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A Project Report on

# "INVESTIGATION OF TRACE METALS BY ICP-MS, ASSESSMENT OF HYDROCHEMISTRY & GROUND WATER QUALITY IN MOTH BLOCK AT JHANSI, UTTAR PRADESH"

*Carried out at*

**NATIONAL INSTITUTE OF HYDROLOGY (NIH), ROORKEE, HARIDWAR, U.K.**

Submitted in partial fulfillment of the requirements for the award of the degree of

***Master of Science (Technology) in Environmental Science & Technology***

**Institute of Environment and Sustainable Development**
**Banaras Hindu University, Varanasi, U.P.-221005**

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**Session: 2013-2016**

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## CANDIDATE'S DECLARATION

I, **Krishna Mohan**, hereby declare that the research project report entitled **"Investigation of trace metals by ICP-MS, Assessment of Hydrochemistry & Ground Water Quality in Moth Block at Jhansi, Uttar Pradesh"** submitted to **Institute of Environment & Sustainable Development, Banaras Hindu University (IESD-BHU), Varanasi** in partial fulfillment of the requirements of the Degree of Master of Science (Tech.) in Environmental Science and Technology, is an independent work carried out by the undersigned during a period of six months, under the guidance and supervision of **Dr. Rajesh Singh, Scientist-C** and **Dr. S.P. Rai, Scientist-E, National Institute of Hydrology** and to the best of knowledge and belief this report has not forms on the basis of award of any Degree/Diploma/Associate/Fellowship or other similar title to any candidate of any university.

Krishna Mohan

DATE: 9-3-2016

(KRISHNA MOHAN)

## ACKNOWLEDGEMENT

The research project work is a golden opportunity for learning and self-development. I consider myself very lucky and honoured to work at National Institute of Hydrology, Roorkee on research project work titled **"Investigation of trace metals by ICP-MS, Assessment of Hydrochemistry & Ground Water Quality in Moth Block at Jhansi"** by considering a study site at Jhansi. I thankfully acknowledge all the arrangement and permissions extended by the NIH to my endeavour.

It is my glowing feeling to place on record our best regards, deepest sense of gratitude to **Dr. A.S Raghubanshi,** Director, IESD-BHU; **Dr. G.S. Singh**, Course Coordinator and **Dr. Kavita Shah,** Dean & Head, Department of Environment and Sustainable Development, IESD who encouragement me for the research project work.

Firstly I would like to express my indebted gratitude and special thanks to our Guide **Dr. Rajesh Singh,** Scientist-C, EH Division and Co-Guide **Dr. S.P. Rai,** Scientist-E, HI Division, National Institute of Hydrology, Roorkee, Uttrakhand, who in spite of being extraordinarily busy with his duties, showed their keen interest, valuable guidance, constant encouragement, enthusiastic involvement, constructive criticism and appreciation throughout the training. I also acknowledge **Er. R.D. Singh**, Scientist-G & Director, NIH for giving me chance to work upon this project. Further we express our heartfelt gratitude and most sincere thanks to **Dr. V. C. Goyal**, Head, Research Coordination and Management Unit, NIH. I am also indebted to **Dr. P.K. Singh, Er. Sumant Kumar, Mr. Rakesh Goyal, Mr. Shyam Lal Prajapti** and **all team member of NIH** who helped me throughout the training period.

Finally, I thank almighty, to my beloved **parents**, for providing me moral and financial support. Last but not the least I would like to extend heartfelt gratitude to my **friends** for their co-operation and lending me a helping hand at the times of adversities.

9-3-2016 Krishna Mohan

**DATE:** **(KRISHNA MOHAN)**

# CONTENT

# ABSTRACT

In recent years, the increasing threat to ground water quality due to human activities has become a matter of great concern.The population of Jhansi is increasing day by day leading to increase in the abstraction and contamination of groundwater, and have increased concern about the fate of groundwater quality. The report presents an assessment of hydrochemistry and groundwater quality index of Moth block of district Jhansi. Twenty groundwater samples from different places of study area (Moth block) were collected and analyzed for pH, Electrical Conductivity (EC), Total Dissolved Solids (TDS), Sodium($Na^+$), Potassium($K^+$), Total Hardness (TH), Calcium($Ca^{2+}$), Magnesium($Mg^{2+}$), Bicarbonate($HCO_3^-$), Sulphate ($SO_4^{2-}$), Nitrate ($NO_3^-$), Fluoride ($F^-$) and Chloride ($Cl^-$). The samples were analysed following standard method.

The variations in pH (7.16-7.87), EC (460-2106 µS/cm), TDS (261.82-1360 mg/L), $Na^+$(25.65-209.37 mg/L), $K^+$ (0.43-12.31 mg/L), TH (75.57-792.77 mg/L), $Ca^{2+}$ (10.90-256.89 mg/L), $Mg^{2+}$(8.34-75.89 mg/L),$HCO_3^-$(253.25-612.75 mg/L), $SO_4^{2-}$ (0.61-247.12 mg/L), $NO_3^-$(2.64-127.61 mg/L),$F^-$ (0.36-6.11 mg/L) and $Cl^-$ (3.52-4.23.25 mg/L)was observed.

Chemical analyses of water samples showed that calcium and bicarbonate arethe dominant cation and anion, respectively. The water type is Ca-Mg-$HCO_3$ based on hydro-chemical faces using Piper's diagram. The results were compared with the drinking water standard (BIS 10500:2012) to assess the suitability for drinking purpose. The suitability for irrigation purpose was assessed with the help of water quality indicators viz., sodium adsorption ratio (SAR) and percent sodium (%Na). The results revealed that the groundwater in the study area is suitable for drinking and irrigation purposes.

The bacteriological parameters for the collected samples were analysed for Total Coliform (0-1100 per 100 ml MPN) and FecalColiform (0-460 per 100 ml MPN). According to BIS (2012), TC and FC in ground water shall not be detectable in any sample for drinking purpose.

Toxicity of a metal depends on its concentration, which adversely affects any biological activity. Almost all the metals are toxic at higher concentration; few of

them are toxic in even in trace e.g. As, Pb, Hg , Cd, etc. The presence of such metals in ground water is a subject of serious concern. Groundwater which contains higher amount of metals and large or trace quantity of toxic metals, affects health to a great extent when it is used for drinking and domestic purposes. The impact of trace metals in drinking water is generally cumulative, by which the prolonged use of such water is dangerous for health. Hence the measurement of trace element concentration and analysis of their periodicity of fluctuation and trend is necessary. The study revealed that the concentration of Al, Cr, Fe, Mn, Ni and Pb crossed the minimum permissible limits of BIS in the most of sites. The concentration of As, Cd, Co, Cu and Zn in the groundwater of the study area were within the limits prescribed by BIS (2012). The maximum concentration of Al, Cr, Fe, Mn, Ni and Pb were recorded as 4.927, 0.0545, 16.822, 0.354, 0.030, and 0.011 respectively.

The WQI was applied to assess the suitability for drinking purpose and it was found that 45%, 35%, 20% collected samples were under poor, marginal, fair designation respectively.On applying HWQI to the collected samples, 45%, 35%, 15%, 5% samples belong to marginal, poor, fair, good designation respectively and 60%,20%, 10%, 10% belong to marginal, poor, fair, good designation respectively in the terms of AWQI. The residents of these areas should be provided with some alternate source of water for drinking or the available groundwater should be utilized after treatment.

# CHAPTER 1: INTRODUCTION

## 1.1 Background

India is blessed with a rich and vast diversity of natural resources, water being one of them. Water is nature's most wonderful, abundant and useful compound. There are many essential elements for the existence of living beings; water is rated to be of greatest importance. Without food, humans can survive for a number of days, but without water one cannot survive for more than a day. Water is not only essential for the lives of animals and plants, but also occupies a unique position in industries.. Groundwater occurs almost everywhere beneath the earth surface not in a single widespread aquifer but in thousands of local aquifer systems and compartments that have similar characters. Knowledge of the occurrence, replenishment, and recovery of groundwater has special significance in arid and semi-arid regions due to discrepancy in monsoonal rainfall, insufficient surface waters and over drafting of groundwater resources. The socio-economic dependency on groundwater is explained over a range of factors by Burke and Moench (2000). Groundwater systems have become the "lender of last resort" and depletion of renewable groundwater stocks is taken as the first indicator of water scarcity (Shah and Indu 2004). Moreover, groundwater is considered to be less vulnerable than surface sources and can therefore help to stabilize agricultural populations and reduce the need for farmers to migrate when drought threatens agricultural livelihoods (Moench 2002). In other words, groundwater resources provide a reliable drought buffer in large regions of the world (Calow et al 1997). The ability to access groundwater plays a major role in reducing risk and increasing incomes (Moench 2003), especially when other modes of irrigation are absent.

India is now the biggest user of groundwater for agriculture in the world. Groundwater irrigation has been expanding at a very rapid pace in India since the 1970s. The data from the Minor Irrigation Census conducted in 2001 shows evidence of the growing numbers of groundwater irrigation structures (wells and tube wells) in the country. Their number stood at around 18.5 million in 2001, of which tube wells accounted for 50%. It is believed that the number of groundwater irrigation structures is now around 27 million with every fourth rural household owning at least one such irrigation structure (Shah 2009). Though groundwater overuse was recognized as a serious problem for quite some time (Dhawan 1995; Moench 1992; Macdonald et al

1995), conventional approaches to groundwater in India until the mid-1990s have involved a clear focus on the "development" of groundwater resources. The mid-1990s saw a slow and reluctant change in thinking, from a development to a management mode. But by then, the proportion of "unsafe" districts in India has grown from 9% in 1995 to 31% in 2004. The area under "unsafe" districts has risen from 5% to 33% and population affected from 7% to 35% within this short span of nine years.

The ground water quality is still important to the community; therefore, it is important to ensure its quality is high at all time so that the consumer health is not compromised. Groundwater resources are affected in principle by three major activities. First of these activities is excessive use of fertilizers and pesticides in agricultural areas. The second one is untreated/partially treated wastewater to the environment. Finally, excessive pumping and improper management of aquifers result. The activity of solid waste disposal in open un-engineered landfill is the one of the factor that cause the ground water pollution due to lack of pollution control interventions such as water proof layer, leachate treatment pond, monitoring wells etc. (MohamadRoshan M. et al, 2007). Groundwater pollution also occurs due to clandestine disposal of toxic wastes, especially from industrial sites, or undetected leakage from pipes, waste storage containers, or underground tanks. According to WHO, about 80% of all the diseases in human beings are caused by water. Once the groundwater is contaminated, its restoration to actual condition requires prolonged time and decontamination is not possible by just stopping the ingress of pollutants from the source. Contamination of groundwater by domestic, industrial effluents and agricultural activity is a serious problem faced by developing countries. The industrial waste water, sewage sludge and solid waste materials are currently being discharged into the environment indiscriminately. These materials enter subsurface aquifers resulting in the pollution of irrigation and drinking water (Girija.T.R. et al., 2007). High rates of mortality and morbidity due to water borne diseases are well known in India. Access to safe drinking water remains an urgent necessity, as 30% of urban and 90% of rural households still depend completely on untreated surface or groundwater (Palanisamy.P.N, Geetha.A et al., 2005).

The quality of water is defined in terms of its physical, chemical and biological parameters. Its development and management plays a vital role in agriculture production, poverty reduction, environmental sustenance and sustainable economic development. In some areas of the world, people face serious drinking water shortage because of the ground water contamination. Assessing risk involves identifying the hazard associated with a particular occurrence, action, or circumstance and determining the probability of that hazard occurring. Hence, evaluation of groundwater quantity and quality is important for the development of further civilization and to establish database for planning future water resources development strategies. The quality of water may depend on geology of particular area, depth of water table, seasonal changes, extent and composition of the dissolved salts depending upon the source of the salt and soil, subsurface environment.

Monitoring of ground water regime is an effort to obtain information on ground water quality through representative sampling. In India, most of the population is dependent on groundwater as the only source of drinking water supply. The groundwater is believed to be comparatively much cleaner and free from pollution than surface water. But prolonged discharge of industrial effluents, domestic sewage and solid waste dumping had resulted in the pollution of groundwater and health problems. Natural phenomenon such as volcano eruption, algae blooms, storms, and earthquakes also cause major changes in water quality and the ecological status of water. As per the latest estimate of Central Pollution Control Board, about 29,000 million litre/day of wastewater generated from class-I cities and class-II towns out of which about 45% is generated from 35 metro-cities alone.( MangukiyaRupal et.al, 2012).

Groundwater in India is at risk of contamination due to rapid and unplanned urbanization, industrialization and indiscriminate disposal of domestic, industrial, agricultural and mining wastes. Public ignorance of environment and related considerations, lack of provisional basic social services, indiscriminate disposal of increasing anthropogenic wastes, unplanned application of agrochemicals, and discharges of improperly treated sewage/industrial effluents; result in excess accumulation of pollutants on the land surface and contamination of water resources. Subsurface leaching of contaminants from landfills as well as seepage from canals, rivers and drains cause severe degradation of the groundwater quality in urban areas. Adsorption/dispersion processes in the soil zone, degrees of evaporation/ recharge and lateral inter-mixing of groundwater determine the level of contaminations in groundwater. In recent years, scarcity of clean and potable drinking water has emerged as the most serious developmental issue in the major cities of India.

In Uttar Pradesh, due to the rising population and thereby increasing demand of water for various purposes its scarcity is becoming evident and getting prominent day by day. In addition to these there are regional imbalances on account of spatial and temporal distributions. Conspicuous to frequent climatic and hydrological droughts, the Bundelkhand region in Uttar Pradesh (and also in Madhya Pradesh) experiences severe agricultural droughts. With majority of population living below poverty line and their livelihood dependant on agriculture and livestock rearing, severe scarcity of food grains and fodder has hit hard on their lives. Administratively, Uttar Pradesh portion of Bundelkhand region (herein after called as UP Bundelkhand) comprises of 48 blocks under the jurisdiction of 7 districts. The geographical area of the UP-Bundelkhand is 2.94 Mha which is about 12.21% of that of the State. Natural and other resources are distinct and abundant in case of western, central and eastern regions; southern region, i.e., U.P. Bundelkhand has only 4.96% of the State's Population, low population density of 280. This region is prone to frequent floods and droughts; only recently, a severe continuous four year cycle drought (2004-08) has been witnessed in the region.

Bundelkhand region in central plains in India is situated between longitude $78^0$ 20'N and $81^0$ 40'N and latitude $23^0$ 20'E and $26^0$ 20'E and comprises of 13 districts covering 7.08 Million Hectares (Mha), out of which six districts comprising of 4.12 Mha are in Madhya Pradesh and seven districts comprising of 2.94 Mha are in Uttar Pradesh. The districts in Madhya Pradesh are Sagar, Damoh, Datia, Panna, Chattarpur, and Tikamgarh and in Uttar Pradesh are Jhansi, Lalitpur, Jalaun, Hamirpur, Banda, Mahoba and Chitrakoot. The area is bounded by Vindhyan Plateau in south to river Yamuna in north, river Ken in east and rivers Betwa, Sindh and Pahuj in west. While the geographical area of Bundelkhand region in Madhya Pradesh is 39% more than that in Uttar Pradesh, population in Bundelkhand region of Madhya Pradesh is around 28 % lesser than that in Uttar Pradesh. Despite the fact that normal rainfall in Madhya Pradesh portion is 17 % more than that in Uttar Pradesh and rainfall pattern being more drought prone in Uttar Pradesh as compared to Madhya Pradesh, higher percentage of population in Uttar Pradesh is attributed to age old and higher level of development of irrigation in Uttar Pradesh. About 82% of the population is dependent on agriculture in both the States. While the Yamuna flows from west to east, its first order tributaries viz., Betwa, Ken, Sindh, Pahuj, Gharara, Bagain and Paisuni flow from south to north. Second order tributaries of the Yamuna namely, Dhasan, Jamuni, Birma, Sonar, Patna, Bewas, Kopra etc., also drain the area. The entire drainage forms a part of Ganga basin. The region generally slopes from south to north. The elevations in the area range from 626 m above mean sea level (amsl) in southern part to 93 m amsl near the Yamuna. The area in Madhya Pradesh is conspicuous of undulating rocky ravine topography coupled with level plains, while the area in Uttar Pradesh gradually slopes from mild ravines to level plains near the Yamuna. Almost entire region of Bundelkhand (UP and MP) is prominently of Vindhyan rocks in southern part and Granites of different kinds at different depths with alluvium soils on top mixed with rocky and boulder outcrops here and there. The geology, hydro-geology, hydrology, soils and the climatic distribution are directly responsible for the agricultural growth and consequently to the livelihood of people in Bundelkhand (both UP and MP).

.Water quality index is defined as a rating reflecting the composite influence of different water quality parameters. Horton (1965) has firstly used the concept of WQI, which was further developed by Brown et. al. (1970) and improved by Deininger (Scottish development department, 1975). Water quality index is one of the most effective tools to communicate information on the quality of any water body. WQI is a mathematical equation used to transform large number of water quality data into a single number. The demand for water has increased over the years and this has led to water scarcity in many parts of the world. The situation is aggravated by the problem of water pollution or contamination. India is heading towards a freshwater crisis mainly due to improper management of water resources and environmental degradation. Water quality index (WQI) is one of the most effective tools to communicate information on the quality of water to the concerned citizens and policy makers.

In this study, the present work is an attempt to measure the water quality of Moth block, Jhansi district, Uttar Pradesh, India.Jhansiregion is located in south western part of Uttar Pradesh state of India. The number of industries in Jhansi, during the last decade, has grown more than ten times and accordingly the problems related to environmental degradation have increased many folds. Most of the wastewater from this area flows to the natural streams without treatment resulting in contamination of surface water as well as groundwater. GIS has wide application in water quality mapping using which informative and user-friendly maps can be obtained. Groundwater being the sole source of drinking water in this area, the sampling and analysis of groundwater from various locations and sources such as hand pumps and bore wells were carried out. The latitude and longitude (Coordinate) of the sampling location were recorded with the help of GPS meter.

## 1.2NEED AND SCOPE FOR WATER QUALITY ASSESSMENT

In India 12% of people get clean drinking water, the rest 88% quench their thirst from polluted lakes, tanks, rivers and wells due to which more than three million people get affected or die from enteric diseases every year. The water borne diseases are jaundice, cholera, typhoid and gastro enteritis etc. This surface water and groundwater is mainly polluted by anthropogenic activities viz. urbanization, industrialization, disposing garbage etc. During exploratory drilling in hard rock areas, tube wells were constructed down to 100-150 meters. In some areas of highly fractured granite, it is difficult to construct the bore well due to highly friable nature of these zones. Thus, tube well could not be constructed in spite of the fractures, having good discharge into the ground. Sometimes in bore wells having high discharge, it is difficult to continue drilling due to heavy backpressure. The district lies in the belt of drought prone regions of Uttar Pradesh. The life of the habitants becomes miserable when the water supply source like dug wells; tanks, ponds etc. dry up due to failure of monsoon

Groundwater (GW) level is declining and also groundwater contamination is reported in various part of India especially in shallow aquifer. Hence, one Block named Moth, located in Jhansi District has been selected for groundwater quality assessment for suitability of drinking and irrigation purposes.

## 1.3OBJECTIVE

The objectives of in this study are-

- Sampling, preservation, and analysis of groundwater covering the entire Moth Block, District Jhansi, Uttar Pradesh, India

- Processing of data as per BIS and WHO norms
- Determination of microbiological analysis by MPN method
- Investigation of trace metal on ICP-MS instrument
- Hydro geochemicalfacies of ground water for water type
- Determination of ground water quality for irrigation suitability by using USSL classification
- To draw correlation matrix of water quality parameter
- Development of WQI

# CHAPTER 2: WATER QUALITY INDEX

Water quality indices object at giving a single value to the water quality of a source on the basis of one or the other system which converts the list of component and their concentration present in a sample into a single value. It is one of the aggregate indices that have been accepted as a rating that reflects the composite influence on the overall quality of numbers of precise water quality characteristics. Water quality index provide information on a rating scale from zero to hundred.

Water Quality Index is defined as a rating reflecting the composite influenceof different water quality parameters. It is one of the most effective tools to describethe water quality that is a simple and stable unit of measure. WQI is calculated fromthe point of view of the suitability of groundwater for human consumption. Itcompiles several key water quality parameters to a single data set expressing the datain a simplified and logical form to act as an indicator for trends overtime.WQI helps in the modification of the policies, which are formulated byvarious environmental monitoring agencies. It takes information from a number ofsources about various water quality parameters and the combination represents andhelps in development of an overall status of a water system. They help inunderstanding the core water quality issues by the policy makers as well as for thegeneral public as users of the water resources.

## 2.1 HISTORY

The concept of water quality index was first introduced 150 years ago in 1848 in Germany(Abbasi , 2002)where the presence of certain organisms inwater was used as indicator of the fitness of a water source.

The indexing process was first developed by Horton (1965) in United States (Tyagi etal., 2013). Dinius (1972) made an attempt to design a rudimentary social accountingsystem which would measure the costs and impact of pollution control efforts andapplied that index on an illustrative basis to data on several streams in Alabama, USA.(Bharti et al., 2011)

Later in 1970s Brown developed a water-quality index similar to Horton's index butwith slight modification in selecting parameters and Delphi method was used forassigning weights (Bharti et al., 2011). This method is later used by Nationalsanitation foundation and is hence known as NSF-WQI (Abbasi et al., 2012)

In 1982, Steinhart et al. applied a novel environmental quality index to sum uptechnical information on the status and trends in Great Lakes ecosystem (Tirkey et al.,2013).

By mid-1990, the water quality index was introduced in Canada by Water QualityGuidelines Task Group of the Canadian Council of Ministers of the Environment(Bharti et al., 2011). The CCMEWQI has been employed by various provinces andEcosystems in Canada to assess water quality.

The US National Sanitation Foundation Water Quality Index (NSFWQI), FloridaStream Water Quality Index (FWQI), British Columbia Water Quality Index(BCWQI), Canadian Water Quality Index (Canadian Council of Ministers of theEnvironment (CCME) and the Oregon Water Quality Index (OWQI) are frequentlyused. (Tirkey et al., 2013).

By 1983 a Water Quality Index method was developed by Bhargava for application tothe raw data in river Yamuna at Delhi, India. (Tirkey et al., 2013). Here the parameteris expressed as a number (ranging from 0 for highly/extremely polluted to 100 forabsolutely unpolluted water) (Jyotiprakash et al., 2015).

## 2.2 STEPS FOR DEVELOPMENT

The following four steps are most often associated with the development ofany WQI; depending on the sophistication being aimed at, additional steps may alsobe taken (Tirkey et al., 2013 and Abbassi et al., 2012):

1. Parameter selection: In this method the parameters are selected on the basis ofthe water quality and its use. The indices used are decided by the judgment ofexperienced professional experts, agencies or government. The selection of the variables are usually from the 5 classes namely oxygen level, eutrophication, health aspects, physical characteristics and dissolved substances, which have the considerable impact on water quality (Abbasi et al.,2012). The parameters used must be limited in number but should be representative of the water quality.

2. Transformation: Parameters are of different scale or units. This step involves the transformation of parameters of different units and dimensions to a common scale within a range. This is achieved by the process of development of sub indices.

3. Assignment of weight: The parameters are divided on the basis of its priority in creating water quality problem. The weights are assigned in terms of its degree of contribution, the largest being given to the most affecting.

4. Aggregation: The sub-indices are aggregated to produce a final index score.

## 2.3 TYPES OF WATER QUALITY INDEX

There are various types of Water quality indexing (Bharti et al., 2011). The water quality indices are divided into five main groups (Sobhani, 2003):

a. Public indices: these indices ignore the kind of water consumption in the evaluation process, such as NSFWQI, Horton.

b. Specific consumption indices: Classification of water is on the basis of usage drinking, industrial, ecosystem preservation etc.). The most important and applicable of these indices are the Oregon and British Columbia indices.

c. Statistical indices: In these indices statistical methods are used. These do not give importance to expert opinions.

d. Designing indices: This category is an instrument, aiding decision making and planning in water quality management.

### 2.3.1 Water Quality Index by Horton

Horton selected 10 most commonly measured water quality variables for his index which consisted of dissolved oxygen (DO), pH, coliforms, specific conductance, alkalinity, and chloride. The index weight ranged from 1 to 4 and the index score was obtained with a linear sum aggregation function.

### 2.3.2 National Sanitation Foundation Water Quality Index (NSFWQI)

This method of water quality index was developed by Brown. He used the Delphi method by selecting parameters rigorously and developing a common scale. Then weights were assigned to each parameter. The National Sanitation Foundation (NSF) supported this index; hence it is also called as NSFWQI. This index represents a general water quality. It does not consider any specific water functions such as drinking water supply, agriculture, industry, etc.

The NSFWQI is expressed mathematically by equation:

$$\text{NSFWQI} = \sum_{i=1}^{n} WiQi$$

Where,

Wi= Weighting factor,

Qi = is the rating value of parameter i,

n = number of sub-indices

Water quality can be ranked as poor, fair, medium good and excellent, according to the NSF-WQI Scale.

### 2.3.3 Bhargava Method

Bhargava method was applied to the raw water quality data at the upstream and downstream of river Yamuna at Delhi, India (Abbassi et al., 2012). Each group contained sets of one type of parameters. The first group consists of Coliform organisms which represents the bacterial quality of drinking water. Heavy metals and toxicants are in the second group. The third group included parameters such as odour, colour, and turbidity that cause physical changes. Organic and inorganic substances such as sulphate, chloride, TDS, etc. were included in the fourth group. The equation used is:

$$\text{WQI}=\prod_{i=1}^{n} fi(Pi)^{1/n}$$

Where,

n = number of relevant variables,

$(P_i)$ = function of sensitivity of thevariable including weight

### 2.3.4 British Columbia Water quality Index (BCWQI)

BCWQI was developed by the Canadian Ministry of Environment. This index is similar to CCME Water Quality Index. The violation is determined by comparison with a predefined limit. The following equation is used to calculate final index value:

$$BCWQI = 100 - \frac{\sqrt{F1^2+F2^2+F3^2/3^2}}{1.453}$$

The value 1.453 is the number used to give assurance to the scale index number from 0-100. Accuracy of this method depends upon the repeated samplings and number of stations. The major drawback of this method is that due to the maximum percentage of deviation, the water quality trend deviates from the standard limit. It fails to determine the number of times it goes above the maximum limit.

### 2.3.5 Oregon Water Quality Index (OWQI)

OWQI is created by Oregon Department of Environmental Quality (ODEQ) during mid-1970. It is calculated by integrating values of eight water quality variables. The parameters covered in this method are temperature, dissolved oxygen (DO), pH, biochemical oxygen demand, ammonia and nitrate nitrogen, total phosphorus, total solids and faecal coliform. The original OWQI was designed after the NSFWQI where the Delphi method was used. The greatest advantage of this index is that the most significant values impart significance to the WQI.

It is given by:

$$WQI = \sqrt{n / \sum_{i=1}^{n} \frac{1}{(SI)^2}}$$

Where,

n = number of sub-indices, SI = is the sub-index of the parameter

### 2.3.6 Weighted Arithmetic Water Quality Index Method

Weighted arithmetic water quality index method classified the water quality according to the degree of purity. It uses common water quality parameters like pH, chlorides, fluorides, alkalinity, DO, sulphates etc.

$$WQI = \frac{\Sigma WiQi}{\Sigma Wi}$$

Where, Qi is the quality rating scale

$$(Qi) = 100*[(Vi-Vo)\div(Si-Vo)]$$

Where,

Vi is estimated concentration of the parameter,

Vo is the ideal value; Vo = 0

(Except for pH =7.0 and DO = 14.6 mg/l) and Si is the standard value

The unit weight ($W_i$) for each water quality parameter is calculated by using thefollowing formula:

$$W_i = K/Si$$

Where,

K = proportionality constant,

Si is the rating of water quality according

## 2.3.7 Canadian Council of Ministers of the Environment Water Quality Index(CCMEWQI)

Our first objective was to select water quality parameters that could be associated with an existing drinking water quality guideline. As the goal was to develop a global index, the parameters selected were based on those in the World Health Organisation's Drinking Water Guidelines. It was concluded that based on the parameters selected, WHO drinking water quality guidelines were representative of a number of national guidelines currently in place, and, therefore were selected for use in our index development.

The WHO guidelines divide water quality parameters into two categories:

i. Health guidelines, which take into account chemical and radiological constituents that have the potential to directly adversely affect human health; and

ii. Acceptability guidelines, which include parameters that may not have any direct health effects but result in objectionable taste or odour in the water.

The CCMEWQI was developed by the Canadian Council of Ministers of theEnvironment. The WQI combines the three measures of variance (scope, frequencyand magnitude) mathematically to produce a single unit less number that representsoverall water quality. Canadian Water Quality Index (CWQI) equation is calculatedusing three factors such as

$$F1 = 100 * \frac{No{:}of\ failed\ variables}{Totalnumberoftests}$$

$$F2 = 100 * \frac{No{:}of\ failed\ variables}{Totalnumberoftests}$$

Calculation of excursions where this is the number of times individual values are greater than the standard value. It is given by the equation below

$$\text{excursion i} = \frac{No{:}of\ failed\ variables}{Totalnumberoftests} - 1$$

$$\text{nse} = \frac{\sum_{i=1}^{n} \text{excursions}}{\text{Total number of tests}}$$

$$F3 = \frac{nse}{0.01nse + 0.01}$$

Where, F1 represents the scope, i.e. the number of variables which do not meet the Standard, F2 frequency by which the objectives are not met, F3 is the amount bywhich the objectives are not met.

The equation for water Quality index is

$$WQI = 100 - \frac{\sqrt{F1^2 + F2^2 + F3^2/3^2}}{1.732}$$

The water quality (designation) is ranked in the following five categories based on the index:

| WQI value | Water Quality | Description |
|---|---|---|
| 95-100 | Excellent | All measurements are within objectives virtually all of the time |
| 80-94 | Good | Conditions rarely depart from natural or desirable levels |
| 65-79 | Fair | Conditions sometimes depart from natural or desirable levels |
| 45-64 | Marginal | Conditions often depart from natural or desirable levels |
| 0-44 | Poor | Conditions usually depart from natural or desirable levels |

# CHAPTER 3: DESCRIPTION OF THE STUDY AREA

This study is based on the ground water quality for developing the ground water quality index for drinking and other various purposes.Study area covers theMoth block, Jhansi is located in the Bundelkhand region of central India.

## 3.1 ABOUT JHANSI DITRICT

Jhansi district in the southwestern part of the Uttar Pradesh lies between $25^0$ 07' and $25^0$ 57' north latitude and $78^0$ 10" and $79^0$ 25" east longitudes. Administratively, Jhansi is divided into four Tehsils namely Jhansi, Moth, Gauratha and Mauranipur and eight blocks namelyBabina, Badagaon, Bamaur, Bangra, Chirgaon, Gursrai, Mauranipur and Moth. Total geographical area of the district is 5024 sq. km. The total district's population was 1998603 out of which 1057436 were males and 941167 females as per 2011 census. Physiographically, the area can be divided into two zones i.e. Southern Bundelkhandpediplane zone and Northern highly eroding composite Plain zone.

Rainfall is the ultimate source of surface, ground, green and blue water resources for raising biomass and other utilities. The average annual rainfall of Bundelkhand in Uttar Pradesh is 876.1 mm with a range of 786.6 to 945.5 mm. About 90% of the rainfall is received in the monsoon season of July to September in about 30-35 events or spells. Rainfall variation within the season is important for crop production and rain in September is crucial for the maturity of Kharif crops and sowing of Rabi crops. Delayed on set of rains, early withdrawal or long dry spells in between also lead to drought like situation.

Main source of irrigation in the district is through ground water and canal. Total length of canal is 1236 km by which 75235 hectare area is irrigated. There are 89 no. of government tubewells through which 3806 hectare area is irrigated. Irrigation by private tubewell is 8678 hectare. Hence 54% area is irrigated by ground water. Net sown area is 326767 hectare and net irrigated area is 196078 ha. The ratio of net irrigated area to net sown area is 60%. For drinking water supply pipe line schemes and India Mark II hand pump exist in the district. There are 739 India Mark II hand pumps for providing water to 863342 persons. The area is chiefly drained by the river Betwa and minor rivers like Dhasan and Pahuj. The Betwa and Pahuj rivers are tributaries of Yamuna and Dhasan is tributary of Betwa. The major tributaries of Dhasan are the Lakheri, Sukhnai, Kureraetc which are mainly ephemeral. All three main rivers are perennial.

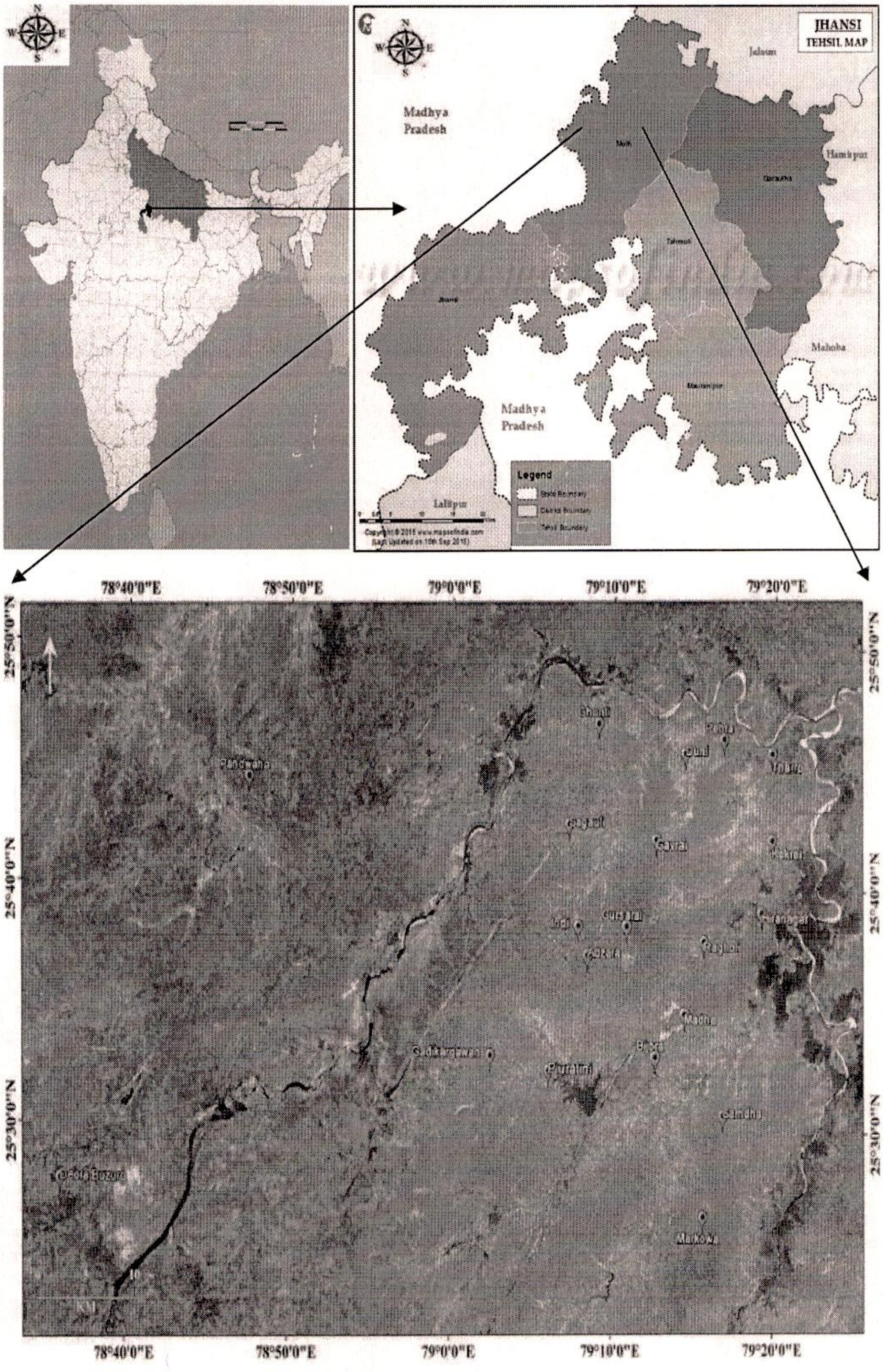



**Figure 1: Location map of Moth block, Jhansi district**

# CHAPTER 4: GROUND WATER SCENARIO

## 4.1HYDROGEOLOGY:

The northern part of the district is occupied by the alluvium of quaternaryage. The alluvium consisting of mainly fine to coarse sand, gravel, pebble, silt,clay and kankar attains a maximum thickness of about 60.00 meters. The alluviums together with the underlying weathered zone of granite-gneissic basement form amore or less homogeneous aquifer system. The northern aquifer system yieldsmoderate quantities of ground water through dug wells and tube wells.

In southern parts of the district, the weathered zone of Bundelkhand granitegneissiccomplex of Archean age and overlying residual soils largely forms theaquifer system. The aquifer system exhibits heterogeneity to some extent due toimpervious nature of frequently occurring outcrops, hillocks and linear quartz reefs. This aquifer has an average thickness of about 20 to 40 meters and yield is limited to moderate through dug wells and tube wells.Ground water occurs under water table conditions in plains. In the graniticterrain ground water occurs in fractures and in fine interstices of the weathered rockmaterial.

### 4.1.1 DEPTH TO WATER LEVEL:

As per depth to water level data of ground water monitoring stations of year2007, pre monsoon water level varies from 2.95 to 15.12mbgl. In generalduring pre monsoon the depth to water level varies from 5 to 15mbgl. Shallow waterlevels are observed only as patches around Moth. Western part of thedistrict normally shows water levels between 5 & 10mbgl. In post monsoon perioddepth to water level varies from 2.47 to 16.07mbgl. Water level fluctuationvaries from 0.85 to 3.65 meters. Shallow water level is observed in canal networkarea. The deepest water level of about 19.00mgl is observed at Eraich in northeasternpart of the district.

### 4.1.2 LONG TERM WATER LEVEL TREND:

The long term water level trend for ten years (1998-2007) of 18 ground watermonitoring wells have shown that only two monitoring stations show rising trend.It varies from 0.0308 to 0.4280 m/year.Remaining wells show annual falling trend varies from 0.0733 to 1.0538 m/year.During pre monsoon period the rising trend is observed at Moth varies from 0.1332 to 0.7180 m/year and remaining 15 ground water monitoringstations show a falling trend varying from 0.0723 to 0.7822 m/year. The yield of deep tube well constructedup to 150mbgl in hard rock area byCGWB varies from 200 to 600lpm at normal drawdown.

### 4.1.3 GROUND WATER QUALITY:

Ground water of the district is colourless, odourless and very slightly alkalinein nature. Electrical conductance ranges from 400-500 micromhos/cm. Out ofthe total samples, 18% of water samples analyzed have high NO3 (above permissiblelimit of 45 mg/l). Fluoride is within permissible limit ranging from 0.08-1.0 mg/l.Phosphate is not found in the district. It is observed that ground water quality issuitable for drinking and irrigation purposes.

### 4.1.4STATUS OF GROUND WATER DEVELOPMENT:

In all blocks of the district ground water development takes place throughdug wells, bore wells and state tubewells.The shallow dugwells are found in canal command area and the deeper onesare located along the Betwariver. The wells generally meet the domestic andirrigation requirements. There are 10594 diesel pumpsets fitted in the dugwells forirrigation. Maximum numbers of diesel pump sets are in Mauranipur block i.e. 1853and minimum are in Babina block i.e. 826. Maximum number of electricpumpsets isin Mauranipur block i.e. 166 and minimum are in Babina block i.e. 7. Maximumnumber of State tubewells for irrigation is in Moth block i.e. 38. The area irrigated through state tubewells andprivate tubewells in the district is 3806 & 8678 ha respectively. In three blocksnamely Moth, Chirgaon and Bamaur, the only source of irrigation is ground watersince the area is devoid of canal network system. Maximum area irrigated throughcanal is in Moth block (31623 hectare) and minimum in Babina (1793 hectare).

Drinking water tubewells have been constructed by Central Ground WaterBoard under exploration programme in town area and villages. The yield of tubewells varies from 200lpm to 600lpm in hard rock areas. The total 42 number of tubewells has beenconstructed in the district so far. Maximum number of hand pumps is in Moth bocki.e. 121 and minimum are in Babina block 72. Depth to these hand pumps varies from30-50 m.

## 4.2 GROUND WATER MANAGEMENT STRATEGY

### 4.2.1 GROUND WATER DEVELOPMENT:

The stage of ground water development in the district is 42.82%. Themaximum stage of ground water development is in Babina block (67.44%) andminimum stage of ground water development is in Bamaur block (15.70%). All eight blocks are in safe category. Hence, all blocks have good scope for further groundwater development through tube wells in northern part (marginal alluvium plain) aswell as southern part (hard rock area). The tube wells of depth upto 25 meters andtapping 12 to 20 meters of granular zone can be constructed in marginal alluviumplain. In hard rock areas the tubewell may be constructed upto 100 to 150 mbgl aftercarrying out hydro geological studies.

### 4.2.2 WATER CONSERVATION STRUCTURE & ARTIFICIALRECHARGE:

In the district, number of tanks, ponds and reservoirs have been constructed inthe district taking advantage of the typical physiography by building dams across themajor and minor streams for storing water for irrigational and domestic purposes.Some important reservoirs are Pahuj dam,Parricha dam, Pahari dam, KamlaSagar andBudhwar Lake. Most of these reservoirs suffer from seepage losses due to fracturednature of Bundelkhand granite and gneisses over these have been constructed.As district is classified into two lithological units 1 (Granite Terrain andPediplane Province) & units II (Composite Plane Province) on the basis of groundwater occurrence. Hence water conservation and artificial recharge scheme may betaken up in the district by way of constructing check dams, nala, bunding, subsurfacedyke and percolation tanks to check the declining water level trends.

# CHAPTER 5: MATERIALS &METHODOLOGY

## 5.1 SAMPLING

Sampling is the first of a series of step leading to the generation of water quality data and is an exceedingly important one. Care must always be taken to ensure obtaining a sample that is truly representative. Further, the integrity of the sample must be maintained from the time of collection to the time of analysis. If the sample is not representative of the system sampled, or if the sample has changed in chemical composition between sampling and analysis, all care taken to provide an accurate analysis will be lost. The sampling network also plays an important role in arriving at valid conclusions and hence utmost care is required for designing the sampling network for the study area.

## 5.2 PRECAUTIONS

1. When the results of successive events are assembled properly, they enable one to better understand the nature, extent, and degree of subsurface contamination.
2. Each ground-water sample must be collected so as to ensure the reliability of analytical determinations.
3. Achieving a specified time the information period requires needs of a ground-water sampling program over careful planning and execution of the sampling design.
4. Each field measurement and water sample collected for laboratory analysis should also be representative of the discrete sampling point within the sampling network.
5. Special care must be taken not to contaminate samples. This includes storing samples in a secure location to preclude conditions which could alter the properties of the sample.
6. Always sample from the anticipated cleanest, i.e., least contaminated location, to the most contaminated location. This minimizes the opportunity for cross-contamination to occur during sampling.
7. Collected samples must remain in the custody of the sampler or sample custodian until the samples are relinquished to another party.
8. Documentation of field sampling is done in a bound logbook

## 5.3 SOURCES OF SAMPLES

A total number of 20 samples were collected and analysed. The ground water samples were collected from IM-II hand pumps & bore wells covering the entire Moth Block of Jhansi district with their GPS coordinates during July 2015 and preserved by adding an appropriate reagent (Jain and Bhatia, 1988; APHA, 1992) for Moth Block, Jhansi District. The hand pumps were continuously pumped for at least 15 minutes prior to the sampling, to ensure that ground water to be sampled was representative of ground water aquifer. All the ground water samples were collected from the drinking water sources, which are being used extensively. Descriptions of ground water sampling location along with their GPS coordinates are given in Table1.

**Table1: Description of Ground Water Sampling Location in Moth Block**

| S. No. | Sample ID. | Location of sample | Longitude | Latitude |
|---|---|---|---|---|
| 1. | G-1 | Markowa | 79.26 | 25.43 |
| 2. | G-2 | Pandwaha | 78.79 | 25.73 |
| 3. | G-3 | Samdha | 79.28 | 25.50 |
| 4. | G-4 | Piuratini | 79.10 | 25.53 |
| 5. | G-5 | Bijora | 79.21 | 25.54 |
| 6. | G-6 | Gadikargawan | 79.04 | 25.54 |
| 7. | G-7 | Madha | 79.24 | 25.57 |
| 8. | G-8 | Adzara | 79.14 | 25.61 |
| 9. | G-9 | Ragholi | 79.26 | 25.62 |
| 10. | G-10 | Gursarai | 79.18 | 25.63 |
| 11. | G-11 | Indi | 79.13 | 25.63 |
| 12. | G-12 | Hiranagar | 79.32 | 25.64 |
| 13. | G-13 | Kakrai | 79.33 | 25.69 |
| 14. | G-14 | Gavrai | 79.21 | 25.69 |
| 15. | G-15 | Sagauli | 79.12 | 25.70 |
| 16. | G-16 | Duni | 79.24 | 25.75 |
| 17. | G-17 | DeoraBuzurg | 78.60 | 25.45 |
| 18. | G-18 | Pehra | 79.28 | 25.76 |
| 19. | G-19 | Tharro | 79.33 | 25.75 |
| 20. | G-20 | Ghonti | 79.15 | 25.77 |

The samples brought to the laboratory for detailed physicochemical, trace metaland bacteriological analysis. The physico-chemical, trace metals and bacteriological analysis were performed following APHA's Standard Methods for the Examination of Water and Wastewater (APHA, 1992).

## 5.4 CHEMICAL AND REAGENTS

All chemicals used for analysis were of analytical reagent grade (Merck/BDH). Standard solutions of metals ions were procured from Merck, Germany. Pesticide standards were procured from Sigma-Aldrich, USA. Bacteriological reagents were procured from HiMedia, India. De-ionized water was used throughout the analysis work. All glassware and other containers used for trace metal analysis were thoroughly cleaned by soaking in detergent followed by soaking in 10% nitric acid for 48 hours and finally rinsed with de-ionized water several times prior to use. All glassware and reagents used for bacteriological analysis were cleaned and sterilized before use.

## 5.5ANALYTICAL METHODOLOGY

The samples were analyzed as per Standard Methods for the Examination of Water and Wastewater (APHA, 1992; Jain and Bhatia, 1988). The details of analytical methods and equipment used in the study are given in Table 2. Ionic balance was calculated and the error in the ionic balance for majority of the samples was within 5%.

The major cations and anions in the samples were analyzed with the help of Dionex IC-5000 Ion Chromatograph. Ion chromatography is a form of liquid chromatography, in which ion exchange resins are employed to separate atomic and molecular ions for analysis. IC involves the retention of ions from the sample being retained based on ionic interactions. Quantification of cations and anions in the sample is based upon calibration curve of standard solutions of respective cations/anions.

Before getting into the individual components of an ICP-MSinstrument, let's take a minute to understand the overallscience of the technique.Samples are introduced into argon plasma as aerosoldroplets. The plasma dries the aerosol, dissociates the molecules, and then removes an electron from the components,thereby forming singly-charged ions, which are directed intoa mass filtering device known as the mass spectrometer.

Perkin-Elmer Inductively Coupled Plasma Mass Spectrometer (ICP-MS) was used for analysis of trace metals. The operational conditions were adjusted in accordance with the manufacture's guidelines to yield optimal determination. The calibration curveof mixed trace metal solution of 10, 50, and 100 ppb were prepared and with the help of same the concentration of metals in the samples were quantified. These calibration curves were determined several times during the period of analysis. The samples were digested in nitric acid and hydrogen peroxide for oxidation/removal of organics in Anton PaarMultiwave PRO Microwave Reaction System and filtered through 0.45 micron filter paper before injecting in ICP-MS.

**Table 2: Details of the analytical method and equipment used in the study**

| Sr. No. | Parameter | Method | Equipment Used |
|---|---|---|---|
| **A.** | **Physicochemical** | | |
| 1 | pH | Electrometric | pH meter –Hach |
| 2 | Electrical Conductivity | Electrometric | Conductivity meter – Hach |
| 3 | Bicarbonate | Titration by $H_2SO_4$ | Digital Burette |
| 4 | Sodium | Flame emission | Flame photometer |
| 5 | Potassium | | |
| 6 | Calcium | Conductivity Method | Ion Chromatograph, Dionex (ICS 5000) |
| 7 | Magnesium | | |
| 8 | Chloride | | |
| 9 | Fluoride | | |
| 10 | Nitrate | | |
| 11 | Sulfate | | |
| **B.** | **Bacteriological** | | |
| 12 | Total coliform | Maximum Probable Number (MPN) method | Bacteriological Incubator |
| 13 | Fecal coliform | | |

| C. | **Trace Metals** | | |
|---|---|---|---|
| 14 | Total Arsenic | Digestion followed by Inductively Coupled Plasma Mass Spectrometry (ICP-MS) | ICP-MS |
| 15 | Aluminium | | |
| 16 | Total Chromium | | |
| 17 | Copper | | |
| 18 | Iron | | |
| 19 | Lead | | |
| 20 | Manganese | | |
| 21 | Cobalt | | |
| 22 | Cadmium | | |
| 23 | Nickel | | |
| 24 | Zinc | | |

# CHAPTER 6: RESULT AND DISCUSSION

Moth Block, Jhansi is an industrial city of Uttar Pradesh. Most of the wastewater from the city finds its way directly to the natural water bodies such as river, pond, etc. due to the insufficient treatment capacity of treatment plants. The contaminants also reach the ground water aquifers and making it unfit for human consumption.Keeping in view of the emerging problem of groundwater contamination, 20 samples covering the length and breadth of the study area was collected. The samples were analyzedfor physical, chemical and biological characteristics as per standardmethods(APHA, 1999).The parameters such as pH, taste, odour, colour, total dissolved solids and total suspended solid indicates the physical characteristics of the groundwater in the study area. The chemical characteristics of the groundwater under the study area were evaluated by the parameters such as total hardness, calcium, magnesium, fluoride, nitrate, chloride, sulphate, alkalinity, potassium, sodium,etc. and biological characteristics were evaluated by total coliform and fecal coliform.

The term heavy metal refers to any metallic chemical element that has a relatively high density and is toxic or poisonous at low concentrations. Examples of heavy metals include mercury (Hg), cadmium (Cd), arsenic (As), chromium (Cr), and lead (Pb) etc. Heavy metals are natural components of the earth's crust. To a small extent they enter our bodies via food, drinking water and air. As trace elements, some heavy metals (e.g. copper, selenium, zinc) are essential to maintain the metabolism of the human body. However, at higher concentrations they can lead to poisoning. Heavy metal poisoning could result, for instance, from drinking-water contamination (e.g. lead pipes), high ambient air concentrations near emission sources, or intake via the food chain. Heavy metals are dangerous because they tend to bioaccumulate. Bioaccumulation means an increase in the concentration of a chemical in a biological organism over time, compared to the chemical's concentration in the environment. Compounds accumulate in living things any time they are taken up and stored faster than they are broken down (metabolized) or excreted. Heavy metals can enter a water supply by industrial and consumer waste, or even from acidic rain breaking down soils and releasing heavy metals into streams, lakes, rivers, and groundwater.

**Table 3: Presents thephysio-chemical parameters concentration and bacteriological analysis**

| Sample ID | pH | EC (µS/cm) | TDS (mg/l) | $F^-$ (mg/l) | $Cl^-$ (mg/l) | $HCO_3^-$ (mg/l) | $SO_4^{2-}$ (mg/l) | $NO_3^-$ (mg/l) | $Ca^{2+}$ (mg/l) | $Mg^{2+}$ (mg/l) | $Na^+$ (mg/l) | $K^+$ (mg/l) | TH (mg/l) | Total Count per 100 ml(MPN) | Faecal Count per 100 ml(MPN) |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| G1 | 7.53 | 659 | 287 | 0.58 | 4.80 | 349.20 | 0.61 | 5.70 | 19.67 | 27.15 | 53.43 | 0.85 | 160.50 | 4 | 4 |
| G2 | 7.45 | 1351 | 662 | 2.98 | 114.25 | 373.87 | 20.46 | 94.81 | 23.12 | 33.35 | 183.37 | 2.37 | 194.54 | 150 | 93 |
| G3 | 7.56 | 695 | 319 | 0.74 | 3.52 | 348.40 | 0.77 | 6.46 | 40.33 | 16.34 | 75.62 | 0.89 | 167.81 | 9 | 9 |
| G4 | 7.48 | 782 | 388 | 0.99 | 19.54 | 374.80 | 6.24 | 22.23 | 49.52 | 32.66 | 65.83 | 3.19 | 257.71 | 240 | 240 |
| G5 | 7.65 | 569 | 262 | 2.14 | 9.00 | 278.80 | 3.51 | 7.10 | 29.99 | 21.35 | 48.23 | 1.11 | 162.51 | 4 | 4 |
| G6 | 7.27 | 1215 | 624 | 2.57 | 98.15 | 395.60 | 18.24 | 60.15 | 88.24 | 44.56 | 112.42 | 1.65 | 403.30 | 93 | 43 |
| G7 | 7.35 | 708 | 453 | 1.01 | 61.26 | 315.60 | 16.20 | 47.00 | 89.56 | 25.65 | 52.29 | 2.41 | 329.07 | 1100 | 460 |
| G8 | 7.42 | 808 | 453 | 0.36 | 54.69 | 314.80 | 51.42 | 17.65 | 50.50 | 34.53 | 85.82 | 0.84 | 267.82 | 4 | 0 |
| G9 | 7.27 | 1131 | 589 | 3.60 | 68.59 | 443.20 | 14.59 | 56.51 | 59.28 | 46.65 | 116.72 | 1.77 | 339.45 | 15 | 4 |
| G10 | 7.47 | 2106 | 1106 | 5.46 | 383.32 | 398.80 | 55.73 | 60.43 | 115.69 | 75.89 | 209.37 | 0.43 | 600.36 | 9 | 4 |
| G11 | 7.42 | 808 | 351 | 0.41 | 31.08 | 292.40 | 29.48 | 11.09 | 46.47 | 35.05 | 50.29 | 0.74 | 259.88 | 4 | 0 |
| G12 | 7.40 | 1079 | 629 | 2.70 | 47.90 | 556.00 | 22.33 | 19.78 | 95.86 | 54.76 | 106.56 | 1.25 | 464.15 | 23 | 0 |
| G13 | 7.16 | 460 | 294 | 2.46 | 46.75 | 253.60 | 5.40 | 6.75 | 54.44 | 24.29 | 25.65 | 1.65 | 235.71 | 0 | 0 |
| G14 | 7.23 | 999 | 444 | 2.36 | 80.53 | 361.63 | 17.02 | 18.34 | 55.41 | 32.55 | 55.31 | 1.42 | 272.00 | 43 | 43 |
| G15 | 7.3 | 1760 | 1360 | 1.91 | 423.25 | 253.25 | 247.12 | 127.61 | 256.89 | 36.71 | 127.72 | 12.31 | 792.77 | 9 | 9 |
| G16 | 7.87 | 827 | 530 | 3.53 | 43.56 | 472.77 | 17.57 | 34.65 | 16.54 | 8.34 | 168.03 | 1.29 | 75.57 | 240 | 43 |
| G17 | 7.64 | 1010 | 576 | 2.70 | 27.79 | 612.75 | 10.28 | 28.56 | 10.90 | 26.24 | 162.07 | 1.28 | 134.84 | 23 | 23 |
| G18 | 7.7 | 627 | 503 | 6.11 | 35.43 | 482.53 | 17.10 | 2.64 | 48.55 | 29.26 | 121.13 | 1.09 | 241.33 | 43 | 15 |
| G19 | 7.63 | 768 | 437 | 5.36 | 62.30 | 346.72 | 17.12 | 7.01 | 29.62 | 28.05 | 112.91 | 1.40 | 189.07 | 4 | 0 |
| G20 | 7.5 | 1208 | 381 | 1.80 | 67.80 | 257.38 | 11.15 | 20.18 | 20.52 | 31.52 | 97.82 | 1.11 | 180.53 | 23 | 23 |
| **BIS A. LIMIT** | **6.5-8.5** | | **500** | **1** | 250 | **200** | | **45** | | | | | **200** | | |

## PHYSICO-CHEMICAL PARAMETERS& BACTERIOLOGICAL ANALYSIS

**pH:**pH is one of the most important water quality parameter due to effect on performance of treatment units and supply lines. It plays an important role in clarification and disinfection. For effective disinfection with chlorine, the pH should preferably be less than 8; however, lower- pH water (<7) is more likely to be corrosive. Failure to minimize corrosion can result in the contamination of drinking-water and adverse effect on its taste and appearance. BIS has prescribed permissible limit of 6.5-8.5. The pH value of groundwater samples in the study area were in the range 7.16 to 7.87.

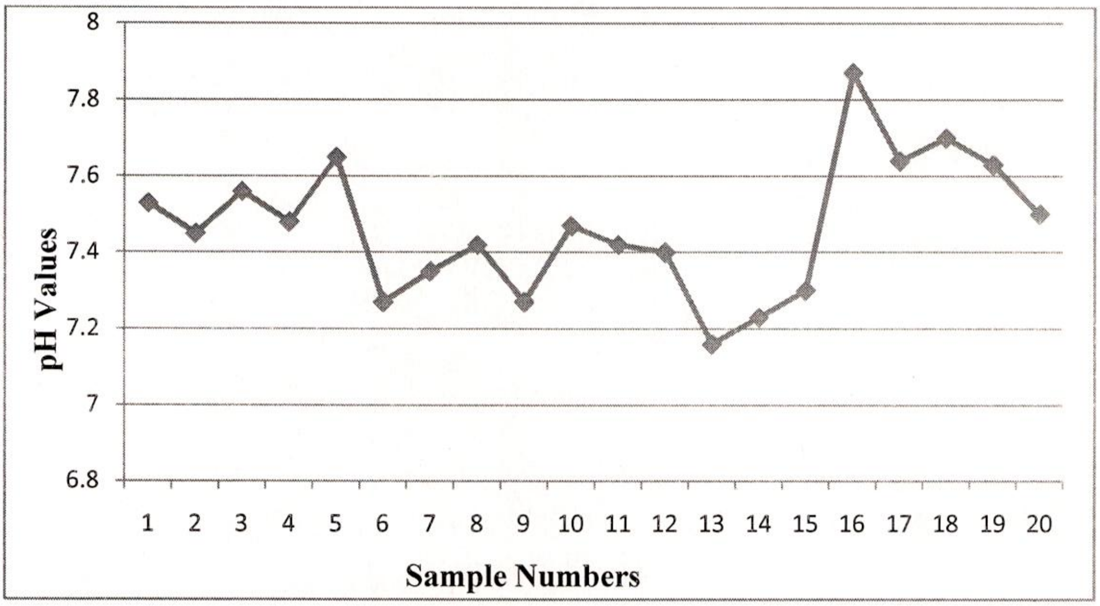



**Figure2:pH values variations in samples.**

**Conductivity:** Conductivity is a measurement of the ability of an aqueous solution to carry an electrical current. Conductivity in water is affected by the presence of dissolved ions such as sodium, potassium, calcium, magnesium, iron, chloride, nitrate, sulphate, phosphate etc.Organic compounds do not conduct electric current very well and hence their contribution to conductivity is very low. Conductivity of water is primarily affected by the geology of the area through which the water flows. Water flowing through granite terrain has lower conductivity, whereas when the water flows through clay soils the conductivity is generally high.

Conductivity is useful parameter to establish water quality. Each source tends to have a relatively constant range of conductivity that, once established, can be used as a baseline for comparison with regular conductivity measurements. Significant changes in conductivity could then be an indicator that a discharge or some other source of pollution has entered a stream. Conductivity of collected samples varies between 460μS/cm to 2106 μS/cm (Figure 3).

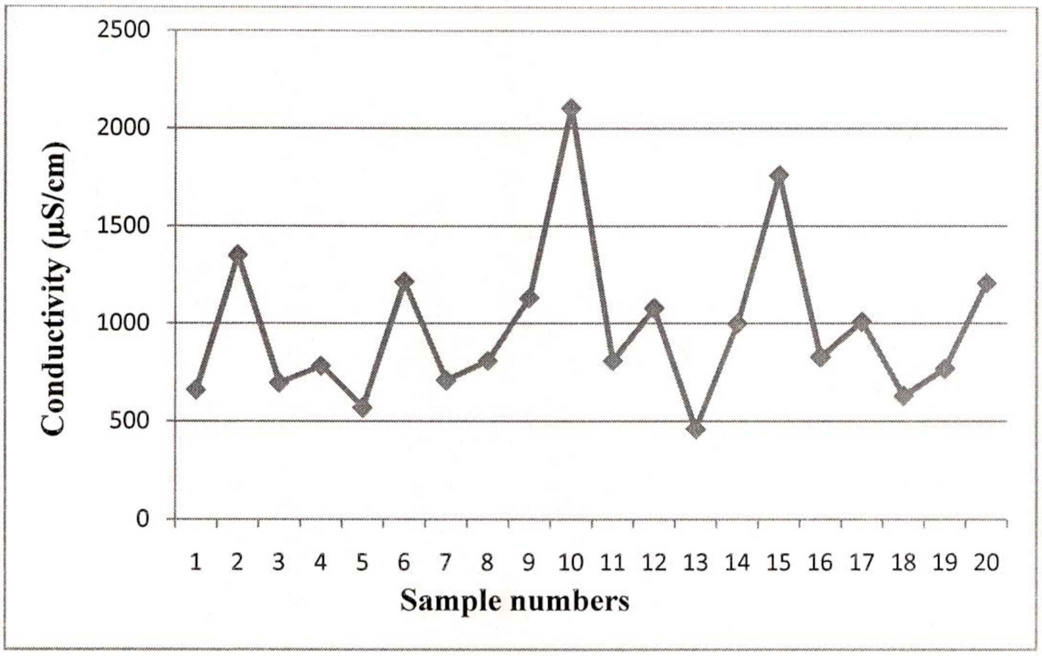



**Figure 3: Electric conductivity variations of samples**

**Total Dissolved Solids:**Total a dissolved solid (TDS) is the term used to describe the inorganic salts and smallamounts of organic matter present in water.The presence of dissolved solids in water may affect its taste. The palatability of drinking water has been rated by panels of tasters in relation to its TDS level as follows: excellent (less than 300 mg/l), good (300-600 mg/l); fair (600-900 mg/l), poor (900-1200 mg/l), and unacceptable (>1200 mg/l). Waterwith extremely low concentrations of TDS may also be unacceptable because of its flat, insipid taste. The presence ofhigh levels of TDS may also be objectionable to consumers, owing to excessive scalingin water pipes, heaters, boilers and household appliances. BIS has prescribed 500 mg/L as the acceptable limit and 2000 mg/L as the permissible limit for TDS in absence of alternate source of drinking water. The guideline is not health based but on the basis of palatability.

TDS of collected samples varies between 261.82mg/L to 1360.14mg/L (Figure 4). TDS of all the samples were well within the permissible limit prescribed by BIS and only 9 sites were having conductivity less than 500 mg/L.

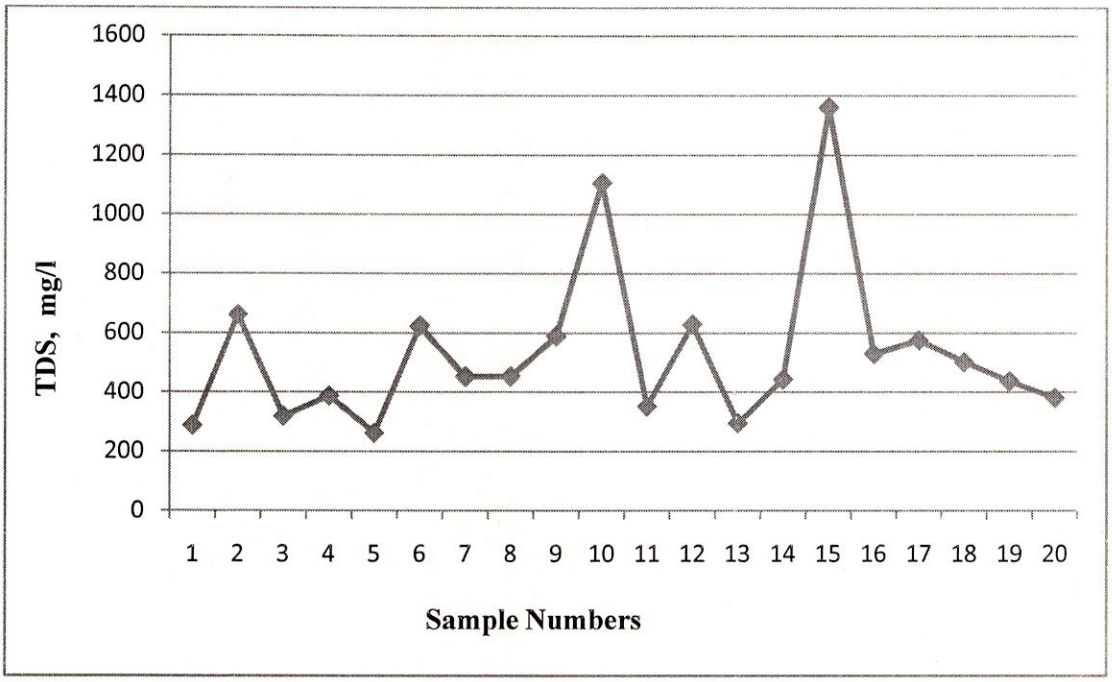



**Figure 4: Total dissolved solid variations of samples**

**Total Hardness:** In fresh water sources, hardness is mainly due to presence of calcium and magnesium salts. Hardness does not pose a health risk. In fact, calcium and magnesium in drinking water ensure daily requirements for these minerals in diet.But hard water can be a nuisance due to the mineral build-up on plumbing fixtures andpoor soap and detergent performance. It often causes aesthetic problems, such as an alkali taste to the water. Temporary hardness more than 200 mg/L as $CaCO_3$may cause scale deposition in the treatmentworks, distribution system and pipe work and tanks within buildings. Water with hardness less than 100 mg/l may, in contrast, havea low buffering capacity and will be more corrosive for water pipes.BIS has prescribed 200 mg/l as the acceptable limit and 600 mg/l as the permissible limit for total hardness in absence of alternate source of drinking water.

BIS limit for calcium is 75 mg/l (acceptable) and 200 mg/L (permissible) and for magnesium the limits are 30 mg/l (acceptable) and 100 mg/L (permissible).Calcium is usually one of the most important contributors to hardness.

The hardness of groundwater samples in the study area were in the range 75.57 to 792.77 (Figure 5). Only two samples from G12 and G15 wereexceeded the permissible limit of 600 mg/L and 40% samples were within the acceptable limit of 200 mg/l.

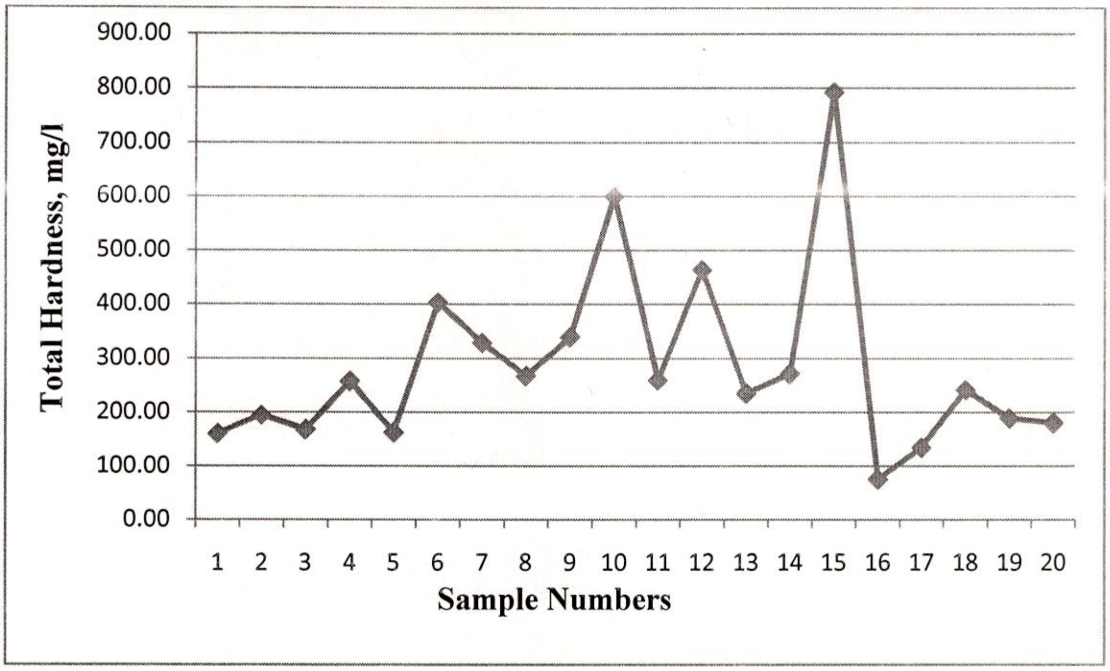



**Figure 5:Total Hardness variations of samples**

The value of calcium in groundwater samples of the study area ranges between 10.90 to 256.89 mg/l (figure 6) and all values except G17sitewere well within the permissible limit of 200 mg/l.

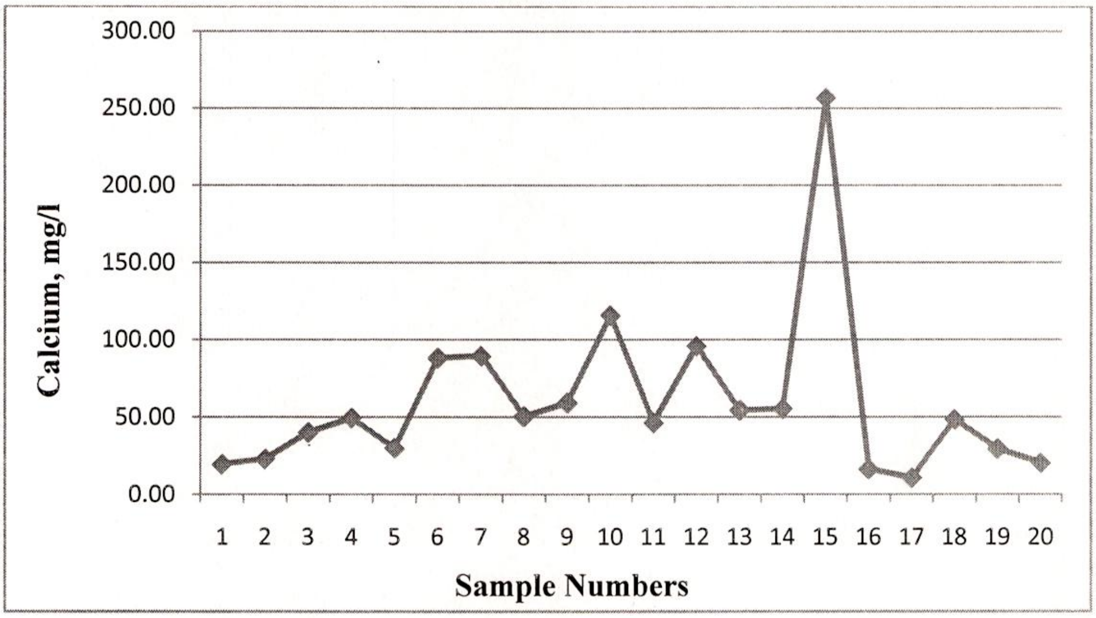



**Figure 6: Calcium values variations of samples**

The values of magnesium were in the range 8.34 and 75.89 mg/l (figure 7). Only 45% samples were having magnesium value within the acceptable limit and no sample exceeded the permissible limit.

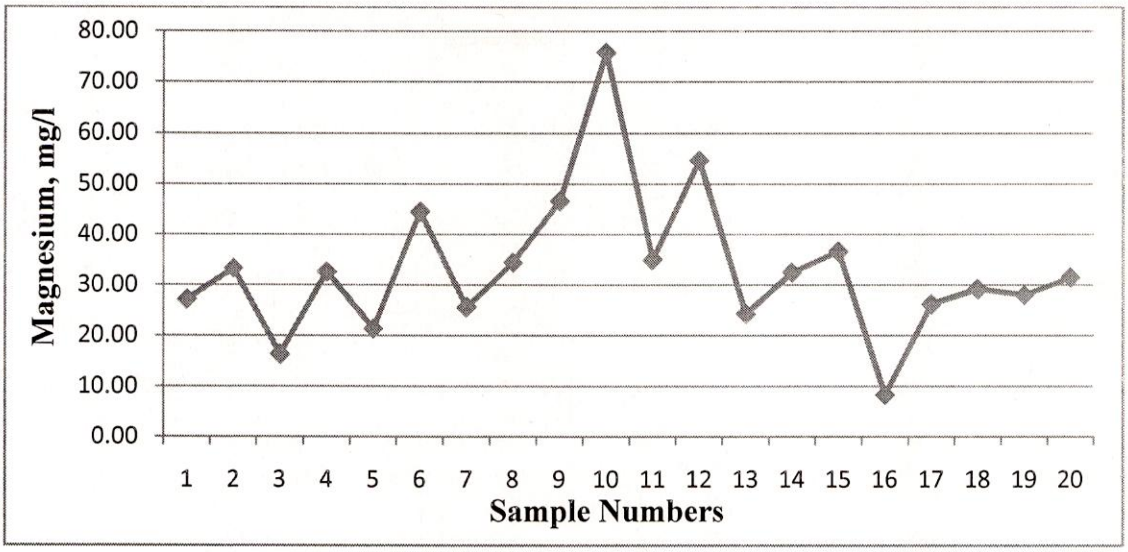



**Figure 7: Magnesium hardness variations of samples**

**Sodium:**Sodium is a very reactive metal, and therefore does not occur in its free form in nature. High sodium intake can have adverse effects on humans with high blood pressure or pregnant women suffering from toxaemia, but contribution from drinking water to daily intake is very small and hence, no health based guideline value has been derived. The taste threshold concentration of sodium in water depends on the associated anionand the temperature of the solution. At room temperature, the average taste thresholdfor sodium is about 200 mg/l. Based on this, WHO has prescribed 200 mg/l as a limit for sodium in drinking water and BIS has not prescribed any limit. The concentration of sodium in groundwater samples of the study area ranges between 25.65 to 209.37mg/l during study period (Figure 8). 95% samples were well within the prescribed limit for sodium.

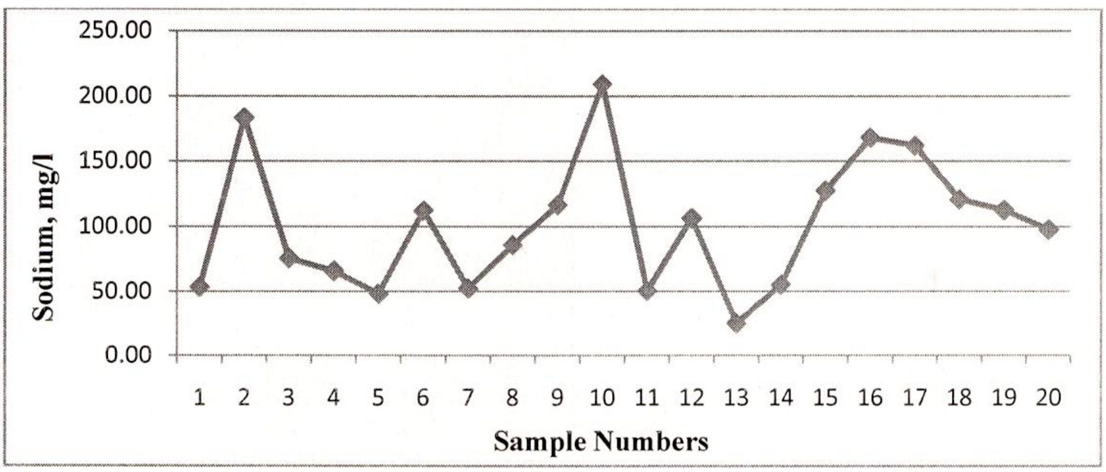



**Figure 8: Sodium variations of samples**

**Potassium:** Potassium is an essential element in humans and is seldom, if ever, found in drinking waterat levels that could be a concern for healthy humans.Adverse health effects due to potassium consumption from drinking-water are unlikely to occur in healthy individuals. Potassium intoxication by ingestion is rare, because potassium is rapidly excreted in the absence of pre-existing kidney damage and because large single doses usually induce vomiting.The value of potassium in groundwater samples of the study area ranges between 0.43 to 12.31 mg/l (Figure 9). The permissible limit of potassium is 10 mg/l, according to the BIS (2012). 95% of the samples were well within the permissible limit.

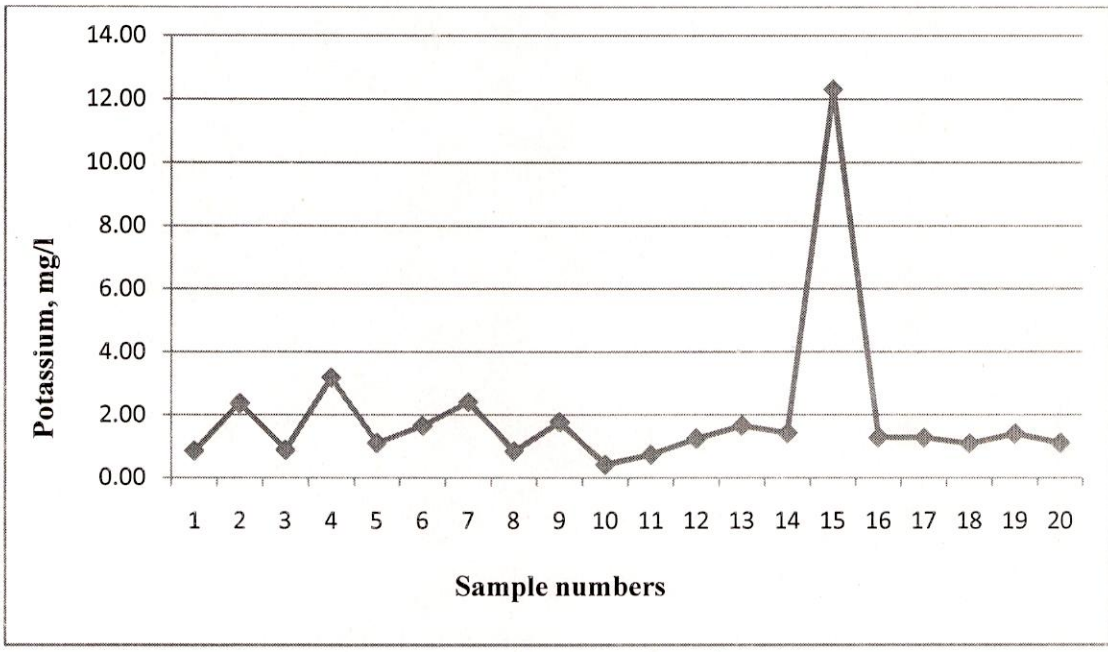



**Figure 9: Potassium variations of samples**

**Alkalinity:** Alkalinity in the water may be due to hydroxides, carbonates, and bicarbonates. The main source of alkalinity is usually from carbonate rocks (limestone). Alkalinity provides buffering capacity to water and is essential to avoid corrosion of supply lines and fixtures.BIS has prescribed 200 mg/l as the acceptable limit and 600 mg/l as the permissible limit for total alkalinity as $CaCO_3$ in absence of alternate source of drinking water.

Bicarbonate ions which are major contributor of alkalinity in the collected water samples were in the range of 253mg/l to 612 mg/l (Figure 10).

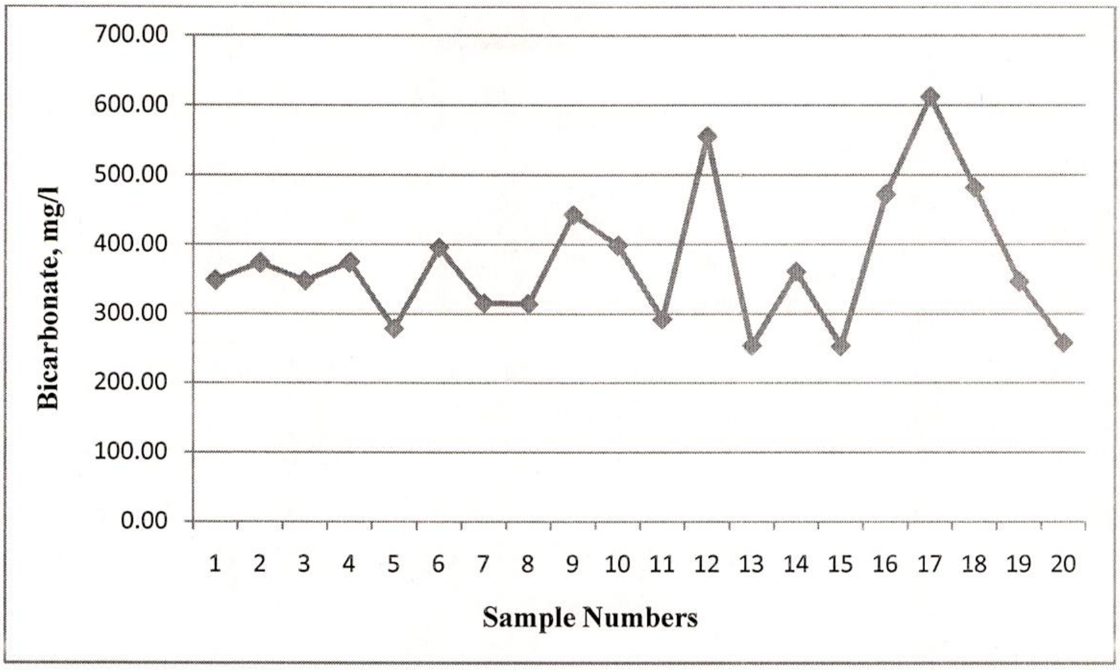



**Figure 10: Bicarbonate variations of samples**

**Fluoride:**Fluoride is found in all natural waters at some concentration. Seawater typically contains about 1 mg/L while rivers and lakes generally exhibit concentrations of less than 0.5 mg/L. In groundwater, however, low or high concentrations of fluoride can occur, depending on the nature of the rocks and the occurrence of fluoride-bearing minerals. Concentrations in water are limited by fluorite solubility, so that in the presence of 40 mg/L calcium it should be limited to 3.1 mg/L. It is the absence of calcium in solution which allows higher concentrations to be stable. High fluoride concentrations may therefore be expected in groundwater from calcium-poor aquifers and in areas where fluoride-bearing minerals are common.Many epidemiological studies have shown that fluoride in drinking water has a narrow range between intakes that cause beneficial and detrimental health effects. Fluoride intake to humans is necessary as long as it does not exceed the limits. Excess fluoride intake causes different types of fluorosis, primarily dental and skeletal fluorosis.BIS has prescribed 1 mg/l as the acceptable limit and 1.5 mg/l as the permissible limit for fluoride in absence of alternate source of drinking water.

The fluoride concentration of groundwater samples in the study area were in the range 0.36 to 6.11 mg/l (Figure 11). Fluoride level in 33.33% samples was well within the acceptable limit and 30% samples were with within permissible limit. 14 samples exceeded the permissible limit.

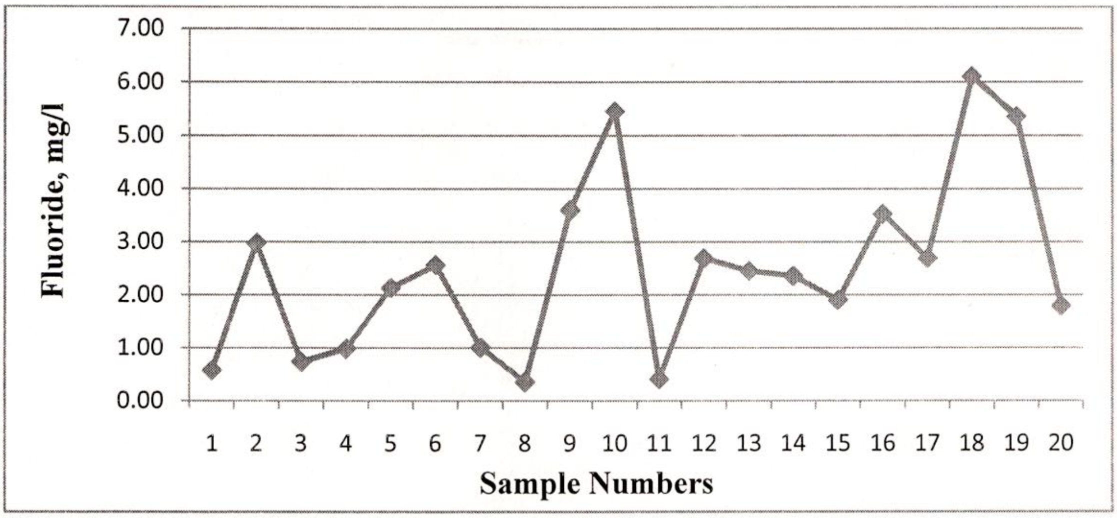



**Figure 11: Fluoride concentration variations of samples**

**Chlorides:**Some common chlorides compounds found in natural water are sodium chloride (NaCl), potassium chloride (KCl), Calcium chloride ($CaCl_2$), and magnesium chloride ($MgCl_2$). High concentrations of chloride give a salty taste to water and beverages. Taste thresholdsfor the chloride anion depend on the associated cations and are in the range of200–300 mg/l for sodium, potassium and calcium chloride. Based on taste threshold, BIS has prescribed 250 mg/l as the acceptable limit and 1000 mg/l as the permissible limit for chloride in absence of alternate source of drinking water. The concentrated of chloride in the collected samples were in the range of 3.52 – 423.25mg/l (Figure 12). Chloride level in 90% samples was well within the acceptable limit and chloride level in all the samples were within permissible limit.

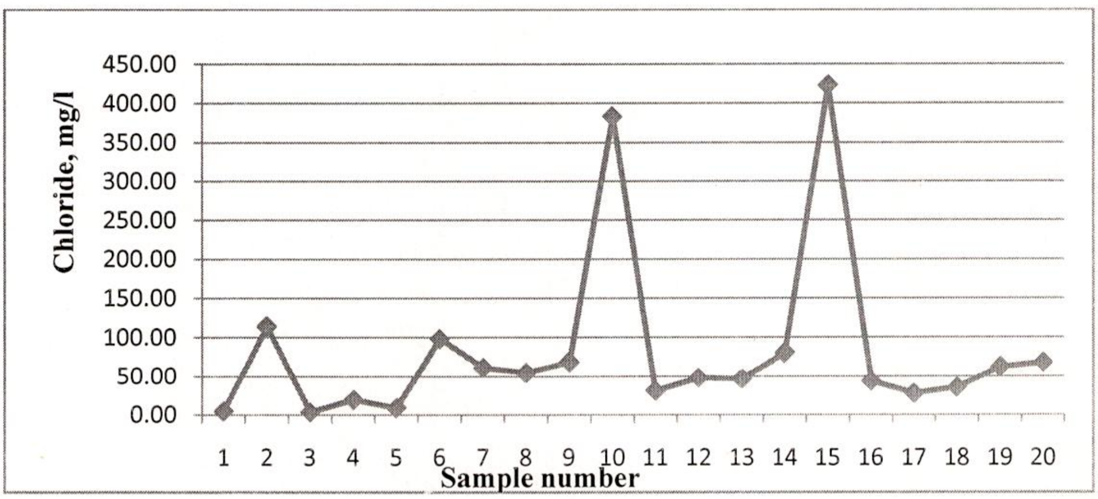



**Figure 12: Chloride concentration variations of samples**

**Sulphate:**The most common form of sulphur in well-oxygenated waters is sulphate. The presence of sulfate in drinking-water can cause noticeable taste, and very highlevels might cause a laxative effect in unaccustomed consumers. Taste impairmentvaries with the nature of the associated cations. Taste thresholds have been found torange from 250 mg/l for sodium sulphate to 1000 mg/l for calcium sulphate.BIS has prescribed 200 mg/l as the acceptable limit and 400 mg/l as the permissible limit for sulphate in absence of alternate source of drinking water.

Sulphate concentration of groundwater samples in the study area varies from 0.61 mg/l to 247.12 mg/l (Figure 13). Sulphate concentration in all the samples except one atG-17,were well within the acceptable limit.

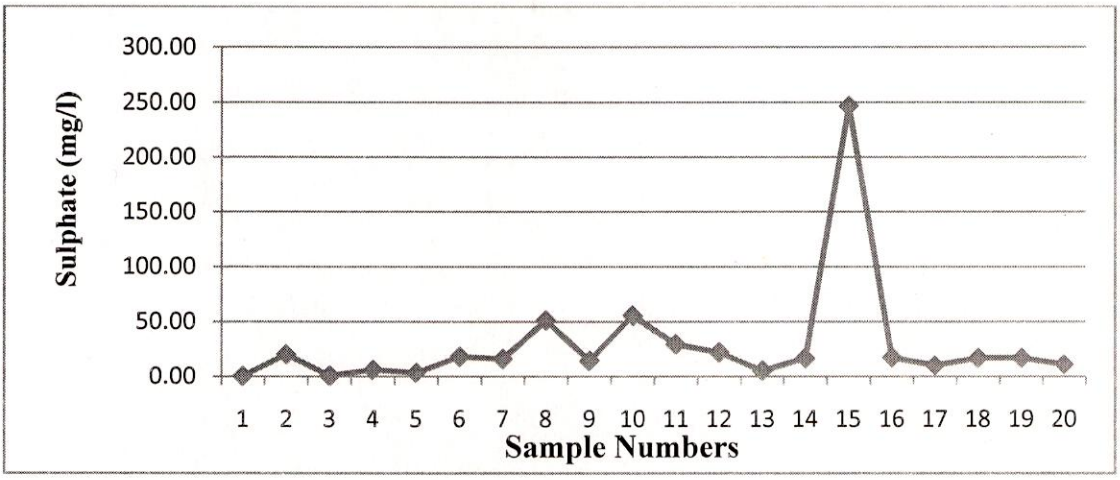



**Figure 13: Potassium variations of samples**

**Nitrate:**Nitrate ($NO_3$) is found naturally in the environment and is an important plant nutrient.It is present at varying concentrations in all plants and is a part of the nitrogencycle.Nitrate can reach both surface water and groundwater as a consequence of agriculturalactivity (including excess application of inorganic nitrogenous fertilizers andmanures), from wastewater disposal and from oxidation of nitrogenous waste productsin human and animal excreta, including septic tanks.Some groundwater may also have nitrate contaminationas aconsequence of leaching from natural vegetation.The presence of nitrate in drinking water is a potential health hazard when present in large quantities. Nitrites are formed by reduction of nitrate in the human body, which combines with haemoglobin in the blood to form methemoglobin that leads to methaemoglobinaemia (blue baby syndrome) in infants. The combination of nitrates with amines, amides, or other nitrogenous compounds through the action of bacteria in the digestive tract results in the formation of nitrosamines, which are potentially carcinogenic. According to the Indian Standard for drinking water, the maximum allowable nitrate concentration in drinking water is 45 mg/L as $NO_3$.Moreover, nitrogen and phosphorus has attracted much attention because of its ability to cause eutrophication in water bodies.

The concentration of nitrate in groundwater samples of the study area ranges between 2.64 to 127.61 mg/l (Figure 14) and all the samples except 6 siteswere well within the acceptable limit.

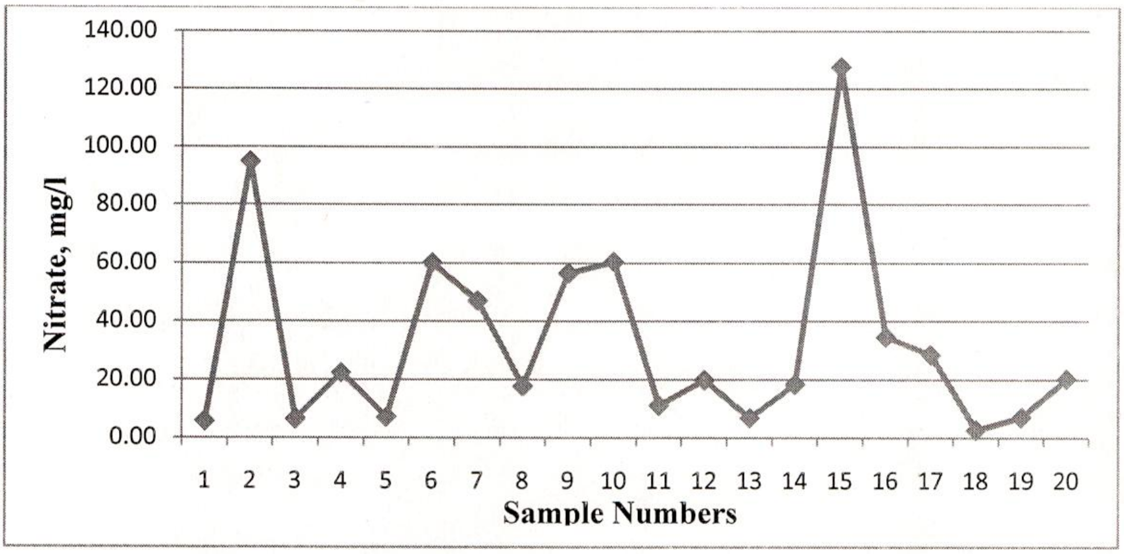



**Figure 14: Nitrate concentration variations samples**

**Total Coliform Bacteria and Faecal Bacteria :**Total coliform bacteria include a wide range of aerobic and facultative anaerobic,Gram-negative, non-spore-forming bacilli capable of growing in the presence ofrelatively high concentrations of bile salts with the fermentation of lactose andproduction of acid or aldehyde within 24 hours at 35–37 °C.Total coliforms include organisms that can survive and grow in water. Hence, theyare not useful as an indicator of faecal pathogens, but they can be used to assess thecleanliness and integrity of distribution systems and the potential presence of bio-films. This test is first in line to micro-biological analysis. Negative results indicate absent of any pathogens. All the collected samples exceptG13 from the study area were positive for total coliform.All the collected samples except 5 sites from the study area were positive for faecal coliform.

**Trace Metal:**Distribution of various heavy metals at different locations and the results of the trace element are presentedin table 1 of the trace elements in the samples areanalyzed as per standard method.Trace metal was determined in the samples after digestion followed by Inductively Coupled Plasma Mass Spectrometry (ICP-MS).

**TABLE 4: Concentration of trace metals in Moth Block, Jhansi District**

| Sample ID | TRACE METALS (CONCENTRATIONS IN PPB) | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|
| | Al | As | Cd | Co | Cr | Cu | Fe | Mn | Ni | Pb | Zn |
| **G1** | 454.07 | 0.93 | 0.07 | 0.71 | 40.13 | 5.08 | 523.76 | 19.19 | 21.32 | 3.16 | 19.77 |
| **G2** | 78.91 | 0.34 | 0.30 | 0.68 | 33.52 | 17.05 | 4344.90 | 42.27 | 24.09 | 11.84 | 155.88 |
| **G3** | 68.28 | 0.13 | 0.11 | 0.14 | 4.81 | 12.10 | 206.72 | 11.55 | 2.05 | 2.68 | 42.33 |
| **G4** | 56.15 | 0.50 | 0..8 | 0.92 | 45.6 | 8.52 | 550.51 | 44.15 | 25.45 | 4.43 | 154.7 |
| **G5** | 58.64 | 0.16 | 0.09 | 0.13 | 4.37 | 6.82 | 228.57 | 9.48 | 2.72 | 1.84 | 48.08 |
| **G6** | 105.53 | 0.23 | 0.06 | 0.57 | 20.58 | 17.68 | 225.23 | 8.76 | 3.71 | 2.45 | 54.40 |
| **G7** | 63.70 | 0.23 | 0.10 | 0.20 | 3.32 | 5.34 | 304.28 | 13.17 | 2.30 | 1.91 | 59.78 |
| **G8** | 14830.80 | 1.61 | 0.61 | 4.2 | 54.50 | 16.46 | 14020.14 | 216.63 | 28.68 | 7.84 | 37.67 |
| **G9** | 46.99 | 0.23 | 0.04 | 0.43 | 29.89 | 3.79 | 630.23 | 10.56 | 14.11 | 2.25 | 14.51 |
| **G10** | 4927.21 | 1.86 | 0.23 | 2.05 | 39.00 | 16.15 | 6038.54 | 81.27 | 20.80 | 4.30 | 18.65 |
| **G11** | 15588 | 2.10 | 0.17 | 4.98 | 54.17 | 18.97 | 16822.52 | 354.34 | 29.54 | 6.47 | 39.36 |
| **G12** | 125.16 | 0.38 | 0.10 | 0.48 | 37.87 | 10.14 | 435.23 | 13.90 | 17.91 | 2.96 | 90.38 |
| **G13** | 107.19 | 0.19 | 0.18 | 0.77 | 37.79 | 5.70 | 476.01 | 34.68 | 30.28 | 4.80 | 193.77 |
| **G14** | 75.72 | 0.31 | 0.05 | 0.45 | 3.41 | 2.53 | 656.61 | 65.00 | 9.06 | 1.98 | 135.74 |
| **G15** | 37.33 | 0.16 | 0.01 | 0.28 | 2.99 | 3.8 | 437.24 | 23.60 | 6.85 | 2.43 | 151.04 |
| **G16** | 35.73 | 0.33 | 0.20 | 0.32 | 3.13 | 4.36 | 944.48 | 8.15 | 8.88 | 1.76 | 76.22 |
| **G17** | 37.33 | 0.16 | 0.01 | 0.28 | 2.99 | 3.83 | 437.24 | 23.61 | 6.85 | 2.43 | 151.04 |
| **G18** | 37.77 | 0.21 | 0.01 | 0.53 | 3.13 | 4.13 | 755.40 | 109.25 | 8.01 | 1.85 | 32.64 |
| **G19** | 31.15 | 0.10 | 0.04 | 0.34 | 3.56 | 7.47 | 487.69 | 26.90 | 8.36 | 4.81 | 434.50 |
| **G20** | 41.60 | 0.26 | 0.14 | 0.35 | 3.38 | 4.98 | 1109.96 | 14.19 | 7.23 | 4.72 | 112.77 |
| **Acceptable Limit** | **30** | **10** | **3** | | **50** | **50** | **300** | **100** | **20** | **10** | **5000** |
| **Permissible Limit** | **200** | **50** | **NR** | | **NR** | **1500** | **NR** | **300** | **NR** | **NR** | **15000** |

**Aluminium:** The maximum allowable concentration and permissible concentration of Al in drinking water is 30 ppb and 200 ppb, respectively according to BIS and WHO. All samples were above the minimumacceptable limits as prescribed by BIS 2012.

**Arsenic:** According to limits prescribed by various authorities (WHO &BIS) it was foundthat all samples were within the minimumacceptable limits as prescribed by BIS 2012(10PPB).

**Cadmium:** According to limits prescribed by various authorities (WHO &BIS) it was foundthat all the samples collected from the sources werefree from Cd.

**Chromium:** The maximum permissible limit of chromium in drinking water according to WHO and BIS is 50 ppb. Small amount of chromium is essential to mammals but in excess it produces harmful effects. The obtaineddata shows that chromium content in water sample expect G8 & G11 are within limits prescribed by BIS 2012.

**Copper:** According to limits prescribed by various authorities (WHO &BIS) it was foundthat all the samples collected from the sources werefree from copper.

**Iron:** According to BIS and WHO the permissible concentration indrinking water in 300 ppb. It is content of haemoglobin, so it is very necessary for allliving organism but in excess promote iron bacteria in water. All samples except G3, G5 and G6 were above the minimumacceptable limits as prescribed by BIS 2012.

**Manganese:** The maximum allowable concentration and permissible concentration of Mn in drinking water is 300 ppb and 100 ppb, respectively according to BIS and WHO. Most of thewater samples analysesexcept G8 had less than 100 ppb.

**Nickel:** The permissible concentration of nickel in groundwater is 20 ppb. Remaining samples are within the permissible limit. G1, G2, G4, G8, G10, G11 and G13 samples are out of the limit.

**Lead:** It is very toxic element, which accumulates in the skeletal structure of man and animal. The minimum permissible concentration of lead in drinking water is 10 ppb. According to BIS almost all the watersamples except G2 had less than 10 ppb of lead.

**Zinc:** Zinc is an essential plant and human nutrient. The maximum allowable concentration and permissibleconcentration of zinc in drinking water are 15000 ppb and 5000 ppb, respectively. According to BIS and WHO thevalues of zinc in all the water samples are below the permissible limit. The concentration of zinc in all watersamples is below 1000 ppb (1 ppm). Hence all the samples collected from all sources are below from maximumpermissible limit for Zinc.

## 6.1 HYDROGEOCHEMICAL FACIES OF GROUNDWATER

In this study, Piper plots were plotted using Aquachem software (Version 14.1) for showing multiple samples and trends in major ions. The Piper plot allows comparisons of 6 parameters between a large numbers of samples. Like all trilinear plots, it does not portray absolute ion concentrations. The main purpose of Piper plots is to show water type of samples.In the Piper diagram, major ions are plotted in thetwo base triangles as cation and anion milliequivalentpercentages. Total cations and total anions are eachconsidered as 100%. The respective cation and anionlocations for an analysis are projected into the diamondfield, which represents the total ion relationship.Piper (1994) tri-linear diagram(Figure 15)has been plotted to study hydrochemicalfacies of groundwater. The Piper diagram includes two triangles to represent cations and anions respectively and one diamond shaped area to represent combination of anions and cations.From the Piper diagram, it is interpreted that groundwater samples fall in the field of Ca-Mg-$HCO_3$ typedemonstrating temporary hardness based on hydro-chemical facies.

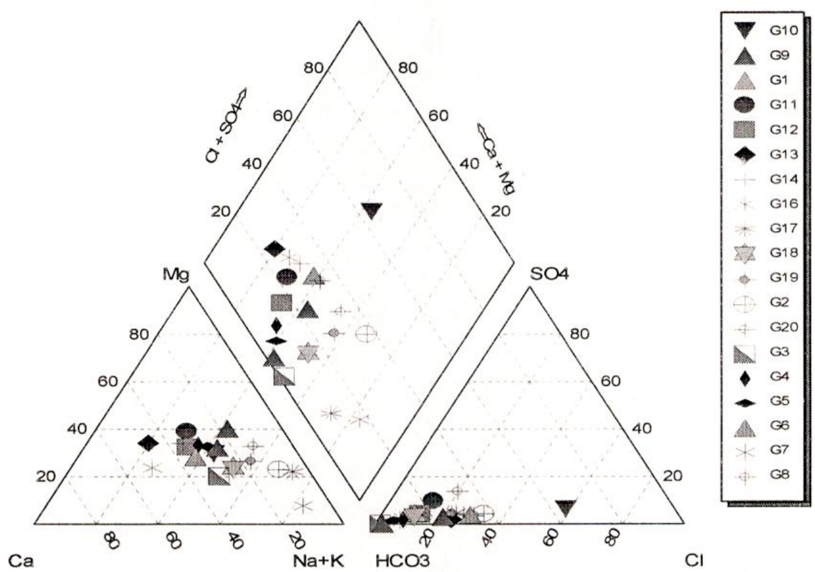



**Figure 15: Piper-trilinear plot for the groundwater samples**

## 6.2 GROUNDWATER QUALITY FOR IRRIGATION SUITABILITY

Groundwater suitability for irrigation purpose in the study area was assessed using Sodium Adsorption ratio (SAR), Percent sodium (%Na) and USSL classification. The recommended classification of irrigation water quality with respect to EC, SAR, %Na is given in Table 5.

**Table 5: Guidelines for evaluation of irrigation water quality**

| Classification Pattern | Category | Range |
|---|---|---|
| EC(μS/cm) (Richards, 1954) | Excellent | <250 |
| | Good | 250-750 |
| | Permissible | 750-2250 |
| | Doubtful | 2250-5000 |
| | Unsuitable | >5000 |
| Sodium Absorption Ratio (SAR) (Richards, 1954) | Low | <10 |
| | Medium | 10-18 |
| | High | 18-26 |
| | Very High | >26 |
| Sodium Percent (Wilcox, 1955) | Excellent | <20 |
| | Good | 20-40 |
| | Permissible | 40-60 |
| | Doubtful | 60-80 |
| | Unsuitable | >80 |

**Sodium Adsorption Ratio (SAR)**

Sodium Adsorption Ratio (SAR) is a measure of the suitability of water for use in irrigation. In general, higher the sodium adsorption ratio, the less suitable the water is for irrigation. Excess sodium in water produces the undesirable effects of changing soil properties and reducing soil permeability. Sodium or alkali hazard is expressed by SAR, which is computed as

$$SAR = Na^{+} / \sqrt{(Ca^{2+} + Mg^{2+})/2}$$

The alkali hazard is expressed in terms of classification of irrigation water as: low (SAR < 10), medium (SAR 10 -18) and very high (SAR > 26). The SAR values in the study area vary from 0.06 – 1.68 (Table 5) which fall under excellent category.

**Percent sodium (% Na)**

Percentsodium (% Na) is also widely used for evaluating the suitability of water quality for irrigation because sodium reacts with the soil to reduce its permeability (CGWB and CPCB, 2000). Sodium content is usually expressed in terms of percent sodium and it is computed with respect to relative proportions of cations present in groundwater, whereas the concentration of ions is expressed in milliequivalents per litre (meq/L) as:

$$Na\% = [(Na^{+} + K^{+})/ (Ca^{2+} + Mg^{2+} + Na^{+} + K^{+})]*100$$

In the study area, values of %Na lie in the range 24.19 – 38.23(Table 6) and hence five site samples lie within the range of 20 – 40 which falls under good category.

**Table 6: EC, SAR and %Na classification for irrigation suitability**

| Sample ID | EC | | SAR | | %Na | |
|---|---|---|---|---|---|---|
| G1 | 659 | Good | 1.83 | Low | 52.84 | Permissible |
| G2 | 1351 | Permissible | 5.72 | Low | 75.71 | Doubtful |
| G3 | 695 | Good | 2.54 | Low | 56.78 | Permissible |
| G4 | 782 | Permissible | 1.78 | Low | 43.54 | Permissible |
| G5 | 569 | Good | 1.65 | Low | 47.91 | Permissible |
| G6 | 1215 | Permissible | 2.43 | Low | 45.54 | Permissible |
| G7 | 708 | Good | 1.25 | Low | 30.78 | Good |
| G8 | 808 | Permissible | 2.28 | Low | 49.98 | Permissible |
| G9 | 1131 | Permissible | 2.75 | Low | 52.01 | Permissible |
| G10 | 2106 | Permissible | 3.72 | Low | 52.16 | Permissible |
| G11 | 808 | Permissible | 1.36 | Low | 37.94 | Good |
| G12 | 1079 | Permissible | 2.15 | Low | 41.23 | Permissible |
| G13 | 460 | Good | 0.73 | Low | 24.19 | Good |
| G14 | 999 | Permissible | 1.46 | Low | 38.23 | Good |
| G15 | 1760 | Permissible | 1.97 | Low | 29.45 | Good |
| G16 | 827 | Permissible | 8.41 | Low | 86.52 | Unsuitable |
| G17 | 1010 | Permissible | 6.07 | Low | 80.84 | Unsuitable |
| G18 | 627 | Good | 3.39 | Low | 60.56 | Doubtful |
| G19 | 768 | Permissible | 3.57 | Low | 65.65 | Doubtful |
| G20 | 1208 | Permissible | 3.17 | Low | 64.80 | Doubtful |

**U.S Salinity Laboratory Classification**

US salinity laboratory (USSL) classification (Richards 1954) evaluates the irrigation water quality on the basis of its electric conductivity (EC) as the indicator of its salt concentration, and SAR as the indicator of its relative sodium activity. Electrical conductivity therefore becomes a satisfactory measure of the salinity hazard involved in the use of water for irrigation. Waters are divided into 4 groups (C1, C2, C3, C4) with respect to conductivity, the dividing points between classes being at 250,750, and 2,250 micromhos/cm. SAR is a measure of sodium hazard and is divided into four groups(S1, S2, S3, S4), the dividing points between classes being at 10,18, and 26. All the water samples fall in C2 & C3 category (Figure 16) which implies salinity hazard is medium to high. As far as sodium hazard is concerned all samples fall under S1 category (Figure 16) implying lowsodicity.

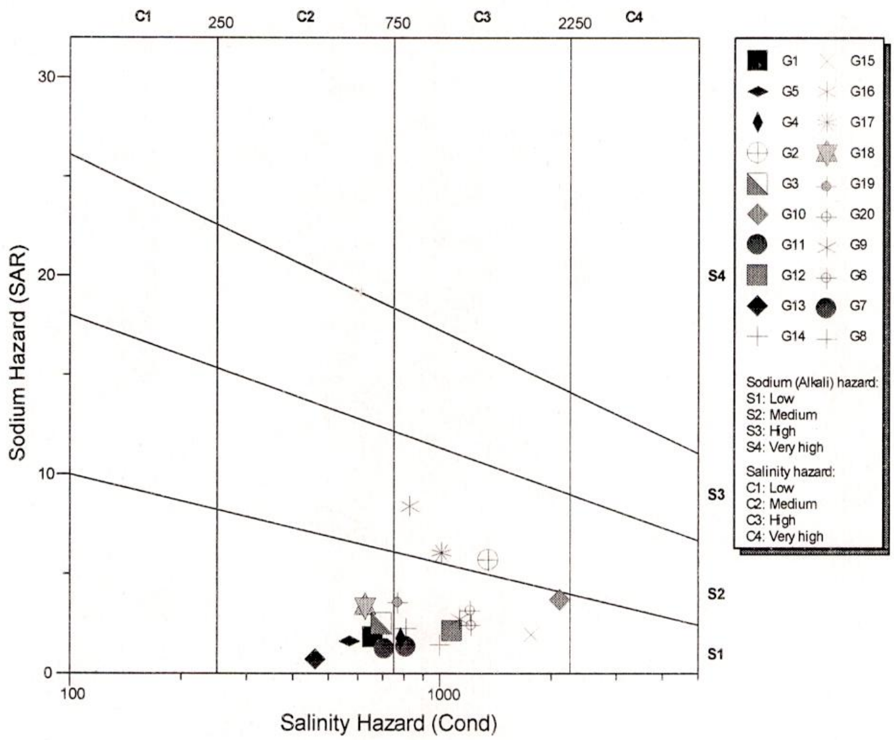



**Figure 16: USSL classification diagram for groundwater**

## 6.3 CORRELATION COEFFICIENT MATRIX OF WATER PARAMETERS

Correlation coefficient (r) value is determined using correlation matrix to identify the highly correlated and interrelated water quality parameters. To test the significance of the pair of parameters p-value is carried out and in order to test the joint effects of several independent variables, without frequent or repeated monitoring of water quality in a location.The relationship between two variables is the correlation coefficient which shows how one variable predicts the other. Associated with correlation coefficient is r, which is the percentage of variance in the dependent variable, explained by the independent variable.

The results of the correlation analysis are considered in the subsequent interpretation. A high correlation coefficient (nearly 1 or -1) means a good relationship between two variables, and a correlation coefficient around zero means no relationship (Muthulakshmi L et al, 2013). Positive values indicate a positive relationship while negative values of r indicate an inverse relationship.

The results of the statistical analysis which are shown in table 7 gave an indication that pH has a strong negative correlation with EC, TDS, $Cl^-$, $SO_4^-$,$NO_3^-$,magnesium, calcium, potassium and weak positive correlation with Fluoride, Sodium,Bicarbonate. The EC has a strong positivecorrelation with TDS,$Cl^-$ weak correlation with all parameters.The TDS strong positivecorrelation with$Cl^-$,$SO_4^-$,$NO_3^-$, calciumweak correlation with all parameters. The Fluorideshowed positive correlation with nitrate, sodium, chloride, magnesium, calcium and bicarbonate. It shows negative correlation with sulphate and potassium. TheChloride has a strong positive and signification correlation with calcium, $SO_4^-$ weak correlation withnitrate, magnesium, potassium & sodium and negative correlation withbicarbonate. The bicarbonate showed negative correlation with sulphate, nitrate, calcium & potassiumand negative correlation with magnesium&sodium. The sulphate showed max.positivecorrelation with calcium &potassium and min. with nitrate, sodium &magnesium. The nitrate showed positive correlation with $Ca^{2+}$, $Mg^{2+}$, $Na^+$ and $K^+$andnegative correlation pH & bicarbonate.Calcium has positive correlation with all the parameter expect pHhas negative correlation. Sodium showed positive correlation with all the parameter. Potassium showed negative correlation with pH, $F^-$&bicarbonate and strong positive with sulphate and calcium. Potassium has weak positive correlation with EC, TDS, $Cl^-$,$NO_3^-$, $Mg^{2+}$& $Na^+$.

| | | PH | EC | TDS | F | Cl | $HCO_3$ | $SO_4$ | $NO_3$ | Ca | Mg | Na | K |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| PH | | 1 | | | | | | | | | | | |
| EC | µS/cm | -0.221 | 1 | | | | | | | | | | |
| TDS | mg/l | -0.182 | 0.880 | 1.000 | | | | | | | | | |
| F | mg/l | 0.288 | 0.290 | 0.339 | 1.000 | | | | | | | | |
| Cl | mg/l | -0.270 | 0.874 | 0.937 | 0.283 | 1.000 | | | | | | | |
| $HCO_3$ | mg/l | 0.361 | 0.075 | 0.110 | 0.418 | -0.179 | 1.000 | | | | | | |
| $SO_4$ | mg/l | -0.238 | 0.581 | 0.819 | -0.018 | 0.813 | -0.264 | 1.000 | | | | | |
| $NO_3$ | mg/l | -0.314 | 0.759 | 0.834 | 0.086 | 0.764 | -0.063 | 0.715 | 1.000 | | | | |
| Ca | mg/l | -0.459 | 0.596 | 0.818 | 0.016 | 0.820 | -0.216 | 0.890 | 0.686 | 1.000 | | | |
| Mg | mg/l | -0.419 | 0.731 | 0.576 | 0.307 | 0.583 | 0.168 | 0.227 | 0.345 | 0.441 | 1 | | |
| Na | mg/l | 0.354 | 0.704 | 0.660 | 0.610 | 0.513 | 0.524 | 0.239 | 0.542 | 0.130 | 0.384 | 1 | |
| K | mg/l | -0.274 | 0.402 | 0.674 | -0.111 | 0.642 | -0.280 | 0.906 | 0.723 | 0.823 | 0.013 | 0.088 | 1 |

**Table 7: Correlation coefficient matrix of water quality parameter**

## 6.4APPLICATION OF CANADIAN WATER QUALITY INDEX

Following the decision to use the WHO guidelines, a drinking water quality index was developed using both health (including microbial) and acceptability measurements. In addition, based on the health and acceptability categories defined by the WHO, two further indices were developed to allow assessment of water quality on two scales 1) human health issues and 2) human acceptability issues. Therefore, the three indices developed were:

1) Drinking Water Quality Index (DWQI); which includes all parameters from the WHO guideline including microbes; and
2) Health Water Quality Index (HWQI); in which only health and microbial measurements are included to assess human health issues; and
3) Acceptability Water Quality Index (AWQI); which only includes acceptability measurements.

The DWQI is composed of both the HWQI and AWQI and, as such, will give an overall 'big picture' as to the quality of water. The Water Quality Index are discussed below

**Table 8: Present the Drinking Water Quality Index with designation**

| SITE CODE | F1 | F2 | EX | NSE | F3 | DWQI | DESIGNATION |
|---|---|---|---|---|---|---|---|
| G1 | 26.31579 | 26.31579 | 20.94753 | 1.102502 | 52.43761 | 62.87414 | Marginal |
| G2 | 47.36842 | 47.36842 | 259.9111 | 13.67953 | 93.18779 | 33.73721 | Poor |
| G3 | 15.78947 | 15.78947 | 17.276 | 0.909263 | 47.62377 | 69.63115 | Fair |
| G4 | 31.57895 | 31.57895 | 480.2678 | 25.27725 | 96.19443 | 38.76687 | Poor |
| G5 | 21.05263 | 21.05263 | 8.090867 | 0.425835 | 29.86566 | 75.65191 | Fair |
| G6 | 36.84211 | 36.84211 | 139.6884 | 7.35202 | 88.02685 | 40.94065 | Poor |
| G7 | 36.84211 | 36.84211 | 1559.838 | 82.09674 | 98.79658 | 35.51181 | Poor |
| G8 | 36.84211 | 36.84211 | 544.1232 | 28.63806 | 96.62596 | 36.61766 | Poor |
| G9 | 42.10526 | 42.10526 | 22.40001 | 1.178948 | 54.10629 | 53.54724 | Marginal |
| G10 | 47.36842 | 47.36842 | 1507.882 | 79.3622 | 98.75563 | 31.10141 | Poor |
| G11 | 36.84211 | 36.84211 | 580.0783 | 30.53044 | 96.82846 | 36.51472 | Poor |
| G12 | 31.57895 | 31.57895 | 28.89795 | 1.520945 | 60.33233 | 56.6611 | Marginal |
| G13 | 26.31579 | 26.31579 | 5.310567 | 0.279504 | 21.84468 | 75.08454 | Fair |
| G14 | 31.57895 | 31.57895 | 88.43329 | 4.654384 | 82.31461 | 45.93008 | Marginal |
| G15 | 52.63158 | 52.63158 | 25.05627 | 1.318751 | 56.87334 | 45.91594 | Marginal |
| G16 | 31.57895 | 31.57895 | 285.9294 | 15.04891 | 93.76905 | 40.0341 | Poor |
| G17 | 31.57895 | 31.57895 | 46.55089 | 2.450047 | 71.01489 | 51.56452 | Marginal |
| G18 | 42.10526 | 42.10526 | 63.19279 | 3.325936 | 76.88362 | 43.85331 | Poor |
| G19 | 21.05263 | 21.05263 | 8.024867 | 0.422361 | 29.69438 | 75.72184 | Fair |
| G20 | 26.31579 | 26.31579 | 47.88163 | 2.520086 | 71.5916 | 53.41395 | Marginal |

**Table 9: Present the Health Water Quality Index with designation**

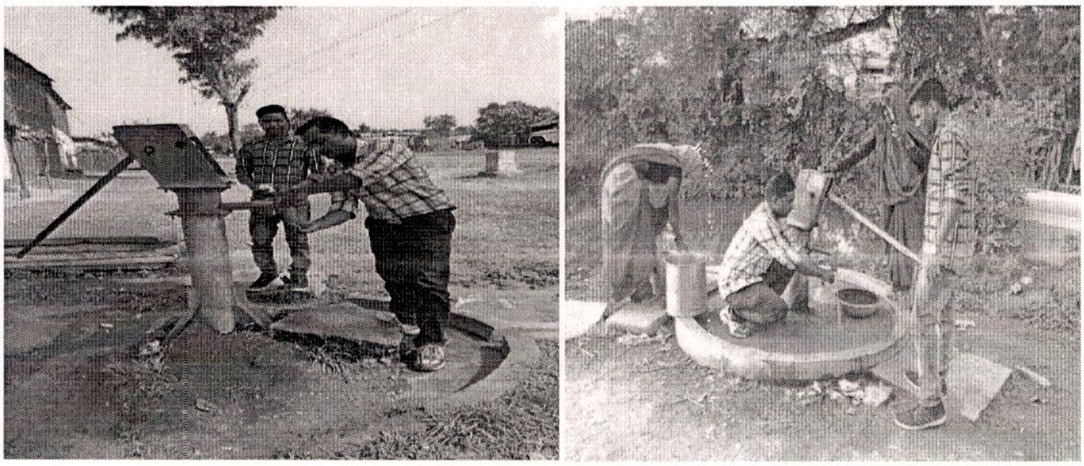
| SITE CODE | F1 | F2 | EX | NSE | F3 | HWQI | DESIGNATION |
|---|---|---|---|---|---|---|---|
| G1 | 30 | 30 | 6.066 | 1.102502 | 37.75675 | 67.20894 | Fair |
| G2 | 60 | 60 | 244.4745 | 13.67953 | 96.07033 | 25.99443 | Poor |
| G3 | 20 | 20 | 16 | 0.909263 | 61.53846 | 60.8965 | Marginal |
| G4 | 30 | 30 | 478.2725 | 25.27725 | 97.95196 | 38.36869 | Poor |
| G5 | 30 | 30 | 7.1362 | 0.425835 | 41.64401 | 65.6759 | Fair |
| G6 | 40 | 40 | 135.9067 | 7.35202 | 93.1463 | 37.0796 | Poor |
| G7 | 40 | 40 | 1558.055 | 82.09674 | 99.36227 | 33.98579 | Poor |
| G8 | 40 | 40 | 4.6903 | 28.63806 | 31.92787 | 62.49606 | Marginal |
| G9 | 40 | 40 | 19.85708 | 1.178948 | 66.5071 | 49.58954 | Marginal |
| G10 | 50 | 50 | 15.8439 | 79.3622 | 61.30615 | 45.96619 | Marginal |
| G11 | 40 | 40 | 6.1038 | 30.53044 | 37.90286 | 60.68546 | Marginal |
| G12 | 20 | 20 | 23.6962 | 1.520945 | 70.32306 | 56.23673 | Marginal |
| G13 | 20 | 20 | 1.9723 | 0.279504 | 16.47386 | 81.10158 | Good |
| G14 | 30 | 30 | 85.3606 | 4.654384 | 89.51349 | 42.80664 | Poor |
| G15 | 40 | 40 | 18.74178 | 1.318751 | 65.20745 | 50.15876 | Marginal |
| G16 | 30 | 30 | 283.5303 | 15.04891 | 96.5932 | 39.08777 | Poor |
| G17 | 30 | 30 | 45.6967 | 2.450047 | 82.04561 | 46.67089 | Marginal |
| G18 | 40 | 40 | 61.204 | 3.325936 | 85.95585 | 40.58892 | Poor |
| G19 | 20 | 20 | 7.3609 | 0.422361 | 42.3993 | 70.57295 | Fair |
| G20 | 30 | 30 | 44.7951 | 2.520086 | 81.75019 | 46.82234 | Marginal |

**Table 10: Present theAcceptabilityWater Quality Index with designation**

| SITE CODE | F1 | F2 | EX | NSE | F3 | AWQI | DESIGNATION |
|---|---|---|---|---|---|---|---|
| G1 | 28.57143 | 28.57143 | 14.88153 | 2.125933 | 68.00955 | 54.32608 | Marginal |
| G2 | 42.85714 | 42.85714 | 17.4216 | 2.4888 | 71.33685 | 45.95394 | Marginal |
| G3 | 14.28571 | 14.28571 | 1.276 | 0.182286 | 15.41808 | 85.32669 | Good |
| G4 | 42.85714 | 42.85714 | 1.995273 | 0.285039 | 22.18135 | 62.73641 | Marginal |
| G5 | 14.28571 | 14.28571 | 0.954667 | 0.136381 | 12.00134 | 86.43254 | Good |
| G6 | 42.85714 | 42.85714 | 3.781707 | 0.540244 | 35.07521 | 59.56887 | Marginal |
| G7 | 42.85714 | 42.85714 | 1.782969 | 0.25471 | 20.3003 | 63.09557 | Marginal |
| G8 | 42.85714 | 42.85714 | 539.4329 | 77.06184 | 98.71896 | 33.11779 | Poor |
| G9 | 57.14286 | 57.14286 | 1.442168 | 0.206024 | 17.08291 | 52.31059 | Marginal |
| G10 | 71.42857 | 71.42857 | 186.1153 | 26.5879 | 96.37522 | 19.39105 | Poor |
| G11 | 42.85714 | 42.85714 | 573.9745 | 81.99635 | 98.79513 | 33.08031 | Poor |
| G12 | 57.14286 | 57.14286 | 5.201754 | 0.743108 | 42.6312 | 47.24737 | Marginal |
| G13 | 42.85714 | 42.85714 | 3.338267 | 0.476895 | 32.29039 | 60.3498 | Marginal |
| G14 | 42.85714 | 42.85714 | 3.072691 | 0.438956 | 30.50516 | 60.82388 | Marginal |
| G15 | 85.71429 | 85.71429 | 6.314491 | 0.90207 | 47.4257 | 24.84667 | Poor |
| G16 | 42.85714 | 42.85714 | 2.399077 | 0.342725 | 25.5246 | 62.02971 | Marginal |
| G17 | 42.85714 | 42.85714 | 0.85419 | 0.122027 | 10.8756 | 64.44736 | Marginal |
| G18 | 57.14286 | 57.14286 | -1.53433 | -0.21919 | -28.0722 | 50.60671 | Marginal |
| G19 | 28.57143 | 28.57143 | 0.663967 | 0.094852 | 8.663486 | 76.14063 | Fair |
| G20 | 28.57143 | 28.57143 | 3.086533 | 0.440933 | 30.60054 | 70.73571 | Fair |

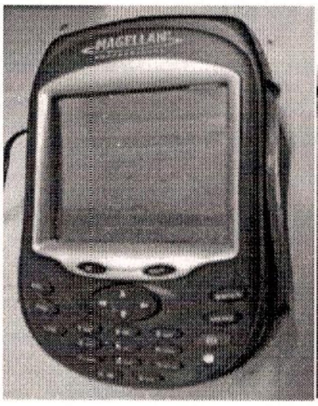
From above tables, it was found that 45%, 35%, 20% collected samples were under poor, marginal, fair designation respectively. On applying HWQI to the collected samples, 45%, 35%, 15%, 5% samples belong to marginal, poor, fair, good designation respectively and 60%, 20%, 10%, 10% belong to marginal, poor, fair, good designation respectively in the terms of AWQI.

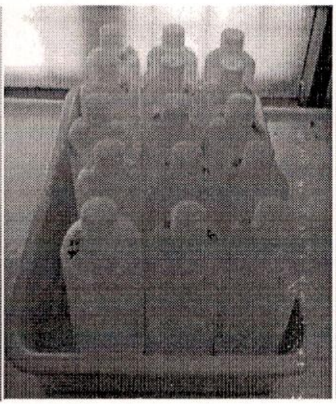
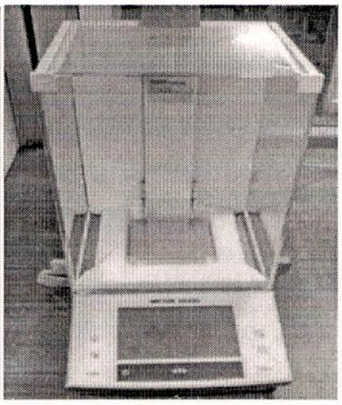
## 6.5 GROUND WATER SAMPLE COLLECTION FROM MOTH BLOCK



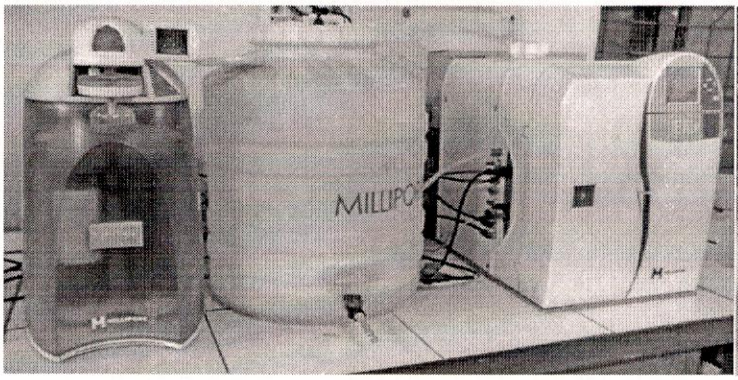
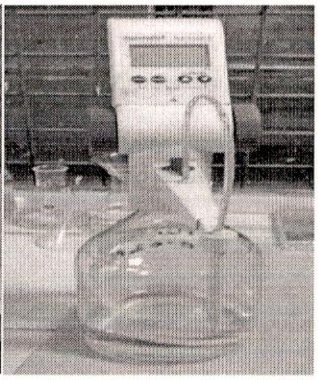
**Cleaning IM-II$^{nd}$ hand pump mouth and collection of sample at site**

## 6.6 LABORATORY EQUIPMENT/APPARATUS USED DURNING WATER SAMPLE ANALYSIS

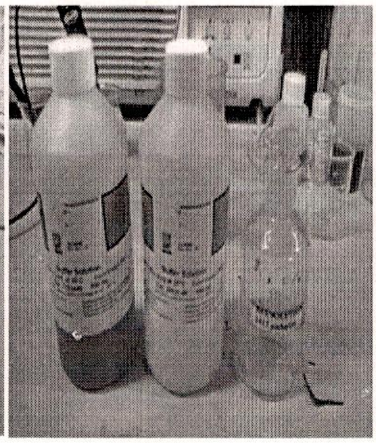


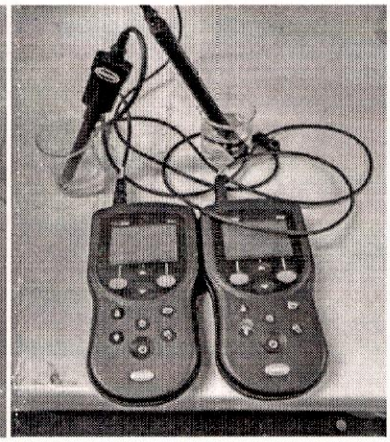



**GPS InstruementCollected Preserve Sample Electronic Balance**

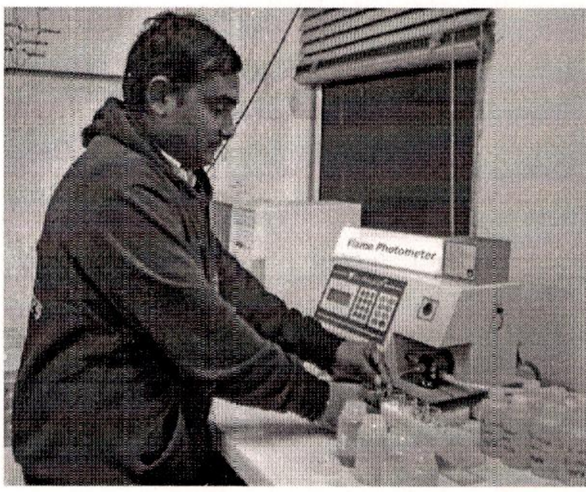



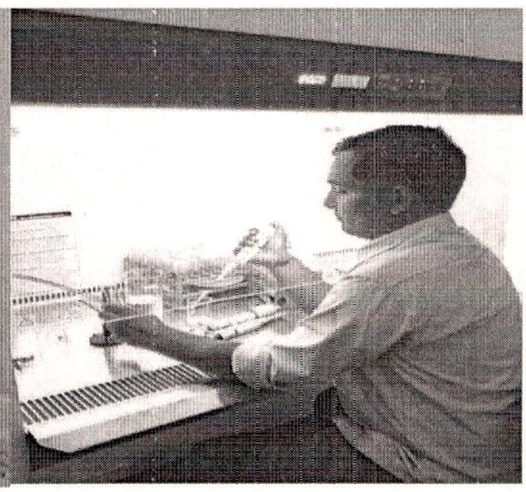
**Ultra Pure and Distill Water Instruement  Digital Burette**

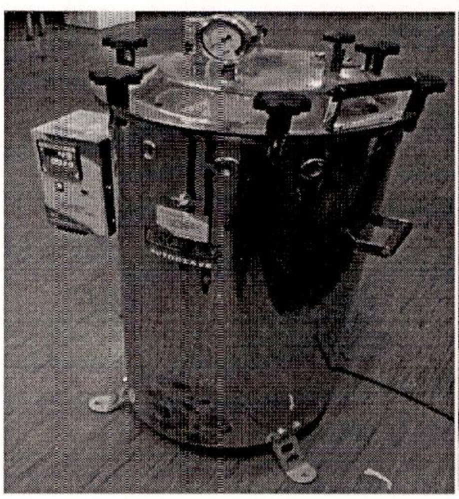


**Electronic Stirer  Buffer &KCl SolutionHach meter for pH & EC**

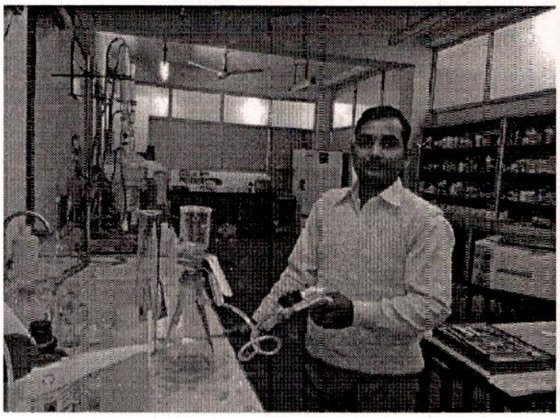


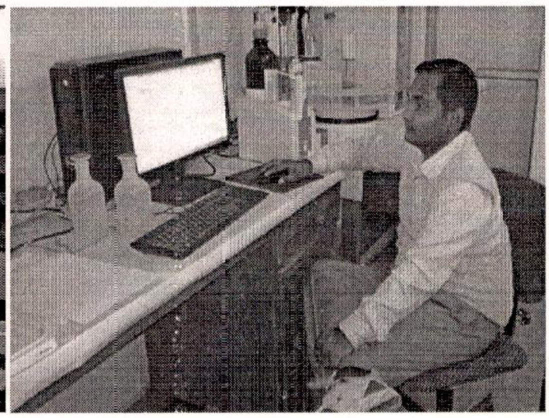



**Working on Flame Photometer & Laminar Flow**

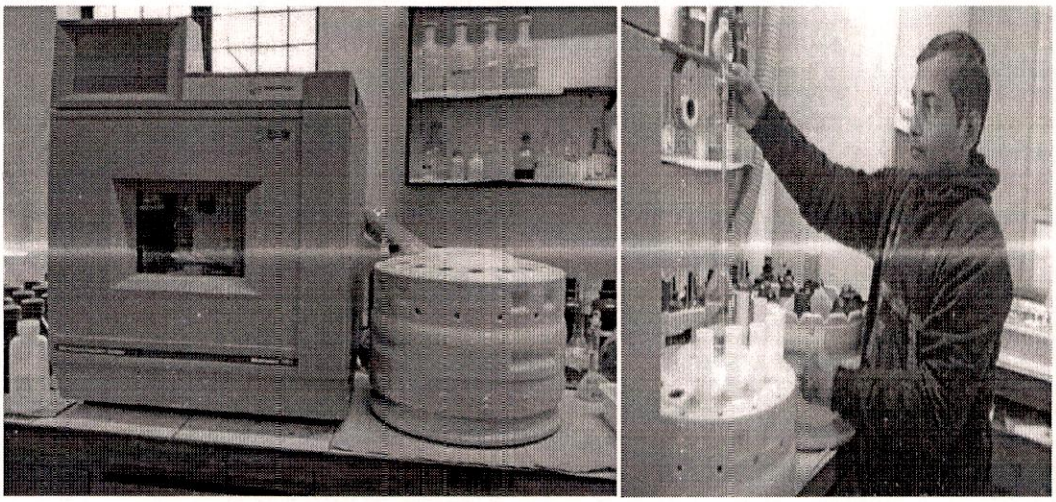



**Autoclave  Bacteriological Incubator**

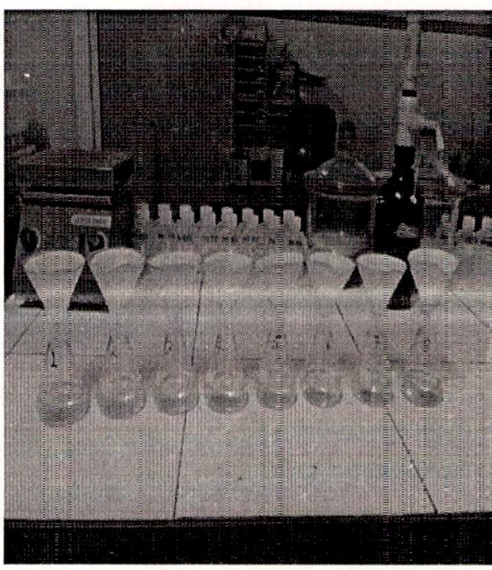


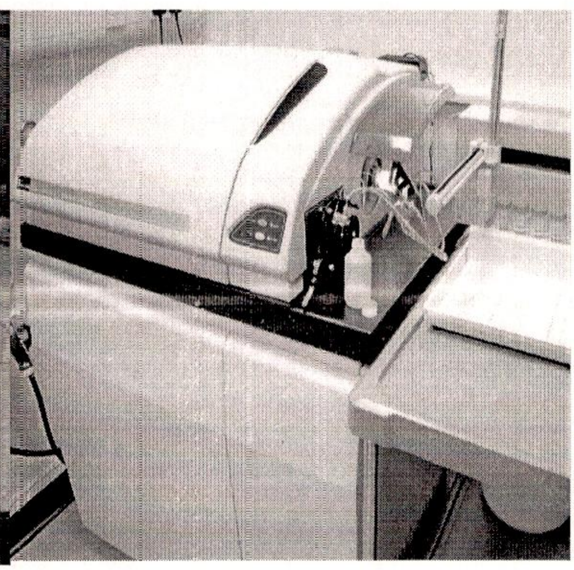


**Preparation of Mobile Phase for IC** **Working on Ion Chromatography**



**Working on Anton Paar Microwave Digester**





**Filtering of the sample after digesting** **ICP-MS Instrument**

# CHAPTER 7: CONCLUSION.

In this study,physiochemical and bacteriological characterization of groundwater of Moth Block, Jhansi District has been carried out. It is revealed from the results and discussion that the condition of water quality in the study area is continuously deteriorating. To assess the suitability of groundwater for drinking purposes, the parameters were compared with the standard permissible limits prescribed by Bureau of Indian Standard (BIS, 10500:2012). It may be concluded that the analyzed groundwater samples are in the permissible range for drinking purpose. Bacteriological contamination was observed in 15 samples of the study area while sample nos. G8, G11, G12, G13 and G19 were found free of bacteriological contamination as per BIS (2012) and can be used for the drinking purposes.The analysis of heavy metals of the samples revealed that Al, As, Cd, Cu, & Zn concentrations fall under permissible limit as prescribed by BIS (2012).According to BIS almost all the watersamples except G2 had less than 10 ppb of lead. Thegroundwater samples were of Ca-Mg-$HCO_3$ types based on hydro chemical facies. On the bases of SAR value, sample nos. G7, G11, G13, G14, & G15 are good for irrigation purpose. The irrigation water quality was also assessed by estimating Salinity and Sodium hazards. USSL classification was done to check the suitability for irrigation purposes. Majoritysamples were found under low-medium range for irrigation. For the DWQI observed 45%, 35%, 20% collected samples were under poor, marginal, fair designation respectively. The collected samples show 45%, 35%, 15%, 5% belong to marginal, poor, fair, good designation respectively in the terms of HWQI where the collected samples of study area were 60%,20%, 10%, 10% belong to marginal, poor, fair, good designation respectively in the terms of AWQI.The residents of these areas should be provided with some alternate source of water for drinking or the available groundwater should be utilized after treatment.

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**Brief overview of National Institute of Hydrology**

NATIONAL INSTITUTE OF HYDROLOGY (NIH) is a premier organisation involved in Research and Development under Ministry of Water Resources, Government of India. NIH was established in 1978 with the main objective of undertaking, aiding, promoting and coordinating systematic and scientific work in all aspects of hydrology. It was established as an autonomous society and is fully funded and aided by the Ministry of Water Resources, Government of India.The Institute is located at Roorkee Town in Hardwar District, Uttarakhand, India. Roorkee, the historic town, is a well known educational & research centre with the I. I. T., Roorkee and a number of R & D organisations viz. Central Building Research Institute, Irrigation Research Institute and Army's Bengal Engineering Group. The studies and research activities at the NIH Roorkee are carried out under five Scientific Divisions. Besides in-house research projects, these Divisions undertake various sponsored and consultancy ii projects. As part of the technology transfer program of the Institute, various training courses/workshops are also organized by the Divisions.The five divisions are as follows:

1. Hydrology Divison
2. Groundwater Hydrology Division
3. Hydrological Investigations Division
4. Surface Water Hydrology Division
5. Resources Systems Division