**Advances in Bioresearch**
Adv. Biores., Vol 11 (5) September 2020: 56-62
©2020 Society of Education, India
Print ISSN 0976-4585; Online ISSN 2277-1573
Journal's URL:http://www.soeagra.com/abr.html
CODEN: ABRDC3
DOI: 10.15515/abr.0976-4585.11.5.5662

Advances in Bioresearch

**ORIGINAL ARTICLE**

# Assessment of Groundwater Quality by Using Water Quality Index Method in Agra and Aligarh City, Uttar Pradesh, India

**Girija[1], Dinesh Kumar Sharma[2] and Harit Priyadarshi [3]**
[1 2]Department of Chemistry, Mangalayatan University, Beswan, Aligarh, Uttar Pradesh, India.
[3]Department of Civil Engineering, Mangalayatan University, Beswan,
Aligarh,Uttar Pradesh, India.

**ABSTRACT**

*Groundwater is ultimate, most reasonable new water asset with nearly balanced concentration of the minerals for human consumption. But unfortunately the deficiency of the clean and pure water increases everyday due to pollution of water and overexploitation, so the drinking water analysis is very important and essential for public health. The current research is expected to assess the groundwater quality of the different locations of Agra and Aligarh city for drinking purposes and other useful human activities. The groundwater quality is assessed by the analysis of thirteen physico-chemical parameters and the calculation of Water Quality Index (WQI) of groundwater samples of Agra and Aligarh city.The Water Quality Index was calculated using Weighted Arithmetic Index Method. Physico-chemical parameters selected for the study were pH, Electrical Conductivity, Alkalinity, Total Dissolved Solids (TDS), Chemical Oxygen Demand (COD), Biochemical Oxygen Demand (BOD), Fluoride and Heavy metals (Cu, Fe, Mn, Ni, Pb and Zn). The values of these parameters are found to be above the acceptable limits, below the acceptable limits as well as partially in the range, as prescribed by Bureau of Indian Standard (BIS) -10500-2012. The WQI for these water samples ranges from 239.7 – 623.3 which shows very poor water quality and unsuitable for drinking. Thus, the study reveals the need for proper treatment and regularly evaluation of groundwater quality and simultaneously indicates the need for the necessary steps to be taken for the protection and up-gradation of water quality.*

***Key words-*** *Groundwater, Physico-chemical parameters, WQI, Agra and Aligarh city*

Received 12.05.2020 Revised 18.06.2020 Accepted 07.08.2020

**How to cite this article:**
Girija, D K Sharma, H Priyadarshi . Assessment of Groundwater Quality by Using Water Quality Index Method in Agra and Aligarh City, Uttar Pradesh, India. Adv. Biores., Vol 11 (5) September 2020: 56-62

## INTRODUCTION

Water is extremely essential for survival of all living organisms. It is an essential component for life on Earth, which contains minerals extremely important in human nutrition. Groundwater is the subsurface water that occurs beneath the water table in the soils and geologic formations that are fully saturated [4]. Despite the large volume of water that covers the surface of the earth, only 1% is inland fresh and easily available for human use. The qualities of groundwater resources vary naturally and widely depending on climate, season, and geology of bedrock as well as anthropogenic activities [12]. Now a day's groundwater contamination is a serious global issue. Persistently expanding degree of pollution with an assortment of poisonous substances and letting down of the groundwater table due to over-exploitation to satisfy internationally expanding water need followed by the declining yearly energize have brought them under extreme conditions everywhere on over the world [15]. The uncontrolled removal of mechanical and metropolitan squanders and the utilization of chemical substances in horticulture (composts, herbicides and pesticides) are the essential causes of groundwater tainting [18]. The water supply for human consumption is often directly sourced from groundwater without any chemical treatment and it is used by the people so the pollution of groundwater has become a cause for major concern [20].

Ground water is most reasonable new water asset for human utilization in both metropolitan just as country territories. The significance of ground water for presence of human culture cannot be overemphasized. There are so many states in India where more than 90% people are dependent on groundwater for drinking and other useful purposes [6, 17, 11].The issues of groundwater quality are

considerably more intense in the regions which are thickly populated, thickly industrialized and have shallow groundwater tables. The groundwater is accepted to be relatively much perfect and liberated from contamination than surface water [7]. However delayed release of modern industrial effluents, homegrown sewage and strong waste dump causes the groundwater to get contaminated and made health issues [13]. Groundwater contamination has gotten a significant subject of public interest for everywhere on over the world. It has been reported that in Aligarh groundwater concentration of Magnesium, Total Hardness, Alkalinity, Cadmium, Iron, pH Lead, TDS, Calcium, Copper, Sulphate, Chloride, Manganese and Chromium is higher than the permissible limit prescribed by the Bureau of Indian standards which indicates signs of water quality deterioration. So, it is necessary to take rational steps to manage water in this region before it becomes a crisis, as this will affect the economy and will also lead to various water borne diseases [8, 6].
Considering the above aspects of surface water pollution, the current research was attempted to investigate the impact of the Groundwater of Agra and Aligarh city. Along these lines in this research the goal of the current research is to analyse the groundwater quality for human consumption based on physicochemical parameters and water quality index values.

## MATERIAL AND METHODS

### Study Area-

Agra city is selected for the study because of the presence of major problems such as inadequate water supply, declining groundwater level and poor water quality. Agra is situated on the bank of Yamuna River. The Agra district is situated in western U.P., between 27.11' degree Latitude North and 78.0' degree to 78.2' degree Longitude East. Its Altitude is 169 meters above sea level. On the North Agra is bounded by Mathura District, on the South it is bounded by Dhaulpur District, on the East it is bounded by Firozabad District and on the West it is bounded by Bharatpur. The average monsoon rainfall during June to September is 628.6 millimeters. Agra has a reputation of being one of the hottest and the coldest towns in India.
Aligarh district is bounded by river Ganga in the west and the river Yamuna in the east. Aligarh district is a part of central Ganga plain of the state covering an area of 5498 square kilometer and lies between $27^0 28'$ and $28^0 10'$latitude North and $77^0 29'$ and $78^0 36'$longitudeEast. The city is the administrative district of Aligarh district. The entire district falling in Upper Ganga Doab. Average monsoon rainfall is 662 millimeters.
**Sample Collection-**Water samples were collected in pre-monsoon season and post-monsoon season from both the cities Agra and Aligarh during the year 2018. Five sampling locations were selected from Agra city namely Sikandra, Dayalbagh, Sadar, Tajmahal area and Collectrate and Five sampling locations namely Dodhpur, Sassnigate, Quarsi, Jevangarh and Jamalpur were selected from Aligarh city. Water samples were collected from thirty different plots of each sampling locations. Mostly, bore wells were considered for sampling. At certain places hand pumps were also considered for the sampling. Samples were collected in pre-cleaned transparent plastic bottles of one litre capacity with necessary precautions. After the collection of samples, sampling bottles were labeled and immediately brought to the laboratory for analysis.
**Analysis of Physicochemical Parameters-**The samples were immediately analysed in the chemistry lab to minimize physicochemical changes. Analysis was carried out for the determination of physico-chemical parameters of drinking water samples using standard procedures shown in table 1.

**Table 1: Methods used for analysis of Physico-chemical parameters**

| S. no. | Parameters | Methods |
|---|---|---|
| 1 | pH | pH meter |
| 2 | Electrical Conductivity | Digital conductivity meter |
| 3 | Alkalinity | Indicator method |
| 4 | TDS | Filtration method |
| 5 | COD | Open reflux method |
| 6 | BOD | Titration method |
| 7 | Heavy metals (Cu,Fe,Mn,Ni,Pb,Zn) | Atomic absorption spectrophotometry |
| 8 | Fluoride | Ions selective electrode method |

**Determination of Water Quality Index(WQI)–**In this research 13 parameters were selected for the calculation of WQI. It has been determined by using drinking water quality standards recommended by

WHO and BIS [3, 19]. The Water Quality Index was calculated using Weighted Arithmetic Index Method. Basically a WQI is a compilation of number of parameters that can be utilized to determine the overall quality of water. The mathematical relation used to calculate WQI is given as-

- WQI= Σ Q i Wi / ΣWi
- Where Q i - Quality rating scale
- Wi - Relative weight
- Wi = 1/Si, Si- Std. permissible value
- Q i = 100 [ (Vn-Vi) /(Vs- Vi) ]
- Vn- actual or test value of the parameter
- Vi- ideal value of the parameter
- Vs- recommended WHO std of the parameter

**RESULTS AND DISCUSSION**

The mean values of different physicochemical parameters at ten sampling locations are represented in table 2 and 3.

**Table 2: Physico-chemical parameters and WQI of Agra city**

| WHO /BIS | Samples-Parameters | Sikandra | | Dayalbagh | | Sadar | | Tajmahal Area | | Collectrate | |
|---|---|---|---|---|---|---|---|---|---|---|---|
| | | Pre. | Post. | Pre. | Post. | Pre. | Post. | Pre. | Post. | Pre. | Post. |
| 6.5-8.5 | pH | 6.80 | 6.85 | 7.10 | 7.20 | 7.0 | 7.5 | 7.20 | 7.30 | 7.10 | 7.20 |
| 5-50 | Cond. | 2.39 | 2.36 | 3.36 | 3.35 | 2.35 | 2.32 | 2.38 | 2.37 | 2.54 | 2.52 |
| 200 | Alkalinity | 740 | 746 | 810 | 818 | 808 | 812 | 938 | 942 | 848 | 852 |
| 500 | TDS | 710 | 700 | 1020 | 1014 | 680 | 670 | 718 | 706 | 760 | 764 |
| 10 | COD | 150 | 148 | 106 | 102 | 110 | 108 | 60 | 56 | 100 | 94 |
| 6.0 | BOD | 1.2 | 1.1 | 1.6 | 1.4 | 1.4 | 1.2 | 1.4 | 1.1 | 1.8 | 1.2 |
| 1.0 | Fluoride | 0.9 | 0.8 | 0.9 | 0.7 | 1.0 | 0.8 | 1.1 | 1.0 | 0.9 | 0.8 |
| .05 | Cu | 0.046 | 0.042 | 0.036 | 0.034 | 0.048 | 0.044 | 0.042 | 0.040 | 0.044 | 0.040 |
| .3 | Fe | 0.196 | 0.192 | 0.100 | 0.098 | 0.120 | 0.118 | 0.150 | 0.146 | 0.214 | 0.210 |
| .1 | Mn | 0.024 | 0.022 | 0.030 | 0.028 | 0.036 | 0.032 | 0.036 | 0.032 | 0.042 | 0.040 |
| .02 | Ni | 0.983 | 0.974 | 0.752 | 0.750 | 0.846 | 0.840 | 0.896 | 0.892 | 0.932 | 0.928 |
| .01 | Pb | 0.092 | 0.086 | 0.216 | 0.218 | 0.306 | 0.306 | 0.344 | 0.338 | 0.130 | 0.128 |
| 5.0 | Zn | 0.523 | 0.518 | 0.706 | 0.704 | 0.520 | 0.510 | 0.462 | 0.460 | 0.668 | 0.662 |
| 50-100 | WQI | 246.6 | 239.7 | 279.9 | 276.5 | 358.4 | 351.8 | 385.7 | 380.5 | 262.1 | 255.9 |

**Table 3: Physico-chemical parameters and WQI of Aligarh city**

| WHO/BIS | Samples-Parameters | Dodhpur | | Sassnigate | | Quarsi | | Jevangarh | | Jamalpur | |
|---|---|---|---|---|---|---|---|---|---|---|---|
| | | Pre. | Post. | Pre. | Post. | Pre. | Post. | Pre. | Post. | Pre. | Post. |
| 6.5-8.5 | pH | 9.30 | 9.40 | 8.4 | 8.5 | 8.3 | 8.4 | 7.3 | 7.4 | 7.1 | 7.2 |
| 5-50 | Cond. | 1.78 | 1.74 | 4.77 | 4.76 | 1.90 | 1.84 | 1.97 | 1.95 | 2.56 | 2.52 |
| 200 | Alkalinity | 1494 | 1508 | 1292 | 1300 | 1080 | 1100 | 1096 | 1106 | 942 | 946 |
| 500 | TDS | 300 | 290 | 880 | 870 | 340 | 338 | 380 | 368 | 740 | 730 |
| 10 | COD | 92 | 85 | 110 | 106 | 76 | 72 | 90 | 88 | 96 | 92 |
| 6.0 | BOD | 0.8 | 0.4 | 0.8 | 0.6 | 1.2 | 1.0 | 1.0 | 0.8 | 0.8 | 0.6 |
| 1.0 | Fluoride | 0.8 | 0.4 | 0.8 | 0.6 | 1.2 | 1.0 | 1.0 | 0.8 | 0.8 | 0.6 |
| .05 | Cu | 0.016 | 0.014 | 0.010 | 0.008 | 0.010 | 0.008 | 0.010 | 0.006 | 0.022 | 0.020 |
| .3 | Fe | 0.334 | 0.330 | 0.230 | 0.228 | 0.248 | 0.240 | 0.228 | 0.224 | 0.307 | 0.300 |
| .1 | Mn | 0.016 | 0.012 | 0.048 | 0.044 | 0.018 | 0.014 | 0.014 | 0.012 | 0.012 | 0.010 |
| .02 | Ni | 2.010 | 2.008 | 1.046 | 1.040 | 1.30 | 1.224 | 1.582 | 1.58 | 1.882 | 1.878 |
| .01 | Pb | 0.476 | 0.470 | 0.134 | 0.132 | 0.236 | 0.230 | 0.272 | 0.270 | 0.386 | 0.382 |
| 5.0 | Zn | 0.446 | 0.442 | 1.264 | 1.260 | 0.304 | 0.300 | 0.208 | 0.202 | 0.402 | 0.400 |
| 50-100 | WQI | 623.31 | 615.7 | 264.3 | 260.1 | 361.5 | 343.9 | 425.7 | 420.6 | 550.1 | 541.9 |

Where Pre. – Pre-monsoon, Post.- Post-monsoon, All the parameters are in mg/l except E. Conductivity which is in µs/m; TDS and Fluoride are in ppm.(All values are mean of three observations for each parameter)

**pH –**The permissible limit of pH for drinking water is 6.5-8.5. It was seen that the pH value of the water appears to be dependent upon the relative quantities of calcium, carbonates and bicarbonates. The water tends to be more alkaline when it possesses carbonates [20, 16]. The pH value of the samples in the study area varied from 6.8-9.4 indicating slightly alkaline nature.

**Electrical Conductivity-** It is a measure of water's capacity to conduct electric current. Most of the salts which are present in water in ionic form are responsible to conduct electric current. The permissible limit for Electrical Conductivity (EC) is 5.00 µS m. Electrical Conductivity value of the study area varied from 1.74-4.77 µs and most of the samples were shown low value from the standards of WHO/BIS prescribed for drinking [9].

**Total Alkalinity-**The Alkalinity in the water is generally imparted by the salts of carbonates, silicates, etc. together with the hydroxyl ions in Free State.The alkalinity of the samples in the study area varied from 740-1508 mg/l as $CaCO_3$ indicated high alkaline nature of water in the study area and all the samples were found exceeding the acceptable limit of WHO/BIS [14].

**Total Dissolved Solids (TDS) -** The permissible limit of TDS for drinking water is 500-2000 ppm (BIS, 2012). Total dissolved solids are present due to the concentrations of all minerals in water and indicate the general nature of salinity of water.Total Dissolved Solids of the samples in the study area varied from 290-1020 ppm and most of the samples were found above the permissible limits of WHO/BIS [8].

**Chemical Oxygen Demand –** Chemical Oxygen Demand is a measure of pollution in aquatic system. COD values of the ground water samples in the present study area varied from 56-150 mg/l and some samples were found exceeding the acceptable limit of WHO/BIS. It may be due to seepage from sewage drainage or industrial discharge in nearby localities [8].

**Biochemical Oxygen Demand –**In the present study BOD values of various ground water samples were found from 0.4-1.8 mg/l and half of the samples were found exceeding the acceptable limit of WHO/BIS [10].

**Fluoride (F)-** Fluoride is found in all natural waters at some concentration. The WHO [19] and BIS (10500- 2012) estimates the maximum allowable limit for fluoride uptake to human's in drinking water as 1.5 mg/l. The fluoride in the ground water samples of the study area varied widely from 0.4- 1.2 ppm and most of the samples were found below with the permissible limits of WHO/BIS [2, 10].

**Copper (Cu)-** Copper is both an essential nutrient and a drinking-water contaminant. Beyond 0.05 mg/l the water imparts astringent taste and cause discoloration and corrosion of pipes, fittings and utensils. The Copper in the groundwater samples of the study area varied widely from 0.006 – 0.048 mg/l and most of the samples were found below the permissible limits of WHO/BIS [1].

**Iron (Fe)-**It is a known fact that iron in trace amounts is essential for nutrition. The iron in the groundwater samples of the study area varied widely from 0.098 – 0.334 mg/l and most of the samples were found below with the permissible limits of WHO/BIS(Gaur, S., et. al., 2012). The permissible limit of iron is 0.3 mg/l respectively. High concentrations of iron generally cause inky flavor, bitter and astringent taste to water.

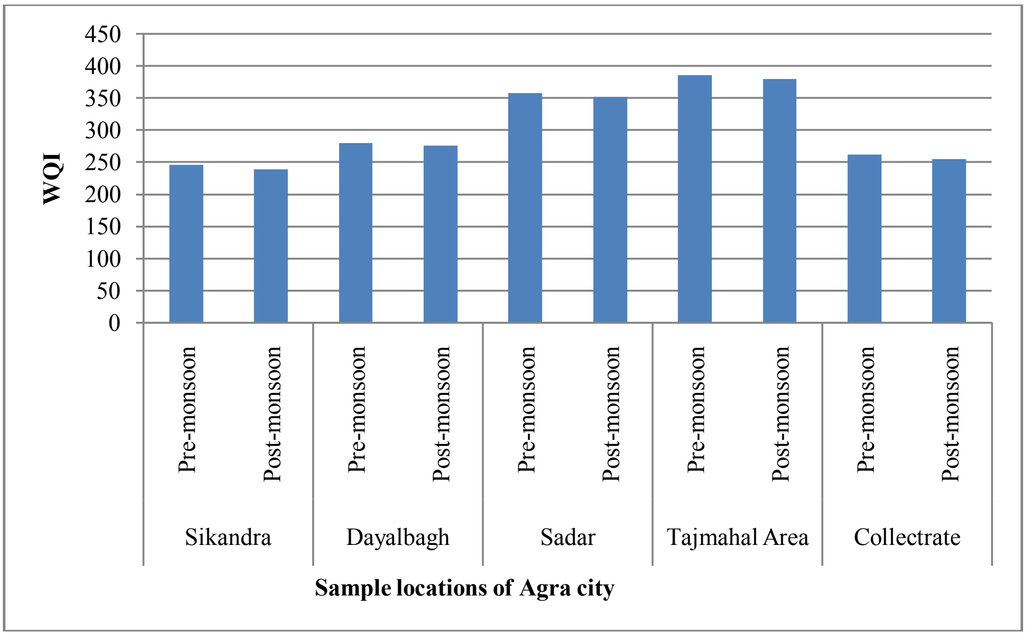
**Manganese (Mn)-**Manganese at levels exceeding 0.1 mg/l, in water supplies causes an undesirable taste in beverages and stains sanitary ware and laundry. The Manganese in the ground water samples of the study area varied widely from 0.010 – 0.048 mg/l and most of the samples were found below the permissible limits of WHO/BIS [5].

**Nickel (Ni) -** Nickel is found naturally in both food and water, and may be increased by human pollution. The permissible limit of Nickel in the groundwater is 0.1mg/l (BIS, 2012). The Nickel in the groundwater samples of the study area varied widely from 0.750 – 2.010 mg/l and most of the samples were found above with the permissible limits of WHO/BIS.

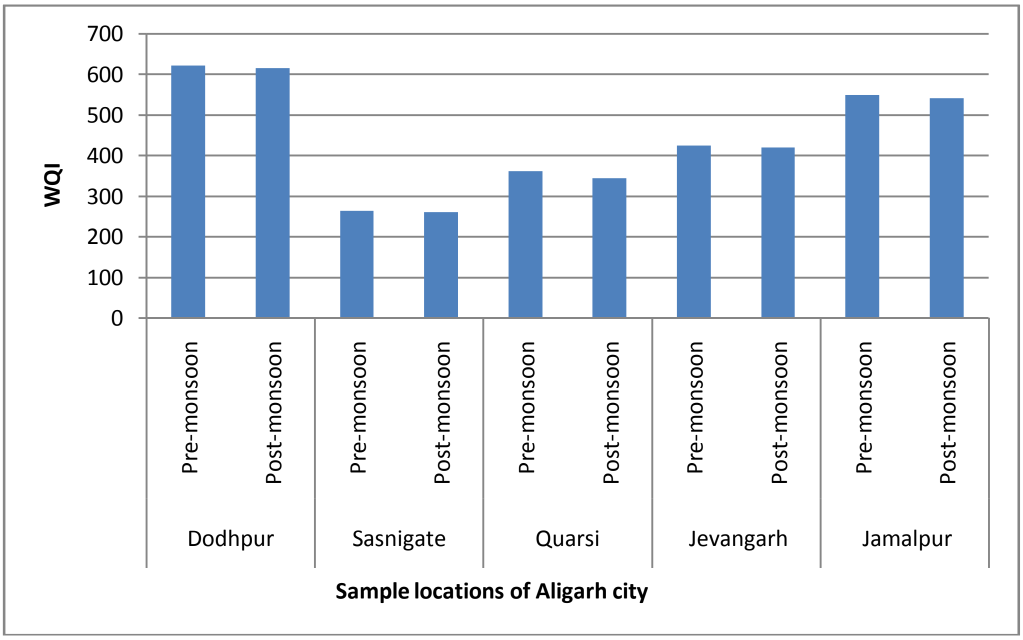
**Lead (Pb)-** Lead is one of the hazardous and potentially harmful polluting agents. The concentrations of lead in the groundwater normally do not exceed 0.05 mg/l, respectively. The lead in the groundwater samples of the study area varied widely from 0.086 – 0.476 mg/l and most of the samples were found above with the permissible limits of WHO/BIS.

**Zinc (Zn)-**Zinc is an essential trace element found in virtually all food and potable water in the form of salts or organic complexes. In general, concentration of zinc in surface water and groundwater normally do not exceed 5mg/l, respectively. The zinc in the groundwater samples of the study area varied widely from 0.202 - 1.264 mg/l and most of the samples were found below the permissible limits of WHO/BIS [1].

**Water Quality Index (WQI)–**WQI is created through the analysis of various physico- chemical parameters of the ground water of selected cities. Values of WQI and various physico- chemical parameters of Agra and Aligarh city are presented in table 2and 3.The values of WQI showed that the ground water quality of the selected sample locations of two cities is found very poor and unsuitable for drinking. It may be due to the over exploitation and anthropogenic activities such as discharge of effluents from industrial, agricultural and domestic uses. There is no change in the water quality of groundwater samples of pre-monsoon and post-monsoon season. 40% groundwater samples are found very poor water quality and 60% groundwater samples are found water quality unsuitable for drinking in overall samples. From calculation of WQI it clearly shows that groundwater quality for these locations of Agra and Aligarh city is highly polluted (Graph 1and 2). Groundwater is not suitable for drinking purposes in these locations. Dodhpur and Jamalpur sampling locations of Aligarh city and Tajmahal Area of Agra city are highly polluted due to dumping of waste materials and sewage water. Water quality classification based on WQI value is presented in table 4.




**Graph 1: Variation of WQI in sample locations of Agra city**




**Graph 2: Variation of WQI in sample locations of Aligarh city**

**Table 4: Water quality classification based on WQI value**

| WQI Value | Water Quality | No. of water samples ( Pre & Post-monsoon) | Percentage of water samples ( Pre &Post-monsoon ) |
|---|---|---|---|
| Less than 50 | Excellent | Nil | Nil |
| 50-100 | Good Water | Nil | Nil |
| 100-200 | Poor Water | Nil | Nil |
| 200-300 | Very Poor Water | 8 | 40 |
| Above 300 | Unsuitable for drinking | 12 | 60 |
| Total samples of Pre & Post -monsoon | | 20 | 100 |

## CONCLUSION

Water is very essential for the existence of mankind and for the development of humans. Groundwater is the major source of water for drinking, agricultural and industrial need in the study area of Agra and Aligarh city.The Water Quality Index (WQI) for twenty ground water samples ranges from 239.7 - 623.3.The high value of WQI at these sampling locations are found to be mainly from the higher values of Alkalinity, Total Dissolved Solids, Chemical Oxygen Demand, Nickel and Lead in the groundwater samples. Copper, Iron, Manganese and Zinc are found below the acceptable limit. About 40% of water samples are foundvery poor in quality and 60% of water samples are of unsuitable for drinking .The groundwater sources of these locations is not suitable for drinking purpose without proper treatment. The groundwater quality of the study area is highly deteriorated mainly due to over exploitation and population pressure. The analysis also reveals that the groundwater of the area needs proper treatment before consumption, and it also needs to be protected from the industrial waste and sewage contamination. Regularly monitoring of groundwater quality is also important for avoidance of contamination in groundwater.

## REFERENCES

1. Anwar K. M, Aggarwal V. (2014), 'Analysis of Groundwater Quality of Aligarh City, (India): Using Water Quality Index', *Curr. World Environment*, Vol. 9 (3), pp. 36.
2. Ashfaq. A. and Ahmad. F. (2014), 'Evaluation of ground water quality of Aligarh city India', *Int. J.Curr. Res. Aca.Rev.*, Vol.2 (8), pp. 323-327.
3. Bureau of Indian Standards, *Specification for drinking water.* 2012; IS: 10500, New Delhi India.
4. Freeze, R. A. and Cherry, J. A., (1979), 'Groundwater', *Englewood Cliffs: Prentice Hall.*
5. Gaur, S., Agrawal, S., Saxena S. K., Goyal ,R. and Kumar D., (2012), 'Biological Effect of Heavy Metal in Drinking Water samples of Western Uttar Pradesh region in India', *Journal of Applied Pharmaceutical Science*, Vol. 2 (7),pp. 177-181.
6. Khwaja, M.A., Bhattacharya, G.S. andAggarwal, V. (2016), 'Analysis of ground water quality of Aligarh city, U.P.', *IJAETMAS,* Vol. 3(9), pp. 41-48.
7. Patil, V. T. andPatil P. R. (2010),'Physicochemical Analysis of Selected Groundwater Samples of Amalner Town in Jalgaon District, Maharashtra, India',*E-Journal of Chemistry*, Vol. 7(1), pp. 111-116.
8. Perween, S. and Fatima, U. (2016), 'Physico-Chemical analysis of ground water quality in Aligarh city, U.P.',*I.J.S.N.*, Vol. 6(3), pp. 397-405.
9. Priyadarshi, H., Girija, SarvPriya, Alvi, S. H. and Rao, S. (2018), 'A study on Physicochemical characteristics of ground water in Aligarh and Agra district, Uttar Pradesh in India', *Indian Journal of Public Health Research and Development double blind peer reviewed Scopus indexed international journal*, Vol. 9 (l2), pp. 339-343.
10. Priyadarshi, Haritet. al, (2019), 'Physico-chemical analysis of selected ground water samples from Sikandra Rau Town and its adjoining villages (Hathras district),Utter Pradesh, India', *International Journal of civil Engineering and Technology*, Vol. 10(2),pp.355-368.
11. Ramachandraiah, C. (2004), 'Right to drinking water in India',*Centre of Economic and Social Science Studies,*Vol. 56.
12. Ramesh, K., and Soorya, V. (2012), 'Hydrochemical Analysis andEvaluation of Groundwater Quality in and around Hosur, Krishnagiri District, Tamil Nadu, India',*International Journal of Research in Chemistry and Environment,* Vol. 2(3), pp. 113-122.
13. Raja, R. E., Sharmila, L., Merlin J. P., and Chritopher, G. (2002),*Indian J Environ Prot.,*Vol. 22(2), pp. 137.
14. Sawyer, Clair, N., Perry, L., Mc. and Gene, F. (2000), *Parkin Chemistry for Environmental Engineering. IV Ed.*, Tata Mc. Graw-Hill, New Delhi.
15. Singh, K. P., Malik, A., Sinha, S., Mohan, D., and Singh, V. K. (2007), *Anal. Chem. Acta.* , pp. 596.
16. Suryanarayana, K. (1995), 'Effect of ground water quality on health hazards in parts of Eastern Ghats', *Indian J. Environmental Protection*, Vol.15(7), pp. 497-500.
17. Tank, D. K. and Singh, C.C.P. (2010), 'Analysis of major ion constituent ground water of Jaipur city',*Nature and Science*, Vol. 8 (10), pp. 1-7.

18. Ullah, R., Malik, R.N. and Qadir, A. (2009), 'Assessment of groundwater contamination in an industrial city, Sialkot, Pakistan',*African Journal of Environmental Science and Technology*, Vol. 3(1), pp. 429-466.
19. WHO, (2011), Guidelines for drinking-water quality, 4th edition.
20. Zafar, A.R. (1966), 'Limnology of the Hussainsagar Lake, Hyderabad, India', *Phykos*, Vol. 5, pp.115-126.