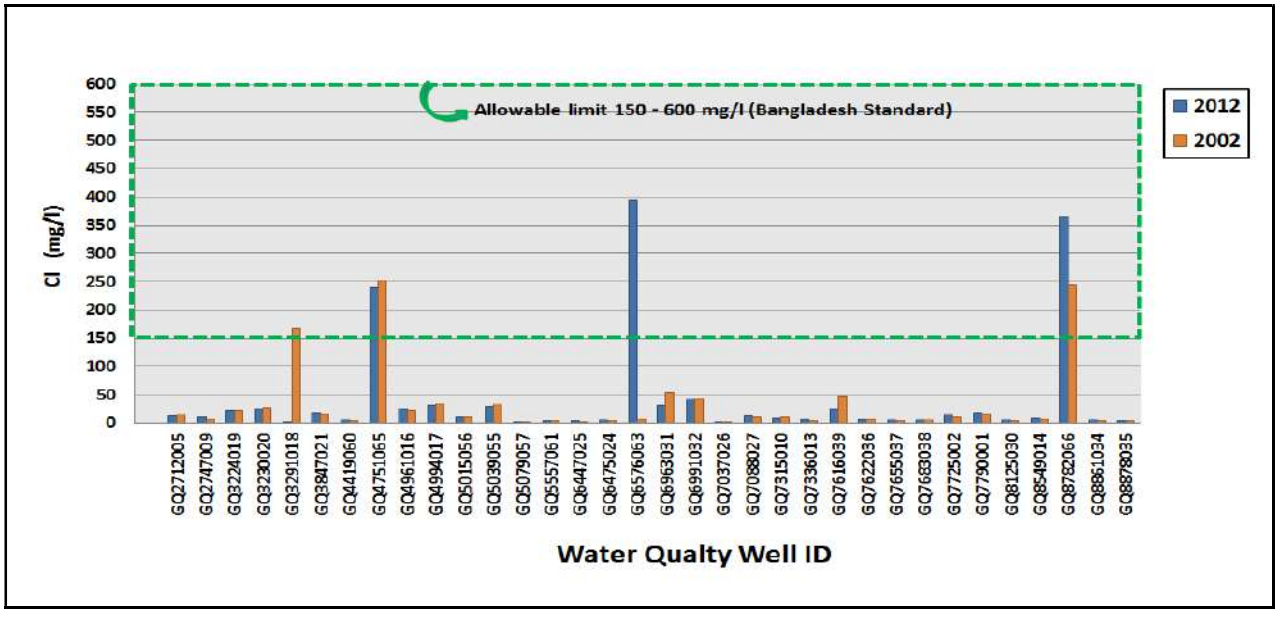


Figure 4.9(vi): Cl^- condition in 2012

Differences in Cl^- condition of ground water in 2002 and 2012 are shown in figures 4.9(v) and 4.9(vi). The same condition is also shown in graph 4.9(b).



Graph 4.9(b): Difference in Cl^- condition of ground water in 2002 and 2012.

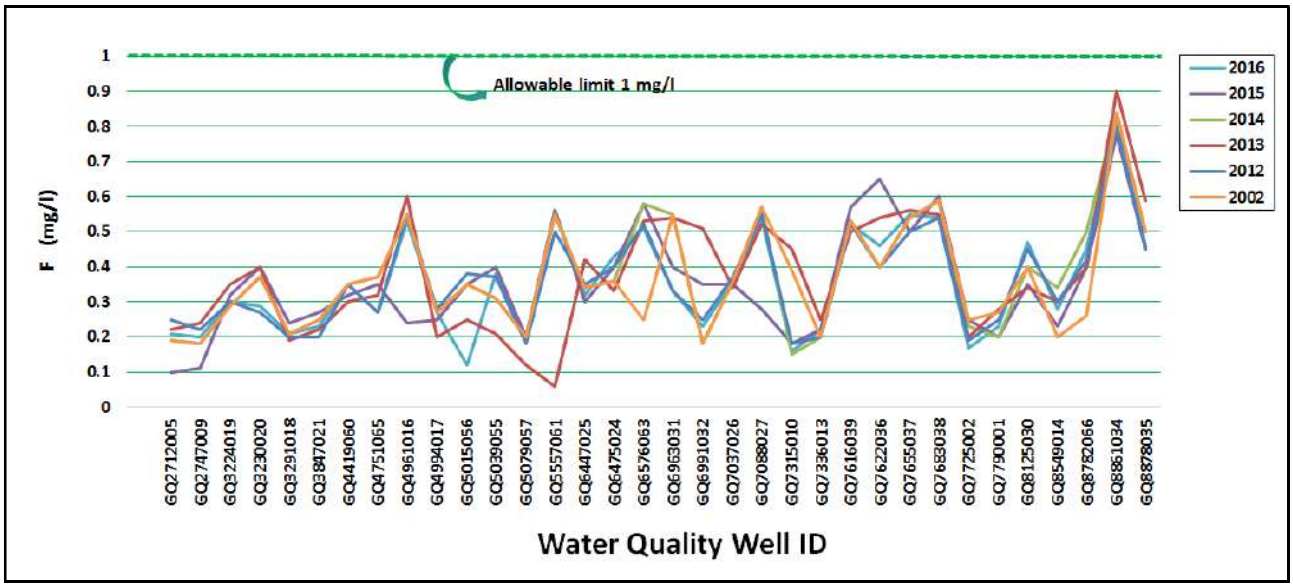
4.10. Fluoride (F^-):

Ground water is the most important source of fluorine intake for human, and fluorine (as F^-) concentration in drinking water is below levels recommended by the WHO (approximately 0.5–1.0 mg/l). Available F^- values of ground water of the reported area in 2002 and 2012 to 2016, are given in the table 4.10.

Sl No.	Name of station	WELL ID	2002	2012	2013	2014	2015	2016	Allowable limit (mg/l) Bangladesh Standard
1	Birganj	GQ2712005	0.19	0.25	0.22	0.19	0.10	0.21	1
2	Hakimpur	GQ2747009	0.18	0.22	0.24	0.18	0.11	0.20	1
3	Gaibandha	GQ3224019	0.29	0.30	0.35	0.29	0.32	0.30	1
4	Gobindaganj	GQ3230020	0.37	0.27	0.40	0.37	0.40	0.29	1
5	Sundarganj	GQ3291018	0.21	0.20	0.19	0.21	0.24	0.21	1
6	Joypurhat Sadar	GQ3847021	0.25	0.20	0.22	0.25	0.27	0.23	1
7	Jhenaidah Sadar	GQ4419060	0.35	0.35	0.30	0.35	0.32	0.35	1
8	Khulna Sadar	GQ4751065	0.37	0.27	0.32	0.37	0.35	0.27	1
9	Nageshwari	GQ4961016	0.55	0.55	0.60	0.55	0.24	0.53	1
10	Ulipur	GQ4994017	0.27	0.28	0.20	0.27	0.25	0.27	1
11	Bheramara	GQ5015056	0.35	0.38	0.25	0.35	0.35	0.12	1
12	Daulatpur	GQ5039055	0.31	0.37	0.21	0.31	0.40	0.38	1
13	Kushtia Sadar	GQ5079057	0.20	0.18	0.12	0.20	0.20	0.19	1
14	Magura Sadar	GQ5557061	0.55	0.50	0.06	0.55	0.56	0.56	1
15	Manda	GQ6447025	0.34	0.35	0.42	0.34	0.30	0.32	1
16	Patnitala	GQ6475024	0.36	0.40	0.33	0.36	0.40	0.43	1
17	Narail Sadar	GQ6576063	0.25	0.52	0.53	0.58	0.58	0.51	1
18	Natore Sadar	GQ6963031	0.55	0.33	0.54	0.55	0.40	0.33	1
19	Singra	GQ6991032	0.18	0.25	0.51	0.18	0.35	0.23	1
20	Gomastapur	GQ7037026	0.36	0.37	0.34	0.36	0.35	0.36	1
21	Shibganj	GQ7088027	0.57	0.55	0.52	0.57	0.28	0.54	1
22	Domar	GQ7315010	0.39	0.18	0.45	0.15	0.18	0.16	1
23	Jaldhaka	GQ7336013	0.20	0.20	0.25	0.20	0.22	0.22	1
24	Bera	GQ7616039	0.53	0.52	0.50	0.53	0.57	0.52	1
25	Chatmohar	GQ7622036	0.40	0.40	0.54	0.40	0.65	0.46	1
26	Pabna Sadar	GQ7655037	0.54	0.50	0.56	0.54	0.50	0.55	1
27	Sujanagar	GQ7683038	0.59	0.54	0.55	0.59	0.60	0.54	1
28	Boda	GQ7725002	0.25	0.19	0.20	0.23	0.25	0.17	1
29	Tentulia	GQ7790001	0.27	0.25	0.28	0.20	0.20	0.23	1
30	Charghat	GQ8125030	0.40	0.45	0.34	0.40	0.35	0.47	1
31	Rangpur Sadar	GQ8549014	0.20	0.30	0.30	0.34	0.23	0.28	1
32	Satkhira Sadar	GQ8782066	0.26	0.42	0.40	0.50	0.40	0.45	1
33	Raiganj	GQ8861034	0.84	0.80	0.90	0.84	0.78	0.82	1
34	Sirajganj Sadar	GQ8878035	0.50	0.45	0.59	0.50	0.45	0.46	1

Table 4.10: F^- values of ground water in 2002 and 2012 to 2016.

All the F^- values lie within the allowable limit (1 mg/l) for Bangladesh standard, which can be clearly seen in graph 4.10(a). The same scenarios are also shown in figures 4.10(i) to 4.10(iv).



Graph 4.10(a): Difference in F^- condition of the ground water in 2002 and 2012 to 2016.

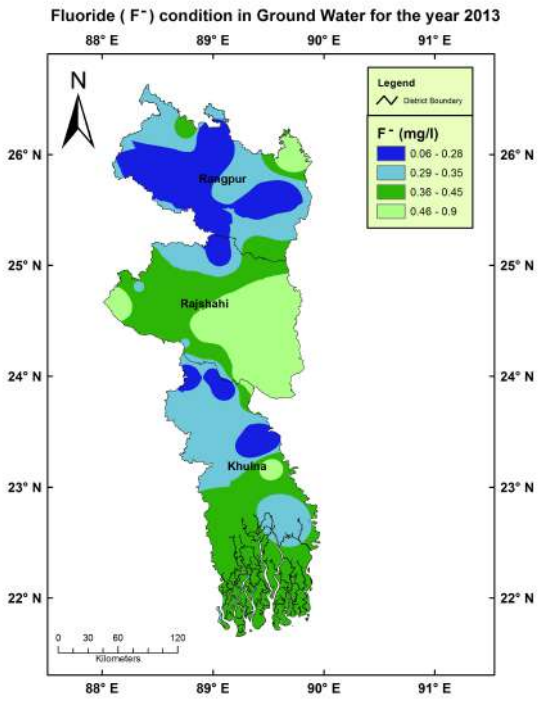


Figure 4.10(v): F⁻ condition in 2013

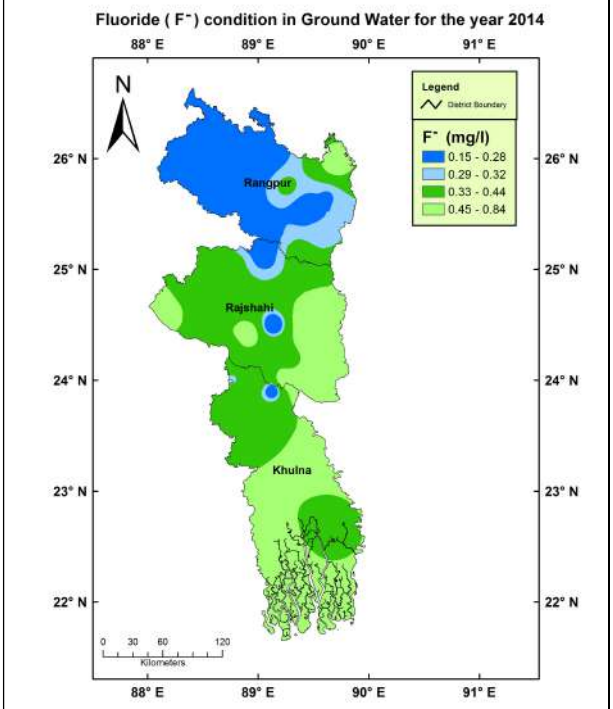


Figure 4.10(v): F⁻ condition in 2014

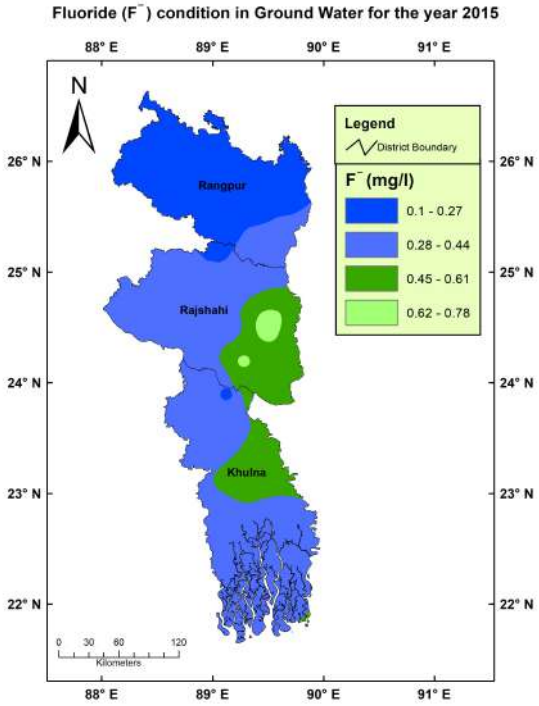


Figure 4.10(v): F⁻ condition in 2015

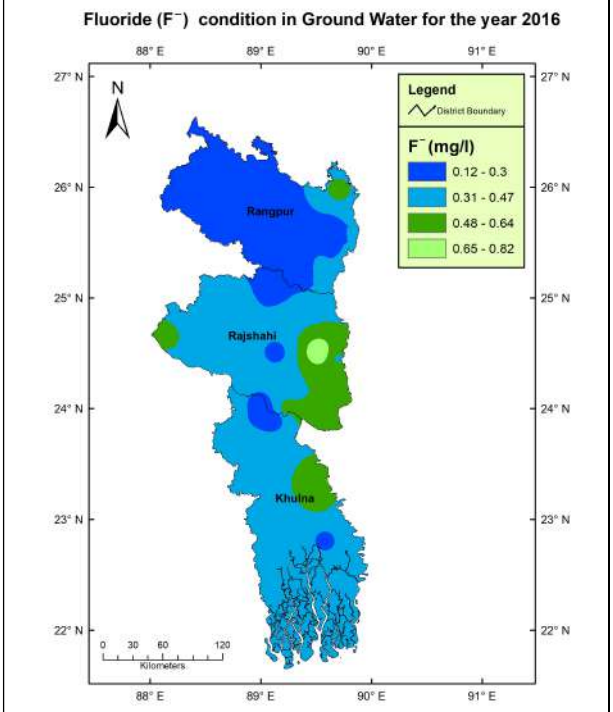


Figure 4.10(v): F⁻ condition in 2016

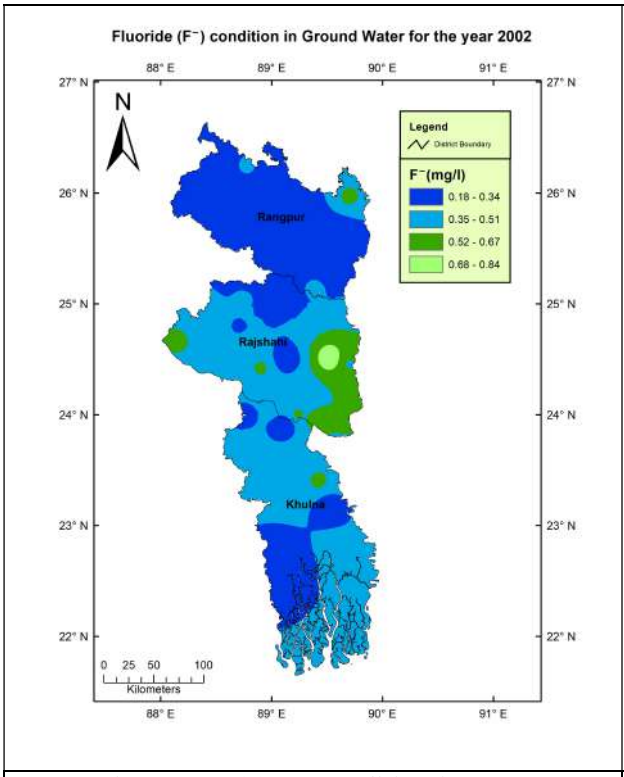


Figure 4.10(v): F⁻ condition in 2002

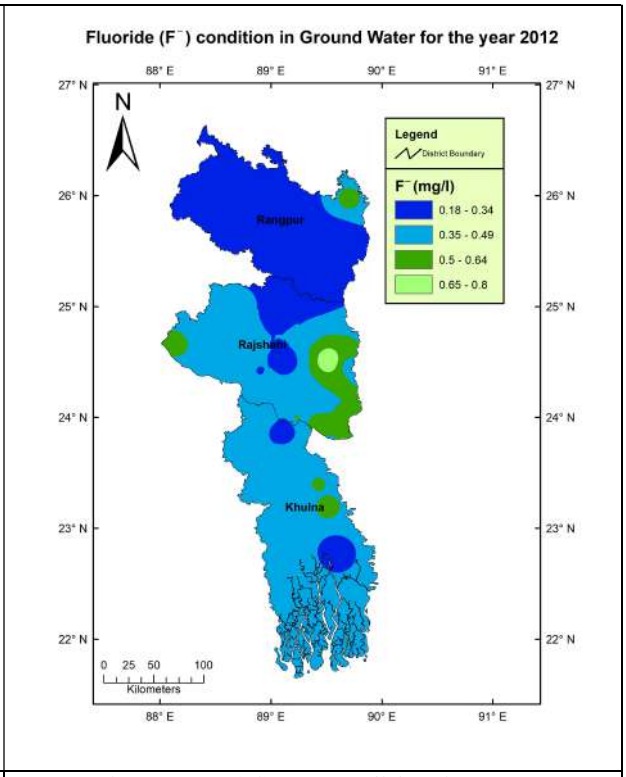
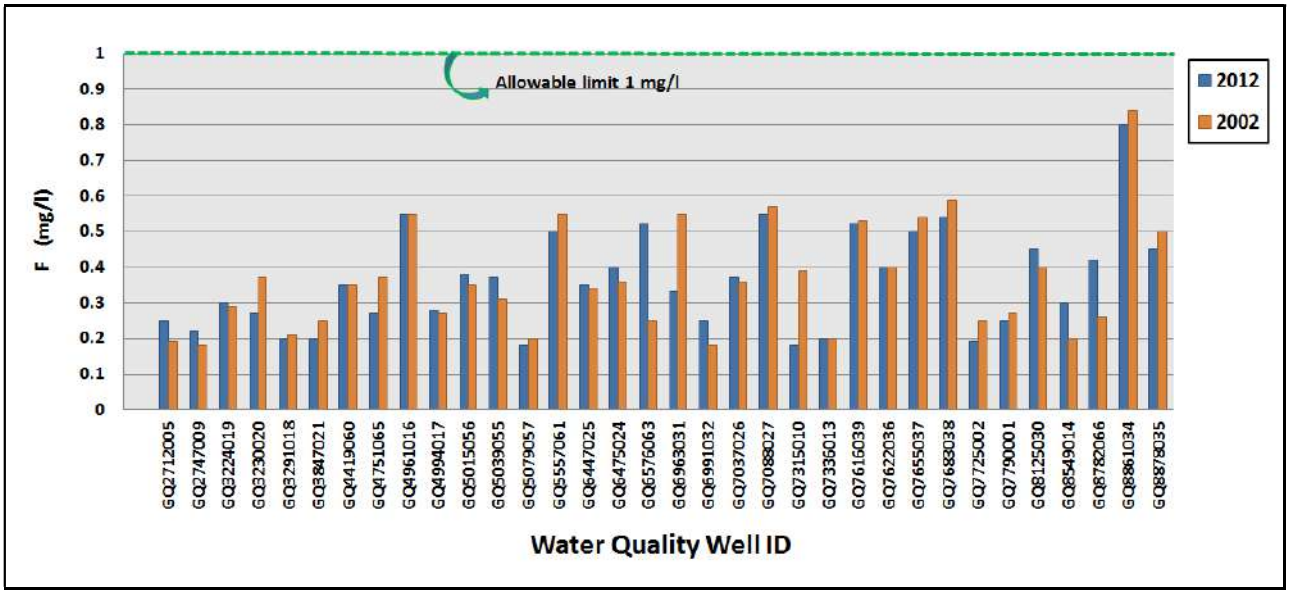


Figure 4.10(vi): F⁻ condition in 2012

Differences in F⁻ condition of ground water in 2002 and 2012 are shown in figures 4.10(v) and 4.10(vi). The same condition is also shown in graph 4.10(b).



Graph 4.10(b): Difference in F⁻ condition of ground water in 2002 and 2012.

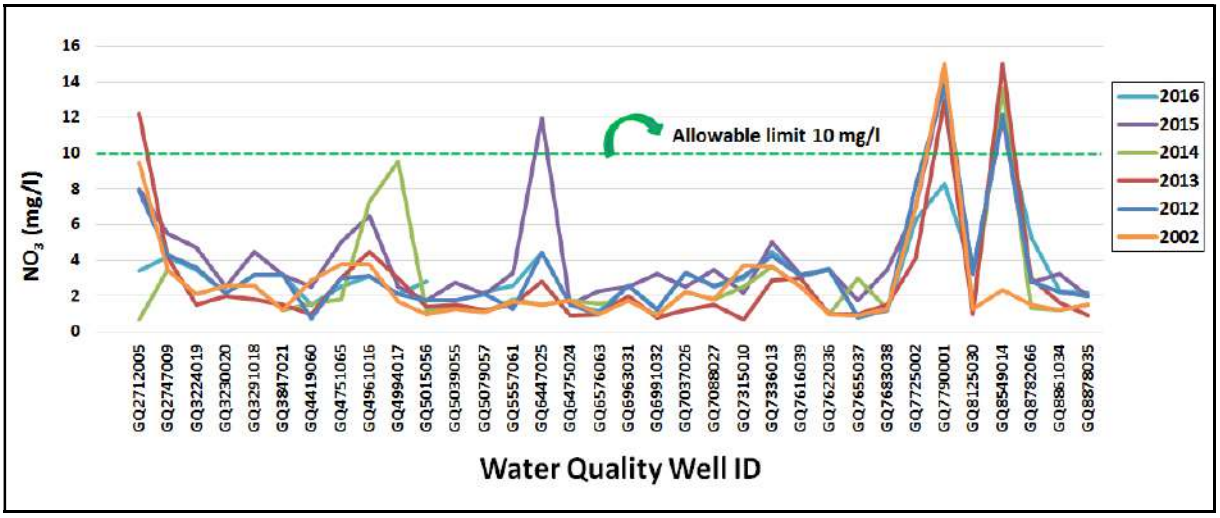
4.11. Nitrate (NO_3^-):

Relatively little of the NO_3^- found in natural waters is of mineral origin, most coming from organic and inorganic sources. Table 4.11 shows the available NO_3^- data of ground water in 2002 and 2012 to 2016 of the reported area.

Sl No.	Name of station	WELL ID	2002	2012	2013	2014	2015	2016	Allowable limit (mg/l)
									Bangladesh Standard
1	Birganj	GQ2712005	9.50	7.90	12.20	0.68	8.00	3.40	10
2	Hakimpur	GQ2747009	3.50	4.30	4.20	3.50	5.50	4.20	10
3	Gaibandha	GQ3224019	2.10	3.57	1.50	2.10	4.75	3.50	10
4	Gobindaganj	GQ3230020	2.60	2.15	2.00	2.60	2.50	2.17	10
5	Sundarganj	GQ3291018	2.60	3.15	1.80	2.60	4.50	3.17	10
6	Joypurhat Sadar	GQ3847021	1.20	3.15	1.50	1.20	3.15	3.17	10
7	Jhenaidah Sadar	GQ4419060	2.90	0.75	1.00	1.59	2.52	1.52	10
8	Khulna Sadar	GQ4751065	3.80	3.00	3.00	1.81	5.05	2.54	10
9	Nageshwari	GQ4961016	3.80	3.10	4.50	7.27	6.50	3.11	10
10	Ulipur	GQ4994017	1.72	2.10	3.00	9.54	2.50	2.13	10
11	Bheramara	GQ5015056	1.00	1.75	1.40	1.13	1.75	2.82	10
12	Daulatpur	GQ5039055	1.25	1.75	1.50	1.36	2.75		10
13	Kushtia Sadar	GQ5079057	1.10	2.10	1.20	1.10	2.10	2.20	10
14	Magura Sadar	GQ5557061	1.70	1.30	1.50	1.81	3.27	2.56	10
15	Manda	GQ6447025	1.50	4.45	2.80	1.50	12.00	4.41	10
16	Patnitala	GQ6475024	1.75	1.50	0.90	1.75	1.50	1.57	10
17	Narail Sadar	GQ6576063	1.00	1.00	1.00	1.59	2.29	1.16	10
18	Natore Sadar	GQ6963031	1.75	2.56	2.00	1.75	2.50	2.56	10
19	Singra	GQ6991032	0.90	1.20	0.80	0.90	3.25	1.26	10
20	Gomastapur	GQ7037026	2.20	3.27	1.20	2.20	2.50	3.29	10
21	Shibganj	GQ7088027	1.80	2.56	1.50	1.80	3.50	2.53	10
22	Domar	GQ7315010	3.70	3.10	0.70	2.50	2.15	3.00	10
23	Jaldhaka	GQ7336013	3.68	4.25	2.89	3.68	5.00	4.50	10
24	Bera	GQ7616039	2.50	3.12	3.00	2.50	3.15	3.19	10
25	Chatmohar	GQ7622036	1.00	3.50	1.00	1.00	3.50	3.56	10
26	Pabna Sadar	GQ7655037	0.90	0.85	0.95	3.00	1.75	0.82	10
27	Sujanagar	GQ7683038	1.30	1.20	1.50	1.30	3.50	1.23	10
28	Boda	GQ7725002	7.00	8.25	4.12		7.00	6.25	10
29	Tentulia	GQ7790001	15.00	13.75	13.00	14.30	14.30	8.32	10
30	Charghat	GQ8125030	1.25	3.34	1.00	1.25	3.25	3.31	10
31	Rangpur Sadar	GQ8549014	2.37	12.14	15.00	13.63	12.00	12.18	10
32	Satkhira Sadar	GQ8782066	1.50	2.80	3.00	1.36	2.77	5.32	10
33	Raiganj	GQ8861034	1.20	2.25	1.65	1.20	3.25	2.29	10
34	Sirajganj Sadar	GQ8878035	1.50	2.00	0.90	1.50	2.00	2.15	10

Table 4.11: NO_3^- values of ground water in 2002 and 2012 to 2016.

Most of the NO_3^- values lie within the allowable limit (10 mg/l) for Bangladesh standard, which is clearly shown in the graph 4.11(a). Areas, where values exceed the allowable limit, are shown as red color in figures 4.11(i) to 4.11(iv).



Graph 4.11(a): Difference in NO_3^- condition of the ground water in 2002 and 2012 to 2016.

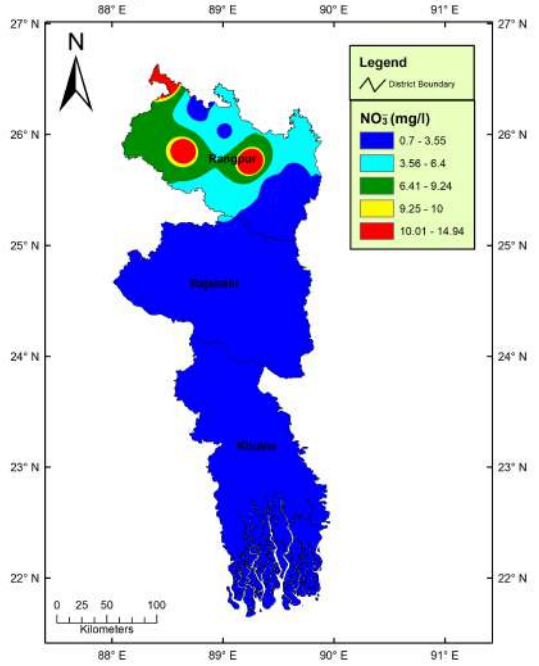


Figure 4.11(i): NO_3^- condition in 2013

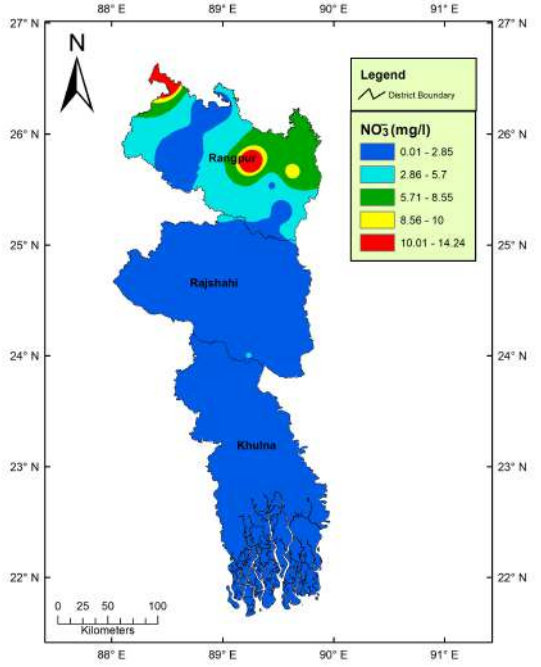


Figure 4.11(ii): NO_3^- condition in 2014

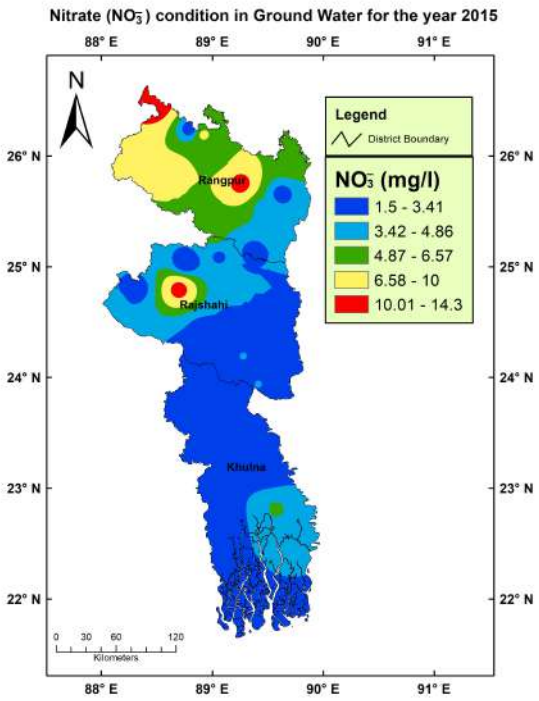


Figure 4.11(iii): NO_3^- condition in 2015

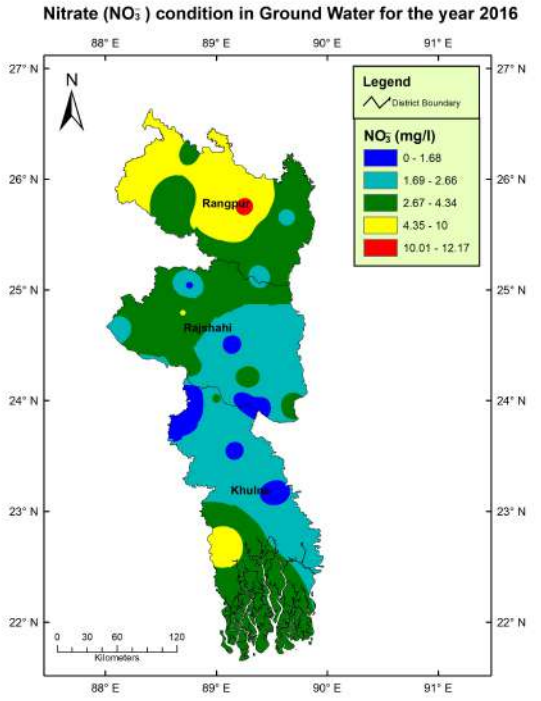


Figure 4.11(iv): NO_3^- condition in 2016

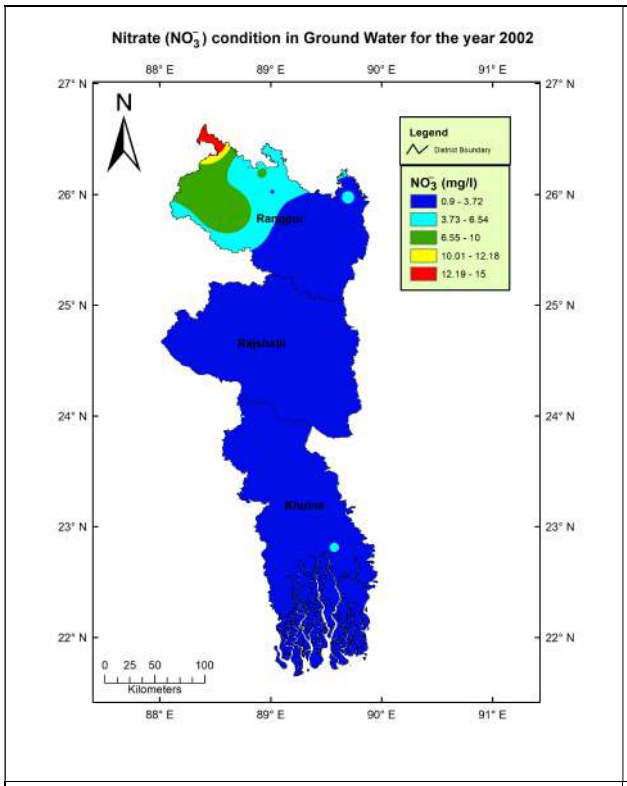


Figure 4.11(v): NO_3^- condition in 2002

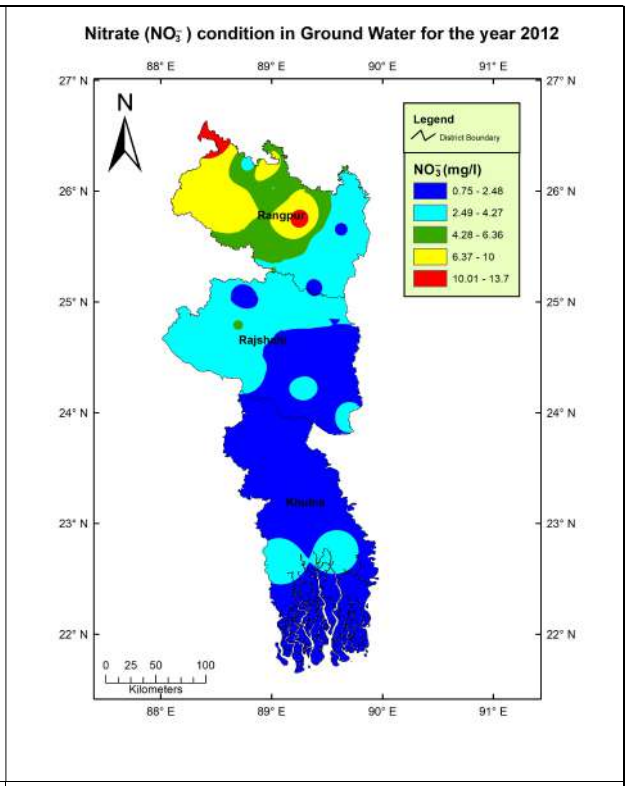
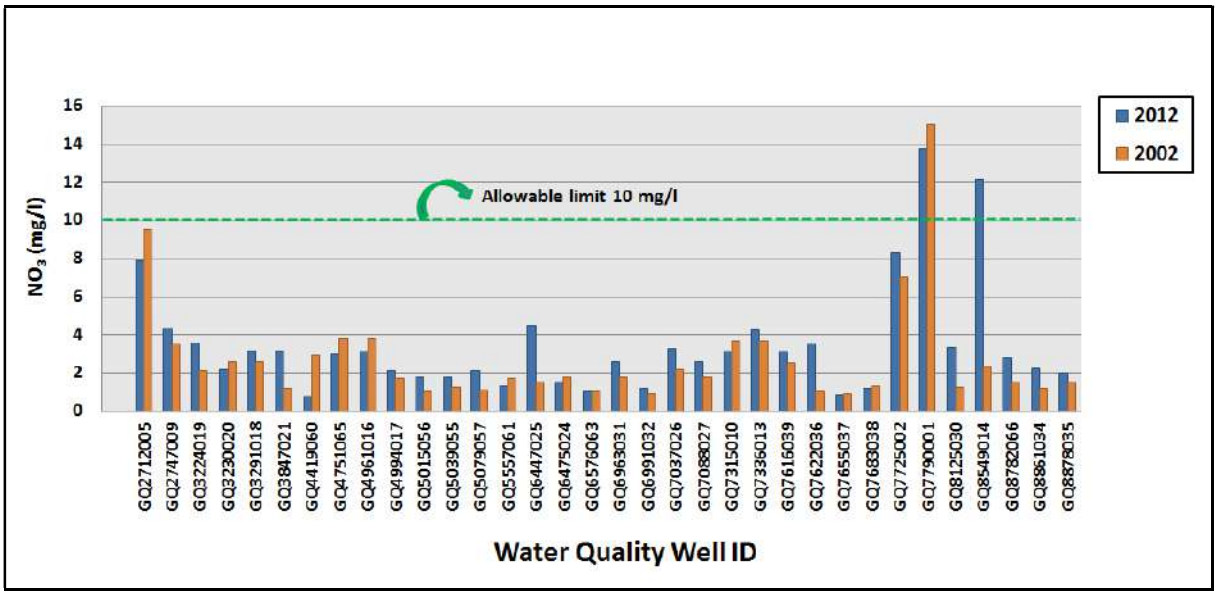


Figure 4.11(vi): NO_3^- condition in 2012

Differences in NO_3^- condition of ground water in 2002 and 2012 are shown in figures 4.11(v) and 4.11(vi). The same difference is also shown in graph 4.11(b).



Graph 4.11(b): Difference in NO_3^- condition of ground water in 2002 and 2012.

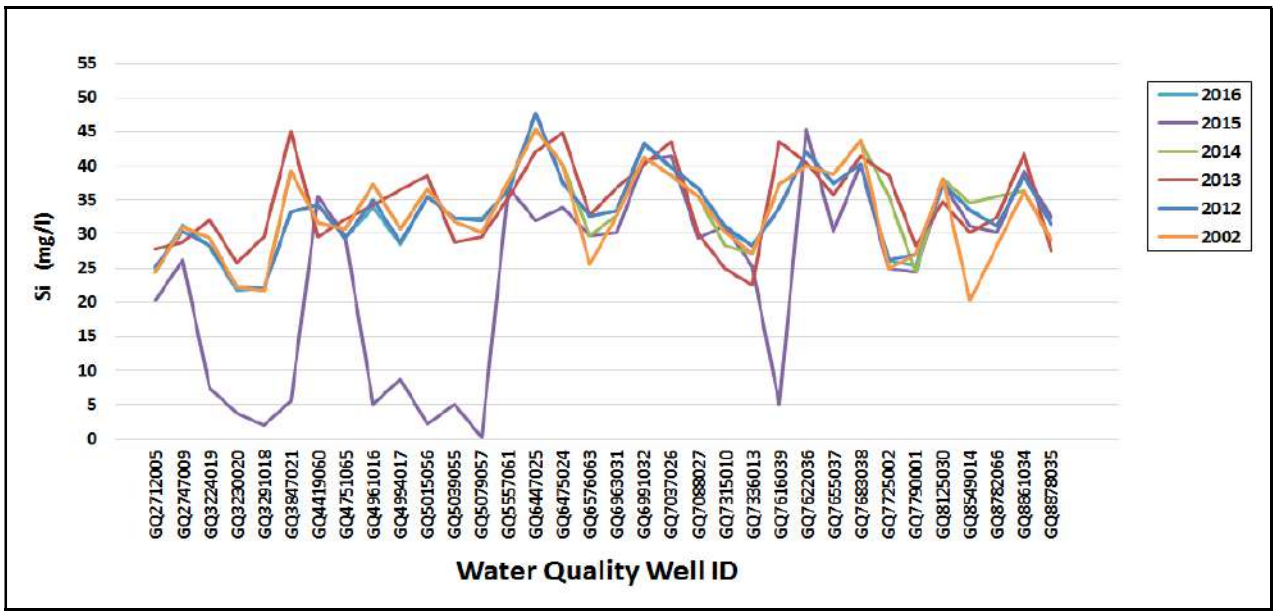
4.12. Silicon (Si):

Silicon (Si) is the most abundant element found in rocks and it will always be present in natural waters. The average Si content in natural water is commonly in the range of 5 to 25 mg/l. Available Si data of ground water of the reported area in 2002 and 2012 to 2016, are given in the table 4.12.

Sl. No	Name of Station	Well ID	Si Value (mg/l)					
			2002	2012	2013	2014	2015	2016
1	Birganj	GQ2712005	24.50	25.25	27.80	24.50	20.30	25.00
2	Hakimpur	GQ2747009	31.00	30.35	28.80	31.00	26.25	31.35
3	Gaibandha	GQ3224019	29.50	28.25	32.20	29.50	7.50	28.10
4	Gobindaganj	GQ3230020	22.15	22.25	25.78	22.15	3.75	21.75
5	Sundarganj	GQ3291018	21.75	22.00	29.67	21.75	2.00	22.00
6	Joypurhat Sadar	GQ3847021	39.25	33.27	45.00	39.25	5.50	33.22
7	Jhenaidah Sadar	GQ4419060	31.75	34.25	29.55	31.75	35.58	34.29
8	Khulna Sadar	GQ4751065	30.75	29.45	32.13	30.75	29.75	29.43
9	Nageshwari	GQ4961016	37.25	35.00	34.20	37.25	5.00	34.00
10	Ulipur	GQ4994017	30.75	28.75	36.54	30.75	8.75	28.50
11	Bheramara	GQ5015056	36.60	35.56	38.53	36.60	2.25	35.58
12	Daulatpur	GQ5039055	31.90	32.34	28.76	31.90	5.00	32.37
13	Kushtia Sadar	GQ5079057	30.25	32.00	29.65	30.25	0.20	32.34
14	Magura Sadar	GQ5557061	37.80	36.65	35.40	37.80	36.77	36.33
15	Manda	GQ6447025	45.25	47.70	42.10	45.25	32.00	47.56
16	Patnitala	GQ6475024	40.15	37.56	44.89	40.15	34.00	37.51
17	Narail Sadar	GQ6576063	25.60	32.66	32.75	29.80	29.75	32.69
18	Natore Sadar	GQ6963031	32.75	33.47	36.73	32.75	30.25	33.47
19	Singra	GQ6991032	41.27	43.38	40.13	41.27	40.75	43.29
20	Gomastapur	GQ7037026	38.50	39.80	43.57	38.50	41.50	39.75
21	Shibganj	GQ7088027	35.50	36.70	30.14	35.50	29.40	36.73
22	Domar	GQ7315010	30.25	31.25	25.00	28.25	31.25	30.50
23	Jaldhaka	GQ7336013	27.20	28.34	22.50	27.20	25.25	28.36
24	Bera	GQ7616039	37.25	33.87	43.56	37.25	5.00	33.83
25	Chatmohar	GQ7622036	40.00	42.12	40.53	40.00	45.25	42.16
26	Pabna Sadar	GQ7655037	38.74	37.39	35.63	38.74	30.40	37.32
27	Sujanagar	GQ7683038	43.75	40.25	41.50	43.75	40.25	40.28
28	Boda	GQ7725002	25.00	26.25	38.50	35.50	25.00	26.00
29	Tentulia	GQ7790001	27.00	27.00	28.30	24.50	24.50	25.50
30	Charghat	GQ8125030	38.15	37.50	34.73	38.15	37.50	37.53
31	Rangpur Sadar	GQ8549014	20.25	33.45	30.25	34.50	31.20	33.55
32	Satkhira Sadar	GQ8782066	28.25	31.26	32.47	35.45	30.25	31.27
33	Raiganj	GQ8861034	36.25	38.54	41.75	36.25	39.25	38.59
34	Sirajganj Sadar	GQ8878035	29.15	31.46	27.55	29.15	32.50	31.41

Table 4.12: Si values of ground water in 2002 and 2012 to 2016.

The highest value is found in Manda in 2012, which is 47.70 mg/l. The lowest value is 0.20 mg/l, found in Kushtia Sadar. This scenario can be seen in the graph 4.12(a) and figures 4.12(i) to 4.12(iv).



Graph 4.12(a): Variation in Si condition of ground water in 2002 and 2012 to 2016.

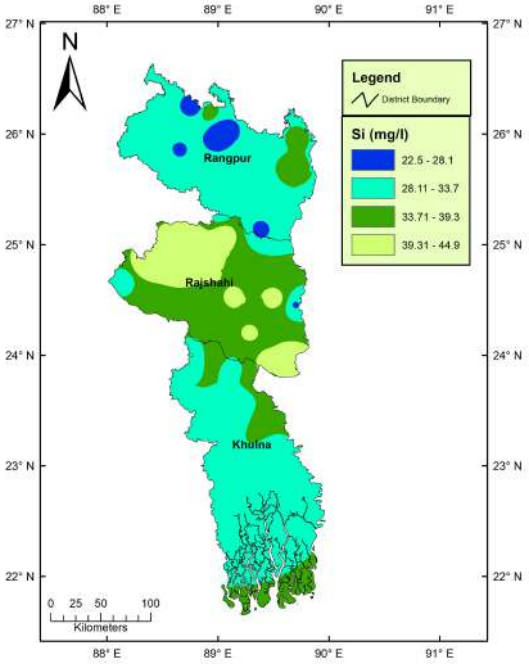


Figure 4.12(i): Si condition in 2013

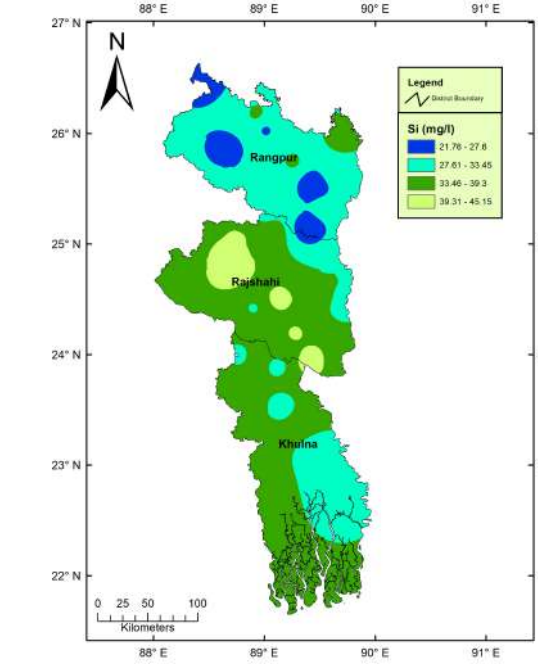


Figure 4.12(ii): Si condition in 2014

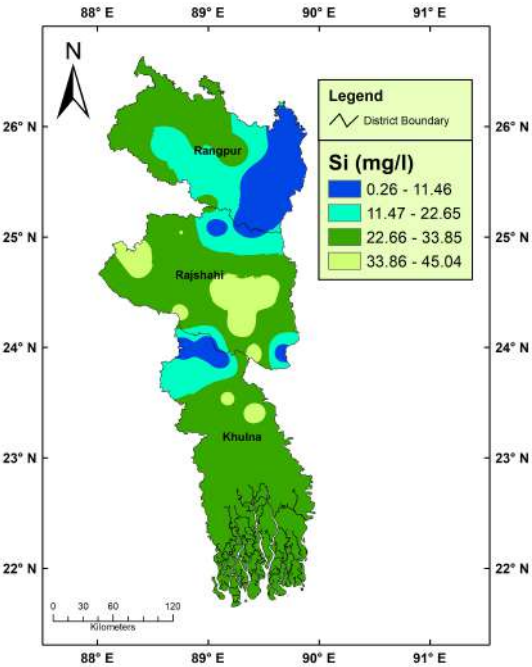


Figure 4.12(iii): Si condition in 2015

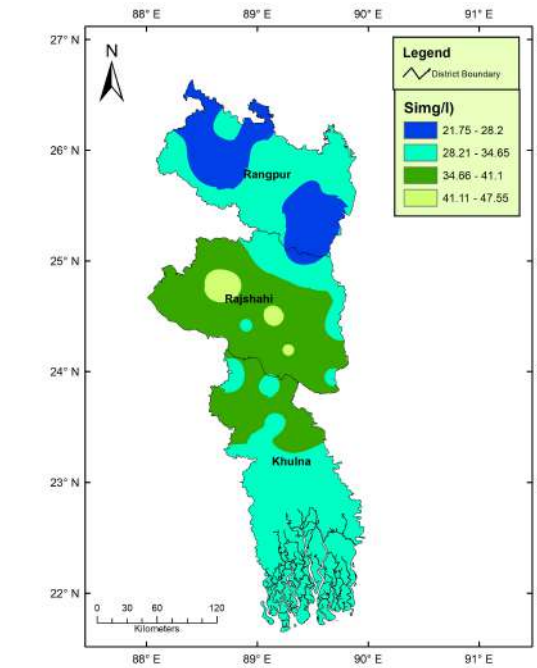


Figure 4.12(iv): Si condition in 2016

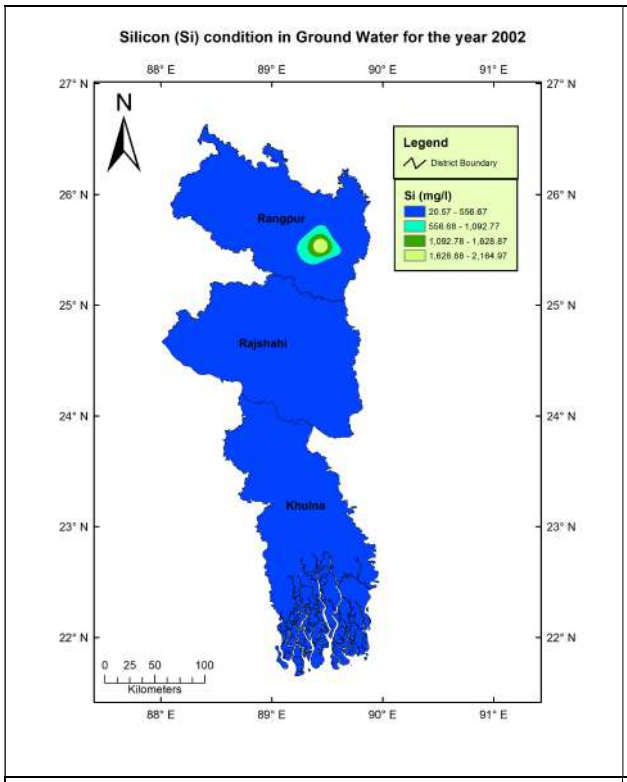


Figure 4.12(v): Si condition in 2002

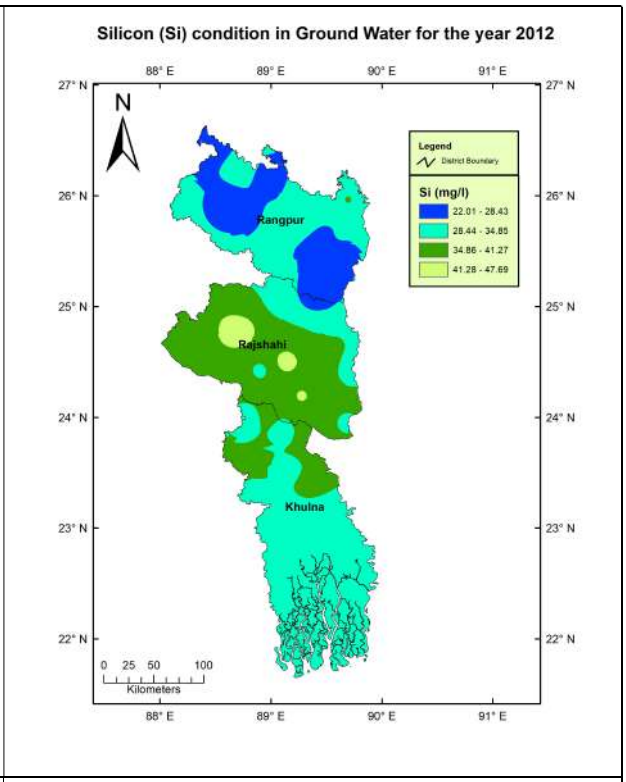
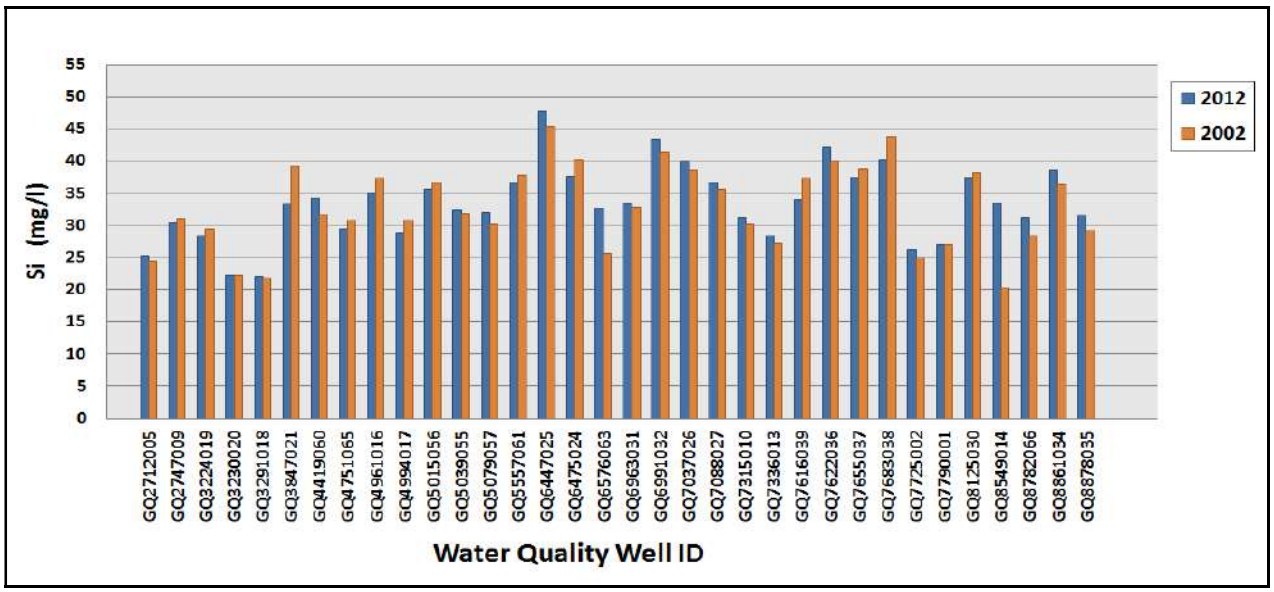


Figure 4.12(vi): Si condition in 2012

Figures 4.12(v) and 4.12(vi) show the differences in Si condition of ground water in 2002 and 2012. The same difference is also shown in graph 4.12(b).



Graph 4.12(b): Variation in Si condition of ground water in 2002 and 2012.

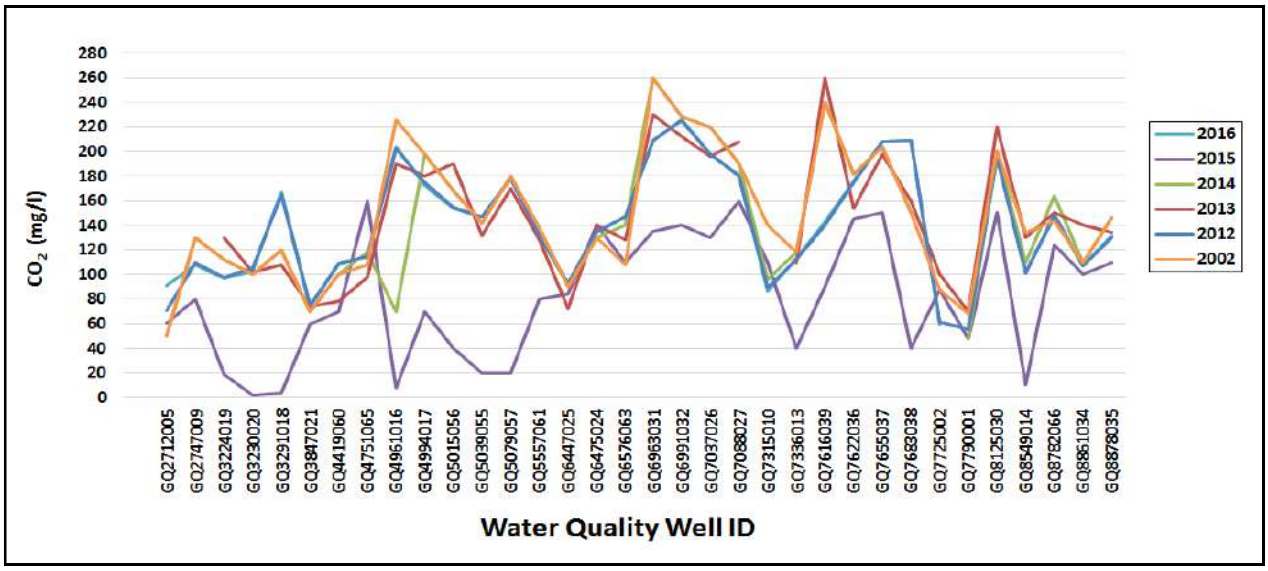
4.13. Carbon Dioxide (CO_2):

Carbon dioxide (CO_2) is present in water in the form of a dissolved gas. Typically, surface waters contain less than 10 ppm free CO_2 while ground water may have much higher concentrations. Table 4.13 shows available CO_2 data of ground water in 2002 and 2012 to 2016, of the reported area.

Sl No.	Name of station	WELL ID	CO_2 Value (mg/l)					
			2002	2012	2013	2014	2015	2016
1	Birganj	GQ2712005	50.00	71.00		50.00	60.69	91.00
2	Hakimpur	GQ2747009	130.00	110.00		130.00	80.00	108.00
3	Gaibandha	GQ3224019	112.00	98.00	130.00	112.00	19.00	97.00
4	Gobindaganj	GQ3230020	100.00	105.00	102.00	100.00	2.00	103.00
5	Sundarganj	GQ3291018	120.00	165.00	108.00	120.00	4.00	167.00
6	Joypurhat Sadar	GQ3847021	70.00	75.00	74.00	70.00	60.00	74.00
7	Jhenaidah Sadar	GQ4419060	100.00	109.00	78.00	100.00	70.00	109.00
8	Khulna Sadar	GQ4751065	108.00	115.00	98.00	118.00	160.00	115.00
9	Nageshwari	GQ4961016	226.00	202.00	190.00	70.00	8.00	204.00
10	Ulipur	GQ4994017	198.00	175.00	180.00	198.00	70.00	172.00
11	Bheramara	GQ5015056	168.00	155.00	190.00	168.00	40.00	154.00
12	Daulatpur	GQ5039055	142.00	147.00	132.00	142.00	20.00	147.00
13	Kushtia Sadar	GQ5079057	180.00	178.00	170.00	180.00	20.00	178.00
14	Magura Sadar	GQ5557061	138.00	132.00	128.00	138.00	80.00	132.00
15	Manda	GQ6447025	90.00	93.00	72.00	90.00	84.00	92.00
16	Patnitala	GQ6475024	130.00	135.00	140.00	130.00	140.00	134.00
17	Narail Sadar	GQ6576063	108.00	147.00	128.00	140.00	110.00	147.00
18	Natore Sadar	GQ6963031	260.00	209.00	230.00	260.00	135.00	209.00
19	Singra	GQ6991032	228.00	226.00	212.00	228.00	140.00	225.00
20	Gomastapur	GQ7037026	220.00	198.00	196.00	220.00	130.00	198.00
21	Shibganj	GQ7088027	190.00	180.00	208.00	190.00	160.00	181.00
22	Domar	GQ7315010	140.00	89.00		96.00	110.00	87.00
23	Jaldhaka	GQ7336013	118.00	112.00	110.00	118.00	40.00	113.00
24	Bera	GQ7616039	240.00	140.00	260.00	240.00	90.00	143.00
25	Chatmohar	GQ7622036	182.00	175.00	154.00	182.00	145.00	176.00
26	Pabna Sadar	GQ7655037	204.00	208.00	198.00	204.00	150.00	208.00
27	Sujanagar	GQ7683038	150.00	209.00	160.00	150.00	40.00	209.00
28	Boda	GQ7725002	88.00	61.00	100.00		88.00	60.00
29	Tentulia	GQ7790001	68.00	55.00	70.00	47.85	47.85	
30	Charghat	GQ8125030	200.00	195.00	220.00	200.00	150.00	196.00
31	Rangpur Sadar	GQ8549014	134.00	101.00	130.00	110.00	10.00	102.00
32	Satkhira Sadar	GQ8782066	144.00	149.00	150.00	164.00	124.00	147.00
33	Raiganj	GQ8861034	110.00	107.00	140.00	110.00	100.00	107.00
34	Sirajganj Sadar	GQ8878035	146.00	130.00	134.00	146.00	110.00	132.00

Table 4.13: CO_2 values of ground water in 2002 and 2012 to 2016.

The highest value is found both in Natore Sadar and Bera, which is 260 mg/l. The lowest value is 2 mg/l, found in Gobindaganj in 2015. The total scenario can be seen in graph 4.13(a) and figure 4.13(i) to 4.13(iv).



Graph 4.13(a): Variation in CO_2 condition of ground water in 2002 and 2012 to 2016.

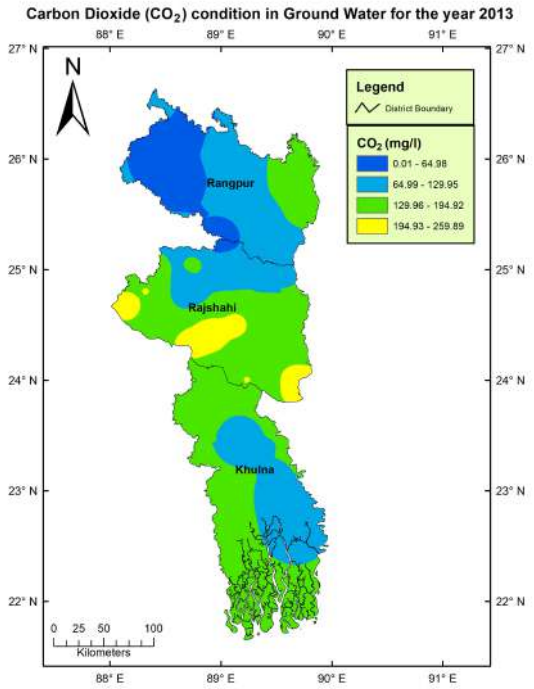


Figure 4.13(i): CO_2 condition in 2013

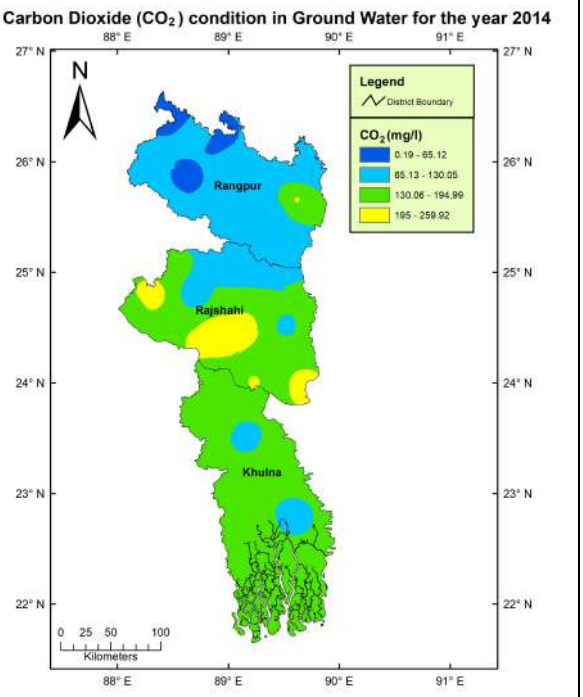


Figure 4.13(ii): CO_2 condition in 2014

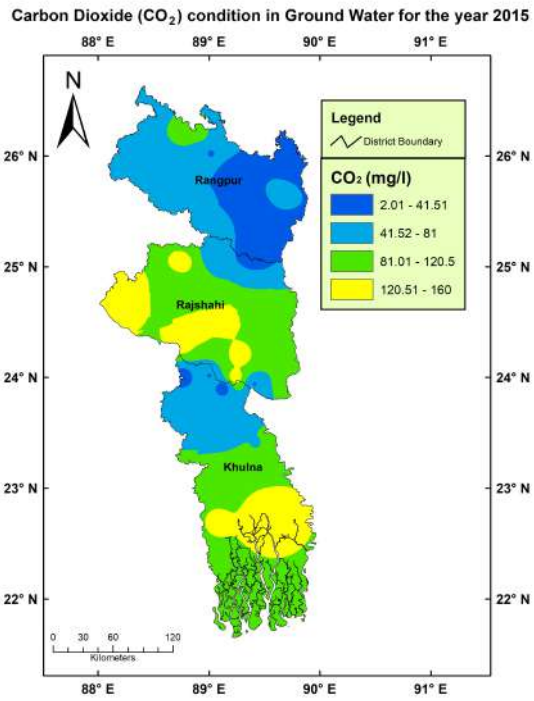


Figure 4.13(iii): CO_2 condition in 2015

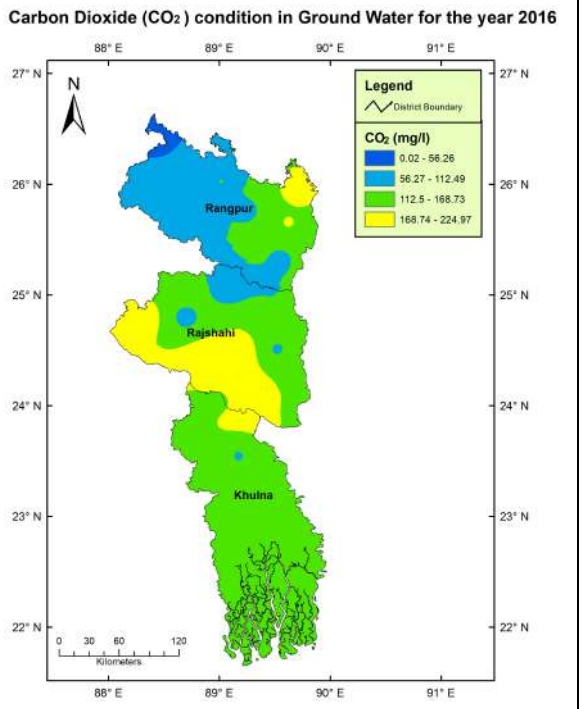


Figure 4.13(iv): CO_2 condition in 2016

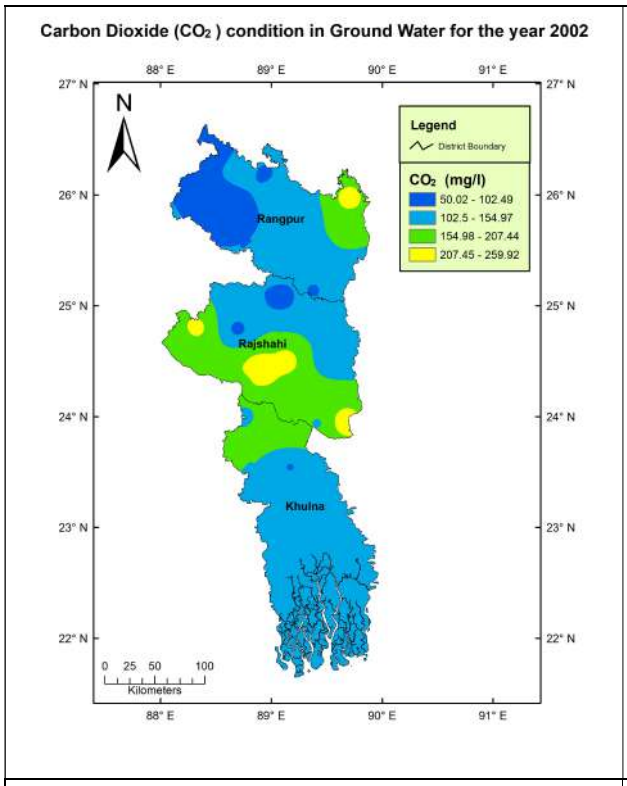


Figure 4.13(v): CO_2 condition in 2002

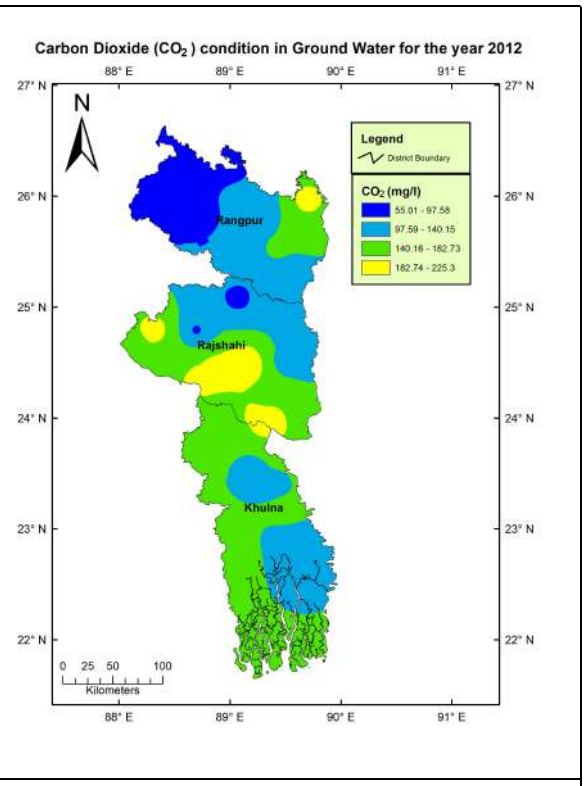
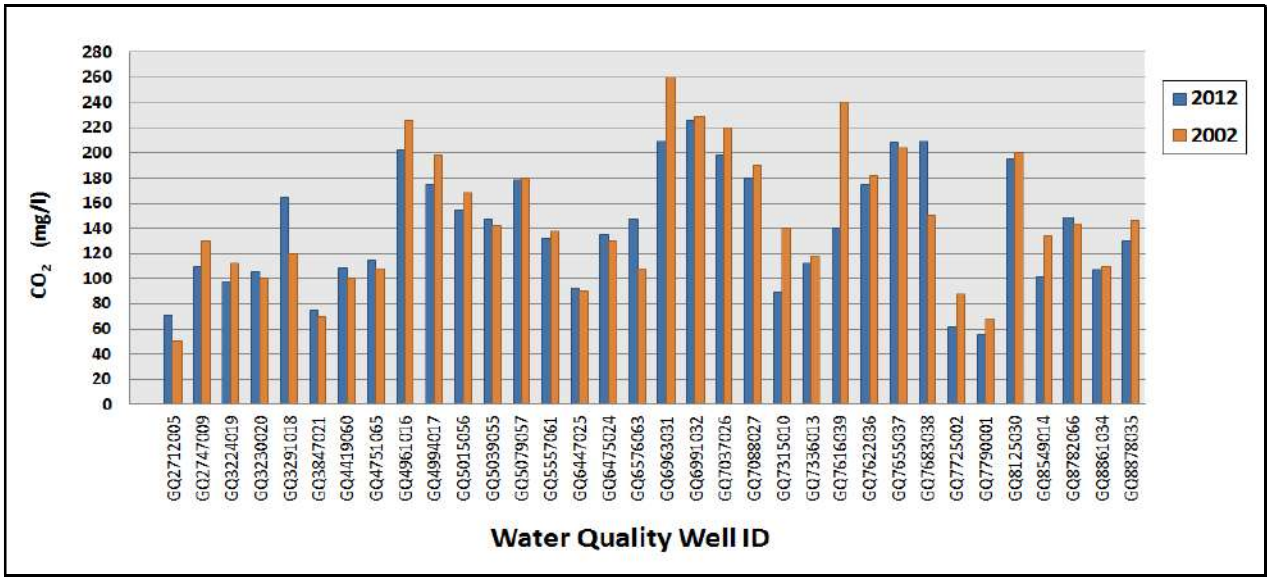


Figure 4.13(vi): CO_2 condition in 2012

Differences in CO_2 condition of ground water in 2002 and 2012 are shown in figures 4.13(v) and 4.13(vi). The same difference is also shown in graph 4.13(b).



Graph 4.13(b): Variation in CO_2 condition of ground water in 2002 and 2012.

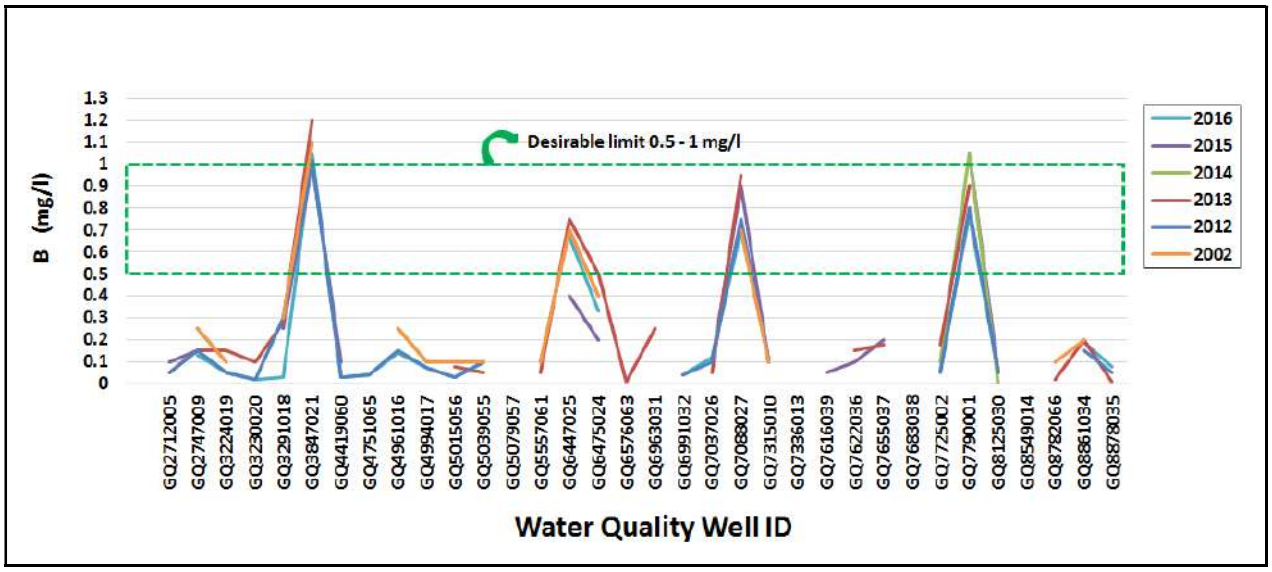
4.14. Boron (B):

Boron (B) naturally occurs as boric acid and boric acid salts. It is released from rocks and soils through weathering, and subsequently ends up in water. As per the eleventh five year plan document of India (2007-12), also known as IS: 10500-2012, the desirable limit for Boron is 0.5 and 1 mg/l in Permissible limit. Table 4.14 shows the available B data of ground water of the reported area in 2002 and 2012 to 2016.

Sl No.	Name of station	WELL ID	2002	2012	2013	2014	2015	2016	Desirable limit (mg/l) as per IS: 10500-2012
1	Birganj	GQ2712005		0.05	0.05		0.10		0.5 - 1
2	Hakimpur	GQ2747009	0.25	0.15	0.15	0.25	0.15	0.13	0.5 - 1
3	Gaibandha	GQ3224019	0.10	0.05	0.15	0.10		0.05	0.5 - 1
4	Gobindaganj	GQ3230020		0.02	0.10			0.02	0.5 - 1
5	Sundarganj	GQ3291018	0.30	0.30	0.28	0.30	0.25	0.03	0.5 - 1
6	Joypurhat Sadar	GQ3847021	1.10	1.02	1.20	1.10	1.00	1.05	0.5 - 1
7	Jhenaidah Sadar	GQ4419060		0.03			0.10	0.03	0.5 - 1
8	Khulna Sadar	GQ4751065		0.04				0.04	0.5 - 1
9	Nageshwari	GQ4961016	0.25	0.15	0.20	0.25		0.14	0.5 - 1
10	Ulipur	GQ4994017	0.10	0.07		0.10	0.10	0.07	0.5 - 1
11	Bheramara	GQ5015056	0.10	0.03	0.08	0.10		0.03	0.5 - 1
12	Daulatpur	GQ5039055	0.10	0.10	0.05	0.10	0.10	0.10	0.5 - 1
13	Kushtia Sadar	GQ5079057							0.5 - 1
14	Magura Sadar	GQ5557061	0.10		0.05	0.10			0.5 - 1
15	Manda	GQ6447025	0.70		0.75	0.70	0.40	0.67	0.5 - 1
16	Patnitala	GQ6475024	0.40	0.30	0.50	0.40	0.20	0.33	0.5 - 1
17	Narail Sadar	GQ6576063			0.01				0.5 - 1
18	Natore Sadar	GQ6963031	0.30		0.25	0.30			0.5 - 1
19	Singra	GQ6991032		0.04				0.04	0.5 - 1
20	Gomastapur	GQ7037026		0.10	0.05		0.10	0.12	0.5 - 1
21	Shibganj	GQ7088027	0.70	0.75	0.95	0.70	0.90	0.70	0.5 - 1
22	Domar	GQ7315010	0.10	0.10			0.10	0.11	0.5 - 1
23	Jaldhaka	GQ7336013							0.5 - 1
24	Bera	GQ7616039		0.05			0.05	0.05	0.5 - 1
25	Chatmohar	GQ7622036			0.15		0.10		0.5 - 1
26	Pabna Sadar	GQ7655037	0.10	0.07	0.18	0.30	0.20	0.07	0.5 - 1
27	Sujanagar	GQ7683038							0.5 - 1
28	Boda	GQ7725002		0.05	0.18	0.10		0.06	0.5 - 1
29	Tentulia	GQ7790001	1.01	0.80	0.90	1.05	1.05	0.77	0.5 - 1
30	Charghat	GQ8125030		0.05		0.00	0.05	0.05	0.5 - 1
31	Rangpur Sadar	GQ8549014							0.5 - 1
32	Satkhira Sadar	GQ8782066	0.10		0.02				0.5 - 1
33	Raiganj	GQ8861034	0.20	0.15	0.20	0.20		0.19	0.5 - 1
34	Sirajganj Sadar	GQ8878035		0.05	0.01		0.20	0.08	0.5 - 1

Table 4.14: Boron (B) values of ground water in 2002 and 2012 to 2016.

Most of the B values lie in the maximum desirable limit (1 mg/l), which is shown in graph 4.14(a). Areas, where values cross this limit, are shown as red color in figures 4.14(i) to 4.14(iv).



Graph 4.14(a): Variation in B condition of ground water in 2002 and 2012 to 2016.

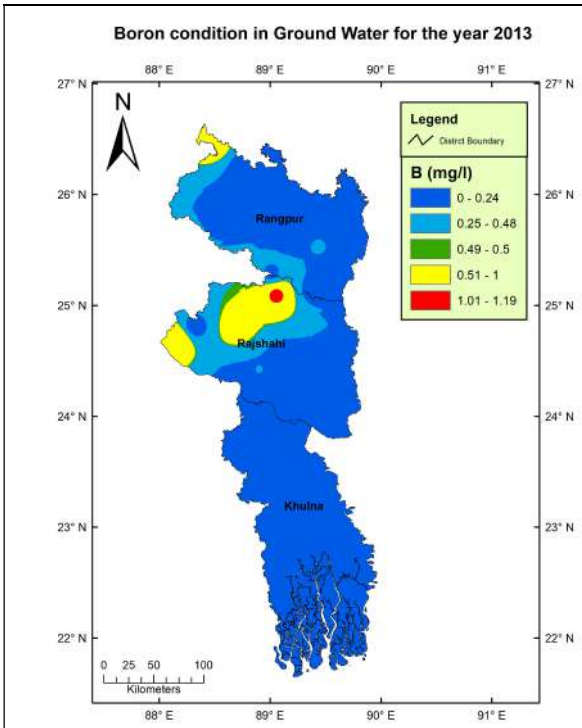


Figure 4.14(i): Boron condition in 2013

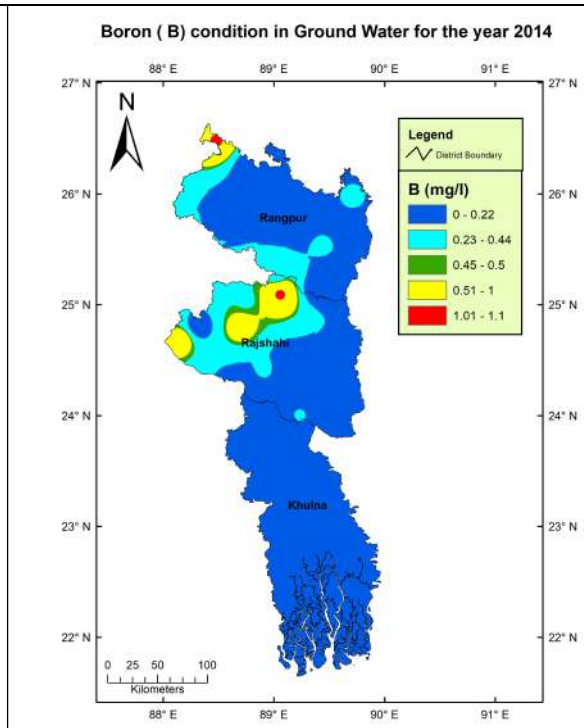


Figure 4.14(ii): Boron condition in 2014

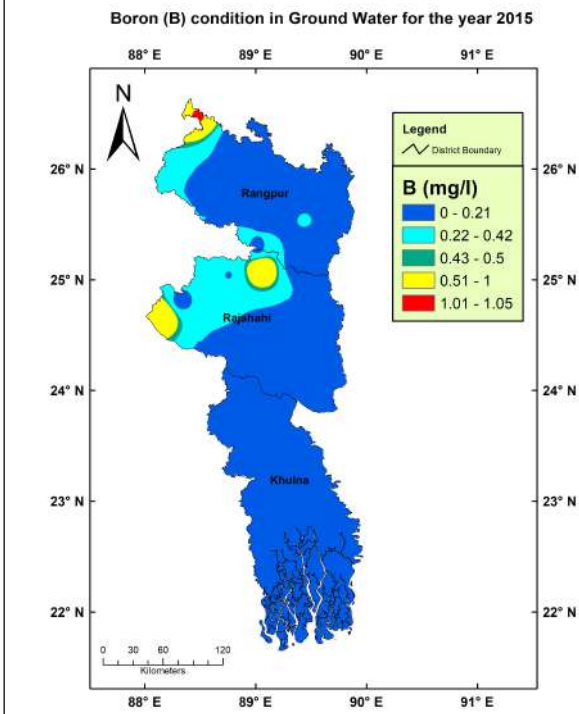


Figure 4.14(iii): Boron condition in 2015

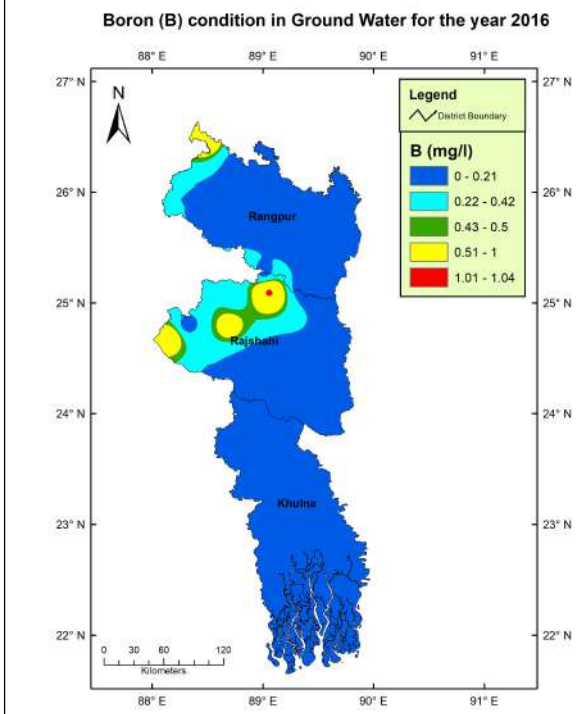


Figure 4.14(iv): Boron condition in 2016

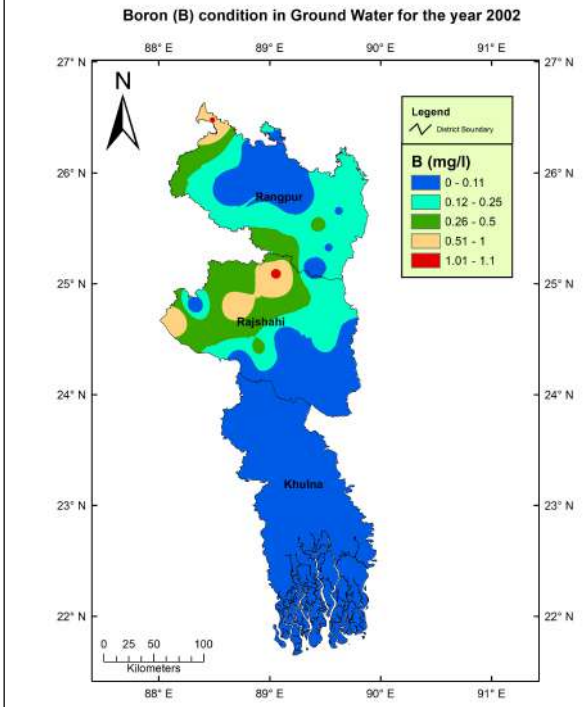


Figure 4.14(v): Boron condition in 2002

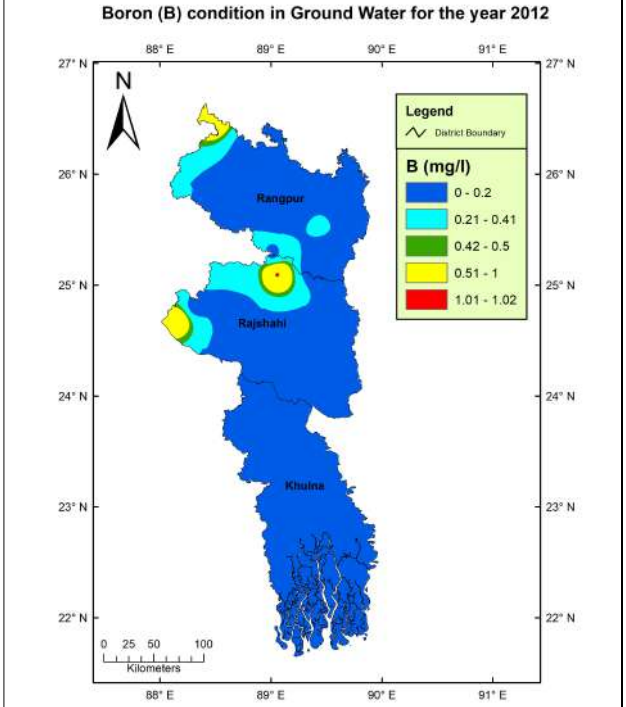
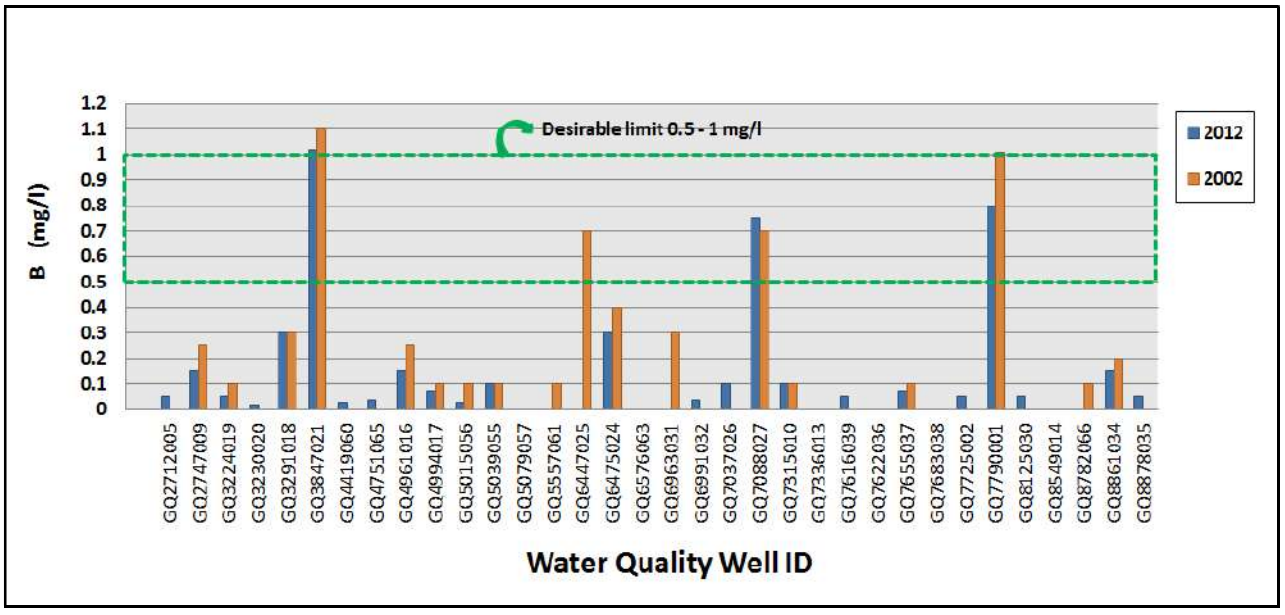


Figure 4.14(vi): Boron condition in 2012

Variations in B condition of ground water in 2002 and 2012 are shown in figures 4.14(v) and 4.14(vi). The same difference is also shown in graph 4.14(b).



Graph 4.14(b): Variation in Boron (B) condition of ground water in 2002 and 2012.

5. Results and Discussions:

Assessment work of the ground water quality parameters show some changes for individual wells in individual year. The pH analysis shows that most of its values lie within the allowable limit (6.5 – 8.5 mol/L) for drinking purpose, except Charghat, Kushtia Sadar, Nageswari etc. Most of the TDS values lie within its allowable limit (1000 mg/l), with exception in Narail Sadar and Shatkhira Sadar.

High concentrations of Ca_2^+ are mainly found in Natore Sadar, Shibganj, Charghat, Narail Sadar, Chatmohar, Sujanagar and Singra, where values exceed its allowable limit (75 mg/l) in certain year. Mg_2^+ analysis shows high concentrations mainly found in Bheramara, Sundarganj, Narail Sadar and Kushtia Sadar, with exceeding its allowable limit (30 – 35 mg/l). Allowable limit (12 mg/l) of K^+ exceeds in Khulna Sadar, Nageshwari, Bheramara and Boda.

The analysis of Fe shows high concentrations in most of the wells, except Sujanagar. Most of the Mn values exceed its allowable limit (0.10 mg/l), with highest concentration is found in Kushtia Sadar in 2016.

Na^+ analysis represents most of its values lie within the allowable limit (200 mg/l), with some exception in Narail Sadar and Shatkhira Sadar. Both the Cl^- and F^- analysis shows all the values lie within their allowable limit.

Most of the NO_3^- values lie within its allowable limit (10 mg/l), with some exception noticed in Tetulia, Rangpur Sadar, Birganj and Manda. The highest Si concentration is found in Manda (47.70 mg/l). CO_2 analysis shows highest value in Natore Sadar and Bera which is 260 mg/l. Whereas, Boron (B) analysis shows its desirable limit (1 mg/l) exceeding condition in Joypurhat Sadar and Tetulia.

6. Conclusion:

The present work reveals that some physico-chemical properties like pH and TDS values in the ground water are mostly within the acceptable limits of Bangladesh standard and pose no risk to the local users for drinking, domestic and irrigation uses. Concentrations of nutrient like NO_3^- and elements like Ca_2^+, Mg_2^+, Na^+, Si, Cl^-, F^-, B and CO_2 are within their acceptable levels in most of the wells. Levels of Ca_2^+ and Mg_2^+ in some wells noticed slightly higher, indicating same mineral rich aquifer in the particular area. Concentrations of Mn and Fe exceed their acceptable levels in most of the wells. Whereas the K^+ data shows its concentrations mostly within the allowable limits. Presence of such metal concentrations may indicates low risk for drinking purpose, but poses no risk for domestic and irrigation uses.

7. References

1. BWDB Database 2019, Groundwater Quality, accessed December 2019, <http://www.hydrology.bwdb.gov.bd/index.php?pagetitle=ground_water_quality_data>.

2. Encyclopedia 2020, *Groundwater Quality*, accessed 10 March 2020, <https://www.encyclopedia.com/environment/energy-government-and-defense-magazines/ground water-quality>.

3. Definition of pH scale. (no date) [Online] [Accessed on July 17, 2019].

   [Retrieved from http://www.businessdictionary.com/definition/pH-scale.html]

4. Groundwater Quality, Physical Geology - 2nd Edition "Open Educational Resources," Hewlett Foundation, [Online] [Accessed on December 11, 2019].

   [Retrieved from https://opentextbc.ca/geology/chapter/14-4-groundwater-quality/]

5. Department of Public Health Engineering, Bangladesh. (no date) *Water Quality Parameters Bangladesh Standards & WHO Guide Lines.* [Online] [Accessed on December 15, 2019].

   [Retrieved from http://old.dphe.gov.bd/index.php?option=com_content&view=article&id=125&Itemid=133]

6. Ions and Ionic Compounds. [Online] [Accessed on March 09, 2020].

   [Retrieved from https://saylordotorg.github.io/text_introductory-chemistry/s07-04-ions-and-ionic-compounds.html]

7. G. Venkatesan, B. Balaji, S. Dhivyabharathi, K.S.S. Lidhuveniya and F. Sylvester Martin. 2013. Water Quality Assessment in Tiruchirappalli, India. Asian Journal of Water, Environment and Pollution, Vol. 10, No. 4 (20 13), pp. 33-42.

   [Retrieved from https://www.researchgate.net/publication/289028945_Water_quality_assessment _in_tiruchirappalli_India]

8. Drinking Water-Specification, 2nd edition, Indian Standard, IS 10500 : 2012

   [Retrieved from https://law.resource.org/pub/in/bis/S06/is.10500.2012.pdf]