International Journal of Enhanced Research in Science Technology & Engineering, ISSN: 2319-7463
Vol. 3 Issue 7, July-2014, pp: (89-101), Impact Factor: 1.252, Available online at: www.erpublications.com

Assessment of Ground Water Quality in Jaipur City (Rajasthan, India)

Jayshri Kala[1], Prof. Gunwant Sharma[2], Prof. Sudhir Kumar[3], Dr. Satish Pipralia[4]
[1]Junior Scientific Officer, Rajasthan State Pollution Control Board, Jaipur, India
[23]Department of Civil Engineering, Malaviya National Institute of Technology, Jaipur, India
[4]Department of Architecture and Planning, Malaviya National Institute of Technology, Jaipur, India

Abstract: An attempt has been made in this investigation to ascertain ground water quality in Jaipur city. Hundred and fifty samples are taken from various parts of the city, and the results are being compared with IS: 10500 standard of the water quality parameter and subsequently computed the water quality index. The samples are collected in 2010 in the pre-monsoon period (March to June). The results reveal that most of the locations have good to excellent water quality. However, nitrate contamination is a concern in the study area as two-fifth of the total number of locations has nitrate levels beyond permissible limits. It signifies poor sanitation condition in the study area. It follows from the research that augmentation of sewerage infrastructure and its coverage is essential to bring down pollution levels in the study area.

Keywords: Jaipur City, Ground water quality, Water quality index.

1. Introduction

Jaipur city is the most populous city of Rajasthan State. Its rapid pace of growth has resulted in severe stress on ground water resources, both in qualitative and quantitative terms. While over exploitation of ground water resources, lack of surface water bodies and adverse climatic conditions aggravates the imbalance between the recharge and draft, the available ground water shall be rendered unfit if pollution levels continue to rise. In the light of the above facts an attempt has been made in this investigation to study the status of ground water quality in Jaipur city.

2. Study Area

Jaipur, the capital city of Rajasthan State in India, is the tenth most populous city of the country. It is located at 26^0 54'N latitude and $75^0$49'E longitude and experiences a continental type of climate. The city witness extreme temperatures both in summer as well as in winters and low to moderate relative humidity. The highest mean monthly maximum temperature of 40.6º C is recorded in May and the lowest mean monthly temperature of 8.3º C is recorded in January. The city receives 90 per cent of its rainfall during the monsoon period (June-September) and the average annual rainfall in the city is 567.70 mm. Studies reveal that probability of exceedance of average annual rainfall in Jaipur city is about 25% and normal drought 19.4% whereas probability of severe and most severe drought is almost negligible (CDP,2005).

The ground water resources assume greater significance in Jaipur city due to the absence of perennial surface water sources. State Ground State Board study (2011) reveals that Jaipur city predominantly depends (86%) on ground water resources for its potable water supply. The current rate of ground water abstraction (95MCM/Annum) is not sustainable. The water table throughout the entire city area has fallen dramatically over the past three decades and continues to decline at an alarming rate, accompanied by increasing concentrations of nitrates in the ground water supply; and that the ground water resources within many parts of Jaipur city will be substantially exhausted in the near future unless appropriate measures are taken to significantly reduce the rate of abstraction and pollution.

International Journal of Enhanced Research in Science Technology & Engineering, ISSN: 2319-7463
Vol. 3 Issue 7, July-2014, pp: (89-101), Impact Factor: 1.252, Available online at: www.erpublications.com

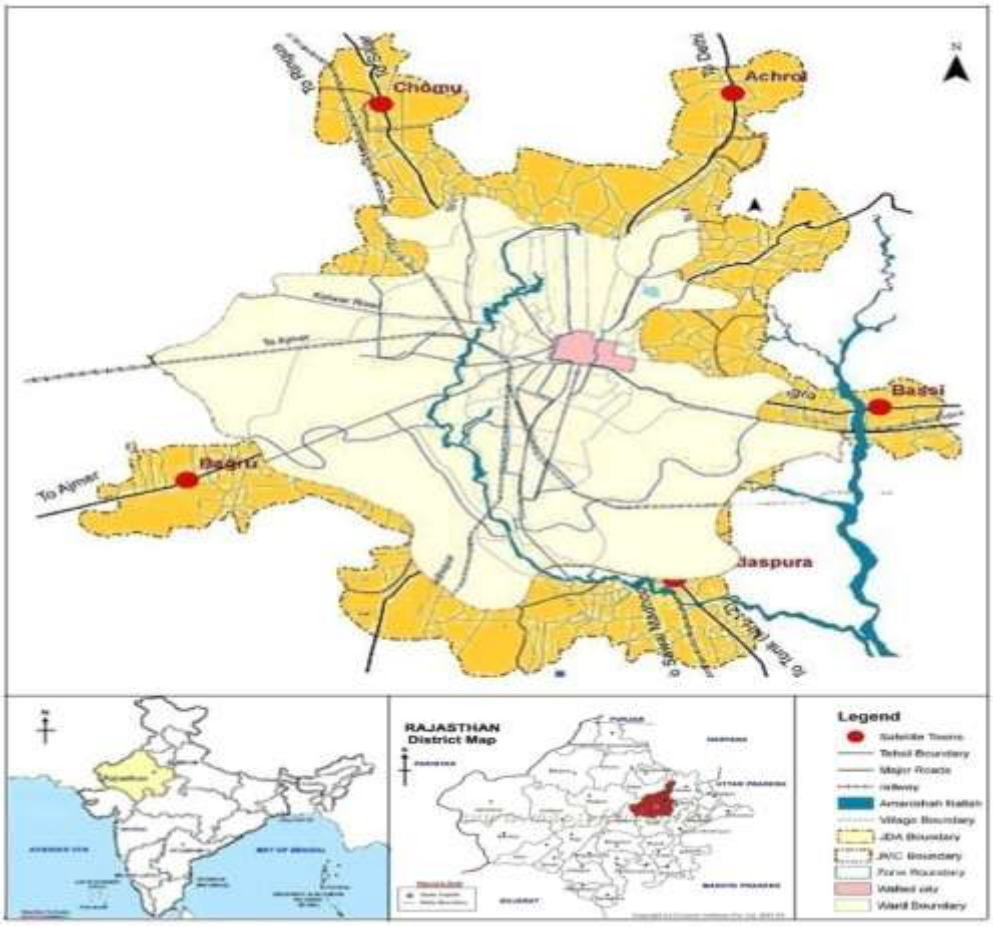

Figure 1: Description of the Study Area

3. Materials and Methods

Jaipur water supply system is categorized in four water supply zones of Public Health Engineering Department (PHED); and the water supply is augmented through 1380 tube wells. A total of 150 tube wells were selected to collect water samples by employing stratified random sample survey technique such that all parts of Jaipur city are suitably represented. Water samples were collected in High density poly ethylene (HDPE) plastic bottles and subsequently analyzed parameters such as pH, total alkalinity, total dissolved solids, chlorides, total hardness, sulphate, nitrate and fluoride as per the experimental procedures suggested in American Public Health Association (APHA) manual. Further, water quality index (WQI) has been computed for each sample. The results are presented in subsequent paragraphs, in sequel.

4. pH

pH is measure of relative acidity or alkalinity of water. It measures the concentration of hydrogen ions in water. If free H+ ions are more than OH- ions, the water will be acidic and vice versa. The pH value is expressed as the negative logarithm of Hydrogen ion concentration:

pH= -log 10 a H^+ ; where H^+ = Activity of hydrogen ions

A pH value of 7 indicates natural water; if the pH value is below 7 the water is acidic and if the value is above 7 the water is considered alkaline. However, pH of natural water is generally over 7 due to presence of sufficient quantities of carbonates.

pH is one of the most important operational water quality parameters. Its control is necessary at all stages of water treatment to ensure satisfactory water clarification and disinfection and to minimize the corrosion of water mains and pipes in household water systems. Failure to minimize corrosion can result in the contamination of drinking-water and in adverse effects on its taste and appearance. Having the above knowledge, this parameter was studied by a digital pH meter in detail and results are presented in Table 1 and Figure 2 and Figure 3.

Table 1: Distribution of pH Level in Jaipur City

Serial No.	pH Range	No. of Samples	Per cent Distribution
1	≤7.5	15	10
2	7.51 - 8.00	62	41
3	8.01 - 8.50	60	40
4	8.51 - 9.00	13	9
Total		**150**	**100**

It is observed from the Table 1 and Figure 2 that the pH values of ground water samples in the study area range between 7.5 to 9.0; and two-fifth (40 per cent) of the total number of samples have pH value 8.00 to 8.50 and almost equal numbers (41 per cent) have the pH value 7.50 to 8.00. Further, it has been observed that one-tenth (10 per cent) of the total number of samples have pH value less than or equal to 7.5 and less than one-tenth (9 per cent) of the total number of samples have pH value more than 8.50. As per WHO norms and Indian standard (IS: 10500) the acceptable range of pH value is 6.5 to 8.5. The analysis of data reveals that nine-tenth (91 per cent) of the total number of samples have pH value within permissible limits and that only less than one-tenth (9 per cent) of the total number of samples have pH value more than permissible limit. The distribution of pH values in Jaipur city is presented in Figure 3.

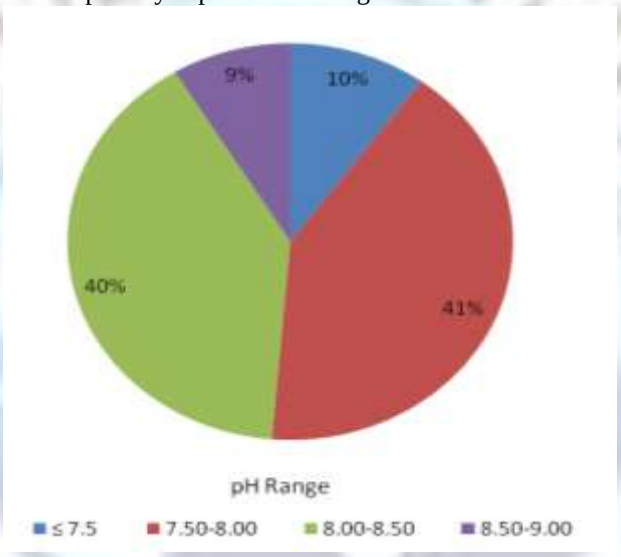

Figure 1: pH levels and per cent share of samples in Jaipur City

Figure 2: Distribution of pH Values in Jaipur City

5. Total dissolved solids (TDS)

Total dissolved solids (TDS) comprise inorganic salts (principally calcium, magnesium, potassium, sodium, bicarbonates, chlorides and sulfates) and small amounts of organic matter that are dissolved in water. TDS in drinking-water originates from natural sources, sewage, urban runoff and industrial wastewater. A high content of dissolved solids elevates the density of water, and reduces solubility of gases and utility of water for drinking, irrigation and industrial purposes. The concentration of TDS determines the palatability of a water sample. The palatability of water with a total dissolved solids (TDS) level of less than about 600 mg/l is generally considered to be good; drinking-water becomes significantly and increasingly unpalatable at TDS levels greater than about 1000 mg/l, and may cause gastro intestinal irritation. On the basis of above knowledge it was considered important to study this parameter and the results are presented in Table 2 and Figure 4 and Figure 5.

Table 2: Distribution of TDS Level in Jaipur City

Serial No.	TDS Range	No. of Samples	Per cent Distribution
1	≤ 500	65	44
2	500-1000	62	41
3	1000-1500	19	13
4	1500-2000	2	1
5	2000-2500	2	1
Total		**150**	**100**

It is evident from the Table 2 and Figure 4 that little more than two-fifth (44 per cent) of the total water samples have TDS less than or equal to 500 mg/l while another two-fifth (41 per cent) have the values between 500-1000 mg/l whereas almost one-eighth (13 per cent) of the total number of samples have TDS between 1000-1500 mg/l and only few samples (2 per cent) have TDS more than 1500 mg/l. As per experimental results the TDS of ground water samples ranged between 228-2140 mg/l. Analyses of results reveal that almost three-fifth (59 per cent) of the total samples are above the desirable limit of 500 mg/l as spelt in IS: 10500. Further, experimental results reveal maximum concentration of TDS in areas of C-scheme and 22 Godown , Amer Road, Goner Road, Sanganer and the values are: 1698 mg/l,1595mg/l, 2050mg/l, 2140mg/l, respectively. The distribution of TDS values in Jaipur city is presented in Figure 5.

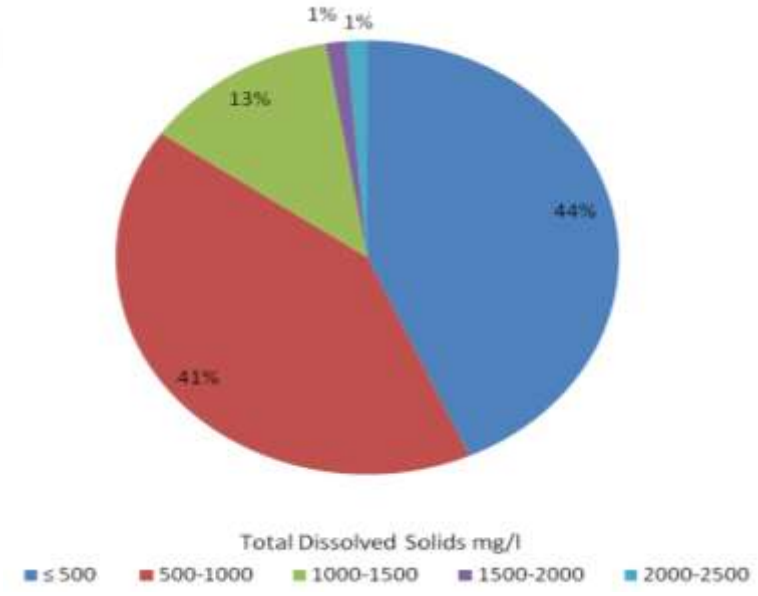

Figure 3: TDS levels and per cent share of samples in Jaipur City

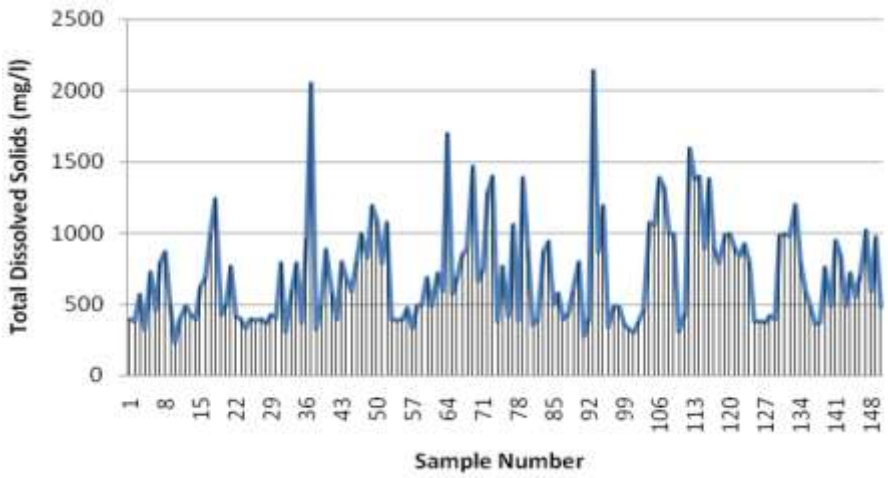

Figure 4: Distribution of TDS Level in Jaipur City

6. Alkalinity

Alkalinity of water is its capacity of combing with hydrogen (H^+) ions i.e. its capacity to neutralize a strong acid; therefore, it affects the palatability of water. A number of bases viz., carbonates, bicarbonates, hydroxides, phosphates, nitrates, silicates, borates etc. contribute to alkalinity, however, in natural waters, carbonates, bicarbonates and hydroxides are considered to be the predominant bases. Thus alkalinity may be expresses as total alkalinity or alkalinity due to individual bases. In this investigation total alkalinity has been computed for the collected samples. Alkalinity in samples was estimates by titrating it with 0.02N H_2SO_4 using phenolphthalein and methyl orange as indicators and the results are presented in Table 3 and Figure 6 and Figure 7.

It is evident from the Table 3 and Figure 6 that one-third (34 per cent) of the total number of samples have total alkalinity less than 200 mg/l while another two-fifth (40 per cent) have values between 200-300mg/l and about one-tenth (11 per cent) of the total number of samples have values between 300-400mg/l whereas a little less than one-sixth (15 per cent) of the total samples have total alkalinity more than 400mg/l. It has been observed that only one-third (34 per cent) of the total number of samples has total alkalinity within the desirable limit of less than 200 mg/l. The distribution of total alkalinity values in Jaipur city is presented in Figure 7.

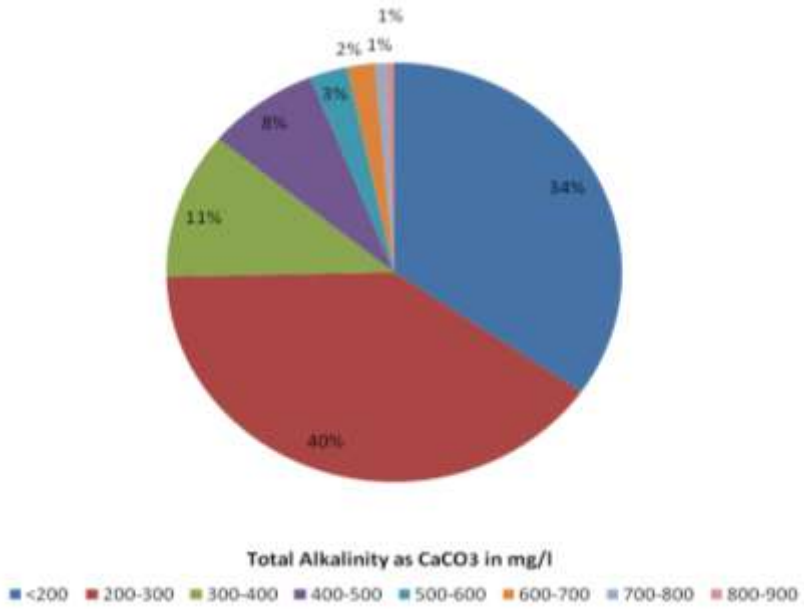

Figure 5: Total Alkalinity and per cent share of samples in Jaipur City

Table 3: Distribution of Total Alkalinity Level in Jaipur City

Serial No.	Total Alkalinity as $CaCO_3$, mg/l	No. of Samples	Per cent Distribution
1.	<200	52	34
2.	200-300	60	40
3.	300-400	17	11
4.	400-500	12	8
5.	500-600	4	3
6.	600-700	3	2
7.	700-800	1	1
8.	800-900	1	1

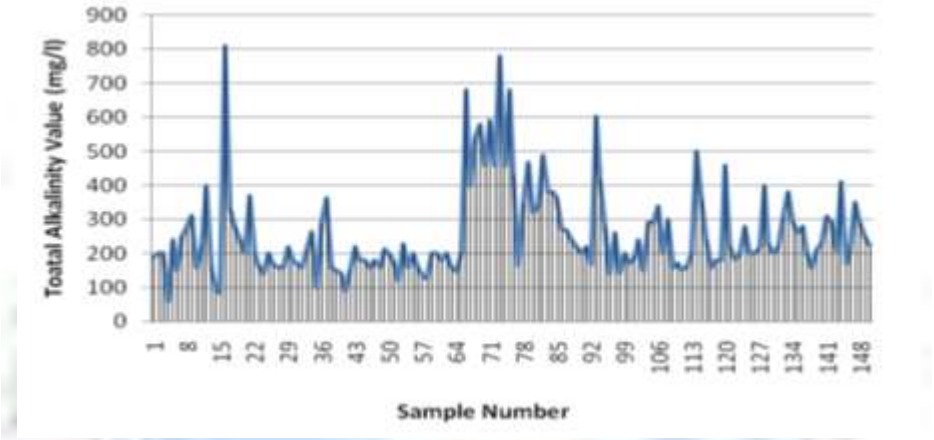

Figure 6: Distribution of Total Alkalinity Level in Jaipur City

7. Hardness

Hardness in water is caused primarily by calcium and magnesium cations and is measured by their concentration in a water sample because they are far high in concentration over other cations. Subject to the interaction of other factors, such as pH and alkalinity, hardness above approximately 200 mg/l may cause scale deposition in the treatment works, distribution system and pipe work and tanks within buildings; less than 100 mg/l hardness have low buffering capacity and become more corrosive for water pipes. It should be removed from the water supply system to prevent scale deposition and to make water suitable for bathing and washing; it has high boiling point, therefore more energy is required for cooking. As per Indian standard (IS: 10500) the acceptable range of hardness is 300mg/l. Total hardness was detected by titrating the sample with 0.02 N EDTA (Chelating agent) solution using Erichrome Black-T (metal ion indicator) and the results are presented in Table 4 and Figure 8 and Figure 9.

Table 4: Distribution of Total Hardness Level in Jaipur City

Serial No.	Total Hardness mg/l	No. of Samples	Per cent Distribution
1.	<300	76	51
2	300-500	43	29
3	500-700	21	14
4	700-900	5	3
5	900-1100	2	1
6	1100-1300	2	1
7	1300-1500	1	1

It is evident from the Table 4 and Figure 8 that half (51 per cent) of the total samples have total hardness of less than 300 mg/l while about three-tenth (29 per cent) have values between 300-500 mg/l and one-fifth of the total samples have total hardness of more than 500mg/l. It is observed further that total hardness of ground water samples ranged between 48-1368mg/l and three-tenth (31 per cent) of the total samples have total hardness beyond permissible limit. The distribution of total hardness in Jaipur city is presented in Figure 8.

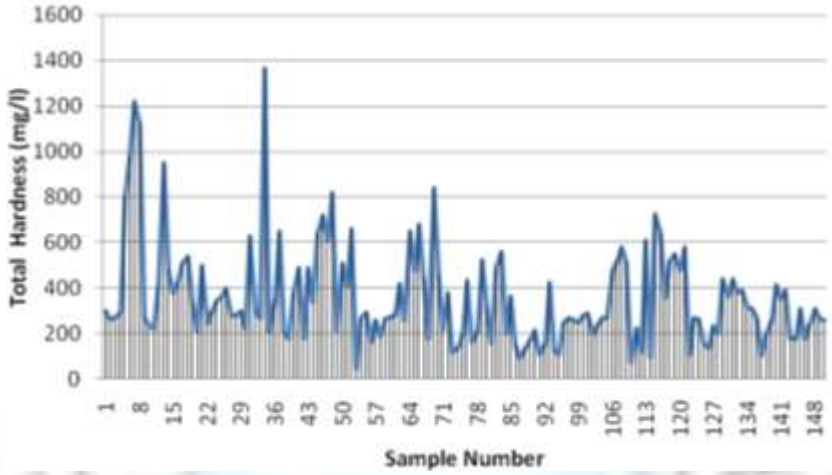

Figure 7: Distribution of Total Hardness Level in Jaipur City

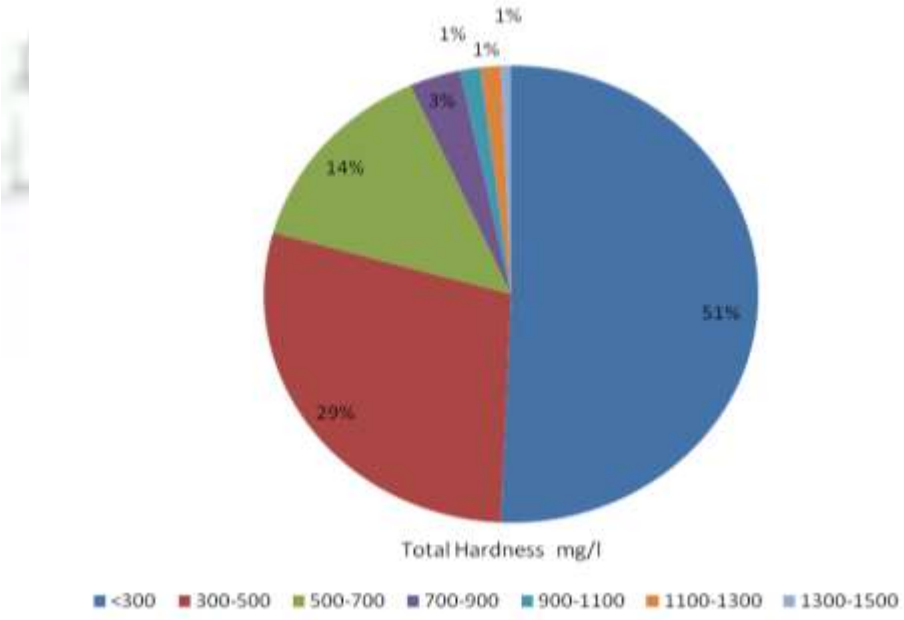

Figure 8: Total Hardness and per cent share of samples in Jaipur City

8. Chloride

Inland natural water, in general, has low chloride concentration, often less than that of bicarbonates and sulphates. A high concentration of chlorides may harm metallic pipes and structures, as well as growing plants and causes laxative effects in humans. In natural fresh water high concentration of chlorides is considered to be an indicator of pollution due to organic wastes of animal origin or industrial contamination. Chloride content above 250 mg/l makes water salty in taste; however, a level up to 1000mg/l is safe to human consumption. Chloride in the collected samples was estimated by using $AgNO_3$ solution as titrant and potassium chromate as an indicator and the results are presented in Table 5 and Figure 10 and Figure 11.

It is evident from the Table 5 and Figure 10 that more than three-fourth (77 per cent) of the total samples have chloride less than 250 mg/l while another one-eighth (13 per cent) have values between 250 – 350 mg/l and only one-tenth (10 per cent) of the total samples have chloride more than 350 mg/l. Further, it has been observed that all the samples have chloride concentration within permissible limit, however, about one-fourth (23 per cent) of the total samples has chloride more than the desirable limit. The distribution of chloride levels in Jaipur city is presented in Figure 11.

Table 5: Distribution of Chloride Level in Jaipur City

Serial No.	Chloride (mg/l)	No. of Samples	Per cent Distribution
1	<250	116	77
2	250-350	20	13
3	350-450	7	5
4	450-550	5	3
5	550-650	1	1
6	650-750	1	1

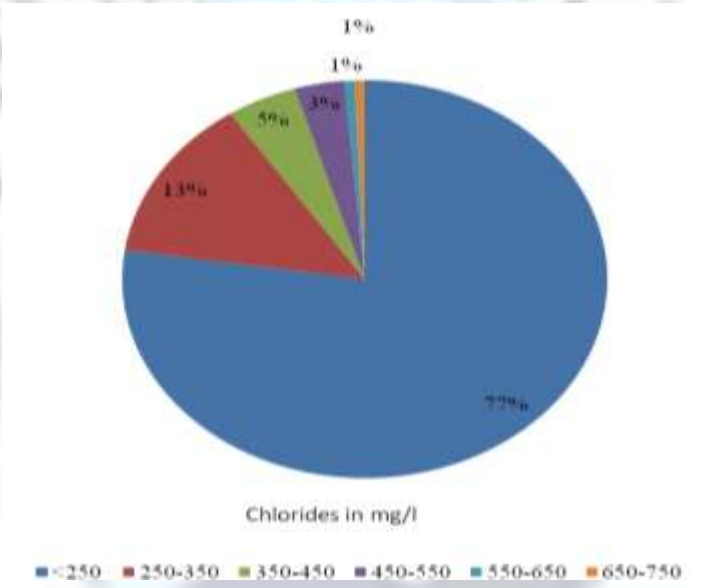

Figure 9: Chloride and per cent share of samples in Jaipur City

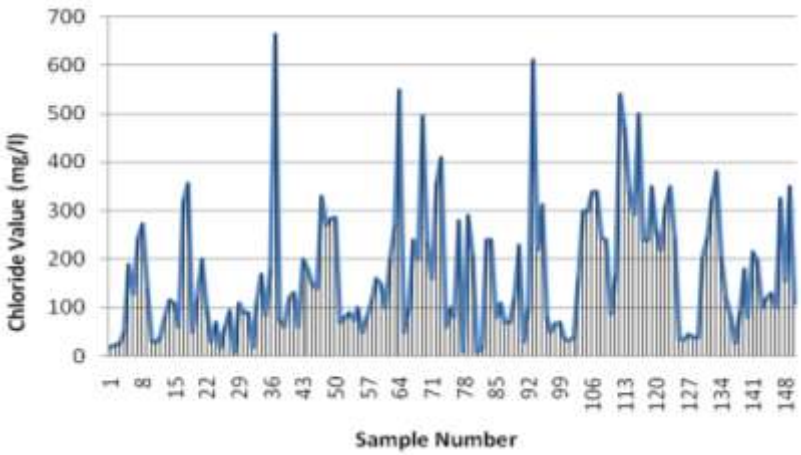

Figure 10: Distribution of Chloride Level in Jaipur City

9. Flouride

Fluorides are more common in ground waters than in surface waters. The main sources of fluoride in water are different fluoride bearing rocks and minerals like fluoride, apatite, amphiboles and micas. The maximum permissible limit for fluoride in drinking water is recommended to be 1.5 mg/l by W.H.O. When present in higher concentration it causes mottling of teeth, skeleton fluorosis, forward bending of vertebral column, deformation of knee joints and other parts of the body, etc. Electrode method was used to estimate fluoride in the collected samples and the results are presented in Table 6 and Figure 12 and Figure 13. It is evident from the Table 6 and Figure 12 that nine-tenth (92 per cent) of the total samples have fluoride less than 1mg/l while another four per cent have fluoride concentration between 1-1.5mg/l and another four per cent samples have fluoride concentration beyond 1.5mg/l. It is evident further that only less than one-tenth (8 per cent) of the total samples has fluoride concentration beyond desirable limits. The distribution of Fluoride values in Jaipur city is presented in Figure 13.

Table 6: Distribution of Fluoride Level in Jaipur City

Serial No.	Fluoride mg/l	No. of Samples	Per cent Distribution
1	≤ 1.00	138	92
2	1.00-1.50	6	4
3	1.50-2.00	3	2
4	2.00-2.50	2	1
5	2.50-3.00	1	1

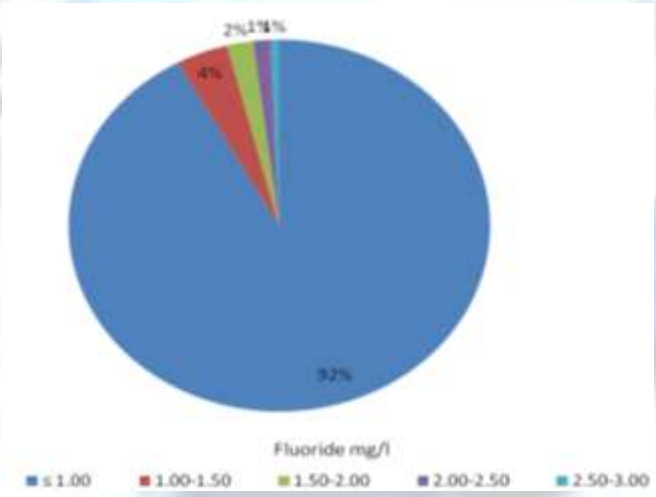

Figure 11: Fluoride and per cent share of samples in Jaipur City

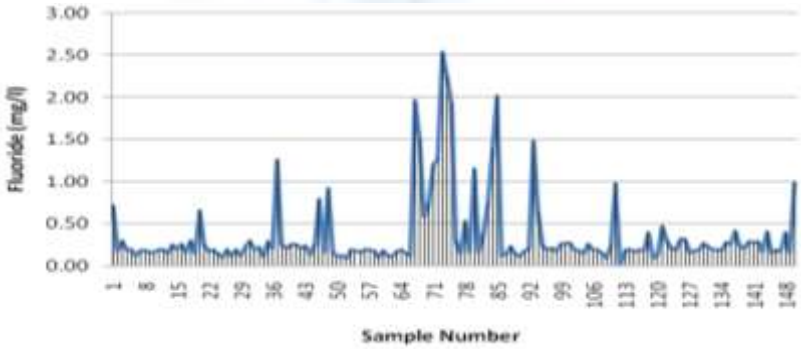

Figure 12: Distribution of Fluoride Level in Jaipur City

10. Nitrate- Nitrogen

Nitrate ($NO3^-$) is found naturally in the environment and is an important plant nutrient. It is the highest oxidized form of nitrogen and in water its most important source is biological oxidation of nitrogenous organic matter of both autochthonous and allochthonous origin. It can reach both surface water and groundwater as a consequence of agricultural activity (including excess application of inorganic nitrogenous fertilizers and manures), from wastewater disposal and from oxidation of nitrogenous waste products in human and animal excreta, including septic tanks. High concentration of nitrate in water is indicative of pollution. In excess, it causes ubiquitous growth of algae. High nitrate content (>40 mg No_3-N/L) may cause blue-baby disease. Nitrate in the collected samples was determined at 220 nm by using spectrophotometer and the results are presented in Table 7 and Figure 14 and Figure 15.

It is evident from the Table and Figure that almost three-fifth (59 per cent) of the total number of samples have nitrate concentration less than or equal to 45 mg/l while another three-tenth (30 per cent) have the values between 46 – 100 mg/l and a little more than one-tenth (11 per cent) of the total samples have nitrate concentration above 100 mg/l. further, it is evident that while three-fifth of the total number of samples have nitrate concentration within desirable limits; only one-tenth (11 per cent) of the samples have nitrate beyond permissible limits. The distribution of nitrate level in Jaipur city is presented in Figure 15.

Table 7: Distribution of Nitrate Level in Jaipur City

Serial No.	Nitrate as NO3, mg/l	No. of Samples	Per cent Distribution
1	≤ 45	89	59
2	46-100	45	30
3	100-150	9	6
4	150-200	4	3
5	200-250	2	1
6	250-300	1	1

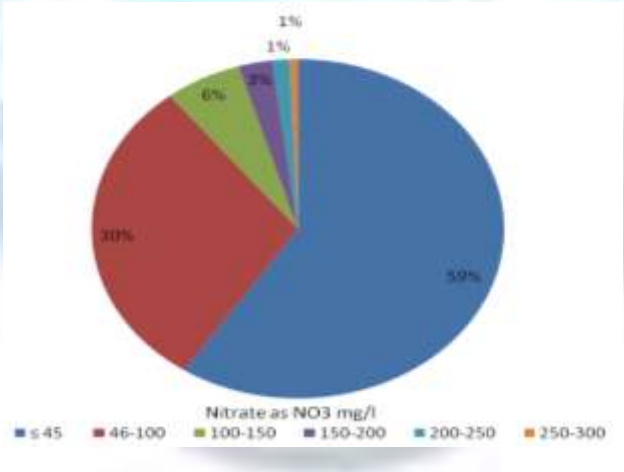

Figure 13: Nitrate and per cent share of samples in Jaipur City

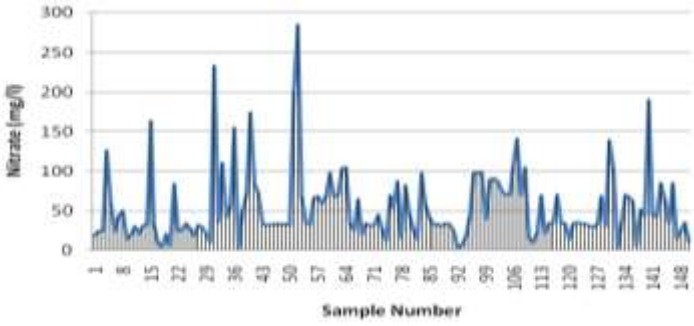

Figure 14: Distribution of Nitrate Level in Jaipur City

11. Sulphate

Sulphates are found in appreciable quantity in all natural waters, particularly high in arid and semi-arid regions where natural water in general have a high salt content. Domestic sewage and industrial effluents, besides biological oxidation of reduced sulfur species, may add to sulphate content of water. In a region where atmospheric sulfer content is high because of industrial and automobile emission, the rain water has high sulfer content. Sulphate salts are mostly soluble in water and impart hardness. Waters with about 500 mg/l sulphate have a better taste and those with 1000mg/l or more sulphate may cause intestinal disorders. Sulphate in the collected samples was estimated by developing turbidity by $BaCl_2$ and measuring its concentration using spectrophotometer at 420nm. Sulphate concentration in all the collected samples has been found within the desirable limits. The distribution of sulphate level in Jaipur city is presented in Figure 16.

Having done the physico-chemical analysis of the ground water samples, an attempt has further been made to compute water quality index of various locations in the study area and is presented in the subsequent section.

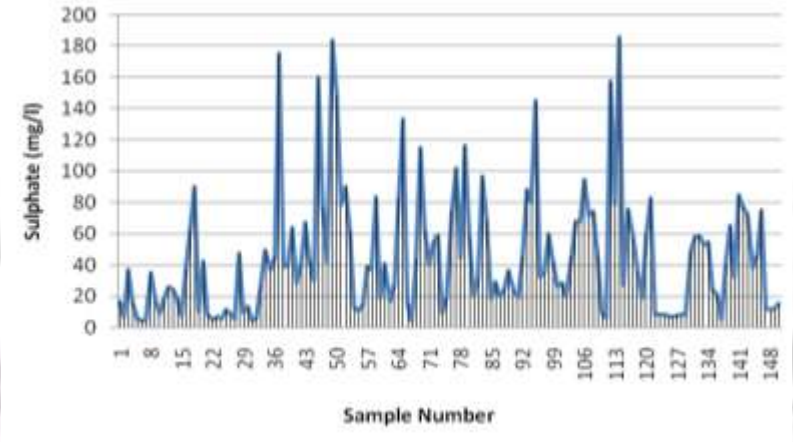

Figure 15: Distribution of Sulphate Level in Jaipur City

12. Water Quality Index

The Water Quality Index (WQI) is a very useful and efficient method for assessing the quality of water (Pradhan et al. 2001; Asadi et al. 2007). It is an attempt to arrive at a single number to express overall water quality at a certain location in order to enable easy comprehension of complex water quality data and to arrive at general idea about the possible problems with the water at the given location. In this investigation, an index value of 0–25 signifies excellent water quality, similarly 26–50 = Good, 51–75 = Poor, 76–100 = Very poor and the index value greater than 100 implies that water is unfit for drinking. To determine the suitability of the groundwater for drinking purposes, WQI has been computed from the following formula:

$$WQI = \text{Anti log}\,[\sum Wn \log 10\, qn\,]$$

Where, Wn, is a weighting factor derived from $Wn = K/Sn$; K, proportionality constant is derived from $K = [1/(\sum n\ n = 1\ 1/Si)]$; S_n and S_i are the IS: 10500 standard values of the water quality parameter. Quality rating (q) is calculated using the formula

$$qni = \{[(Vactual - Videal)/(Vstandard - Videal)] \times 100\}$$

where, q_{ni}, quality rating of ith parameter for a total of n water quality parameters; V_{actual}, value of the water quality parameter obtained from laboratory analysis; V_{ideal}, value of water quality parameter obtained from the standard tables; V_{ideal} for pH = 7 and for other parameters it is equivalent to zero; $V_{standard}$, IS: 10500 standard of the water quality parameter. The results are presented in Table and Figure.

It is observed from the table and figure that three-fifth (60 per cent) of the total number of samples have excellent water quality, followed by about one-fourth (24 per cent) samples have good water quality; whereas eight per cent samples have poor to very poor water quality and another eight per cent samples have water quality unfit for drinking purposes.

Table 8: Distribution of Ground Water Quality in Jaipur City

S.No.	Range	Category	No. of locations	Per cent Distribution
1	0-25	Excellent	91	60
2	26-50	Good	36	24
3	51-75	Poor	7	5
4	76-100	Very poor	4	3
5	>100	Unfit for drinking	12	8

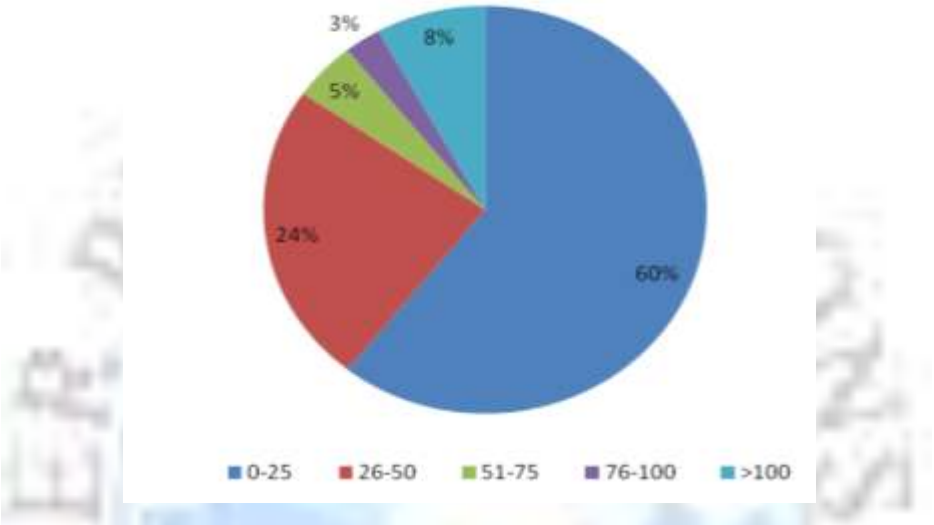

Figure 16: Ground Water Quality and Per cent share of samples in Jaipur City

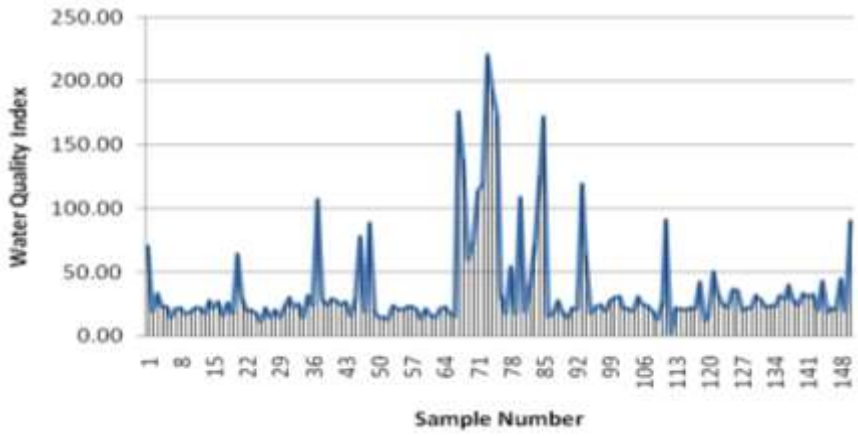

Figure 17: Distribution of Ground Water Quality in Jaipur City

13. Acknowledgements

1. Central Pollution Control Board, New Delhi, India
2. Dr. D. N. Pandey, Member Secretary; Rajasthan State Pollution Control Board, Jaipur, Rajasthan, India.

14. Conclusion

An attempt has been made in this investigation to ascertain ground water quality in Jaipur city. Hundered and fifty samples were taken from various parts of the city, and the results are being compared with IS: 10500 standard of the water quality parameter and subsequently computed the water quality index. The results reveal that most of the locations (84 per cent) have good to excellent water quality. However, nitrate contamination is a concern in the study area as two-fifth (41 per cent) of the total number of locations has nitrate levels beyond permissible limits. It signifies poor sanitation condition in the study area. It follows from the research that augmentation of sewerage infrastructure and its coverage is essential to bring down pollution levels in the study area.

References

[1]. Jaipur City Development Plan, 2005, Urban Development Department, Government of Rajasthan, Jaipur.
[2]. Annual Report, 2011, Rajasthan State Ground Water Board, Jaipur.
[3]. APHA (1985) Standard methods for the examination of water and waste water (16th ed.), Washington D.C: American Public Health Association, American Water Work Association, Water Pollution Control Federation.
[4]. Worl Health Organization (WHO), 1996, Guidelines for Drinking Water Quality 2, Geneva, 231.
[5]. Bureau of Indian Standards, 2010, Drinking Water Specification
[6]. Pandit ,M., Bhardwaj K., , Vinay, Pareek, N., 2009. Urbanization impact on hydrogeological regime in Jaipur Urban Block: a rapidly growing urban center in NW India.Environmentalist (2009) 29:341–347.
[7]. Chatterjee R., Tarafder G., Paul, S., 2010. Groundwater quality assessment of Dhanbad district,Jharkhand, India.Bull Eng Geol Environ (2010) 69:137–141.