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RESEARCH ARTICLE

STATUS OF DRINKING WATER QUALITY OF LUDHIANA DISTRICT, PUNJAB, INDIA

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ABSTRACT

The Ludhiana is one of the fastest growing and most centrally located district of Punjab. It is the largest city in Punjab, both in terms of area (3860 sq km) and population (approximately 34, 87,882 as per 2011 census). Ludhiana is the first metropolitan city, popularly known as "Manchester of India". The rapid population growth in Ludhiana continues to be a matter of concern due to its manifold effects on environment and one of the most important being groundwater contamination and overexploitation. The major driving force affecting the study area is increase in population due to urbanization and industrialization seems to have a severe impact on the climate change as indicated by change in temperature, rainfall pattern and relative humidity in the study area.44 groundwater samples were analyzed during pre-monsoon and post-monsoon periods respectively from different depths to evaluate the groundwater quality for drinking purposes. For this purpose, the implementation of the sustainable management water will require an integrated approach to strike a fine balance between urbanization and environmental protection.

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INTRODUCTION

The chemical properties of water (groundwater and surfacewater) are very significant to study their impact on water (ground and surfacewater). The quality of the groundwater varies with depth of the aquifer and its proximity to the canals. In addition, the distribution of rainfall pattern also influences the hydrochemical nature of the groundwater. In general, chemistry of ground water is interrelated with geology and hydrology of the area, physico-chemical characteristics of rocks and soils through which water percolates, nature of plant cover, extent of pollution and various other regional and local factors. Over exploitation and direct anthropogenic alteration of the land cover such as agriculture, deforestation, mining, urbanization and interference on hydrological regime like irrigation and damming have resulted in a marked change in water quality in various catchment areas (Sreekumar *et al*., 2009). Easily and regularly available clean drinking water is still a harsh task to achieve not only in deserts but also in most of the small towns and mega cities (Mehta, 2011). The United Nations has proclaimed the years of 2005-2015 as the international decade for action on. Water for life. (United Nation's General Assembly, 2004). According to FAO's definition of sustainable agricultural development given in (1990a) "A*ppropriate steps must be taken to ensure that agricultural activities do not adversely affect water quality so that subsequent uses of water for different purposes are not impaired."* The various geochemical parameters used for this purpose are described in this paper. The paper deals with the hydrochemistry of water (surface and groundwater) to evaluate their impact drinking water quality of the study area.

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Description of the study area

Geographically, Ludhiana district lies between North Latitude 30^{o}-34' and 31^{o}-01' and East longitude 75^{o}-18' and 76^{o}-20' as shown in Figure.1. It is the most centrally located district of Punjab. It is the largest city in Punjab, both in terms of area (3860 sq km) and population (approximately 34, 87,882 as per 2011 census). Ludhiana is the first metropolitan city, popularly known as "Manchester of India**".** The district constitutes a typical alluvial plain. It owes its origin to the augmentation of the Sutlej River. The alluvium deposited by the river was reworked by aeolian activities to give rise to a number of small dunes and sand mounds. The climate of the district is characterized as tropical steppe (hot and semi-arid) except a brief spell of monsoon season in a very hot summer and a bracing winter. There has been a consistent increase in the average minimum and maximum temperature in Ludhiana District due to climate change. The rainfall in the district increases from southwest towards the northeast. The average annual rainfall is 681mm.

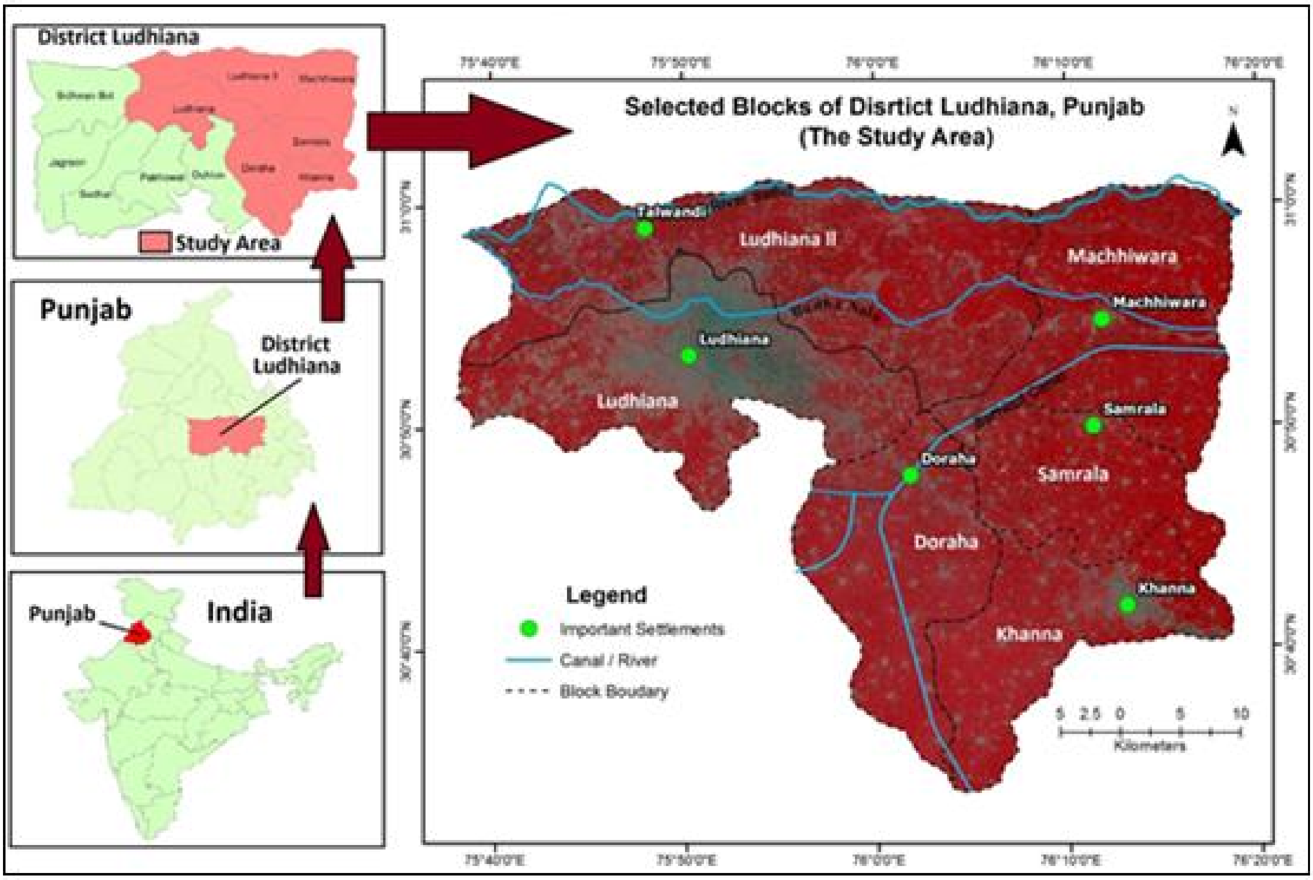

Figure 1. Location Map of Study Area

Based on the average monthly rainfall pattern, months have been categorized as major rainfall season (June-September), and intermediate rainfall season (January-May) and minor rainfall season (October-December). The monthly average relative humidity of Ludhiana district shows the cyclic. As per 2011 census, the population touched the mark of 34,87,882 which shows that the population increased almost double during the span of 30 years (1981-2011). The increase in population due to urbanization and industrialization seems to have a severe impact on the climate change as indicated by change in temperature, rainfall pattern and relative humidity in the study area. After the great strides in the field of agriculture, the total number of industries has increased tremendously after 1980s. The maximum exports of Rs.23 billion were from district Ludhiana comprising 57.5% of total exports from the state (Tiwana *et al*., 2005), which have severe effect on the quality of water and thus affecting its quality.

MATERIALS AND METHODS

For performing the present study, a well-tested scientific, systematic and proven methodology was adopted. The field and laboratory investigations carried out for the present study are discussed below.

Field Investigations and Sample collection

- Reconnaissance survey was carried out to familiarize with the research area and to collect the preliminary baseline data pertaining to sustainable agriculture in the area and meteorological parameters from different government and non-government organizations.
- A total of 44 groundwater samples were identified to collect the samples of ground water from the study area.
- Careful sampling was done to collect the water samples (groundwater) from the area covering the selected blocks.
- The water samples were collected in clean polythene bottle of two-liter capacity. Bottles were thoroughly rinsed two to three times with distilled water and the sample water to ensure no contamination at the time of sampling.
- Before collecting sample initially, the hand pump and tubewell was run for ten minutes so that the stagnant water in contact with metallic casing was removed and fresh water sample representative of that particular aquifer was acquired. Thereafter, water samples in duplicate were filled to the capacity of the bottle, sealed and labeled.
- 44 groundwater samples were collected from the tube wells and hand pumps from the six developmental blocks of Ludhiana district during pre-monsoon (May 2012 and 2013) and post-monsoon (November 2012 and 2013) were collected to study the quality of ground water and to assess their suitability for drinking purposes.
- The physical parameters such as pH, electrical conductivity (EC), total dissolved solids (TDS) and temperature were measured in the field using water and soil analysis kit. To ensure accuracy in the data, the analyses were repeated 2-3 times and mean values were calculated.

Laboratory Investigations

Determination of Water Quality

- The chemical analysis of water samples were analyzed in the geochemical laboratory of the Department of Geology Panjab University, Chandigarh, immediately after bringing the samples to the laboratory according to the standard methodology given by American Public Health Association (2005), Bureau of Indian Standards (BIS, 2012) and Indian Meteorological Department (IMD, 2013).
- Water samples were filtered with the help of Whatman filter paper No.71 to remove the suspended and extraneous matter.
- The account of analytical methods used for chemical analysis of the groundwater samples acquired from the study area along with description is given in brief in Table 1.

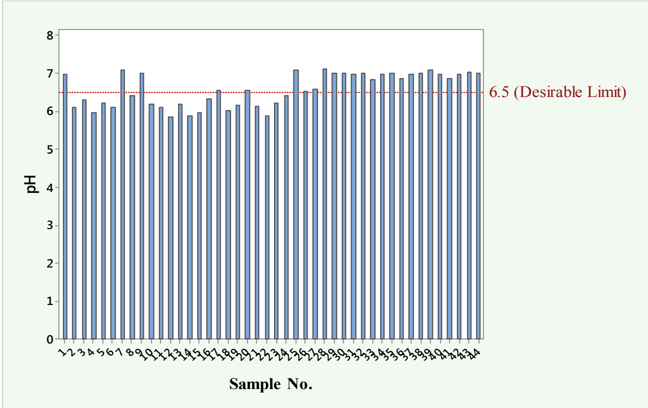

Figure 1. pH of groundwater of the study area

The unit of measurement of specific conductance is micro-siemens /cm (µS/cm at25 ^{0}C). In the present study, EC values of groundwater ranged between 514µS/cm to 1317µS/cm with the mean value of 898.40µS/cm and 512µS/cm to 1310µS/cm with the mean value of 876.77 µS/cm during pre and post monsoon, respectively as shown in Figure 2.

Table 1. Summary of analytical methods used for chemical analysis of the water samples

Parameters	Analytical Methods
Temperature (^{0}C)	Thermometer
Electrical Conductivity (EC)	Soil and Water analysis kit (Electronic India,model-161)
Total Dissolved Solids (TDS)	By Factor (multiplying EC with 0.65)
pH	pH meter
Turbidity	Nephelometer
Calcium	Titremetry (EDTA as titrant and murexide as indicator))
Magnesium	Titremetry (EDTA as titrant and erichrome black T as indicator)
Sodium	Flame photometer
Potassium	Flame photometer
Chloride	Titremetry ($AgNO_3$ with potassium chromate as indicator)
Sulphate	Spectrophotometer ($BaCl_2$ as conditioning agent)
Fluoride	Spectrophotometer (SPADNS reagent)
Nitrate	Spectrophotometer (Phenol disulphonic acid)

The data were subjected to statistical analysis using different computer programmes like Minitab16, Microsoft Office Excel, Map Info. 6.5 and Rockworks 15. The results and discussions following the field and laboratory investigations are discussed in sequel.

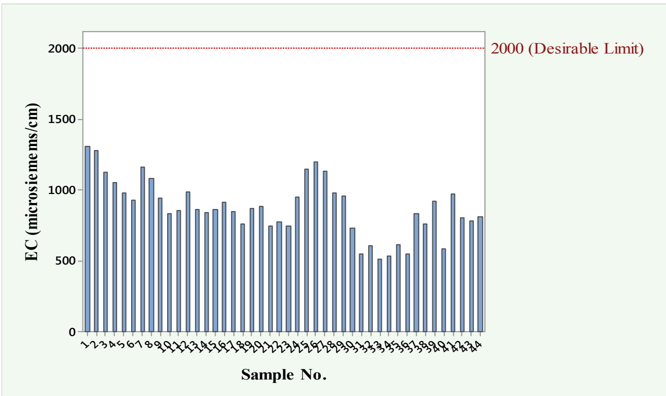

Figure 2. EC of groundwater of the study area

RESULTS AND DISCUSSION

Chemical analysis of groundwater and surface water

pH

The pH is dependent on carbon dioxide-carbonate-bicarbonate equilibrium in most natural waters (Abowei, 2010).The pH is an important indicator for the water quality and thus provides an important information in many types of solubility calculations and geochemical equilibrium (Hem, 1985). The pH value of groundwater during pre-monsoon season varied between 6.41 to 7.58 with the average value 6.83 and during post-monsoon varied from 5.87 to 7.12 with the average value 6.59 as shown in Figure1.

EC

The term EC denotes the characteristics of a medium to passage of electricity and is a function of temperature, type of ions present and concentration of various ions (Walton, 1970).

Total Dissolved Solid (TDS)

Total Dissolved Solids are the measure of total concentrations of all the constituents dissolved in water. Carbonates, bicarbonates, magnesium, sodium, silica and sulfates and chlorides of calcium form the major part while the minor part includes the potassium, chloride, nitrate and boron. The chemical in equilibrium between the water and deposited salts resulted in increased value of TDS in groundwater (Durfor and Becker, 1964). The high value of TDS results in laxative effect on human system. The concentration of TDS in groundwater ranged from 334mg/l to 856mg/l during pre-monsoon with the average value of 583.9mg/l and varied from 332mg/l to 851mg/l with the average value of 569.9mg/l during post-monsoon as shown in Figure 3.

Total Hardness

Calcium and magnesium ions cause the principal hardness in fresh waters. The degree of hardness of drinking water may be classified in terms of its calcium carbonate concentrations as given by McNeely *et al*. (1979), Durfor and Becker (1964) and Environment Protection Agency (EPA, 1973). The concentration of total hardness in the groundwater of the study area during pre- monsoon varies from 471.66mg/l to 587.43mg/l with the mean value of 508.29mg/l and 186.2mg/l to 475.02mg/l with the mean value of 349.49mg/l during post-monsoon as shown in Figure 4.

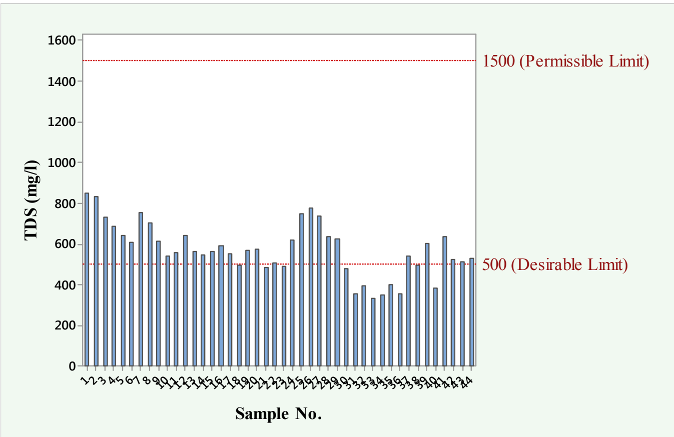

Figure 3. TDS of groundwater of the study area

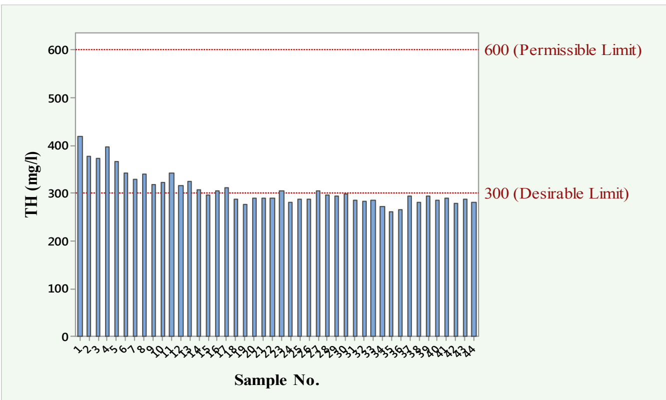

Figure 4. TH of groundwater of the study area

Calcium

Calcium is the second major constituent after bicarbonate in most surface water of the world and is generally among the top three to four ions in groundwater (Hem, 1985). Calcium in the groundwater varied from 63.23 mg/l – 109.63 mg/l with the average value of 77.90mg/l during pre-monsoon and 63.04mg/l – 109.21mg/l with the average value of 76.21mg during post-monsoon as shown in Figure 5.

Magnesium

It is an essential element of our body and its daily requirement for the adult is 200- 300 mg. Excess of magnesium in our body leads to laxative effect and its deficiency leads to many structural and functional changes, chronic mal absorption problems, chronic renal failure, severe diarrhoea and protein calorie malnutrition (Montgomery, 1985). The amount of magnesium in groundwater during pre-monsoon varied from 23.06mg/l to 40.21mg/l with the mean value of 29.92mg/l and 23.11mg/l to 35.84mg/l with the mean value of 28.49mg/l during post-monsoon as shown in Figure 6.

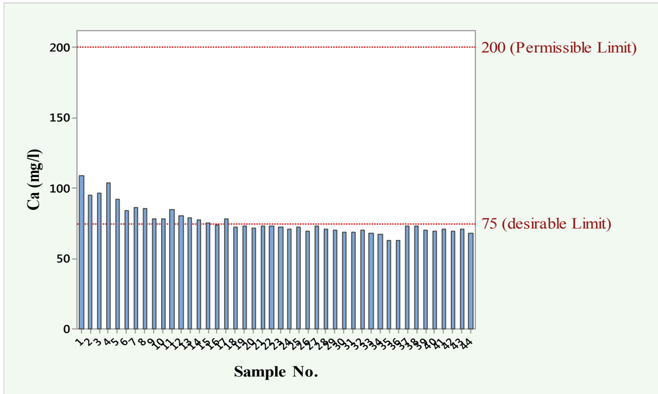

Figure 5. Ca^{2+} of groundwater of the study area

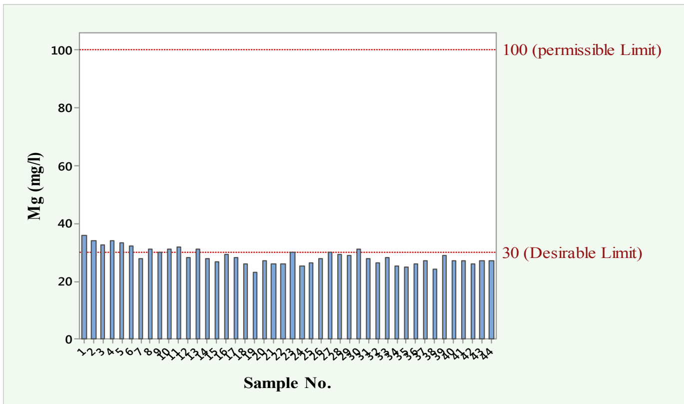

Figure 6. Mg^{2+} of groundwater of the study area

Sodium

As far as health is concerned sodium is the most abundant cation in the extra cellular fluid. The minimum sodium requirement for our body is 120mg/day (WHO, 1996). The amount of sodium in groundwater during pre-monsoon varied from 30.01mg/l to 50.31mg/l with the mean value of 40.35mg/l and 30.82mg/l to 50.31mg/l with the mean value of 40.99mg/l during post-monsoon as shown in Figure 7.

Potassium

The amount of potassium in soil is controlled by amount of clays, organic matter and moisture content (Buckmann and Brady, 1960).

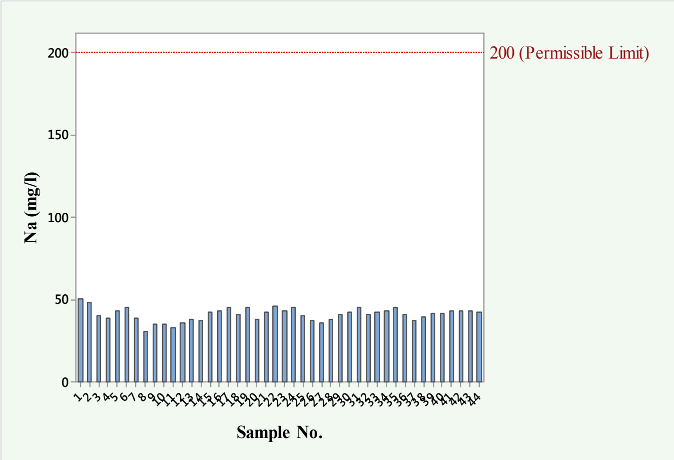

Figure 7. Na^+ of groundwater of the study area

Higher concentration of potassium is an indication of the groundwater pollution. The concentration of potassium in groundwater varied between 7.01mg/l to 31.63mg/l with mean value 12.95mg/l during pre-monsoon and 7.98mg/l to 29.8mg/l with mean value 12.58mg/l during post-monsoon as shown in Figure 8.

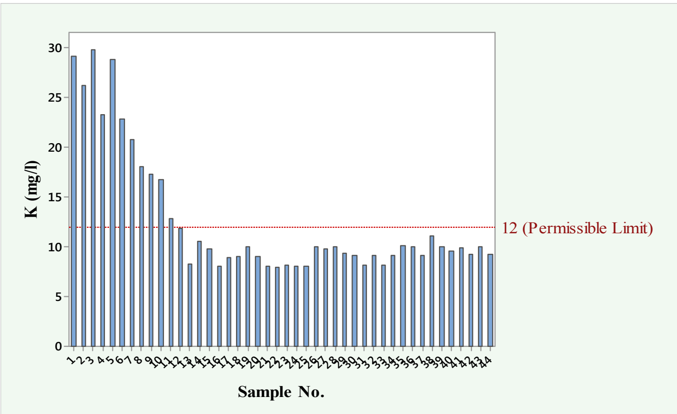

Figure 8. K^+ of groundwater of the study area

Bicarbonate

The water charged with CO_2 passes through soil and rock dissolves carbonate to give bicarbonate (Berner, 1971). The concentration of bicarbonate in groundwater during pre-monsoon varied between 102mg/l to 110mg/l with the mean value of 104.5mg/l and 102mg/l to 109mg/l with the mean value of 103.7mg/l during post-monsoon as shown in Figure 9.

Chloride

Chloride is the major inorganic anion in water and wastewater. The concentration of chloride is generally less than that of sulphates and bicarbonates (Trivedy and Goel, 1986). The concentration of chloride in groundwater varied between 6.04mg/l to 20.05mg/l with the mean value of 10.2mg/l during pre-monsoon and 5.96mg/l to 18.13mg/l with the mean value of 8.96mg/l during post-monsoon as shown in Figure 10.

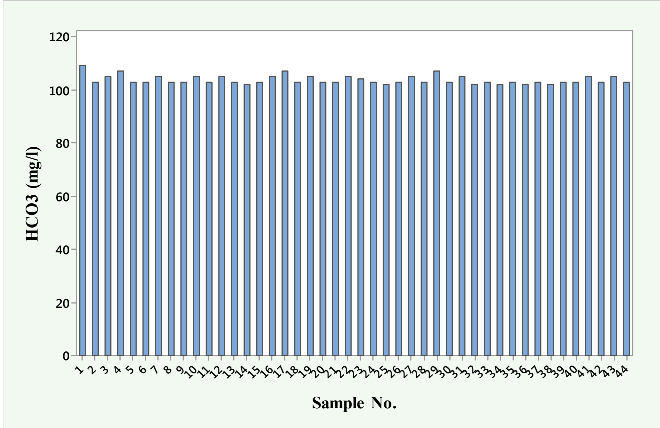

Figure 9. HCO_3^- of groundwater of the study area

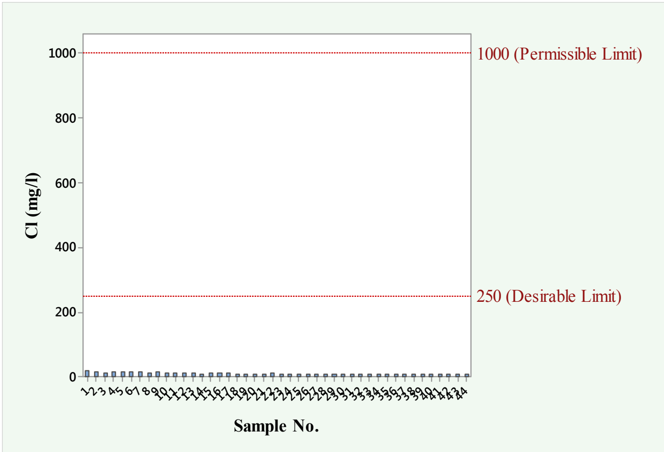

Figure 10. Cl^- of groundwater of the study area

Sulphate

Sulphate is commonly found anion in most natural waters. Higher concentrations of sulphate ions (200-300mg/l) in drinking waters may result in a therapeutic effect to human beings (Mc Neely *et al*., 1979). The concentration of sulphate in groundwater ranged between 5.02mg/l to 13.61mg/l with the mean value of 8.20mg/l during pre-monsoon and 5.02mg/l to 13.61mg/l with the mean value of 7.26mg/l during post-monsoon as shown in Figure 11.

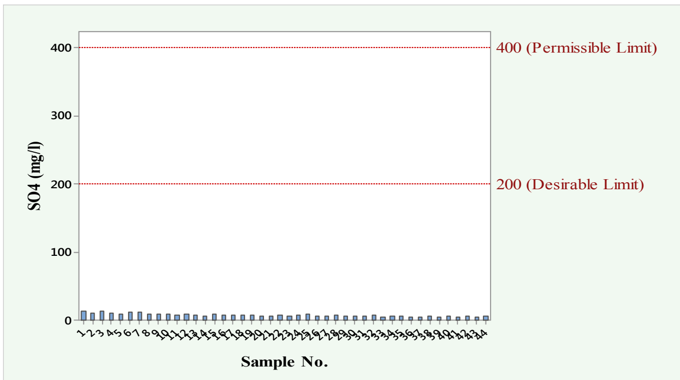

Figure 11. SO_4^{2-} in groundwater of the study area

Nitrate

Natural nitrate level in groundwater is generally very low (less than 10mg/l) but gradually increases due to human activities like agriculture, industry, domestic effluents and emissions from combustion engines (WHO, 1996). The concentration of nitrate in groundwater of the study area varied between 33.12mg/l to 92.01mg/l with the mean value of 45.8mg/l during pre-monsoon and 33.01mg/l to 91.84mg/l with the mean value of 43.92 during post-monsoon as shown in Figure 12.

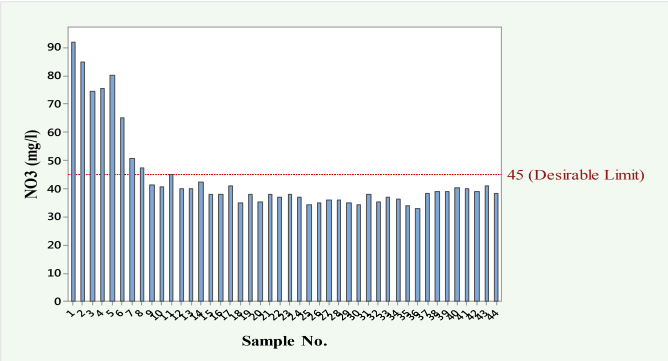

Figure 12. NO_3^- in ground water of the study area

Phosphate

Phosphorous is important to plants and animal metabolism and as an essential nutrient used by biota (Matthess, 1982). Phosphate concentration in the groundwater of study area ranged between 0.011mg/l to 0.093mg/l with the mean value 0.03mg/l during pre-monsoon and 0.011mg/l to 0.74mg/l with the mean value of 0.09mg/l during post-monsoon as shown in Figure 13.

Fluoride (F^-)

Fluoride is the most electronegative of all the halogens as it has unique chemical characteristics. Fluoride present in volcanic gases may be the important sources of fluoride in drinking water (Hem, 1985). Fluoride concentration in groundwater ranged between 0.68mg/l to 1.1mg/l with the mean value of 0.84mg/l during pre-monsoon and 0.53mg/l to 1.1mg/l with the mean value of 0.83mg/l during post-monsoon as shown in Figure 14.

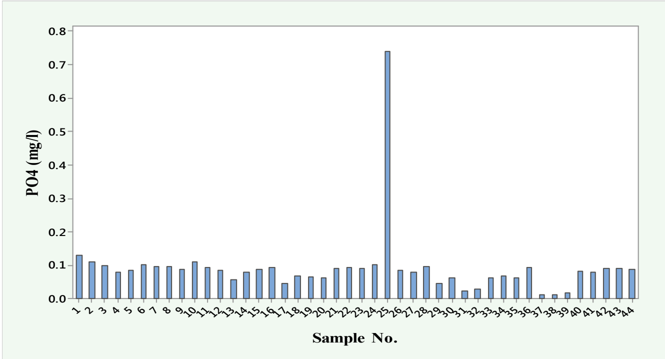

Figure 13. PO_4^{2-} in ground water of the study area

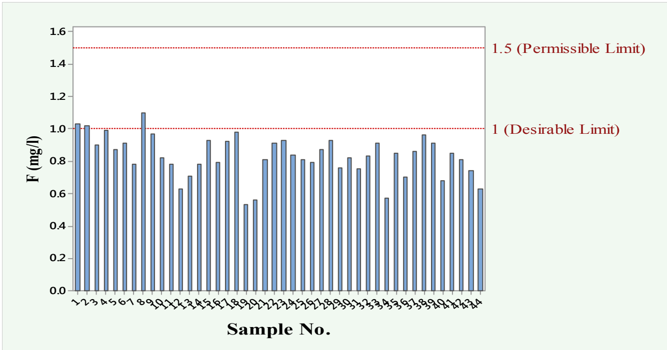

Figure 14. F^- in groundwater of the study area

RESULTS AND DISCUSSION

Table 2 show the summary statistics of groundwater sampled in the study area.

Conclusion

Increasing population in Ludhiana has caused rapid changes in water quality and increased environmental degradation. Major effect of increase in urbanization, industrialization and agricultural activities is seen on water resources which are getting depleted due to over extraction of groundwater resources and brought the study area under over exploited category where no more groundwater exploitation is possible. The status of water resources in Ludhiana district becomes a serious challenge. The policies should be formulated according to the need of the present environment. The over-exploited blocks need immediate sustainable effective management plan.

Parameters	Maximum permissible limit for drinking water	Maximum desirable limit for drinking water	No. of ground water samples analyzed	No. of samples above permissible limit	No. of samples above desirable limit/ %
EC	0-2000µS/cm	750µS/cm	44	Nil	09 / 20.45%
TDS	2000mg/l	500mg/l	44	Nil	32/ 72.72%
pH	No Relaxation	6.5 -8.5	44	Nil	Nil
Ca^{2+}	200mg/l	75mg/l	44	Nil	21 / 47.72%
Mg^{2+}	100 mg/l	30 mg/l	44	Nil	12 / 27.27%
Na^+	200mg/l		44	Nil	Nil
K^+	12 mg/l		44	Nil	Nil
Cl^-	1000mg/l	250mg/l	44	Nil	Nil
F^-	1.5 mg/l	1 mg/l	44	Nil	03 / 6.81%
SO_4^{2-}	400 mg/l	200 mg/l	44	Nil	Nil
NO_3^-	No relaxation	45mg/l	44	Nil	08 / 18.18%

General population awareness through mass-media, campaigns, public speaking should be conducted to sensitize the harmful impacts of soil and water health on agriculture.

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