Available online at www.ewijst.org

ISSN: 0975-7112 (Print)
ISSN: 0975-7120 (Online)

Environ. We Int. J. Sci. Tech. 13 (2018) 99-117

Environment & We
An International
Journal of Science
& Technology

Assessment of Groundwater Quality in Different Land Uses in Ghaziabad District of Uttar Pradesh, India

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Article history:
Received 11 April 2018
Received in revised form
17 July 2018
Accepted 28 July 2018
Available online
31 July 2018

Keywords:
Groundwater quality;
Ghaziabad district; Land use;
Heavy metals;
GWQI

Abstract

In Ghaziabad district of Uttar Pradesh, groundwater is one of the substantial resources that need great concern as it is consumed by all the sectors of domestic, irrigation and industrial purposes. The present study examined the groundwater quality of the district on the basis of land use types. A total number of 26 sites were identified in the district from residential, industrial and agricultural areas during pre-monsoon (May 2017) season. The groundwater samples were investigated for major physicochemical parameters and heavy metal analysis. The influence of anthropogenic activities on the quality of groundwater showed that iron, cadmium and nickel were predominant heavy metals that were exceeding the permissible limits of BIS 2012 standards. Ground Water Quality Index (GWQI) was applied for evaluating the impact of land use on the overall quality of groundwater and resulted as about 69% of the samples were found unfit for drinking. In accordance with the standards, it was assessed that the quality of the groundwater is deteriorating at an alarming rate due to the improper management of the land use activities in the district.

Introduction

Groundwater is a valuable natural resource found beneath the earth surface, which benefits diverse life forms. It not only helps in regulating the annual flowing of the rivers and wetlands but also conserves the quality by diluting the accumulated effluents (Lerner and Harris, 2009). The overlying landscapes influence the groundwater by discharging excess nutrient and toxic chemicals that affect the quality of groundwater to a greater extent (Ouyang, 2011). A numerous anthropogenic and natural sources trigger the groundwater pollution. Land use mismanagement leads to degradation of groundwater quality, which governed, by the type of land use activity. Due to augmented use of groundwater in immense purposes, the availability and quality of groundwater is declining at faster rates.

Ground Water Quality Index (GWQI) is a widely used technique for estimating the suitability of drinking water (Asadi *et al.,* 2007). This technique helps in drawing the relative picture of water quality and enables further appraisal and improvement of the water issues for any area (Bordalo *et al.,* 2006). Sometimes, groundwater quality estimation becomes a complex phenomenon when general groundwater quality is affected by various stress factors (Bodrud-Doza *et al.,* 2016). Numerous researchers studied groundwater quality estimation through several indices methods that are based on the relative parameters weightage and overall categorization and assessment of water quality (Singh *et al.,* 2013; Gupta and Sarma 2013; Vasanthavigar *et al.,* 2010). Thus, these indices ease in estimating the pollution levels by assessing the inclusive water quality and resolving the difficulties for the area managers and decision makers for sustainable management of the groundwater resources. Thus, these indices ease in estimating the pollution levels by assessing the inclusive water quality and resolving the difficulties for the area managers and decision makers for sustainable management of the groundwater resources.

The present study focuses on the assessment of groundwater quality in Ghaziabad district of Uttar Pradesh based on the diverse land use pattern of the region. The district is densely populated and holds various residential, commercial complexes, industrial and agricultural areas. Major industries in the district include food processing, rubber, plastic and petroleum, chemical and chemical products, electric machinery equipment and so on ^(Industries at Ghaziabad). The agricultural activities include the cultivation of major crops such as wheat, mustard, rice, sugarcane etc. The utilization of fertilizers and pesticides and intense land use based pressures on the resources contribute to quality deterioration and decreasing groundwater availability. Moreover, only fragmented studies have been done in and around the Ghaziabad city (Singh *et al.,* 2014, 2012). Recent studies within the district focused on the groundwater pollution related with industrial outlook (Chabukdhara *et al.,* 2017; Kumari *et al.,* 2013). By appraising the quality of groundwater of Ghaziabad district on the basis of land use pattern and integrating the GWQI method would highlight and assess the issues responsible for the contamination in the concerned area in an extensive manner.

Materials and Methods

Study area

Ghaziabad is one of the emerging sub-urban districts of western Uttar Pradesh lies between the longitudes 77º12′E to 77º42′E and latitudes 28º36′N and 28º55′N (Figure 1). It shares its proximity to National Capital Territory (NCT) of Delhi, which is situated in the middle of the Ganga-Yamuna doab, *i.e.*, on the old flood plain of river Hindon. The major rivers that flow through the district are Ganga and Yamuna with the tributaries of

Hindon and Kali rivers. Ganga canal also aids in the irrigation and drinking water supply of the district. The physiographical area can be divided into three major regions viz., i) older alluvial plain, ii) older flood plain and iii) active flood plain. Rainfall is predominantly due to south west-monsoon (CGWB, 2009).

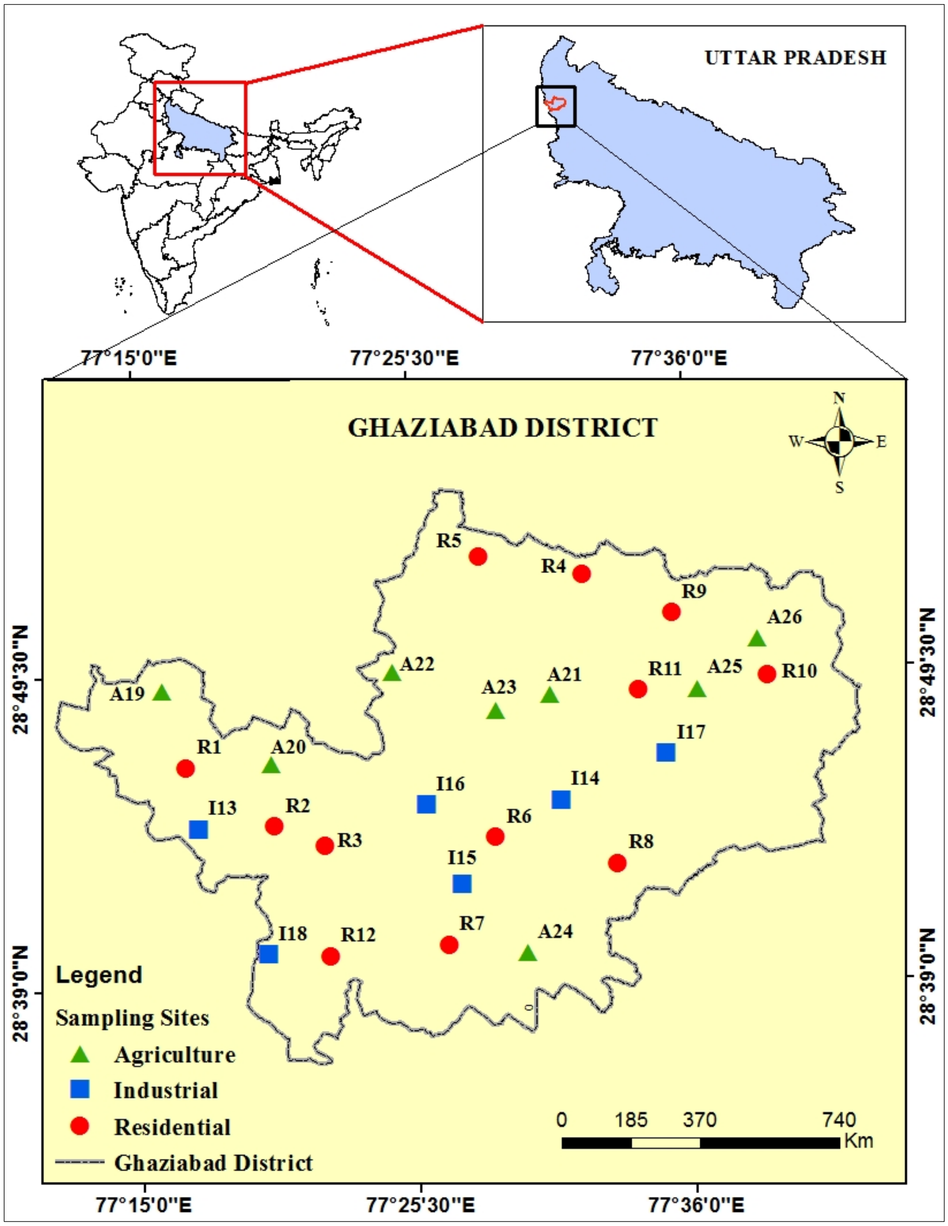


Figure 1 Sampling sites locations in Ghaziabad district

Sample collection and analytical procedures

Based on the land use categorization, 26 sites have been identified which consists have 12 residential, 6 industrial and 8 agricultural sites as outlined in Table 1. Groundwater samples, majorly consumed for the drinking and domestic purposes, were collected from India Mark II deep well and local hand pumps (depth ranging from ~40-60 ft.) during pre-monsoon season (May 2017). After flushing out the water for 10-15 minutes, samples were collected in two liter polyethylene bottles so as to remove the standing water.

Table 1. Groundwater samplings sites and coordinate points of Ghaziabad district

Sampling Sites	Location of SamplingSites	Sampling Sites Coordinates		Land Use Type
		Longitude	Latitude	
R1	Pabhi Sadakpur	77°16'52.64"E	28°46'27.04"N	Residential
R2	Jawali	77°20'12.12"E	28°44'25.98"N	Residential
R3	Farukh Nagar	77°22'6.85"E	28°43'44.65"N	Residential
R4	Niwari Village	77°32'6.97"E	28°52'41.98"N	Residential
R5	Khindora	77°28'9.94"E	28°53'21.76"N	Residential
R6	Duhai	77°28'36.40"E	28°43'56.78"N	Residential
R7	Ghaziabad City	77°26'45.81"E	28°40'22.40"N	Residential
R8	Nahal	77°33'14.14"E	28°42'59.61"N	Residential
R9	Santpura	77°35'28.78"E	28°51'21.60"N	Residential
R10	Palauta	77°39'5.11"E	28°49'11.71"N	Residential
R11	SikriKhurd	77°34'8.68"E	28°48'46.76"N	Residential
R12	Vasundara	77°22'13.98"E	28°40'3.61"N	Residential
I13	Balram Nagar	77°17'16.51"E	28°44'23.82"N	Industrial
I14	Muradnagar Ordinance Factory	77°31'7.53"E	28°45'9.072"N	Industrial
I15	Guldhar	77°27'17.20"E	28°42'23.00"N	Industrial
I16	Makraida	77°25'59.26"E	28°45'4.93"N	Brick Factory
I17	Kalchhina	77°35'9.74"E	28°46'39.32"N	Gas Factory
I18	Surya Nagar	77°19'51.81"E	28°40'9.40"N	Industrial
A19	Manduala Village	77°15'59.90"E	28°49'2.46"N	Agriculture
A20	Chirauri	77°20'6"E	28°46'31.90"N	Agriculture
A21	Didoli	77°30'45.61"E	28°48'42.91"N	Agriculture
A22	Nekpur	77°24'45.97"E	28°49'32.98"N	Agriculture
A23	Kakra	77°28'41.05"E	28°48'13.32"N	Agriculture
A24	Sadikpur	77°29'44.16"E	28°40'3.72"N	Agriculture
A25	Khanjarpur	77°36'23.90"E	28°48'48.38"N	Agriculture
A26	Muradabad	77°38'43.94"E	28°50'27.09"N	Agriculture

For heavy metal analysis, samples were collected in pre-washed and rinsed with 10% HNO_3 acidified polyethylene bottle and preserved with HNO_3 to maintain pH below 2. All the samples were collected and preserved for analysis and stored at 4^0C until analysis was performed and transported to the laboratory conditions. The major physicochemical analysis was performed through the standard protocol mentioned in APHA (2005) as summarized in Table 2.

For determination of heavy metals, samples were digested with 10 ml conc. HNO_3 and filtered using Whatman No. 42 filter paper. The heavy metals viz., Fe, Zn, Mn, Cu, Cr, Ni and Cd were analyzed through the standard procedure by using atomic absorption spectrophotometer (AAS) with minimum detection limit range of 0.001-0.020 ppm (Agilent 280 FS AA). All the methods applied were standardized and parameters were analyzed and recorded in the triplicates and average values were reported.

Results and Discussion

The statistical summary and graphical representations of the analytical results for the physicochemical and heavy metals in the groundwater samples based on the land use categorization in Ghaziabad district are presented in Table 3, Figure 2(a-l) and Figure 3(i-vii).

Table 2. Physicochemical parameters and analytical methods with BIS 2012 for drinking water

Parameters	Units	Formula	Analytical Method	BIS Standards (IS10500:2012)	
				Desirable Limit	Max. Permissible Limit
pH	On Scale	-	pH meter	6.5	8.5
Electrical Conductivity	µS/cm	EC	Conductivity Meter	-	-
Total Dissolved Solids	mg/L	TDS	Gravimetric	500	2000
Total Alkalinity	mg/L as $CaCO_3$	TA	Acid Titration	200	600
Total Hardness	mg/L as $CaCO_3$	TH	EDTA Titration	200	600
Calcium	mg/L	Ca^{2+}	EDTA Titration	75	200
Magnesium	mg/L	Mg^{2+}	-	30	100
Chloride	mg/L	Cl^-	Argentometric	250	1000
Sulphate	mg/L	SO_4^{2-}	Turbidimetric	200	400
Nitrate	mg/L	NO_3^-	UV Spectrophotometer	45	No Relaxation
Fluoride	mg/L	F^-	SPADNS Method	1	1.5
Sodium	mg/L	Na^+	AAS#	-	200$
Potassium	mg/L	K^+	AAS#	-	12$
Iron	mg/L	Fe	AAS	0.3	No Relaxation
Zinc	mg/L	Zn	AAS	5	15
Manganese	mg/L	Mn	AAS	0.1	0.3
Copper	mg/L	Cu	AAS	0.05	1.5
Chromium	mg/L	Cr	AAS	0.05	No Relaxation
Nickel	mg/L	Ni	AAS	0.02	No Relaxation
Cadmium	mg/L	Cd	AAS	0.003	No Relaxation

*Atomic Absorption Spectrophotometer; #Emission Mode, $WHO (2011)

Physicochemical analysis

The hydrogen ion concentration (pH) is an indicator of the acidity or alkalinity of the solution. In the present study, pH remains slightly alkaline in nature with no marked deviation for the residential, industrial and agriculture sites and recorded within the desirable limit of pH 6.5-8.5 (BIS 2012) as shown in Figure 2(a).

Electrical conductivity (EC) measures the water capacity to convey the electric current such that the higher EC shows enrichment of dissolved salts in the groundwater. The highest ranges of EC were found in residential site R1 (Pabhi Sadakpur), densely populated area, with 2190 µS/cm and in industrial site I18 (Surya Nagar) with 2920 µS/cm (Figure 2b), which might be due to the influence from high domestic or industrial discharges. EC, in agricultural sites, varies from 578-1154 µS/cm showed a decreasing trend in comparison with above two land uses which may be due to the dissolved and dissolution effect in the irrigation activities that is caused mainly by the agricultural runoff. The water consumed with higher total dissolved solids (TDS) values (>500mg/L) for drinking purposes can induce gastrointestinal infections (Dar *et al.,* 2011). TDS values were higher in the residential and industrial sites exceeding the BIS desirable limit of >500mg/L. The maximum TDS is at industrial site I18 (Surya Nagar) with 2675 mg/L as shown in Figure 2(b) which is in the vicinity of Sahibabad industrial sector that might influence the groundwater quality by releasing the industrial effluents and contributing high TDS values within the site. However, agricultural sites showed a lower range of TDS 170-825 mg/L that accounts the constituents dissolution while irrigating the fields.

Total Alkalinity (TA) of groundwater rises due to presence of bicarbonate (HCO_3), carbonate (CO_3^{2-}) and hydroxide ions (OH^-) and forms the acid neutralizing capacity of the water. The desirable limit of TA in water is 200 mg/L. The values of TA were greater in industrial areas with mean value of 390 mg/L as $CaCO_3$ in comparison to residential; 362.5 mg/L as $CaCO_3$ and agricultural sites 343.8 mg/L as $CaCO_3$, but recorded within the permissible limit of 600 mg/L as $CaCO_3$ (BIS, 2012).

Total Hardness (TH) of the groundwater is caused predominantly due to the presence of calcium (Ca^{2+}) and magnesium (Mg^{2+}) cations. The highest value of TH were recorded in the industrial site I18 (Surya Nagar) with 640 mg/L as $CaCO_3$ as shown in Figure 2(d); exceeding the permissible limits of 600 mg/L as $CaCO_3$ due to the industrial wastes discharges. The residential and agricultural sites recorded the values of 148-560 and 188-344 mg/L as $CaCO_3$, respectively.. However, the values were found within the permissible limits (BIS, 2012). The presence of divalent cations such as Ca^{2+} and Mg^{2+} influence the hardness of drinking and irrigation water (Kumari *et al.,* 2013). The observed calcium and magnesium ion were ranged between 36.87-112.2 mg/L and 13.66-95.60 mg/L in residential; 44.9-153.9 and 17.5-62.5 mg/L in industrial and 36.9-78.5 and 16.6-45.9 mg/L in agricultural sites, respectively. The values of Ca^{2+} and Mg^{2+}cations in the three land use types were found within the given permissible limit of 200 mg/L and 100 mg/L respectively (BIS, 2012) as shown in Figure 2 (e) and (f).

Table 3 Statistical descriptions of physicochemical and heavy metals analysis based on land use

Parameters	RESIDENTIAL			INDUSTRIAL			AGRICULTURE		
	Range	Mean	SD	Range	Mean	SD	Range	Mean	SD
pH	7.22-7.90	7.48	0.20	7.4-7.7	7.51	0.13	7.4-7.76	7.53	0.13
EC	408-2190	1034.17	545.34	685-2920	1438	927.9	578-1154	762.6	182.9
TDS	280-1450	650.80	341.8	105-2675	886.6	917.3	170-825	451.3	219.5
TA	190-530	362.5	101.27	210-500	390	110.6	300-410	343.8	35.43
TH	148-560	298.33	126.59	232-640	367.3	149.4	188-344	282	62.37
Ca^{2+}	36.87-112.2	66.13	22.60	44.9-153.9	82.56	37.24	36.9-78.5	60.71	13.19
Mg^{2+}	13.66-95.60	32.53	23.20	17.5-62.5	39.4	16.02	16.6-45.9	32.09	9.63
Cl^-	9.9-426	110.05	132.30	8.52-1053.6	274.2	413.5	7.1-71	31.42	26.48
SO_4^{2-}	26.9-171.5	51.07	41.87	27.9-179.5	80.23	66	19.23-125.4	41.83	35.22
NO_3^-	0.32-37.1	6.17	10.05	0.59-3.66	2.05	1.36	0.15-5.9	1.92	1.88
F^-	0.12-1.2	0.564	0.36	0.15-1.54	0.82	0.55	0.12-1.03	0.43	0.28
Na^+	21.18-313	134.05	93.89	134.04-528.7	246.03	155.5	80.8-209.3	135.9	37.62
K^+	9.26-25.69	15.15	4.3	12.03-55.9	26.3	17.54	11.63-18.34	15.77	2.34
Fe	0.01-19.49	2.36	5.7	0.03-0.76	0.23	0.28	0.03-3.9	0.77	1.28
Zn	*N.D.-1.77	0.48	0.61	0.08-2.93	0.78	1.08	0.06-1.62	0.42	0.50
Mn	0.003-1.31	0.15	0.37	0.05-0.17	0.1	0.05	0.02-0.23	0.12	0.06
Cu	0.01-0.2	0.03	0.05	0.01-0.03	0.02	0.008	0.01-0.026	0.016	0.005
Cr	0.005-0.04	0.02	0.01	0.002-0.06	0.032	0.02	0.002-0.003	0.016	0.012
Ni	0.02-0.10	0.07	0.02	0.033-0.11	0.06	0.03	0.04-0.097	0.078	0.017
Cd	N.D.-0.02	0.01	0.01	N.D.-0.016	0.007	0.01	N.D.-0.016	0.013	0.005

All the parameters are in mg/L units except pH (on scale), EC (µS/cm) and Total Hardness and Total Alkalinity (mg/L as $CaCO_3$). **SD:** Standard deviation ***N.D.:** Not Detected

The sources of chloride (Cl^-) include weathering, leaching from sedimentary rocks and soil; domestic and municipal effluents (Sarath Prasanth *et al.,* 2012). In the study area, the chloride levels were highest at the industrial site I18 with 1053.7 mg/L (Figure 2g) recorded in the industrial vicinity of Surya Nagar which might be due to the leaching of salts fromanthropogenic industrial based activities as it is majorly occupied by several chemical, food processing, electrical units etc. Higher concentrations of Cl^- induce a salty taste in water. The value of Cl^- ranges with 9.9-426 mg/L and 7.1-71 mg/L in residential and agriculture, respectively and within the permissible range of 1000 mg/L (BIS 2012).

Sulphate (SO_4^{2-}) concentrations greater than 400 mg/L leads to laxative effect on human organs. The three land use types of residential, industrial and agricultural sites having sulphate levels were found within the maximum limits of 400 mg/L (BIS 2012) and varies from 26.9-171.5 mg/L, 27.9-179.5 mg/L and 19.23-125.4mg/L, respectively as shown in Figure 2(h).

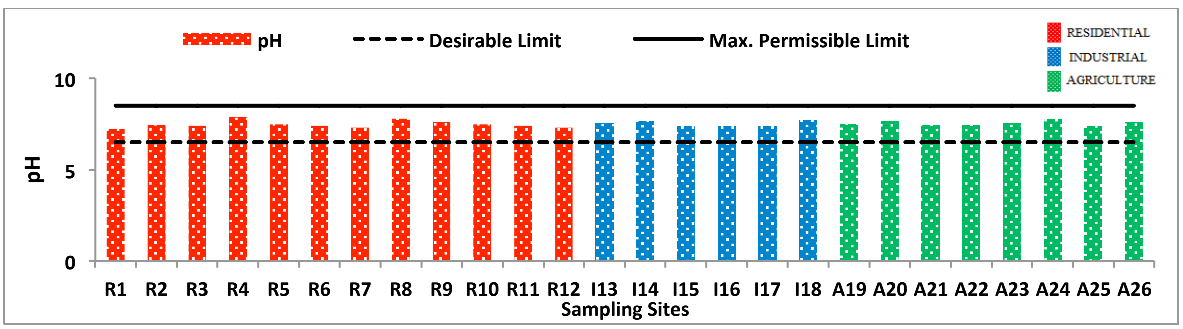
Nitrate (NO_3^-) contamination is a major problem in groundwater systems and higher concentrations likely to cause diseases such as methemoglobinemia, gastric cancer, thyroid disease and diabetes (Krishna Kumar *et al.,* 2011). Nitrate concentration exceeds in groundwater as the resultant of domestic wastewater discharge and usage of fertilizers. The values of nitrate in the groundwater vary from 0.32-37.1mg/L, 0.59-3.66 mg/L and 0.15-5.9 mg/L for residential, industrial and agriculture, respectively. All the respective samples were within the permissible limits of 45 mg/L as per BIS 2012 (Figure 2i).

Fluoride (F^-) element required in trace amounts for the development of teeth and bones, however, exposure to higher values of F^- greater than 1.5 mg/L causes fluorosis. The maximum values of F^- found in the industrial sites ranges from 0.15-1.54 mg/L crossing the permissible limits of 1.5 mg/L. The residential (0.12-1.2 mg/L) and agriculture (0.12-1.03 mg/L) sites indicated the values within the permissible limits. Some anthropogenic activities also contribute to the large amount of fluoride. The highest value of fluoride found at site I13 (Balram Nagar) where several stone crushing and steel and iron industrial units prominent (Figure 2j).

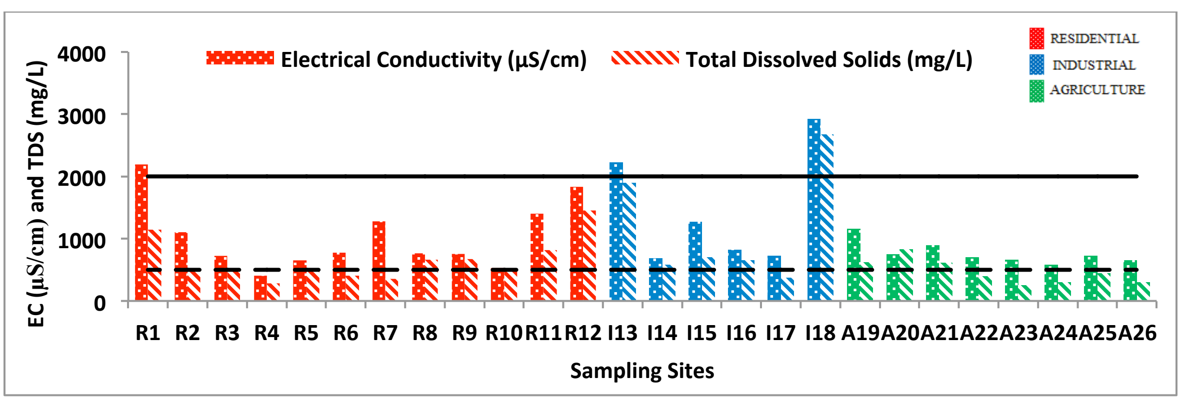
Sodium (Na^+) cation accounts approximately 53 to 69% of the total cations in the natural water due to the silicate weathering and/or dissolution of salts that are retained by the action of evaporation, human and agricultural activities and poor drainage systems (Krishna Kumar *et al.,* 2015). It also regulates and maintains the fluid balance of the human body and their higher uptakes by the consumer induce physiological changes. The concentration of Na^+ varied from 21.18-313 mg/L (residential), 134.04-528.7 mg/L (industrial) and 80.8-209.3 mg/L (agriculture) and these elevated concentrations of Na^+ exceeding the permissible limits of 200 mg/L (WHO 2011) for sites R1, R10, R12, I13, I18 and A26 as shown in Figure 2(k). The residential sites of R1(Pabhi Sadakpur) and R10 (Palauta) are densely populated and involves in small agriculture fields that might induce combined effect of salts discharge at higher proportions. For R12 (Vasundara) is a densely populated residential sectors and the improper waste disposal was encountered at the site. As sites I13 and I18 are the prominent industrial locations within the district, releasing the untreated effluents caused the increasing concentration of Na^+ other than the natural sources.

Potassium (K^+) is a naturally occurring element that found in lesser quantities as compared to Ca^{2+}, Mg^{2+} and Na^+. It sustains the plant physiology and controls the metabolism in human being. The value of K^+ in the study area for residential and agriculture sites were 9.26-25.69 mg/L and 11.63-18.34 mg/L as compared with industrial sites showed higher ranges of the K^+ of 12.03-55.60 mg/L. About 84% of the samples crossed the permissible limit of 12 mg/L (WHO, 2011) as shown in Figure 2(l), which indicates the potassium forms of complexes and also found as an important constituent in rocks and fertilizers. Potassium water softeners are being used replacing the sodium water softeners as an insight that potassium is beneficial for the health (Kumari *et al.,* 2013). The higher concentrations of Na^+ and K^+ in the groundwater may also originate from mineralogical soil, cation-exchange process and particularly from agriculture and industrial activities discharges. Eventually, the higher concentrations of Na^+ and K^+ in the groundwater increase in the residence time.

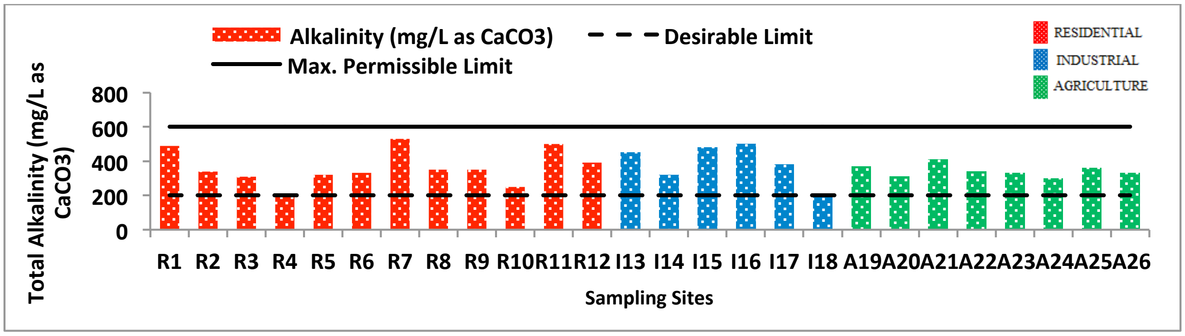
In the above land use category, the residential sites showed all the physicochemical water quality parameters within the max. permissible limits except EC that was recorded highest at site R1(Pabhi Sadakpur). Similarly, for the agricultural sites, all the quality parameters were within the range of permissible limits. However, for the industrial areas of the Ghaziabad district, sites I13 (EC and F^-) and I18 (EC, TH, Cl^-) exceeded the limits, which show the influence of the improper discharging from the industrial units.



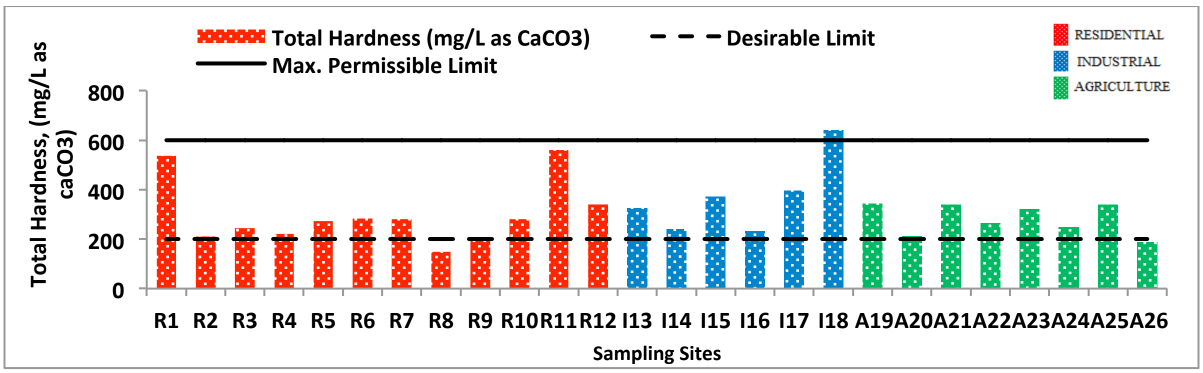
(a) pH



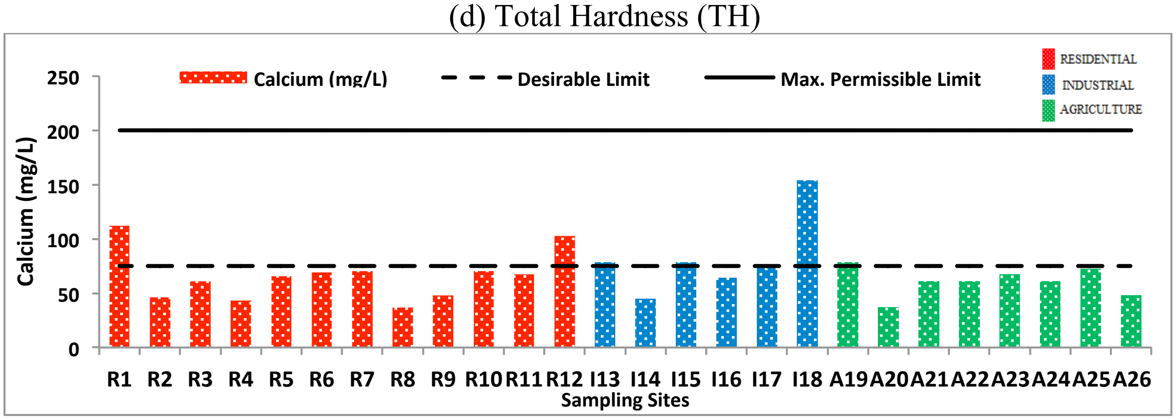
(b) Electrical Conductivity (EC) and Total Dissolved Solids (TDS)



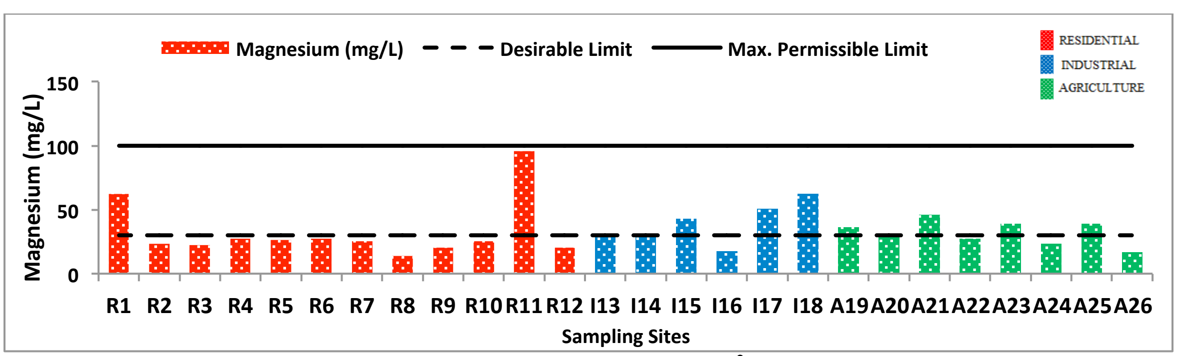
(c) Total Alkalinity (TA)



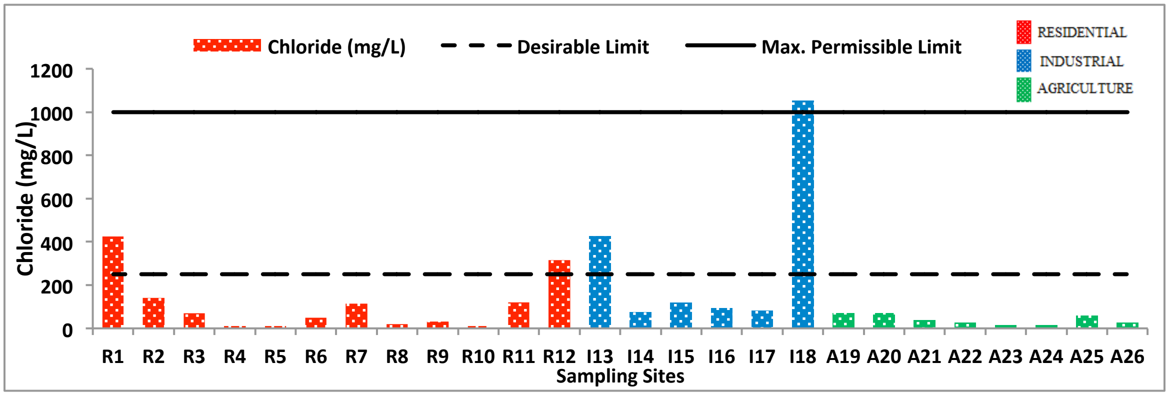
(d) Total Hardness (TH)



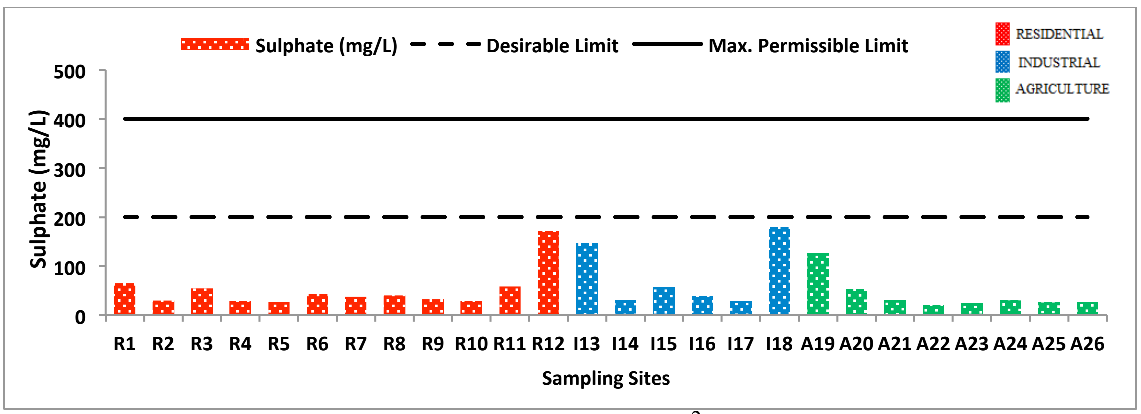
(e) Calcium (Ca^{2+})



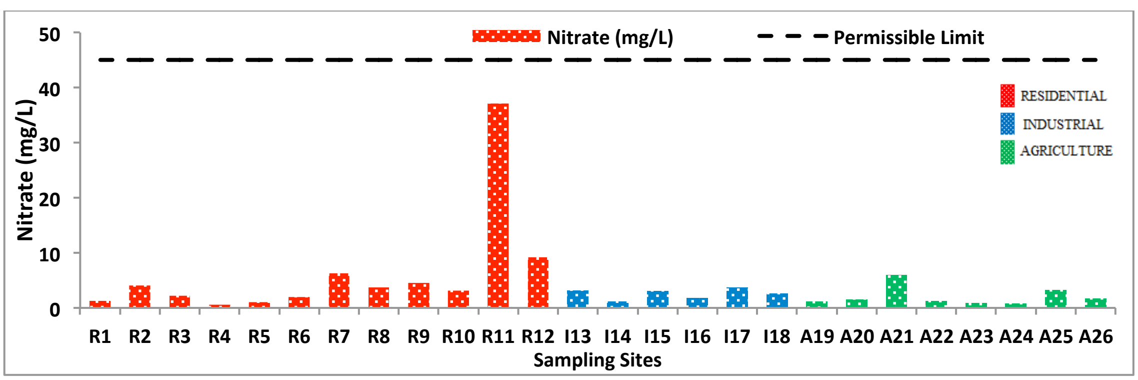
(f) Magnesium (Mg^{2+})



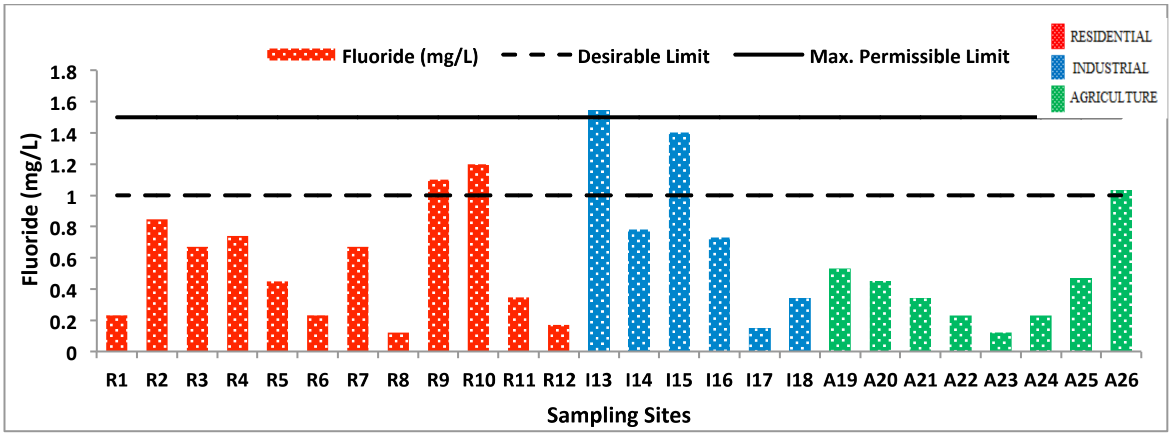
(g) Chloride (Cl^-)



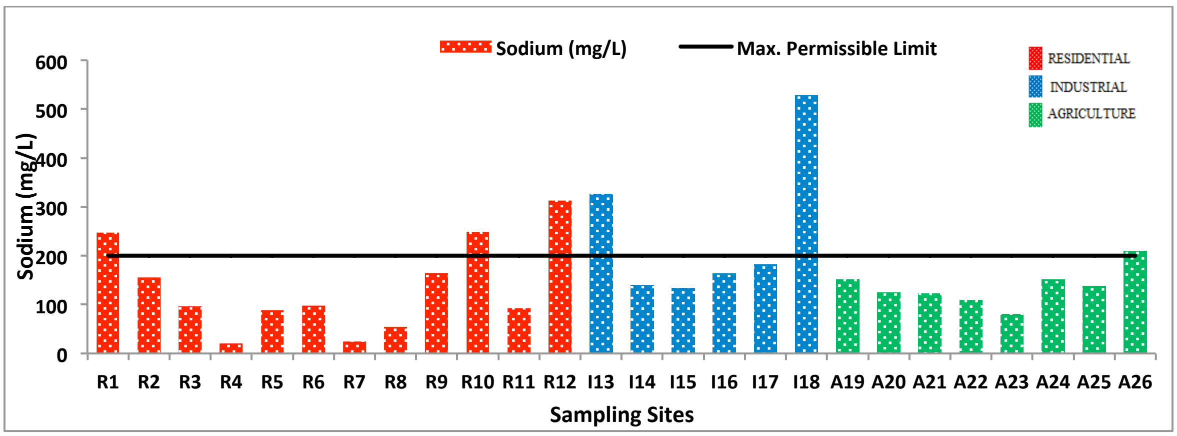
(h) Sulphate (SO_4^{2-})



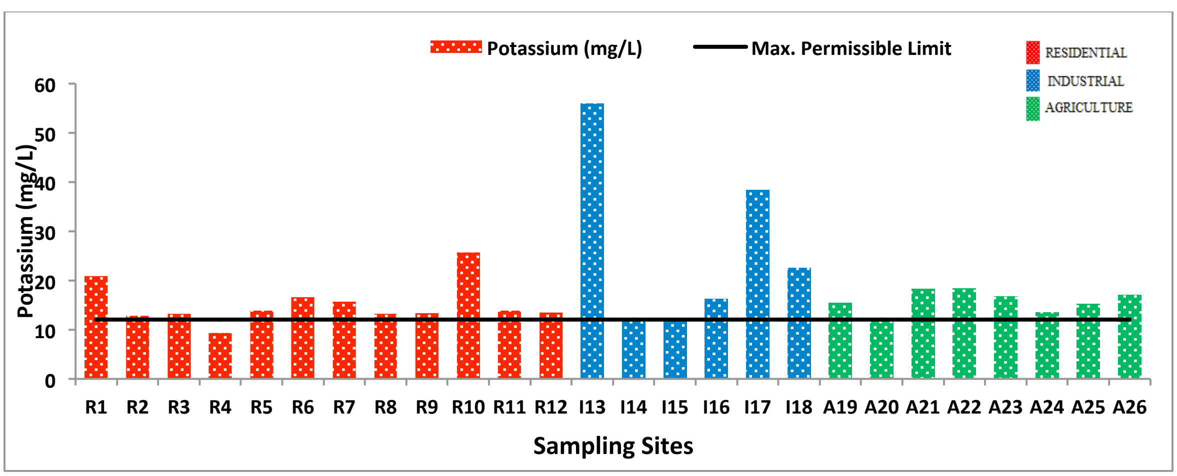
(i) Nitrate (NO_3^-)



(j) Fluoride (F^-)



(k) Sodium (Na^+)



(l) Potassium (K^+)

Figure 2(a-l) Physicochemical analysis for the groundwater in the respective land use category in with compliance with BIS standards

Heavy metals analysis

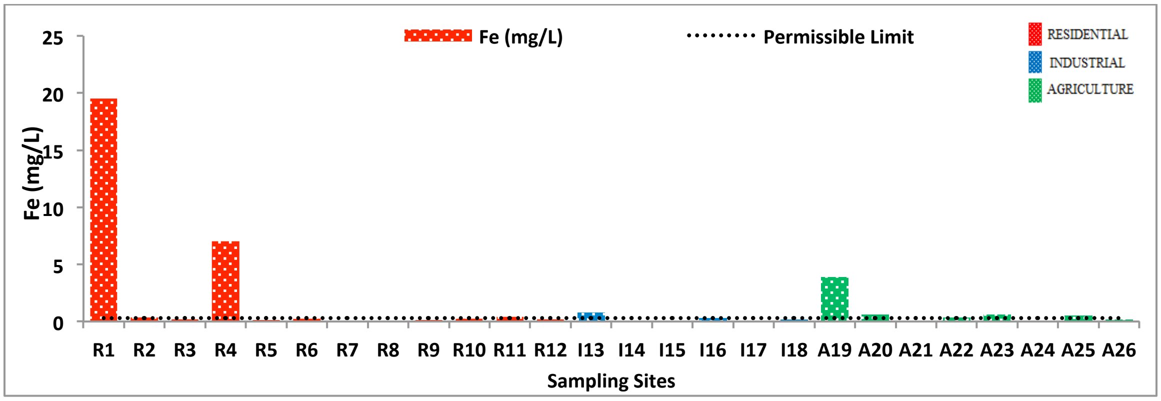
Iron (Fe) is observed as the key metal in groundwater samples and the higher concentration of Fe was found in the residential sites (0.01-19.49 mg/L). Rusting of the pipes and/or hand pumps might contribute to presence of Fe in the groundwater. However, Fe is predominantly found as the natural element in the Earth surface and can be involved as the geogenic in the nature. Moreover, the values of Fe for the industrial sites (0.03-0.76 mg/L) and agricultural areas (0.03-3.9 mg/L) were also exceeding the permissible limit of 0.3 mg/L (BIS 2012). Similar results were reported by Singh *et al.* (2014). The interaction of oxidized Fe bearing minerals and dissolution of Fe_2CO_3 might be the reason for iron contamination in the groundwater. About, 34% of the groundwater samples were exceeding the permissible limit (Figure 3i). The mean concentration of Zinc (Zn) in residential with 0.48 mg/L, industrial with 0.78 mg/L and in agricultural sites with 0.42 mg/L; were found within the safe limits of 5 mg/L (BIS 2012) as shown in Figure 3(ii).

The concentration of Manganese (Mn) in residential areas ranging from 0.003-1.31 mg/L was within the permissible limit of 0.3 mg/L. The highest value of Mn was recorded at site R1 (Pabhi Sadakpur) shown in Figure 3(iii) and shows the proximity to major urban disposal sites as it is densely populated area. The levels were safe for industrial (0.05-0.17 mg/L) and agricultural sites (0.02-0.23 mg/L). According to Kumari *et al.* (2013) Mn stimulates the Fe bearing bacteria in the groundwater.

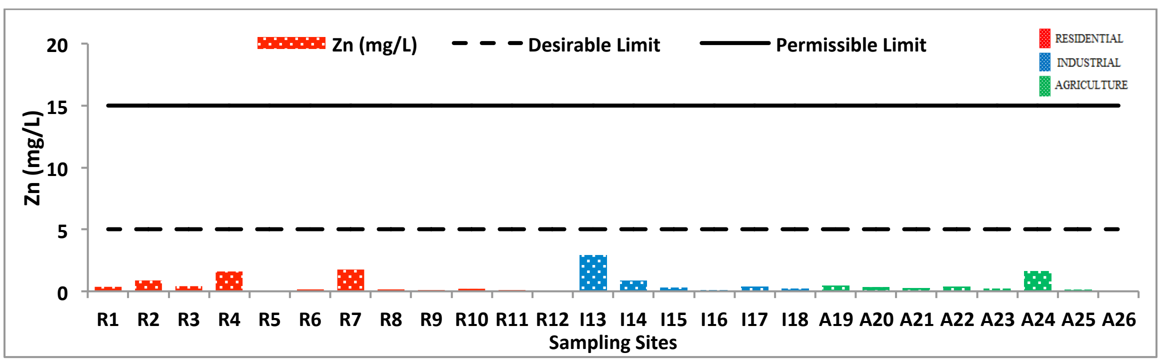
The heavy metals such as copper (Cu) and chromium (Cr) are the essential elements required in trace amounts but in excess amounts, leads to toxicity. However, Cu and Cr are found within their permissible limit of 1.5 mg/L and 0.05 mg/L respectively, (BIS 2012) shown in Figure 3(iv) and 3(v). Cu values range from 0.01-0.2 mg/L, 0.01-0.03 mg/L and 0.01-0.026 mg/L in residential, industrial and agricultural sites, respectively. Similarly, Cr is discharged predominantly from dye and paints pigments, wood preservatives and used in the metal alloys. Cr values vary from 0.005-0.04 mg/L in residential and 0.002-0.003 mg/L in agricultural sitesand were within the safe limits of 0.5 mg/L. However, higher amounts of Cr with 0.06 mg/L were observed in industrial sites I13 (Balram Nagar) and I18 (Surya Nagar), which is due to the improper waste disposal in the proximity of industrial sites.

Nickel (Ni) is mainly used in the production of stainless steel and nickel alloys. The safe limit for Ni concentration is 0.02 mg/L (BIS 2012) and exceeded in residential with mean values of 0.07 mg/L, 0.06 in agricultural 0.078mg/L and industrial sites having 0.06 mg/L. The exceeding values of Ni were found in all the samples for each type of land use (Figure 3vi); which might be due to the dissolution of the Ni bearing rocks and geo-genic process. Similar results were reported by Chabukdhara *et al.* (2017) for urban and peri-urban sites and Kumari *et al.* (2013) for industrial sites of Ghaziabad district. Also, leaching of Ni from some hand pumps could be the reason as mainly they are made up of stainless steel.

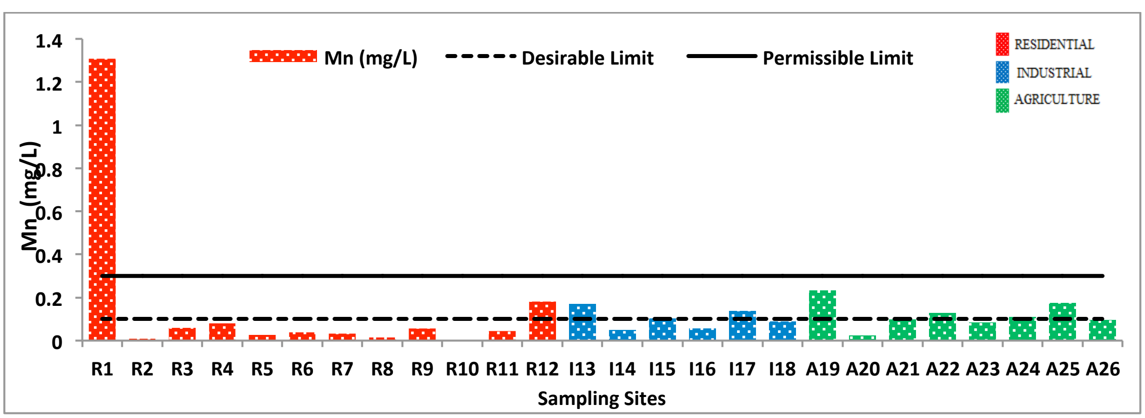
Cadmium (Cd) is highly toxic metal if ingested in trace amounts as it gets accumulated mainly in liver and kidneys on exposure (Chabukdhara *et al.,* 2017). The mean concentration of Cd was higher with mean values in residential (0.01mg/L), industrial (0.007 mg/L) and agricultural sites (0.013 mg/L) i.e., about 69% of the samples were exceeding the permissible limits 0.003 mg/L (BIS 2012) as shown in Figure 2(vii). The prominent sources of Cd are steel industries, batteries and plastic industries. Wastewater pollution, fertilizers and local air pollution also cause Cd contamination of groundwater, which could be the reason for the increasing value of Cd in the region.



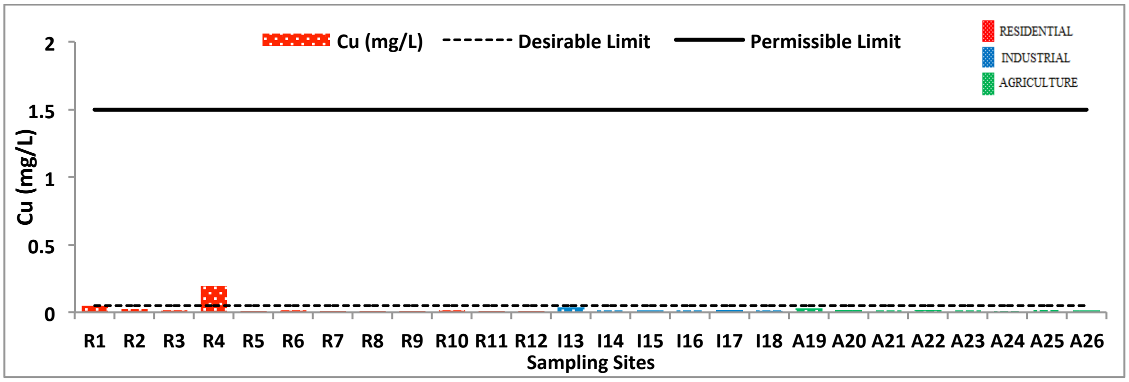
(i) Iron (Fe)



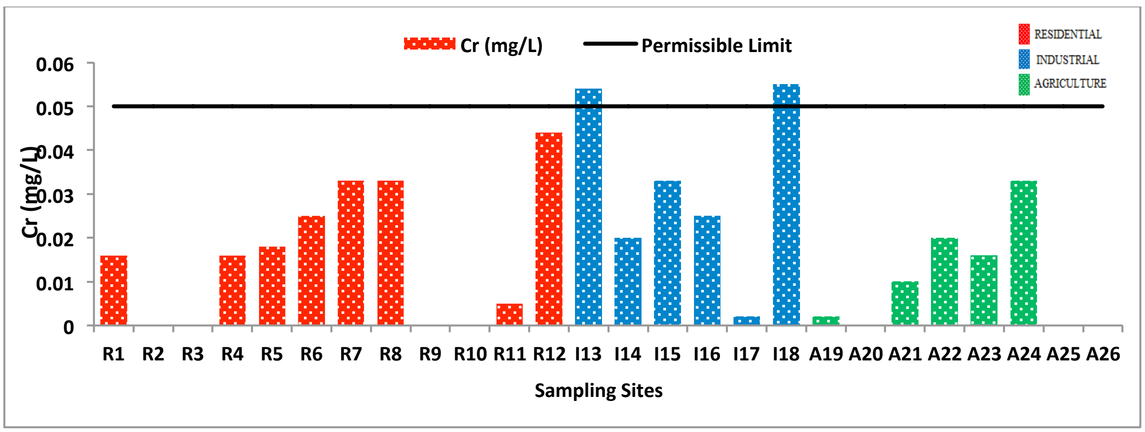
(ii) Zinc (Zn)



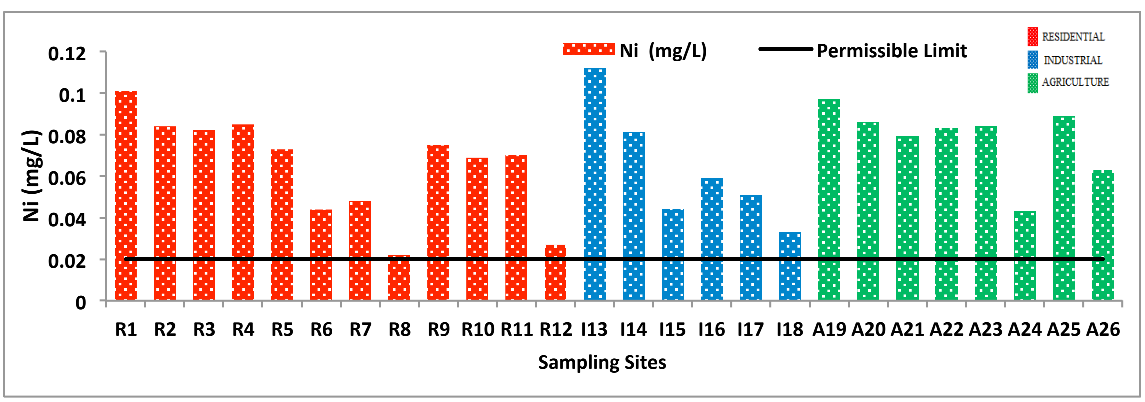
(iii) Manganese (Mn)



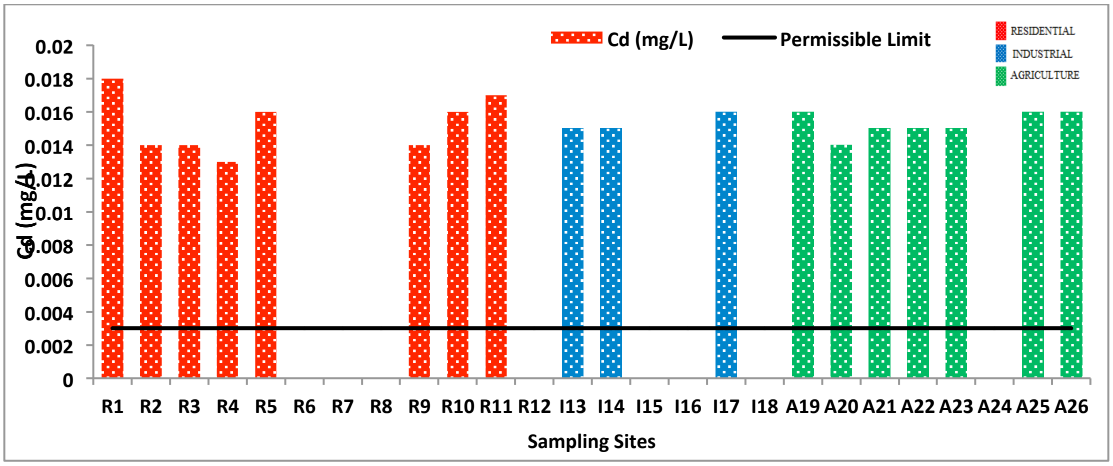
(iv) Copper (Cu)



(v) Chromium (Cr)



(vi) Nickel (Ni)



(vii) Cadmium (Cd)

Figure3 (i-vii). Heavy metals analysis for the groundwater samples for the respective land use category in compliance with BIS standards

Evaluation through Ground Water Quality Index (GWQI)

Ground Water Quality Index (GWQI) is one of the effective tools for assessing theinclusive quality of water. In order to determine the suitability for the drinking purposes, GWQI is calculated by the following formula (Asadi *et al.,* 2007).

$$\mathbf{GWQI} = \boldsymbol{Antilog}[\sum W_{n=1}^{n} \log_{10} q_n],$$

where,
W_n = Weightage factor calculated as follow, $\mathbf{W_n = K/S_n}$
K = Proportionality constant derived from following equation**;**

$$\mathbf{K} = [\mathbf{1}/(\textstyle\sum_{n=1}^{n} \mathbf{1}/S_i)],$$

where,
S_i and $S_n$are recommended drinking water standards as per BIS.

$$\textbf{Quality rating; } q_n = [\{(V_a - V_i) / (V_s - V_i) \times 100\}],$$

Where**,**
q_{ni}= Quality rating of the i^{th} parameter for total n parameters,
V_a = Value of the parameter obtained from actual laboratory experiment
V_i = Value of the parameter from the standard. The value taken for pH = 7 and for other parameters it is zero.
V_s = BIS standard value for the respective parameter (Table 3).

Table 4. Groundwater quality parameters and their assigned weightage (W_n)

PARAMETERS	BIS STANDARD (Permissible Limit)	Weight (Wn)
pH	8.5	0.00029
TDS (mg/L)	2000	0.00000
TA (mg/L as $CaCO_3$)	600	0.00000
TH (mg/L as $CaCO_3$)	600	0.00000
Ca^{2+}(mg/L)	200	0.00001
Mg^{2+} (mg/L)	100	0.00002
Cl^- (mg/L)	1000	0.00000
SO_4^{2-} (mg/L)	400	0.00001
NO_3^- (mg/L)	45	0.00005
F^- (mg/L)	1.5	0.00162
Na^+ (mg/L)	200	0.00005
K^+ (mg/L)	12	0.00020
Fe (mg/L)	0.3	0.00810
Zn (mg/L)	15	0.00016
Mn (mg/L)	0.3	0.00810
Cd (mg/L)	0.003	0.80972
Cr (mg/L)	0.05	0.04858
Ni (mg/L)	0.02	0.12146
Cu (mg/L)	1.5	0.00162

Table 5. GWQI based classification of groundwater quality.

S.No.	GWQI Value	Ground Water Quality	Explanation
1.	<50	Excellent	Good for human health
2.	50-100	Good Water	Fit for human consumption
3.	100-200	Poor Water	Water not on good condition
4.	200-300	Very Poor Water	Need attention before use
5.	>300	Unfit for drinking	Need too much attention

Source: Kumari *et al.* (2013)

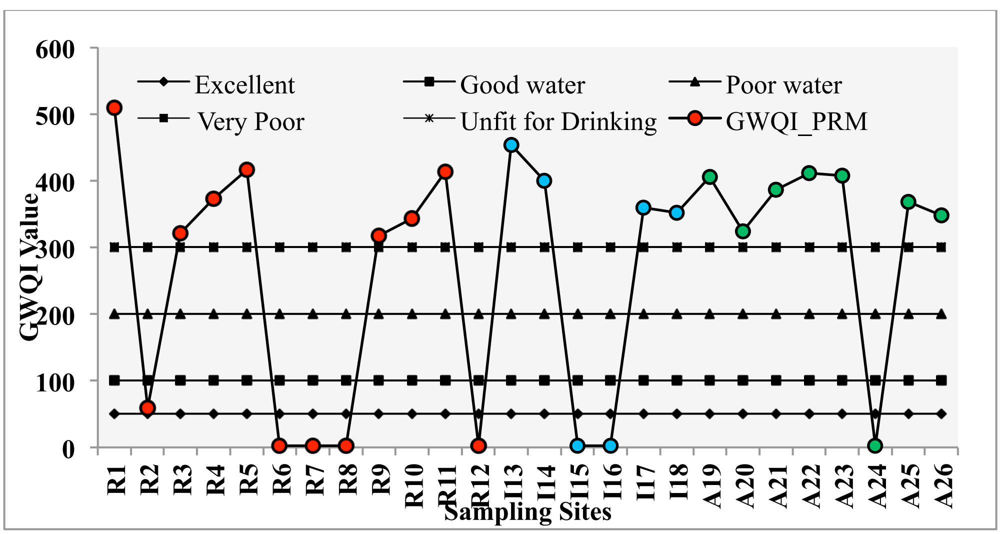


Figure 4. GWQI values for the groundwater in pre-monsoon season

The groundwater quality was classified into excellent, good water, poor water, very poor and unfit for drinking categories based on the GWQI values (Table 5). Based on the classification, about 69% of the groundwater samples found unfit for drinking category and overall groundwater quality is not potable (Table 6). The study area of Ghaziabad district is immensely polluted from the industrial and rapid urbanization. The inclusive study of impact of land use based on residential, industrial and agricultural sites influence the groundwater and its quality. Some of the sites within the region showed excellent water, which could be the reason as no respective parameter, is exceeding the limits of BIS 2012. These sites are also affected by the industrial effluent and wastes discharges from densely populated sites.

Table 6. GWQI value for the respective sites in Ghaziabad district

Site	Location Name	Ground Water Quality Index	
		GWQI VALUE	GWI QUALITY
R1	Pabhi Sadakpur	509.33	Unfit for Drinking
R2	Jawali	59.33	Good Water
R3	Farukh Nagar	321.48	Unfit for Drinking
R4	Niwari Village	373.11	Unfit for Drinking
R5	Khindora	415.81	Unfit for Drinking
R6	Duhai	2.48	Excellent
R7	Ghaziabad City	2.51	Excellent
R8	Nahal	2.23	Excellent
R9	Santpura	316.96	Unfit for Drinking
R10	Palauta	343.64	Unfit for Drinking
R11	SikriKhurd	413.71	Unfit for Drinking
R12	Vasundara	2.42	Excellent
I13	Balram Nagar	453.84	Unfit for Drinking
I14	Muradnagar Ordinance Factory	399.58	Unfit for Drinking
I15	Guldhar	2.58	Excellent Water
I16	Makraida	2.58	Excellent Water
I17	Kalchhina	359.66	Unfit For Drinking
I18	Surya Nagar	351.44	Unfit For Drinking
A19	Manduala Village	405.60	Unfit For Drinking
A20	Chirauri	324.04	Unfit for Drinking
A21	Didoli	386.81	Unfit For Drinking
A22	Nekpur	410.96	Unfit For Drinking
A23	Kakra	407.19	Unfit For Drinking
A24	Sadikpur	2.50	Excellent
A25	Khanjarpur	367.96	Unfit For Drinking
A26	Muradabad	347.70	Unfit For Drinking

Conclusion

The present study investigated the status of groundwater quality of Ghaziabad district of Uttar Pradesh based on the land use types. The higher concentrations of the major physicochemical and heavy metals such as EC, TDS, TH, Cl^-, F^- , major cations (Na^+ and K^+); Fe, Cd and Ni are degrading the quality of groundwater through the major influence of emerging urbanization and industrialization. The elevated levels of various constituents direct the dominance of anthropogenic activities within the region. The quality of groundwater was examined for the drinking purposes in compliance with BIS 2012 standards by integrating the GWQI, which offers the inclusive property of drinking water quality. Results revealed that about 69% of the samples were in the category of unfit for drinking. An immediate attention should be given in order to reduce the contamination through land use activities and heavy metals pollution loading need to be checked especially for Fe, Cd and Ni for the shallow and deep aquifer levels.

Acknowledgement: The authors wish to acknowledge the financial support by providing scholarship and laboratory facility from USEM, GGS Indraprastha University, Delhi.

Authors Contribution: *Shipra Tyagi (Ph.D. Scholar) performed the research work, data collection and writing of the manuscript; Kiranmay Sarma (Associate Professor) is the corresponding author of the manuscript and contributed to editing of the manuscript.*

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