Analysis of groundwater quality using water quality index: A case study of greater Noida (Region), Uttar Pradesh (U.P), India

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Abstract: The objectives of this study are to analyze the underground water quality of Greater Noida region by water quality index. Nine physico-chemical parameters such as Calcium, Magnesium, Chloride, Sulphate, Total Hardness, Fluoride, Nitrate, Total Dissolved Solids, Alkalinity collected from 10 different locations since a period of 2015. In this study 90% water samples were found good quality and only 10% water samples falls under moderately poor category. The water quality index ranges from 16.49 to 64.65. Therefore there is a need of some treatment before usage and also required to protect that area from contamination.

1. Introduction

Ground water is a good source of fresh water resource which is the biggest issues in front of the policy makers for its sustainable utilization. Natural filtration through soil and sediments makes the ground water free from organic impurities (Karanth, 1989). Various major controlling ground water chemistry factors are regional geology, geochemically process and landuse patterns (Kumar, Ramanathan, Rao, & Kumar, 2006; Liu, Jang, Chen, Lin, & Lou, 2008; Matthess, 1982; Rajesh, Brindha, 

PUBLIC INTEREST STATEMENT

In the present study drinking ground water quality index has been assessed in the region of Greater Noida, U.P. (India). It has been observed that the quality of water is good in the study area except one location. The analysis reveals the fact that the ground water quality of the country requires to be determined in order to evaluate the degree of water treatment before using it for drinking and other usages. The determination of the suitability of water and degree of treatment for consumption is very much essential for the use of water quality to mankind.
Murugan, & Elango, 2012; Zhu & Schwartz, 2011). Major ion chemistry of ground water is also influenced by the evaporation and irrigation return flow (Guo & Wang, 2004; Hudak, 2000; Rajmohan & Elango, 2006; Stigter, van Ooijen, Post, Appelo, & Carvalho Dill, 1998). Ground water quality and quantity is deteriorating at a very fast rate due to anthropogenic activities. Major provocation for general public, researchers and water managers are the ground water flow and its storage in hard rock regions (Ballukraya & Sakthivadivel, 2002; De Silva & Weatherhead, 1997; Negrel et al., 2011), either its quality and quantity also affected (Gupta & Singh, 1988; Robins & Smedley, 1994; Singhal, Niwas, & Singhal, 1988). A great major issue is the limitation of ground water resource and its long term sustainability (Foster, Hirata, Gomes, D’Elia, & Paris, 2002; Singhal et al., 1988). Ground water quality have been determined in various parts of India by many researchers (Abbas, Khan, Sentivelan, & Shabudeen, 2002; Bishnoi & Arora, 2007; Gupta & Deshpande, 2004; Gupta, Mahato, Roy, Datta, & Saha, 2008; Jagadap, Kachowe, Despande, & Kelkar, 2002; Kaul, Mahajan, & Nandy, 1999; Kumar, Ranjan, Ramanathan, Singh, & Srivastava, 2014; Prasad, 1998; Shivran, Kumar, & Singh, 2006; Singh & Chandel, 2006; Singh, Singh, Kumar, Gupta, & Mukherjee, 2009; Singh, Srivastava, Gupta, & Mukherjee, 2012; Singh, Srivastava, & Pandey, 2013a; Singh, Srivastava, Pandey, & Gautam, 2013b; Singh et al., 2015; Srivivasamoorthy et al., 2011). Over withdrawal of ground water is deteriorating the ground water quality (Karma, Lal, Singh, & Boonstra, 2002; Négrel, Lemière, Machard de Grammont, Billaud, & Sengupta, 2007; Singh, Sinha, Bisht, & Banerjee, 2002) achieving in the higher salinity, Nitrate, Iron, Fluoride, and other heavy metals in ground water. Excessive use of fertilizers and pesticides, untreated sewage treatment system (Gautam, Sharma, Tripathi, Ahirwar, & Singh, 2013) and mixing of non-treated municipal and industrial effluents with ground water (Rao, Reddy, & Nayudu, 1997; Vasanthavigar, Srivivasamoorthy, & Prasanna, 2012; Wen, Wu, Su, & Zhang, 2005) are deteriorating the ground water quality. WQI provides a composite influence of different water quality parameters. Water quality index provides information on the quality of any water body. Mathematical equation of WQI transform large number of water quality data into a single number. Most effective tool to transmit information on the quality of water concern to citizens and policy makers is evaluated by WQI.

2. Study area

Greater Noida is one of the important city located in the Gautam Buddha Nagar district of Uttar Pradesh state (India). It is located at a latitude of 28.47 44°N and longitude of 77.50 40°E. It comprises 124 villages with a population of 107,676 (till March 2014). The area of Greater Noida is about 40,000 hectares broadly bounded by national highway NH-24 in the North West. The city comes under NCR (National capital Territory) region of Delhi. The total land use cover is 13,570.00 hectares with 30.0 hectares of commercial area and 1,970.03 hectares of the total institutional area. The water supply in the area is done through overhead tanks, tube wells, trunks and other supply lines. At present nearly 460 km length of sewerage network, 500 km length of drainage and nearly 500 km length of water supply lines subsists in the area (wikipedia.org) (Figure 1).
3. Sampling and analysis

A total number of nine samples from ten different locations of Greater Noida (region) were collected for the study. The sampling locations are mentioned in the Figure 2. The samples were collected from different sources such as Government hand pumps (GHP), General hand pumps (HP), Borwells (BOR) and preserved as per the methods prescribed in American Public Health Association manual [APHA-2320, 1999]. In the present study water quality index were determined and the results were compared with the values prescribed in various water quality standards such as Bureau of Indian Standards (BIS), Indian Standards (IS) (BIS, 2012) and World Health Organization (WHO, 2012). All the chemical concentrations are expressed in mg/l. Merits and demerits of water quality index are mentioned in the Table 1.

3.1. Water quality index determination

Most effective tool to monitor the surface as well as groundwater pollution is the water quality index which can be used efficiently in improving the water quality programmes. Water quality index gives information on a rating scale from zero to hundred. Nine parameters were performed to designed the water quality index.

![Figure 2. Location map where water samples have been collected.](image)

### Table 1. Merits and demerits of water quality index

| S. no | Merits                                                                 | Demerits                                                                 |
|-------|------------------------------------------------------------------------|--------------------------------------------------------------------------|
| 1     | Represents the data in single index value in rapid and objective manner | Evaluates general water quality, it does not represent precise use of water |
| 2     | Provides a composite influence of different water quality parameters    | Loss of information of single variable                                    |
| 3     | Index value reveals to a potential water use                            | Easy to manipulate                                                        |
| 4     | Relevant tool for water quality determination in a particular location | Loss of information on communication between variables                    |
| 5     | Flexible in the collection of input parameters                          | Does not represent suitable information about the real quality situation of the water |
| 6     | Easy to calculate                                                       | A single number cannot describes the whole information about water quality without considering many other water quality parameters |
| 7     | Represents the suitability of both surface and groundwater              | Does not provide health hazards such as toxic, metals and bacteria etc    |
In present study, three steps of water quality index are defined by Hameed, Alobaidy, Abid, and Mauloom (2010). In the first step each of the nine parameters (Calcium, Magnesium, Chloride, Sulphate, Total Hardness, Fluoride, Nitrate, Total Dissolved Solids, Alkalinity) have been assigned a weight ($w_i$) according to its relative importance on the comprehensive quality of water which range from 1 to 5. The maximum weight of 5 were assigned to the parameter which influence more significantly the water quality and minimum weight of 1 is selected to the least regnant the water Quality.

In the second step, relative weight ($W_i$) is computed from the following equation

$$W_i = \frac{w_i}{\sum_{i=1}^{n} w_i}$$

where $W_i$ and $w_i$ is the relative weight and weight of each parameter respectively and total number of parameters is $n$.

In the third step, Quality rating scale ($q_i$) for each parameters were computed by dividing its standard concentration prescribed by the guidelines of BIS

$$q_i = \left(\frac{c_i}{s_i}\right) \times 100$$

where $q_i$ is the quality rating scale, the concentration of each chemically parameters is $c_i$ in each water sample in mg/l, $s_i$ is the Indian standard water parameters in mg/l prescribed by the guidelines of BIS. For calculating water quality index, the $S_i$ is first determined for each chemically parameters which was calculated by the following equation.

$$S_i = w_i \times q_i$$

$$WQI = \sum_{i=1}^{n} S_i$$

where, the sub index of $i^{th}$ parameters is $S_i$, the rating of each concentration of $i^{th}$ parameters is $q_i$, and the number of parameters is $n$.

Calculated water quality index were classified into five groups excellent water to water unsuitable for drinking of range water quality index for drinking purpose is given in the Table 4.

4. Results and discussion
Greater Noida is a business city of Uttar Pradesh. The effluents of industries discharge directly to the natural water bodies such as pond, rivers etc. without any insufficient treatment of treatment plants. The effluents also dispersion into the ground water aquifers and making it unsuitable for human utilization.

4.1. Physico-chemical parameters

4.1.1. Calcium
Calcium serves in our body as vascular contraction, muscle contraction, blood clotting and nerve transmission. Taking lesser amount of calcium is associated increased risk of nephrolithiasis, osteoporosis, hypertension, colorectal cancer and coronary artery diseases obesity and insulin resistance. High content of calcium and magnesium in drinking water should be avoided in the case of kidney stone or bladder stone. The highest calcium value is observed to be 88.00 mg/l at location S-10 and lowest value is 11.00 mg/l at two locations S-6 and S-8. However, the calcium values at all locations are found to be below the permissible limits being prescribed in (BIS, 2012) for drinking water (Figure 3).
4.1.2. Magnesium
Due to deficiency of magnesium various risks to humans increases such as hypertension, vasoconstrictions, atherosclerotic vascular disease, cardiac, eclampsia in pregnant women, acute myocardial infaction and osteoporosis etc. Magnesium >125 mg/l may show laxative affects. The highest magnesium value is observed to be 37.00 mg/l at S-10 and lowest value is 6.00 mg/l at S-6 and S-8. However, the magnesium values at all locations are found to be below the acceptable limits being prescribed in (BIS, 2012) for drinking water (Figure 4).

4.1.3. Chloride concentration
Chlorides are found in natural water due to leaching of chloride containing rocks and soils discharges of effluents from chemical industries, ice-cream plant effluent, sewage disposal, irrigation drainage. Higher concentration of chloride is harmful to heart and kidney diseases of the peoples, indigestion, taste, palatability and corrosion are also affected. The highest chloride value is observed to be 170.0 mg/l at S-10 and lowest value is 16.0 mg/l at S-6. However, the chloride values at all locations are found to be below the acceptable limits being prescribed in (BIS, 2012) for drinking water (Figure 5).
4.1.4. Sulphate concentration
Contaminated water and waste water has high sulphate concentration. Gastro intestinal irritation are produced due to high concentration of sulphate. The highest sulphate value is observed to be 15.00 mg/l at S-10 and lowest value is 2.00 mg/l at S-6 and S-9. However, the sulphate values at all locations are found to be below the allowable limits being prescribed in (WHO, 2012) for drinking water (Figure 6).

4.1.5. Total hardness
Hardness due to bicarbonate of calcium or magnesium is temporary hardness and the hardness due to chloride, sulphates and nitrates of calcium and magnesium is permanent hardness. Due to permanent hardness soap consumption will be more. It also produces calcification of arteries. It also affects water supply system by forming scale. Urinary concretions, stomach disorder and diseases of kidney or bladder are produced by hardness without no conclusive proof. The highest total hardness value is observed to be 295.00 mg/l at S-10 and lowest value is 52.00 mg/l at S-6. However, the total hardness values at S-10 are found to be more than the permissible limits being prescribed in (WHO, 2012) for drinking water (Figure 7).

4.1.6. Fluoride concentration
Fluoride is a geochemical contaminant. Fluoride in small dosage influences the dental system. Higher concentration of fluoride causes dental and skeletal fluorosis. The fluoride values are observed to be 0.10 mg/l at all locations. However, the fluoride values at all locations are found to be below the acceptable limits being prescribed in (BIS, 2012) for drinking water (Figure 8).

4.1.7. Nitrate concentration
Nitrate is found in groundwater due to leaching of nitrate with the percolating water to the soil. Infant methaeglobinaemia is produced at very high toxic nitrate concentration. It also affects cardiovascular system and nervous system and also produces gastric cancer. The highest nitrate value is observed to be 9.00 mg/l at S-10 and lowest value is 1.00 mg/l at S-8. However, the chloride values at all locations are found to be below the acceptable limit being prescribed in (BIS, 2012) for drinking water (Figure 9).
4.1.8. Total dissolved solids
Estimation of total dissolved solid (TDS) is useful to the suitability of water for drinking, agriculture and industrial purpose. TDS is the sum of potassium, calcium, sodium, magnesium, carbonates, bicarbonates, chlorides, organic matter, phosphate and other particles. Higher concentration of TDS produces gastro-intestinal irritation in human body. The highest total dissolved solids value is observed to be 701.00 mg/l at S-10 and lowest value is 351.00 mg/l at S-4. However, the total dissolved solids values at S-10 are found to be more than the permissible limits being prescribed in (BIS, 2012) for drinking water (Figure 10).

4.1.9. Alkalinity
The highest alkalinity value is observed to be 230.00 mg/l at S-10 and lowest value is 30.00 mg/l at S-6. However, the alkalinity value at S-10 are found to be more than the acceptable limit being prescribed in (BIS, 2012) for drinking water (Figure 11).
5. Water quality index analysis

The physico-checmical parameters of Greater Noida region with their BIS and WHO water quality prescribed values, corresponding weightage factor ($W_i$), assigned with the help of equation 1 and the values are presented in the Table 2. WQI were calculated from equation 2 and 3. The WQI results are shown in Table 3. Classification of all the water samples were categorized by taking the standard water quality index bases which are shown in the Table 4. Obtained results revealed that the ground water qualities of 10 locations were found good quality ranges from 0–25 and 26–50. And only one place under moderately poor category ranges from 51–75.

### Table 2. Various physico-chemical parameters

| Parameters    | Weightage ($w_i$) | Relative weight ($W_i$) | Standard concentration (mg/l) ($S_i$) |
|---------------|-------------------|-------------------------|--------------------------------------|
| Calcium       | 3                 | 0.075                   | 75                                   |
| Magnesium     | 3                 | 0.075                   | 30                                   |
| Chloride      | 5                 | 0.125                   | 250                                  |
| Sulphate      | 5                 | 0.125                   | 200                                  |
| Total hardness| 3                 | 0.075                   | 300                                  |
| Fluoride      | 4                 | 0.10                    | 1                                    |
| Nitrate       | 5                 | 0.125                   | 45                                   |
| TDS           | 5                 | 0.125                   | 500                                  |
| Alkalinity    | 3                 | 0.075                   | 200                                  |

### Table 3. Details of the index rate and type of water for various samples obtained in the analysis

| Sample | Location               | Index rate | Type of water     |
|--------|------------------------|------------|-------------------|
| S-1    | Beta- IInd             | 30.70      | Good water        |
| S-2    | Omicron (EWS)          | 39.22      | Good water        |
| S-3    | Ecotech-2              | 33.23      | Good water        |
| S-4    | Sector-2 (Near Bhatta) | 22.64      | Excellent water   |
| S-5    | Sector-16 Swarn Nagri  | 30.92      | Good water        |
| S-6    | Ecotech-12, Sector-16  | 16.49      | Excellent water   |
| S-7    | Tech Zone-4, Sector-6  | 29.13      | Good water        |
| S-8    | Sector-3               | 19.54      | Excellent water   |
| S-9    | Omicron-1st OHT        | 28.21      | Good water        |
| S-10   | Chhatravas (SC/ST)     | 64.65      | Poor water        |
6. Conclusion

In the present study 90% water samples were found good quality and only 10% water samples falls under moderately poor category. The water quality index ranges from 16.49 to 64.65. Therefore there is a need of some treatment before usage and also required to protect that area from contamination. The rain water harvesting structures should be installed to restore the ground water aquifers for improvement of ground water resources in order to maintain the quality and quantity of ground water reservoir and thus diluting the higher concentration of chemical constituents and dissolved salts. Public awareness program should be begun to enhance the knowledge and awareness to save water pollution on human being around their dweller.

Table 4. Range of water quality index for drinking purpose

| S. no | Range | Type of water |
|-------|-------|---------------|
| 1     | 0–25  | Excellent     |
| 2     | 26–50 | Good          |
| 3     | 51–75 | Poor          |
| 4     | 76–100| Very poor     |
| 5     | >100  | Unsuitable for drinking purpose |

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