

## **Study of water quality of shallow groundwater**

**Javed Ali<sup>1\*</sup>, Mayank Kumar<sup>1</sup>, Sakshi Saraf<sup>1</sup> and Tanu Jain<sup>2</sup>**

<sup>1</sup>College of Technology, G.B. Pant University of Agriculture & Technology, Pantnagar, Uttarakhand, India

<sup>2</sup>Sardar Bhagwan Singh Postgraduate Institute of Biomedical Sciences & Research, University, Dehradun, India

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### **ABSTRACT**

*Survival of living organism and socioeconomic development depend largely on the availability of water. Ground water is a main source of water for irrigation, industries, recreation, domestic and drinking purpose. With the increasing population and industries, the requirement of water is increasing day by day and as industries are growing the pollutants from these are also increasing and so the quality is decreasing day by day at an alarming rate. The present study had been conducted in the Sitarganj area of Udham Singh Nagar, Uttarakhand, India to study the physico-chemical characteristics of water from the shallow aquifer and the extent of pollution and to judge the suitability of water for irrigation, industrial and domestic use. In this study, it was found that the shallow aquifer ground water was not safe for the drinking purpose with respect to all the parameters taken together. But it was found that water samples from most of the locations were suitable for irrigation purpose.*

**Keywords:** Water quality; Aquifer; Pollution; Groundwater; Irrigation; Physicochemical characteristics.

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### **INTRODUCTION**

Water is one of the most important components of our environmental resources, for all living organism. Survival of human and socio-economic development depends largely on the availability and use of water in agriculture industry. The evolution of irrigated agriculture in large alluvial basin traces the interaction of human society with nature. To begin with, water was needed largely for irrigating crops; public health, industry and recreation claimed a very small percentage of the total water supply. The requirement of water increased with time to meet the requirement of more food and industries with increasing population. Ground water resources meet the increasing demand of water for domestic and industrial purposes. Water pollution is a phenomenon characterized by deterioration of the quality as a result of various human activities. The poor quality of drinking water in our country is more due to contamination than due to inferiority of the sources. It has been estimated that about 25% of the irrigated land of world is affected to some degree by water salinity.

There are various parameters which determine water quality for various uses. These are odour, color, taste, acidity, alkalinity, hardness, total dissolved solids etc. These parameters should have certain normal value. If these deviate from their normal values, the quality of water changes i.e., change of water quality negatively is synonymous with degradation and pollution of water.

Water pollution occurs when waste products or other substances change the chemical or biological characteristics of the water and degrade water quality so that animals, plants or human uses of the water are affected. Pollutants include plant nutrients, bacteria, viruses, pesticides, herbicides, hydrocarbons (including petrol and oil), heavy metals and other toxic chemicals. Shallow groundwater is often affected by land use. Chemicals or microorganism (bacteria and viruses) may filter through the soil to water table is shallow and soils are sandy. Groundwater in deeper (confined) aquifers beneath layers of rock or clay that do not let water through has better protection from pollution because it is not directly connected to the surface environment.

Agriculture, including commercial livestock and poultry farming, is the source of many organic and inorganic

pollutants in surface waters and groundwater. These contaminants include both sediment from the erosion of cropland and compounds of phosphorous and nitrogen that partly originate in animal wastes and commercial fertilizers. Animal wastes are high in oxygen demanding material, nitrogen and phosphorous and often harbor pathogenic organisms. Wastes from commercial feeders are contained and disposed of on land; their main threat to natural waters, therefore, is via runoff and leaching.

Contamination can enter the water bodies through one or more of the following ways.

1. Diffuse agricultural sources: wash off and soil erosion from agricultural lands carrying material applied agricultural use, mainly fertilizers, herbicides and pesticides.
2. Diffuse urban sources: run off from city streets, from horticultural, gardening and commercial activities in the environment and from industrial sites and storage areas.
3. Direct point source: transfer of pollution from municipal industrial liquid waste disposal sites and from municipal and household hazardous waste and refuse disposal sites.

The processes of bioaccumulation and bio magnifications are extremely important in the distribution of toxic substances (discharged in waste effluents) in fresh water ecosystems. The concentration of pollutants within the organism due to bioaccumulation and bio magnifications depends on the duration of exposure of the organism to the contaminated environment and its trophic level in the food chain. Several fold increases in trace contaminants have been commonly observed in lakes and estuarine environments.

The poor quality of drinking water in India is more due to contamination than due to inferiority of the sources. Agriculture, including commercial livestock and poultry Farming, is the source of many organic and inorganic pollutants in surface waters and groundwater. These contaminants include both sediment from the erosion of cropland and compounds of phosphorous and nitrogen that partly originate in animal wastes and commercial fertilizers. Animal wastes are high in oxygen demanding material, nitrogen and phosphorous and often harbor pathogenic organisms. Wastes from commercial feeders are contained and disposed of on land; their main threat to natural waters, therefore, is via runoff and leaching. Control may involve settling basins from liquids, limited biological treatment in aerobic or anaerobic lagoons and a variety of other methods.

The degradation of water quality has severe effects in context with drinking, agriculture, industrial purposes. Drinking impure water results in various harmful diseases like diarrhea, blue baby disease in case of excess of nitrite in water. In industries if water has more hardness due to chloride and sulphide, it is not suitable for cleaning purposes. In agriculture, if water has more salt concentration then it reduces permeability of soil and infiltration is reduced. More Nitrate concentration is harmful for drinking but safe for irrigation. There are several other effects which should be looked into.

## MATERIALS AND METHODS

### 2.1 Description of area

The study area i.e., the area adjoining Sitarganj, Shakti Farm, Shahdora and Pulbhatta, is spread in the inter-basin of Saryu and Gola river, it is also located between three major water reservoirs named Baighul reservoir, Dhora reservoir and Nanak Sagar reservoir in Udham Singh Nagar district of Uttarakhand.

#### 2.1.2 Topography

The topography of study area has elevation of 298 metres (978 feet) from sea level, study area has variation from *Bhabar* to *Tarai*. *Tarai* occurs south of *Bhabar* with gentle slope towards south. The maximum width of *Tarai* belt is encountered in Kashipur, Nagla, and Khatima section and is about 26 km in north and south.

### 2.2 Collection of sample

The water samples for physico-chemical analysis were collected from hand pump of twenty locations of study area. Samples were collected using plastic bottles and were kept in incubator so that no or minimum changes occur in physico-chemical characteristics of the water samples.

**Map of Study Area is as follows:** map is showing the study area and various locations from where water samples have been collected for the physico-chemical analysis.

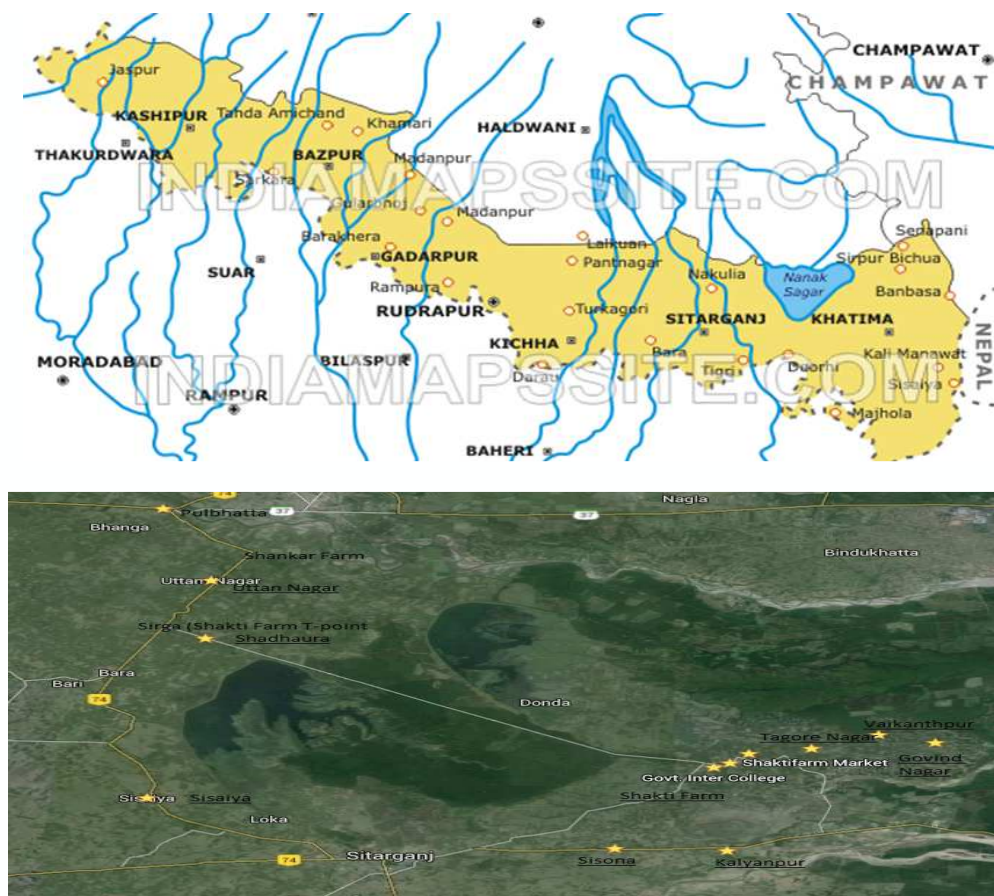


Fig 1. Location of sampled hand pumps in the study area

## 2.3 Physico-Chemical Analysis

### 2.3.1 Odour, Color, Temperature and pH

The odour was measured by inhaling; color was identified by visual interpretation. The cap of electrode of pH meter was removed and the electrode was dipped into water sample and few minutes time was allowed until reading is stabilized. The reading shown on the display of pH meter was pH of sample.

### 2.3.2 Turbidity

The Turbidity was determined with the help of Multi-parameter water Quality Instrument known as (TROLL 9500). The turbidity measurement is a default. Measurement of the equipment with the help of the electrode.

### 2.3.3 Acidity

The measurement of acidity in the water samples was carried out by the standard analytical method. The reagents used in the analytical method were Phenolphthalein indicator solution, which has prepared by dissolving 500 mg Phenolphthalein in 500ml ethyl or isopropyl-alcohol and 50 ml distilled water; Methyl Orange indicator (0.5) obtained by dissolving 0.5 mg methyl orange in 100 ml distilled water; Sodiumhydroxide (0.05N) prepared by adding 40g NaOH in distilled water and making the volume to 1000 ml. Further 50 ml of this solution were diluted to 1000 ml, to get a solution of 0.05N. for measurement of acidity of the water 10 ml of colour less sample was taken in a conical flask. Three drops of Methyl indicator were added to it. The sample was titrated with 0.05N solution of Sodium Hydroxide until the color change to faint pink at the end. At the end point three drops of phenolphthalein indicator was added to it and continued until the content turned pink. The calculations are performed by using the following equation.

$$\text{Total Acidity} = \frac{\text{Volume of NaOH} \times 50 \times 1000}{\text{Volume of the sample taken for titration}} \dots (2.1)$$

### 2.3.4 Free CO<sub>2</sub>

A volume of 100 ml of water sample was taken in a conical flask and 3-4 drops of phenolphthalein indicator was added to it. The sample was titrated with 0.05N NaOH until pink colour appeared at the endpoint. Free carbon dioxide was calculated using following equation.

$$\text{Free Carbon Dioxide} = \frac{\text{Volume} \times \text{Normality of NaOH} \times 44 \times 1000}{\text{Volume of the sample taken for titration}} \dots (2.2)$$

### 2.3.5 Conductance

The electrical conductivity was measured by pocket EC tester (conductance meter). The EC tester was set ON and cap of electrode of was removed to dip the electrode into the water sample and few minutes time was allowed to the tester to stabilize. The reading shown on the display of conductance meter was taken as conductance of the sample.

### 2.3.6 Nitrate

The nitrate-nitrogen was measured by using Multi parameter Water Quality Instrument (TROLL9500). The nitrate sensor was inserted on the marked port of the instrument. The instrument was first calibrated for low, medium and high concentration of NO<sub>3</sub> by known values of the ammonium nitrate solutions. After calibration the sensor was dipped into the water sample of unknown nitrate concentration and the reading from the display of the instrument, was noted down as nitrate content of water sample.

### 2.3.7 Calcium, Magnesium Content and Hardness

Hardness is an indication of the amount of salts of calcium and magnesium in the water. Calcium and magnesium are essential elements for the plant growth that are reported in parts of element per million parts water (ppm) on the weight basis. Calcium in the range of 40-100 ppm, and magnesium in the range of 30-50 ppm are considered desirable for irrigation water. The classification of water on the basis of hardness, as CaCO<sub>3</sub> is given in Table 3.1.

The Ca, Mg content and hardness was measured through standard analytical methods. Ethylene-Di-amine Tetra Acetic acid (EDTA solution) (0.01N) was prepared by dissolving 3.723g of disodium salt of EDTA in distilled water to prepare one liter of solution. The prepared solution was stored in polyethylene bottle. Sodium Hydroxide (1N) solution was obtained by dissolving 40g of NaOH in distilled water to make one liter of solution. Murexide oxide indicator was prepared by mixing 0.2 g of ammonium purpurate in 100g of NaCl and grinding it well. Sodium sulphide solution was prepared by dissolving 5 g of hydrated. sodiumsulphide (Na<sub>2</sub>S.9H<sub>2</sub>O) in 100 ml distilled water. Sodium sulphide solution was stored in tightly closed bottle to prevent oxidation. Buffer solution was obtained by dissolving the two solutions A and B. The solution A was made by dissolving 1.9 g NH<sub>4</sub>Cl in 143 ml of concentrated NH<sub>4</sub>OH. The solution B was obtained by dissolving 1.179 g di-sodium EDTA and 0.78 g of Magnesium Sulphatehepta hydrated in 50 ml of distilled water.

**Table 2.1 Classification of water on the basis of hardness (as CaCO<sub>3</sub>, mg/l)**

classification	Hardness (as CaCO <sub>3</sub> , mg/l)
soft	0-17.1
Slightly hard	17.1-60
Moderately hard	60-120
Hard	120-180
Very hard	180 and above

The Ca, Mg content and hardness was measured through standard analytical methods. Ethylene-Di-amine Tetra Acetic acid (EDTA solution) (0.01N) was prepared by dissolving 3.723g of disodium salt of EDTA in distilled water to prepare one liter of solution. The prepared solution was stored in polyethylene bottle. Sodium Hydroxide (1N) solution was obtained by dissolving 40g of NaOH in distilled water to make one liter of solution. Murexide oxide indicator was prepared by mixing 0.2 g of ammonium purpurate in 100g of NaCl and grinding it well. Sodium sulphide solution was prepared by dissolving 5 g of hydrated. sodiumsulphide (Na<sub>2</sub>S.9H<sub>2</sub>O) in 100 ml distilled water. Sodium sulphide solution was stored in tightly closed bottle to prevent oxidation. Buffer solution was obtained by dissolving the two solutions A and B. The solution A was made by dissolving 1.9 g NH<sub>4</sub>Cl in 143 ml of concentrated NH<sub>4</sub>OH. The solution B was obtained by dissolving 1.179 g di-sodium EDTA and 0.78 g of Magnesium Sulphatehepta hydrated in 50 ml of distilled water.

Both the solution were mixed and diluted to 250 ml with distilled water. Erichrome Black-indicator was prepared by mixing 0.01 mg of Erichrome Black-T in 100 mg NaCl and grinding it.

#### (i) Calcium content

First 10 ml of sample was taken and then diluted to 50ml by adding distilled were 0.2 ml of NaOH sol. (1N) and 0.2g Murexide indicator were added to it. Solution was titrated against EDT A sol. until pink color changed to purple. The content of Ca in sample is calculated by.

$$\text{Ca (mg/l)} = \frac{\text{Vol. of EDTA used} \times 400.8}{\text{Volume of sample taken for titration}} \dots\dots(2.3)$$

**(ii) Total hardness**

First 10 ml of sample was taken in a conical flask and diluted to 50 ml. Then 1 ml of buffer sol. and 2g of Erichrome Black-T indicator were added to it, the colour of solution was changed to wine red. The contents were then titrated against EDTA solution until the wine red color changes to blue at the end point.

The value of total hardness, calcium hardness and magnesium hardness were calculated using following equations:

$$\text{Total hardness(as CaCO}_3\text{)} = \frac{\text{Vol. of EDTA used} \times 1000}{\text{Volume of sample taken for titration}} \dots\dots(2.4)$$

**(iii) Calcium hardness**

Calcium hardness was calculated directly from the concentration of calcium in the water.

$$\text{Calcium hardness as CaCO}_3 \text{ (mg/l)} = \text{Calcium content (mg/l)} \times 2.497$$

**(iv) Magnesium hardness**

Magnesium hardness can be calculated by subtracting calcium hardness from total hardness.

$$\text{Magnesium hardness as CaCO}_3 \text{ (mg/l)} = (\text{Total hardness} - \text{Calcium hardness})$$

**(v) Magnesium content**

The magnesium content is estimated by using the following formula.

$$\text{Magnesium, mg/l} = \text{magnesium hardness} \times 0.244$$

**2.3.8 Chloride content**

Although chloride is essential to the plant in very low amounts, it can cause toxicity to sensitive crops at high conc. like sodium, high chloride concentration cause more problems when applied with sprinkler irrigation. Leaf burn under sprinkler from both sodium and chloride can be reduced by night time irrigation or application on cool, cloudy days. The effect of chloride concentration on the crops can be classified as follows (Table 2.2):

Chloride (mg/l)	Effect on crops
Below 70	Generally safe for plant
70-140	Sensitive plants shows injury
141-350	Moderately tolerant plants show injury
Above 350	Can cause severe problems

The Chloride content was measured through standard analytical methods by using 0.02 N Silver Nitrate and 5 Potassium Chromate solutions. Silver Nitrate (0.02N) was prepared by dissolving 3Ag of AgNO<sub>3</sub> in distilled water and diluting it to 1000 ml. Because of the oxidizing properties of the silver nitrate the solution was kept in dark (Amber) bottle. Potassium Chromate solution (5) was obtained by dissolving 5g of Potassium Chromate in 100 ml of distilled water.

50 ml of water from sample was taken into a flask and 2 ml of Potassium chromate solution was added to it. Then this solution was titrated against 0.02N Silver Nitrate solution until persistent red tinged appeared. The value was calculated using following equation.

$$\text{Chloride( mg/l)} = \frac{(\text{Volume and Normality}) \text{ of AgNO}_3 \times 35.5 \times 1000}{\text{Volume of sample taken for titration}} \dots\dots(2.5)$$

**2.3.9 Measurement of alkalinity**

The alkalinity was estimated through standard method. Hydrochloric acid solution (0.01N) was prepared by diluting 12N concentrated HCl (specific gravity 1.18) to 12 times to prepare 1N HCl and diluted again to 10 times to make 0.1N HCl and standardized it against sodium carbonate solution. Methyl orange indicator soln., 0.05 was prepared by dissolving 0.5g of methyl orange in 100 ml of distilled water.

Phenolphthalein indicator solution can be prepared by dissolving 0.5g of phenolphthalein in 50 ml of 95 Ethanol and 50ml of distilled water was added to it. Add 0.05N carbon dioxide free NaOH drop wise until the solution turned faint pink. Sodium carbonate solution; 0.1N was obtained by dissolving 5.3g of sodium in distilled water to

prepare 100 ml of sol.

100 ml of sol. was taken and 2 drops of phenolphthalein indicator was added to it. If color changed to pink, titration was done 0.1N HCl until the color disappeared at the end point, then 3 drops of methyl orange indicator were added to and titration was continued until the yellow color changed to pink at end point. For samples which did not changed color after addition of phenolphthalein, 3 drops of methyl orange indicator were added and titrated with 0.1N HCl until the yellow color changed to pink at the end point. The value was calculated using the following equations:

$$\text{Total alkalinity (as CaCO}_3\text{) (mg/l)} = \frac{(A \times \text{Normality}) \text{ of HCl} \times 50 \times 1000}{\text{Volume of sample taken for titration}} \dots(2.6)$$

where A= ml of total HCl used with phenolphthalein and methyl orange indicators.

### 2.3.10 Measurement of Ammonia

The ammonia was measured by using Multi-Parameter water quality Instrument (TROLL 9500). The NH<sub>4</sub> sensor was inserted at the marked port of instrument. After calibration for low, medium and high concentration of NH<sub>4</sub>, the sensor was dipped into water sample of unknown ammonium concentration and the reading from the display of the instrument, was noted down as concentration of Ammonia in the sample.

### 2.3.11 Sodium

The amount of sodium is less than 200mg/l. sodium is not considered a toxic metal, and normal adults may consume 5,000 to 10,000 milligram per day without any adverse effects. The average intake of sodium from water is only a small fraction of that consumed in normal diet. The recommended maximum level of people suffering from certain medical conditions such as hypertension, congestive heart failure or heart disease is 20mg/l. If in doubt, consult a physician. Sodium is a significant factor in assessing water for irrigation and plant watering. High levels affect soil structures and a plant's ability to take water.

The sodium content in water sample are estimated by using Flame Photometer in water quality testing lab of the department.

### 2.3.12 Potassium

There is no guideline or recommended limit for potassium in water. Water softeners that regenerate using potassium chloride can significantly raise the level of potassium in water. It is recommended that people with kidney diseases or other conditions such as heart diseases, coronary artery disease, hypertension, diabetes and those who take medication that interferes with how the body handles potassium do not drink water from a water softener that use potassium chloride.

The potassium content in water samples are estimated by using Flame photometer in the water quality testing lab of the department.

## 2.4 Irrigation water quality

The parameters which determine the irrigation water quality are divided into three categories: physical, chemical and biological. The chemical characteristics of irrigation water refer to the content of salt in the water as parameters derived from the composition of salts in the water, parameters such as EC/TDS (Electrical Conductivity/ Total Dissolved Solids), SAR (Sodium Adsorption Ratio) alkalinity and hardness. The main problem related to irrigation water quality is the water salinity. Water salinity, refers to the total amount of salts dissolved in the water but it does not indicate which salts are present in it.

High level of salts in the irrigation water reduces water availability to the crop (because of osmotic pressure) and cause yield reduction. Above a certain threshold, reduction in crop yield is proportional to the increase in salinity level. Different crops vary in their tolerance to salinity and therefore have different thresholds and yield reduction rates.

The most common parameters used for determining the irrigation water quality, in relation with its salinity, are EC and TDS. The suitability of an irrigation water depends upon several factors, such as, water quality, soil type, plant characteristics, irrigation method, drainage, climate and the local conditions. The integral effect of these factors on the suitability of irrigation water (SI) can be expressed by relationship given below:

$$\text{Suitability of irrigation water, SI} = \int QSPCD$$

Where

Q = quality of irrigation water, that is total salt concentration, relative proportion of cations, etc;

S = soil type, texture, structure, permeability, fertility, calcium carbonate content, type of clay minerals and initial level of salinity and alkalinity before irrigation;

P = salt tolerance characteristics of the crop to be grown, its variety and growth stage;

C = climate, that is total rainfall, its distribution and evaporation characteristics; and

D = drainage conditions, depth of water table, nature of soil profile, presence of hard pan or lime Concentration and management practices.

Irrigation, water can be classified in five classes depending upon its chemical properties, as given below in Table 2.3

**Table 2.3 Guideline for evaluation of irrigation water quality**

Water class	Sodium (Na), %	Electrical conductivity ( $\mu\text{S}/\text{cm}$ )	SAR	RSC, meq/l
Excellent	<20	<250	<10	<1.25
Good	20-40	250-750	10-18	1.25-2.0
Medium	40-60	750-2250	18-26	2.0-2.5
Bad	60-80	2250-4000	>26	2.5-3.0
Very bad	>80	>4000	>26	>3

SOURCE: (BIS 11624:1986)

## RESULTS AND DISCUSSION

The study was conducted for the regions of Shahdaura, Shemalpur, Shakti Farm, Shaktigara, Vaikutpur, Govindnagar, Kalyanpur, Sisona, Sisaiya, Sirga, Uttam Nagar, Shankar Farm and Pulbhatta. The samples collected from identified locations were tested for 18 parameters using standard methods, in Water Quality and Pollution Control Laboratory, Department of Irrigation and Drainage Engineering. The values of different parameters obtained from lab analysis of the samples are shown in Table 3.1. The desirable and permissible limits of water quality parameters in details for various uses as suggested by BIS has been reproduced in appendices the result analysis of the present study are discussed parameter wise as given below .

### 3.1 Color, Odour, pH

The samples are mostly odourless and colorless except samples collected from the hand pumps located at Viakanthpur no.1 and Uttam Nagar near Gurudwara Buddha Sahib. The colour of water from these locations was having the light yellow color. The light yellow color may be due to the higher concentrations of total dissolved solids and iron, in water samples.

The pH of the water sample was found in the ranges 6.3 at Uttam Nagar to 7.5 at Shakti Farm, Tagore Nagar. According to WHO (1992) Standards, best and ideal pH value for human consumption is 7.0, but it may vary from 6.8 to 8.5. Hence the water from other places except Vaikanthpur no.1 (6.5), Uttam Nagar (6.3), Sisaiya (6.6), Sisona (6.5), Shankar Farm Gautiya (6.4), Shakti Farm (GGIC) (6.5) and Govind Nagar (6.7) were not safe for human consumption from the point of view of pH.

The normal range for the irrigation use is from 6.5 to 8.4, so samples from Uttam Nagar (6.3) may not be suitable for irrigation purpose.

### 3.2 Total Dissolved Solids (TDS)

The TDS of water samples was found in the range of 220 to 1020 mg/l. The highest TDS value was 1020 mg/l was observed in the samples collected from Uttam Nagar and lowest in Vaikanthpur (Panch Quarter) 220 mg/l. For the drinking purpose the TDS must be in between 500 to 2000 mg/l which shows water sample collected from Shakti Farm (Tagore Nagar), ShankarFarm, Sahdaura, Sisona, Shakti Farm (GGIC), Kalyanpur, Shakti Farm (Bema Sewa Kendra) Sisona, Shaktigarh, Sirga, Pulbhatta, Vaikanthpur (Panch Quarter), Shakti Farm (Main Market), Shamalpur are suitable for the drinking purposes.

### 3.3 Chloride

The concentration of chloride varied between 4.26mg/l to 217.26 mg/l. The minimum value of 4.26mg/l was observed in Shakti Farm (Bema Sewa Kendra) and maximum concentration of 217.26 mg/l was observed in Uttam Nagar. As per BIS standards the permissible value of chloride for domestic purpose is 200 to 600 mg/l. The results indicate that water from all locations is safe for drinking. The concentration of chloride is found less than 200 mg/l at all locations except UttamNagar.

### 3.4 Alkalinity

The alkalinity of the samples varied from 190 to 730 mg/l. as per BIS the value of alkalinity be in the range of 200mg/l to 550mg/l. The alkalinity of water from Uttam Nagar (730 mg/l), Shankar Farm Gutiya (585 mg/l) may lead to the corrosion and is not safe for the drinking purposes due to higher concentration of bi-carbonates. This is due to dissolution of Carbon dioxide and alkalinity imparts bitter taste.

### 3.5 Acidity

The acidity of sample varied between 17.5 mg/l at Vaikanthpur (Panch Quarter) to 145 mg/l at Uttam Nagar. The reason of higher acidity is the higher concentration of chloride in water.

### 3.6 Free Carbon dioxide

The Carbon dioxide level varied from 13.2 mg/l at Vaikanthpur (Panch Quarter) to 127.6mg/l at Uttam Nagar. Uttam Nagar reading is showing that the maximum dissolution of carbon dioxide in it. The higher value of free carbon dioxide in water makes it bitter in taste.

### 3.7 Total Hardness

In ground water hardness is mainly due to carbonates, bicarbonates, chlorides, sulphates of calcium and magnesium. Data revealed that value of hardness are ranged between 48 mg/l Shakti Farm (Main Market) to 154 mg/l in Uttam Nagar. The permissible limit of total hardness is 100-500 mg/l. The water is safe for domestic use in all the locations.

### 3.8 Calcium Hardness

The calcium hardness of the sample varied from 20.01 mg/l at Vaikanthpur (Panch Quarter) to 66.04mg/l at Shankar Farm Gutiya, which is well in permissible range of 75mg/l to 200mg/l.

### 3.9 Magnesium Hardness

The Mg hardness varied from 31.17 mg/l to 133.96 mg/l in Shakti Farm (Main Market) and Uttam Nagar, respectively.

### 3.10 Calcium Content

The maximum Calcium content in the water sample collected was 26.45 mg/l at Shankar Farm Gutiya minimum 8.02 mg/l at Vaikanthpur (Panch Quarter). It could be because of calcium salts. Water with high calcium content is undesirable to use.

### 3.11 Magnesium Content

The maximum magnesium content was found in 32.68 mg/l at Uttam Nagar and minimum of 7.60 mg/l at Shakti Farm (Main Market). The high magnesium content could be because of the accumulation of magnesium salts and because of this it could have diuretic, cathartic, laxative effects if it is present in high concentrations.

### 3.12 Sodium content

The highest Sodium content found 22mg/l at Sirga, Shakti Farm and minimum of 8mg/l at Vaikanthpur and Shankar Farm.

### 3.13 Potassium Content

The highest potassium content was found at Shadoura 24mg/l and minimum of 14mg/l at Vaikanthpur and Shankar Farm.

### 3.14 Conductance

The conductance of the water samples varied from 330  $\mu$ s/cm at Vaikanthpur (Panch Quarter) to 1520  $\mu$ s/cm at Uttam Nagar. The value at Uttam Nagar indicates the concentration of total dissolved solids, which is confirmed from the TDS value (1020mg/l) at the location. The water from five locations has EC value more than 750 $\mu$ s/cm but less than 2500  $\mu$ s/cm, indicating water in medium category from the point of irrigation. The water from shallow aquifer of these locations should be used for irrigation with precaution and ample drainage facilities.

### 3.15 Ammonium

The ammonia of sample varied from minimum of 0.01 mg/l Shadoura, Sisona, Shamalpura, Vaikanthpur and Govind Nagar to maximum of 58.15 mg/l Shankar Farm Gautiya.



TABLE 3.1 Physico-chemical characteristics of the water samples

Properties	Location of Sampled Hand Pumps									
	Shadoura (Mujitee Sweet Shop)	Shadoura (M.K depot)	Shamalpara (Bengali Colony)	Shakti Farm (BeemaSewa Kendra)	Shakti Farm (GGIC)	Shaktigara (Shastri Ward 2)	Shakti Farm (Main Market)	Shakti Farm (Tagore Nagar)	Vaikantapur (Number 1)	Vaikantapur (Panch Quarter)
Odour	Odourless	Odourless	Odourless	Odourless	Odourless	Odourless	Odourless	Odourless	Objectionable	Odourless
Colour	Colourless	Colourless	Colourless	Colourless	Colourless	Colourless	Colourless	Colourless	Light yellow	Colourless
pH	7.3	6.9	6.9	6.8	6.6	6.8	6.8	7.5	6.5	6.8
Turbidity(NTU)	10	3.6	1.8	0.7	0.5	1.2	0.4	0.2	5	0.1
TDS (mg/l)	440	310	400	270	280	270	270	310	570	220
Conductance, EC (µS/cm)	650	460	600	400	410	400	400	470	850	330
Chloride (mg/l)	32.66	8.52	9.96	4.26	7.1	14.2	4.26	18.46	66.74	5.68
Acidity(mg/l)	55	20	32.5	20	27.5	25	25	30	75	17.5
Free CO <sub>2</sub> (mg/l)	35.2	19.8	26.4	19.8	24.2	22	15.4	46.2	72.6	13.2
Alkalinity (mg/l)	485	285	340	225	210	230	235	345	500	190
Ca content (mg/l)	19.23	16.03	13.62	14.42	12.82	14.42	16.83	17.64	18.43	8.02
Mg content (mg/l)	15.31	8.77	13.26	14.05	11.99	11.60	7.60	9.84	13.07	10.73
Ca hardness (mg/l)	48.02	40.03	34.01	36.01	32.01	36.01	42.02	44.03	46.02	20.02
Mg hardness (mg/l)	62.77	35.97	13.26	57.58	49.16	47.58	31.17	40.37	53.57	43.98
Total hardness (mg/l)	82	52	68	72	62	62	48	58	72	52
Sodium (mg/l)	10	14	12	15	16	14	13	14	19	8
Potassium (mg/l)	24	21	22	19	20	18	19	24	21	14
Iron (mg/l)	1.15	0.6	0.35	0.75	0.065	0.8	0.04	5.5	9.15	0.05
Ammonium (mg/l)	0.01	0.06	2.65	5.68	6.3	5.96	0.6	0.04	0.02	0.01
Nitrate (mg/l)	0.77	1.1	1.2	0.77	0.77	0.87	0.5	0.8	1.05	1.26

TABLE 3.1 Physico-chemical characteristics of the water samples (contd..)

Properties	Location of Sampled Hand Pumps									
	Govind Nagar (PandavGaon)	Kalyanpur	Sisona (KumaonFurnitures)	Sisona (Bartutabag)	Sisaiya (Taneja Store)	Sirga (Shakti Farm T-Point)	Uttam Nagar (Gurudwara Buddha Sahib)	Shankar Farm	Shankar Farm Gutiya	Pulbhatta
Odour	Odourless	Odourless	Odourless	Odourless	Odourless	Odourless	Objectionable	Odourless	Odourless	Odourless
Colour	Colourless	Colourless	Colourless	Colourless	Colourless	Colourless	Light yellow	Colourless	Colourless	Colourless
pH	6.7	6.5	6.5	7.1	6.6	6.9	6.3	7.2	6.4	7.2
Turbidity (NTU)	3.5	0.7	1	0.8	4.4	1.2	0.2	1.2	0.4	0.6
TDS (mg/l)	420	440	360	560	890	420	1020	490	690	440
Conductance, EC (µS/cm)	620	650	530	830	1320	620	1520	730	1030	660
Chloride (mg/l)	4.26	26.98	14.1	42.6	71	18.46	217.26	45.44	78.1	7.1
Acidity(mg/l)	55	47.5	65	70	67.5	57.5	145	55	72.5	30
Free CO <sub>2</sub> (mg/l)	55	55	44	55	70.4	41.8	127.3	55	88	30.8
Alkalinity (mg/l)	390	395	320	345	480	420	730	485	585	385
Ca content (mg/l)	20.84	24.84	20.04	24.84	16.03	16.83	20.04	21.64	26.45	25.65
Mg content (mg/l)	8.58	19.32	12.68	13.46	20.48	17.36	32.69	17.65	27.78	12.29
Ca hardness (mg/l)	52.04	62.03	50.04	62.03	40.03	42.02	50.04	54.04	66.05	64.05
Mg hardness (mg/l)	35.16	79.16	51.96	55.16	83.97	71.17	133.9	72.36	101.5	50.35
Total hardness (mg/l)	56	104	72	80	100	88	154	94	128	76
Sodium (mg/l)	11	18	16	22	18	14	21	8	16	12
Potassium (mg/l)	17	22	21	20	21	22	23	14	21	18
Iron (mg/l)	0.7	1.1	2.6	1.55	0.95	0.7	1.6	1.3	0.7	0.25
Ammonium (mg/l)	0.01	0.6	0.78	58.14	3.3	0.04	27.1	10.65	0.4	0.07
Nitrate (mg/l)	1.3	0.8	0.9	0.85	0.5	1	1.87	0.82	1.2	0.99

3.16 Nitrate

The nitrate of the water sampled varied from 0.5mg/l sisaiya to 1.87mg/l Uttam Nagar. The less value of nitrate shows that there is very less leaching of fertilizer in the aquifer.

CONCLUSION

All the samples were collected and analysis in the Water Quality Laboratory of the Department of Irrigation and Drainage Engineering .The samples were analyzed using standard methods. Based on the results of analysis, the following are the conclusions:

- I. The ground water samples taken from the shallow aquifers through hand pumps were found odourless and colourless, except at Viakanthpur no.1 and Uttamnagar near Gurudwara Buddha Sahib, were found to have light yellow colour.
- II. The study revealed that the shallow aquifer ground water was not safe for the drinking purpose with respect to all the parameters taken together. It shouldn't be used for drinking without treatment of particular parameter as the concentration of various constituents was found beyond the safe limits given by BIS.
- III. The water samples from most of the locations were found suitable for irrigation purpose as the samples have the concentrations of Total Dissolved Solids, the criteria for measuring EC within the limits prescribed by BIS.

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