Int. J. Econ. Environ. Geol. Vol. 9 (3)63-70, 2018

Journal home page: www.econ-environ-geol.org

Open Access

ISSN: 2223-957X

Evaluation of Groundwater Quality of Aligarh City, (India): Using Statistical Techniques Approach

Aqsa Irfan*, Shadab Khurshid

Department of Geology, Aligarh Muslim University, Aligarh, India

*****Email: aqsairfan.amu@gmail.com

Received: *21 July, 2018* ***Accepted:*** *16 August, 2018*

Abstract: Examination of the idea of groundwater of a particular area has a phenomenal importance in both drinking and irrigational purposes. Water which is essential for all the living beings for their existence and metabolism plays a major role in the ecosystem. Unethical human involvement and exploitation of the groundwater resources leads to water quality degradation. Present examination has been directed and administered to analyze the chemistry of groundwater of the Aligarh city. This has been led by collecting the groundwater samples of the study area and subjecting the samples to the entire physicochemical investigation. Groundwater samples were collected from 45 different reviewing stations line missing during the year 2016 for the appraisal of groundwater nature of the study area. High coefficient of variance indicates variability of the physicochemical parameters and groundwater samples concentration. The clear measurable investigation was done close to Pearson correlation. From the connection examination, it is discovered that an incredibly strong relationship exists between electrical conductivity (EC) with hardness (0.82), magnesium (0.82) and sulfate (0.81) then again hardness is likewise showing correlation with calcium (0.86), magnesium (0.95) and sulfate (0.83). lead and cadmium fixation in the water samples was observed to be a part of the most extremely reasonable breaking point suggested by Bureau of Indian Standard (BIS 2012) and demonstrates 100% concentration in groundwater samples of the study area. Concentration of total dissolved solid (TDS), magnesium (Mg), sodium (Na), sulfate (So_4), lead (Pb), nickel (Ni), chromium (Cr) and cadmium (Cd) are furthermore found beyond the maximum permissible limit endorsed by Bureau of Indian Standard (BIS 2012). This reveals water quality deterioration in Aligarh city which needs some treatment before consumption and needs to be protected from contamination. It is therefore suggested that a regular monitoring of groundwater is carried out.

Keywords: Groundwater, physiochemical characteristic, statistical analysis, Aligarh, India.

Introduction

Ground water is utilized both for household and industrial water supply and water systems throughout the world. Over the recent four decades, there has been required an immense increase for fresh water because of the quick development of population and increased rate of industrialization. Human wellbeing is encouraged by the vast majority of the rural improvement exercises especially in connection with excessive use of manures and poor sanitary condition. As per World Health Organization (WHO 2013) association, around 80% of the considerable number of infections in an individual are mainly caused by water. Once the ground water is polluted, its quality cannot be reestablished by preventing the toxins from the source.

It is estimated that about 2.1 billion people lack access to safe, readily available water at home, and 4.5 billion, lack safely managed sanitation, according to a recent report by WHO and UNICEF (2017). The Joint Monitoring Programmed (JMP) report, progress on drinking water, sanitation and hygiene update and sustainable development goal baselines, presents the first global assessment of “safely managed” drinking water and sanitation services (2017). The overriding conclusion is that too many people still lack access, particularly in rural areas.

During last two decades an increase in population spontaneous urbanization, unhindered investigation strategies and dumping of the untreated water at unsuitable places makes the ground water contaminated (Pandey et. al, 2008**)**. Groundwater development being subsurface phenomenon, its recognition and area depends on incidental investigation of some directly observable terrains like land, geomorphological, structural and their hydrological trade mark (Wani, 2009).

Groundwater is the primary natural resource and precious natural asset, which has attained an important position in overall water resource development plans and program of a developing country like India, which has a predominantly agricultural economy (Pradeep Kumar and Srinivas 2012). Groundwater system of an area depends on a number of factors, such as general geology, degree of chemical weathering of various rock types, quality of recharge water and inputs from sources other than water–rock interaction resulting in a complex groundwater quality (Guler and Thyne, 2004).
Groundwater usage has expanded at a disturbing rate over a time of three decades in the study region (Umar et. al, 2009). It is verifiable truth that no straight forward reason can be ascribed for the disintegration of water quality as it is reliant on a few water quality parameters. There exists solid assemblage.

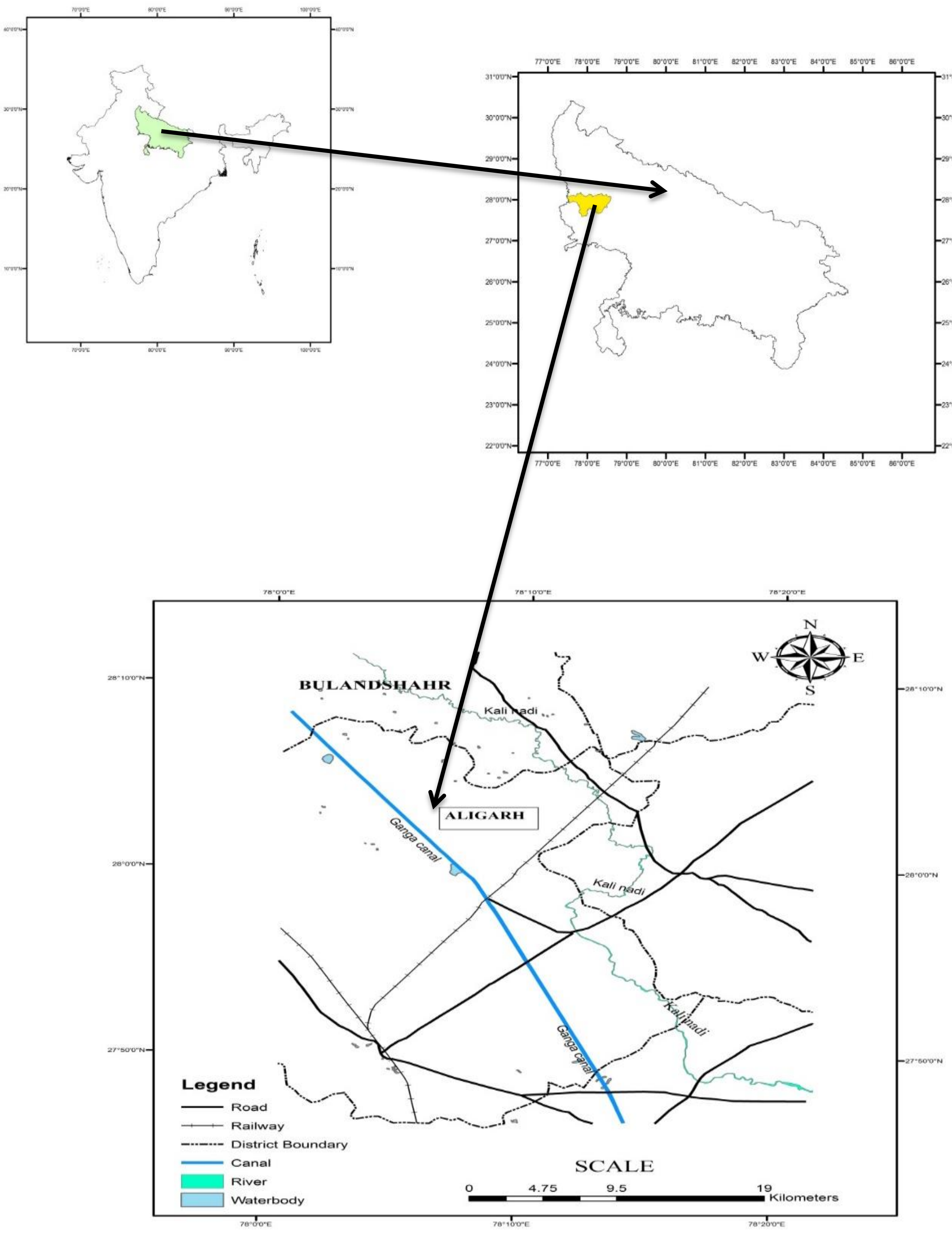

Fig. 1. Map showing the study area

Table 1. Based on the borehole log the subsurface geology of Aligarh district after CGWB (2012-2013).

Sequence of geological foundation	Depth range (m bgl)		Age
Alluvium	0 – 360		Quaternary
Siwalik (upper middle)	360	620	Neogene
Lower Bhander limestone (upper Vindhyans)	620	2061	Upper Proterozoic
Bundelkhand Granite(basement rock)	>2061		Archean

Bansal et.al (2004) completed investigation on gorund water nature, groundwater usage has been expanded at a large scale over a time of three decades in the Aligarh district (Umar et. al, 2009). It is verifiable truth that no straight forward reason can be ascribed for the disintegration of water quality as it is reliant on a few water quality parameters. The goal of this examination was to explore the extent of pollutants present in the groundwater of Aligarh region during the last 10 years i.e. from 1996 – 2006. Umar et.al., (2001) did microbiological quality investigation of groundwater and the results of the examination indicated microbial defilement in shallow groundwater. Throughout the years with an expanding population result in increasing urban activities, in addition to an absence of legitimate natural control measures, required regular checking of the water quality (Bansal et.al., 2008)

Environmental concerns related to groundwater (GW) generally focus on the impact of pollution and its quality of degradation in relation to human uses, particularly domestic supply. Adverse quality conditions increase the investment in irrigation and health, as well as decrease agricultural production. This, in turn, reduces agrarian economy and deteriorates improvement in the living conditions of rural people (Deshpande and Aher, 2011).

Geology and Hydrogeology

The subsurface geology of the study region encompasses Bundelkhand granite rock age 3000 ma as the Basement rock which is overlain by the rocks of Upper Vindhyans and alluvium of Quaternary age. The Quaternary alluvium incorporates beds of sand down to 620 meters that contains few aquifer structures in the central Ganga basin CGWB (2012-2013). Strati-graphically it is a buildup of alternate layers of gravel, sand and clay of Quaternary age. The thickness of alluvium increases towards north. The alluvium constitutes an asymmetry prism of sediments with its axis of thickest deposits running close to Himalayan Foot hills. Extensive five geological, geophysical surveys have been carried out in Ganga basin since last 3-4 decades. According to Singh (1989), the Gangetic plain is a part of active foreland basin of Indian plate.

The subsurface geology of the area is revealed by borehole log drilled at Aligarh railway station by Central Groundwater Board. The bed rock encountered at the depth of 340 meter bgl is red shale CGWB (2012-2013). The alluvial sequence forms the major aquifer in the area. Groundwater in the area occurs both under water table and in semi confined to confined conditions depending upon the absence or presence of aquitard and aquiclude as confining beds. The shallow aquifer is phreatic in nature whereas deep aquifer is semi confined to confined in nature. The rainfall forms the main source of Groundwater recharge. The district is entirely covered by unconsolidated Quaternary sediments, which have been classified into older alluvium and newer alluvium. The older alluvium also designated as a Varanasi alluvium covers most parts of the district and consists of a thick sequence of brownish yellow silt clay with kankar (calcareous concretions) and grey to brown, micaceous fine to medium sand. These sediments have further been differentiated into silty clay facies and sandy facies. The silt clay facies comprising brownish silt clay with kankar (calcareous concretions) is widely exposed in the eastern part of the district. The sandy facies occur as isolated sand mounds in the area to the west of Aligarh and also Yamuna and Ganga rivers in the east. The newer alluvium is further subdivided into terraces alluvium and channel alluvium. The terrace alluvium unconformably overlies the Varanasi alluvium, and is composed of cyclic sequence of thin bedded to laminate grey silt, clay and grey micaceous fine to medium grained sand. The channel alluvium is confined along the banks of the Ganga and Yamuna rivers and is represented by point/- channel/- lateral sand bars and silt.

Materials and Methods

Forty-five groundwater samples were collected from different delegate inspecting stations set up for chemical analysis in November 2016 (post-monsoon period) depicting the post monsoon period. Sixteen different parameters were chosen such as pH, EC, TH, TDS, Ca^{2+}, Mg^{2+}, Cl^-, Na^+, K^+, $SO4^-$, $NO3^-$, F, Pb, Ni, Cr, and Cd as the groundwater quality factors for investigations. The water tests were examined according to the standard technique for BIS (2012). EC and pH was estimated by digital portable meter and

Table 2. Parameters exceeding the permissible limit.

Serial No	Parameters	Permissible limit as per BIS 2012	Analytical result of the samples		sample exceeding permissible limit	Percentage
			Minimum	Maximum	Number	%
1	pH	6.5-8.5	7.3	8.8	9	20
2	EC in µ Mohs/cm	750	100	2700	29	64
3	Hardness mg/l	500	132	960	9	20
4	TDS mg/l	500	12.4	2031	24	53
5	Calcium mg/l	75	11.2	189.1	10	22
6	Magnesium mg/l	30	12.67	118.9	38	84
7	Sodium mg/l	200	60	420	29	64
8	Potassium mg/l	15	9	99	43	95
9	Chloride mg/l	200	25	465	12	26
10	Sulphate mg/l	200	117	445	15	33
11	Nitrate mg/l	45	0.33	91.34	9	33
12	Flouride mg/l	1	0	2.03	10	22
13	Lead mg/l	0.01	0.17	12	45	100
14	Nickel mg/l	0.07	0.02	6.5	44	97
15	Chromium mg/l	0.05	0.07	2.7	43	95
16	Cadmium mg/l	0.003	0.2	1.13	45	100

TDS were determined by the volumetric method. The concentration of Ca^{2+}, Mg^{2+}, Cl^{-}, TH were determined by volumetric method. EDTA titration method is used to determine the calcium and magnesium concentration in water samples. Chloride concentration was identified by titration with silver nitrate solution. Flame emission photometry done for assurance of sodium and potassium concentration in groundwater samples, sulfate, nitrate and fluoride concentrations determined by spectrophotometer whereas the heavy metals Pb, Cr, Cd, Ni assessed using Atomic Absorption Spectrophotometer (AAS).

Results and Discussion

The pH: pH is considered as an imperative natural factor and gives a critical piece factor and a bit of infuriation in numerous sorts of geochemical equilibrium or dissolvability computation (Shyamala et.al., 2008). The pH values were in the limit of 7.3 – 8.8 in the examination territory. 20% of the groundwater tests are exceeding the possible recommended limit prescribed by Bureau of Indian Standard (BIS 2012) demonstrating the alkaline nature of groundwater in the study area.

Electrical Conductivity: Electrical conductivity is a valuable device to assess the purity of water (Acharya et. al 2008). EC ranges between 100 – 2700 µ/um, 64% of the samples were exceeded the permisible limit of drinking water endorsed by BIS 2012. High EC demonstrates the existence of broken down inorganic substances in ionized shapes in the study area.

Total Dissolved Solids: TDS is generally related with conductivity. As indicated by WHO (2013) water sample containing TDS over 500 mg/L is viewed as dangerous for drinking water supplies. In the examination area the estimations of TDS ranges from 12.4 – 2031 mg/L, 53% of the water samples exceeded the limits prescribed by BIS 2012.

Total Hardness: Hardness of water is related to its capacity to produce lather from soap and is caused by the presence of soluble salt of calcium, magnesium, and iron and manganese. It is characterized by the reduction of lather efficiency of water with soap. Classifying water up to hardness 75 mg/l brings it under soft water type category, 75 – 150 mg/l is moderately soft water type, 157 – 300 mg/l is hard water type and more than 300 mg/l is very hard type of water (Ranjith Kumar, 2011). In the study area hardness ranges from 132 – 960 mg/L. 88.88% samples exceed the permissible limit (200 mg/L) recommended by BIS (2012). Therefore, it uncovers the hard nature of groundwater in the investigation zone.

Table 3. Statistical analysis post monsoon 2016.

	pH	EC	Hardness	TDS	Ca^{+2}	Mg^{2+}	Na^{+}	K^{+}
Minimum	7.3	100	132	12.4	11.22	12.67	60	9
Maximum	8.8	2700	960	2031	189.18	118.9	420	99
Mean	8.21	1131	383	757	64	54.56	240	41.82
Variance	0.12	484919	28006	286108	756	762	8683	298.74
SD	0.35	696	167	534	27	27.61	93.2	17.28
Skewness	-0.46	0.7	1.19	0.87	2.27	0.77	0.11	1.63
Kurtosis	-0.35	-0.44	1.86	-0.23	9.14	-0.16	-0.64	3.95
Median	8.3	1000	348	607	59.32	50.68	248	39
Mode	5	6	2	0	3	3	4	5
	Cl^{-}	**So_4^{-}**	**NO_3^{-}**	**F^{-}**	**Pb**	**Ni**	**Cr**	**Cd**
Minimum	25.6	117	0.33	0	0.17	0.02	0.07	0.2
Maximum	465	445	91.34	2.03	12	6.5	2.7	1.13
Mean	157	212	23.65	0.73	5.86	3.46	1.38	0.42
Variance	19290	6236	661	0.2	9.9	3.47	0.4	0.02
Standard Deviation	138	79	25.73	0.45	3.14	1.86	0.63	0.15
Skewness	0.97	1.43	1.22	0.88	-0.08	-0.12	-0.24	2
Kurtosis	-0.47	1.37	0.65	1.28	-0.82	-0.92	-0.15	7.71
Median	85.2	187	14.04	0.71	5.8	3.66	1.4	0.39
Mode	3	0	3	2	2	2	2	4

Calcium and Magnesium: The fifth most abundant natural element on the earth is calcium. Source of Ca and Mg in the fresh water system is through the weathering of rocks, especially limestone (marble, dolomite, gypsum, fluorite and apatite). The calcium concentration varies from 11.2 – 159 mg/l and 22% of the water samples are exceeding the standard limit (75 mg/l) prescribed by BIS 2012. Magnesium is the eighth most abundant natural element on the earth's crust. Magnesium may contribute undesirable taste to drinking water. Magnesium values in groundwater ranged between 12.6 – 118 mg/l and 84% of the samples magnesium content are found over as far as possible (30 mg/l) endorsed by BIS (2012) which shows hard nature of water in the investigation locale.

Chloride: Chloride is considered an important entity in groundwater though its presence in central rocks is insignificant. Processes like evaporation, repeated evaporation, dissolution of salts, contract with evaporative bodies, and presence of entrapped water during sedimentation of sea water intrusion are few processes responsible for the high concentration of chloride in groundwater (Shaikh and Mandre, 2009). Chloride values range from 25 to 465 mg/l, and highest estimation of chloride was recorded as 465 mg/l and a However, chloride concentration exceeds that of sodium concentration due to base exchange processes.

Sodium: Most abundant element on the earth, all the groundwater contains some sodium because most rocks soil contains sodium compounds from which sodium is easily dissolved. The sodium concentration is being found in between 60-420mg/l. 64% of the samples are exceeding the most elevated alluring point of confinement (200 mg/l) endorsed by BIS 2012.

Potassium: Weathering of rocks is the major source of potassium in natural fresh water but the disposal of waste increased the quantity of potassium in the water. (Trivedy of Goel, 1984). The concentration of potassium varies from 9 – 99 mg/l in the study area.95% of the samples are surpassing the BIS allowable point of confinement which is 15 mg/l of drinking water (2012).

Sulphate: The Sulphur content is only2ppm in atmospheric precipitation but high content of sulfur is made possible in groundwater through oxidation, precipitation of solution concentration as water transverse through rock. In the study area sulphate concentration varies from 117 – 445 mg/l with a maximum value of 445 mg/l. 33% of the samples are exceeding the standard limit (200 mg/l) recommended by BIS (2012).

Nitrate: Nitrate is a major constituent in the atmosphere but a very minor constituent of rocks. In rain water the average concentration of nitrate is only

0.2 ppm hence its average concentration in groundwater remains below 5 ppm. In the study area maximum concentration of nitrate is found to be 91.37 mg/l and 33% of the samples are exceeding the maximum permissible limit (45 mg/l) recommended by BIS 2012. The main source of nitrate is decaying organic matter, sewage wastes and application of fertilizer.

Fluoride: Fluoride is naturally present in some food stuffs as well as in water. It is harmful for both animals and human beings when its concentration exceeds 1 mg/l in drinking water. When its level is found above 1.5 mg/l, mottling of teeth and skeletal fluorosis has been reported.

Lead: Lead is one of the poisonous agents. Lead poisoning symptoms usually develop slowly. Anthropogenic activities are mainly responsible for the increased concentration of lead in natural water (Goel, 1997). In pesticides such as lead arsenate, lead is extensively used which has caused neurological diseases among children. It has been reported that Pb exposure causes hypertension (Beevers and other 1976). Lead poisoning leads to symptoms of intestinal cramps, peripheral nerve paralysis-, anemia and fatigue. The lead concentration in the water samples ranged between 0.17-12 mg/l. Moreover, 100% of the water samples exceeded the concentration of lead prescribed by BIS (0.01) mg/l (2001).

Nickel: Nickel is not commonly found in natural deposit. The concentration of nickel in the study area ranges from 0.02 – 6.5 mg/l. Effluent of electroplating wastes, steel alloys industries, dyes and textiles, nickel and cadmium batteries of chemical industries are the possible source of nickel in groundwater. About 97% of the samples are above the permissible limit (0.07 mg/l) recommended by (BIS 2012). On the basis of results, it shows that all the samples are having high Ni distribution (mean, median, standard deviation, skewness, kurtosis) is an important statistical tool for identifying the distribution pattern of the different water quality parameters in groundwater samples. Pearson correlation analysis as shown in Table 4, is an approach, which provides initiative similarity relationship between sample entire data. Table 3, Indicates the normal distribution analysis pattern of different water quality parameters where significant variations between mean and median for parameters viz. hardness, TDS, Ca, Mg, Cl, No_3, So_4 indicate that these parameters were not found to be completely distributed in a normal and systemic way in the samples. However, small difference of mean and median parameters was found to be distributed normally in groundwater. Parameter such as pH, Fluoride, Pb, Ni, Cr, Cd, Na and K indicate that these parameters were found to be distributed normally in groundwater. Parameters Ph, EC, TDS, Mg, Na, Cl, Pb, Ni, Cr in the water samples have negative values of kurtosis, which indicate that the distribution of these parameters have flat peak compared to normal distribution pattern. The negative value of skewness of pH (–0.46), Pb (–0.08), Ni (–0.12), Cr (– 0.24) reveals that the data were distributed towards the lower values or having a negative tail in the negative direction. The skewness value for EC (0.7), TH (1.19), TDS (0.87), Ca (2.27), Mg (0.77), Na (0.11), K (1.63), Cl (0.97), SO4 (1.43), NO3 (1.22), F (0.88), Cd (2) showed that their tail disseminated towards the higher esteems which pointed out that information were appropriated in the correct direction of the tail. Relationship among water quality parameters incredibly encourages the undertaking of fast monitoring of water quality. Table 3 exhibits the Pearson correlation coefficient lattice between significant compound characters of groundwater of the examination region. The variables having coefficient esteem (r) >0.50 are viewed as noteworthy.

The analytical data shows a close significant positive association of EC with hardness (0.82), TDS (0.66), Ca^{2+} (0.65), Mg^{2+} (0.82), Na^+ (0.82), K^+ (0.68), $Cl^–$ (0.67), $SO4^–$ (0.81). It is concluded that EC has increased with increasing of these parameters in groundwater samples. Hardness showing correlation with Ca^{2+} (0.86), Mg^{2+} (0.95), Na^+ (0.6), $Cl^–$ (0.67), $SO4^{2–}$ (0.83) and $NO3^–$ (0.51) indicates that hardness has increased with the increase in these parameters of groundwater. TDS with Mg^{2+} (0.55), Na^+ (0.59), K^+ (0.58), Ca^{2+} with Mg^{2+} (0.67), $SO4^–$ (0.75). Magnesium with Na^+ (0.63), K^+ (0.51), $Cl^–$ (0.69), $SO4^–$ (0.77) and sodium with K^+ (0.54), $Cl^–$ (0.54) and $SO4^–$ (0.54).

It indicates that TDS has increased with the increasing concentration of magnesium, sodium, and potassium in groundwater. Calcium concentration increased with the increasing concentration of magnesium, and sulphate, whereas the magnesium and sodium concentration has increased with increased of potassium, chloride and sulphate concentration in groundwater.

pH content showed negative correlation with EC (–0.76), TH (–0.68), TDS (–0.62), Ca (–0.61), Mg (–0.64), Na (–0.61), K (– 0.57), Cl (–0.6), So4 (–0.69), No3 (–0.35), Pb (–0.1), Ni (–0.13) and Cr (–0.29).

EC is showing a negative correlation with fluoride (–0.06) and cadmium (–0.03) which indicates a decreasing trend in EC with the increasing concentration of cadmium and fluoride. Hardness shows negative correlation with cadmium (–0.02) indicating that with increased concentration of cadmium, the concentration of hardness decreases. TDS is having a negative correlation with fluoride (–0.12). Calcium has a negative correlation with cadmium (– 0.02), magnesium is having a negative correlation with F (–0.01), Cd (–0.01) and Na has a negative correlation with F (– 0.19), and Cd (–0.1) reflecting a decreasing trend in Na and Mg concentration with Increasing concentration of fluoride and cadmium in the water samples.

Table 4. Pearson correlation between different water quality parameter post monsoons 2016.

	pH	EC	Hardness	TDS	Ca^{2+}	Mg^{2+}	Na^{+}
pH	1						
EC	-0.76	1					
Hardness	-0.68	0.82	1				
TDS	-0.62	0.66	0.48	1			
Calcium	-0.61	0.65	0.86	0.25	1		
Magnesium	-0.64	0.82	0.95	0.55	0.67	1	
Sodium	-0.61	0.82	0.6	0.59	0.41	0.63	1
Potassium	-0.57	0.68	0.46	0.58	0.29	0.51	0.54
Chloride	-0.6	0.67	0.67	0.41	0.49	0.69	0.54
Sulphate	-0.69	0.81	0.83	0.47	0.75	0.77	0.54
Nitrate	-0.35	0.41	0.51	0.11	0.48	0.46	0.33
Fluoride	0.01	-0.06	0.07	-0.12	0.19	-0.01	-0.19
Lead	-0.1	0.2	0.26	0.06	0.32	0.19	0.09
Nickel	-0.13	0.25	0.22	0.27	0.07	0.28	0.25
Chromium	-0.29	0.32	0.31	0.38	0.24	0.31	0.33
Cadmium	0.07	-0.03	-0.02	0.19	-0.02	-0.018	-0.12
	k^{+}	Cl^{-}	SO_4^{-}	NO_3^{-}	F^{-}	Pb	Ni
Potassium	1						
Chloride	0.51	1					
Sulphate	0.43	0.64	1				
Nitrate	0.08	0.32	0.32	1			
Fluoride	-0.04	-0.005	0.09	0.04	1		
Lead	0.13	0.17	0.22	0.21	0.32	1	
Nickel	0.12	0.09	-0.009	0.36	0.06	0.11	1
Chromium	0.38	0.35	0.124	0.21	-0.009	0.42	0.32
Cadmium	-0.14	-0.05	0.16	-0.09	-0.14	-0.19	-0.18
	Cr						
Chromium	1						
Cadmium	-0.01						

Conclusion

The analysis of water samples reveals information about the major ion and trace element concentration gathered from different bore wells in Aligarh. The examination of water samples was carried out and the water is not found suitable for drinking purpose. The total hardness suggested that 88.8% of the water sample are found above permissible limit (200 mg/L) endorsed by BIS (2012) and is undesirable for drinking. PH shows the alkaline nature of groundwater in all samples. Higher concentrations of substantial poisonous metals are observed, which may involve different health hazard (lead, chromium, cadmium). The relationship network demonstrates that the EC is principally controlled by hardness. The pH content shows negative correlation with EC, hardness, TDS, Ca^{2+} $Mg^{2+,}$ Na^{+}, K^{+}, Cl^{-}, SO_4^{-}, NO_3^{-},Pb, Ni and Cr. From the experimental analysis of water samples, results show a deterioration in water quality due to the heavy metals which indicates that some preventive measures should be taken to minimize the concentration of heavy metals in the aquifer system.

Acknowledgement

Authors' are appreciative of Prof. Syed Ahmad Ali Chairman, Department of Geology, A.M.U., Aligarh for giving necessary facilities.

References

Acharya, G. D., Hathi, M. V., Patel, A. D., Paramar, K. C. (2008). Chemical properties of groundwater in Bhiloda taluka region, north Gujarat, India. E – Journal of Chemistry, **5** (4) 792-776.

Akram Javed; M. H. Wani. (2009). Delineation of groundwater potential zones in Kak and water shed eastern Rajasthan, using remote sensing and G-1S techniques, *Journal Geological Society of India*, **73**, 229 – 236.

B/S (2012) Indian standard specification for drinking water, B.S 10500.

Beevers D. G., Erskine E., Robertson M., Beattie A. D., Campbell B. C., Goldberg A., Moore M. R., Hawthrone V. M. (1976). Blood lead to hypertension. Lancet, **2**,1–3

Bansal, O. P. (2004). Uptake of heavy metals by crop plants poll. Res., **23,** 501-506.

Deshpande, S. M. and Aher, K. R. (2011). Hydro geochemistry and quality assessment of groundwater in Chikalthana industrial area of Aurangabad, Maharashtra, India. Bionano Frontier, **4** (1), p.157-161

Goel, PK (1997). Water pollution causes, effects and control. New Age International Publishers.

G.N. Pradeep Kumar, P. Srinivas (2012). Evaluation of groundwater resources and estimation of stage of groundwater development in a basin – A case study. https://doi.org/10.1002/ird.628

Geoffrey Thyne, Cuneyt Guler, Eileen Poeter (2008). Sequential analysis of hydrochemical data for watershed characterization. https://doi.org/10.1111/j.17456584.2004.tb02725.x

Saravanakumar. K, Kumar, R. Ranjith. (2011) Analysis of water quality parameters of groundwater near Ambattur industrial area, Tamil Nadu, India. *Indian Journal of Science and Technology*, **4** (5)

Marwari, R. Khan T. I. (2012). Physiological and biochemical adverse effects of heavy metal on brassics tolerance grown in Sanganer area, *India. Journal of Environmental Science Engineering*. **54** (2), 249 – 259.

Pandey, S. K. and Tiwari, S. (2008). Physiochemical analysis of groundwater of selected area of Ghazipur City – A case *study Nature and Sciences*, **6** (4), 25 – 28.

Sabhapandit, Pranab; Mishra, A. K. (2011). Physicochemical characteristics of groundwater in Gohpur subdivision of sanitpur district, Assam (India) *Journal of Environmental Science Engineering*, **53** (1), 89 – 96.

Saravana, K; Kumar, R. R. (2011). Analysis of water quality parameters of groundwater, Amrattur industrial area, Tamil Naidu, India. *Indian Journal of Science of Technology*, **4** (5), 560 – 562.

Shaikh, A. H, Mandre, P. N (2009). Seasonal study of physicochemical parameters of drinking water in Khed (Lote) industrial area, Sodh, Samiksha our Mulyankan, *International Research Journal*. **2** (7), 1-6 (2002).

Shyamala, R., Shanthi, M. and Lalitha, P. (2008). Physicochemical analysis of borewell water samples of Telungupalayam area in Coimbatore District, Tamil Naidu, *India E Journal of Chemistry*, **5** (4), 924 – 929.

Singh, I. B; & Bajpai, V. N. (1989). Significance of syn depositional tectonics in the facies development of the Gangetic alluvium near Kanpur, Uttar Pradesh. *Journal of Geological Society of India*, **34**, 61-66.

Trivedy, R. K, Goel, R. K. (1984). Chemical biological methods for water pollution studies. *Environmental Publication*, Karad, India.

Umar, R., Ahmed, F., Alam, M., Khan, A. Muqtada, (2009). Hydrochemical characteristics and seasonal variation in groundwater quality of an alluvial aquifer in parts of central Ganga plain, western Uttar Pradesh, *India Env. Geol.*, **58,** 1295 – 1300.

Umar, R., Umar, A., Khurshid, S., Ahmed, I (2001) Microbial contamination in the groundwater of Aligarh City. *Jour Geol. Soc. of India*, **58**, 157 – 162.