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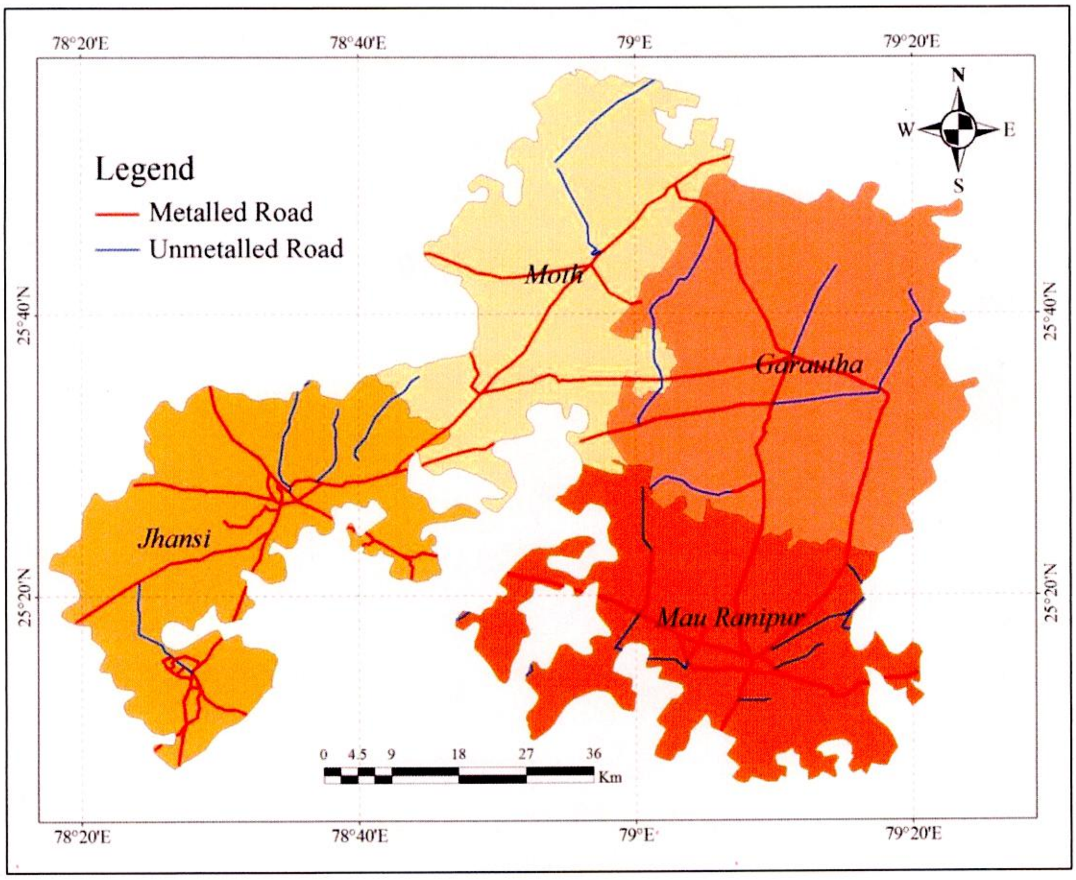
"GROUNDWATER QUALITY INVESTIGATIONS OF MOTH BLOCK OF JHANSI DISTRICT, BUNDELKHAND REGION"



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ABSTRACT

In recent years, the increasing threat to ground water quality due to human activities has become a matter of great concern. Jhansi area sprawling and incoming of new industries around it 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 observed were 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).

Chemical analyses of water samples showed that calcium and bicarbonate are the 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 and water quality indicators viz., sodium adsorption ratio (SAR) and percent sodium (%Na) were determined to assess the suitability for irrigation purpose. The results revealed that the groundwater in the study area is suitable for drinking and irrigation purposes.

Bacteriological analysis variations observed were in TC (0-1100 per 100 ml MPN) and FC (0-460 per 100 ml MPN). As we know that according to BIS TC and FC in ground water shall not be detectable in any 100 ml 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 low concentration quantity but few others are 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 metal in drinking water is generally cumulative, by which the prolonged use of such waters is dangerous for health. Hence the measurement of trace elements concentration and analysis of their periodicity of fluctuation and trend is necessary. The study revealed that the concentrations of Al, Cr, Fe, Mn, Ni and Pb crossed the minimum permissible limits of BIS in the most of sites and alarming condition. The concentration of As, Cd, Co, Cu and Zn 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.

For the Drinking Water Quality Index 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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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. (Mohamad Roshan 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. Depending upon the economic considerations and infrastructure development, UP-Bundelkhand is the poorest region in comparison with western, central and eastern regions 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. Jhansi region 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.

1.2 NEED 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 exploratory, tubes well 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.

1.3 OBJECTIVE

The objectives of in this study are-

- Water Quality analysis (major cation and anion) of groundwater
- Identification of Hydro geochemical facies 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

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 surface water 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 in a raw form, more than 150 years ago in 1848 in Germany where the presence of certain organisms in water 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 for assigning 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 to the 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).

Thus WQI is being developed especially in India, Canada, Europe with respect to thespecial application required.

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 also be 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 weightages:*** 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 effecting.

*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 is applied to the raw water quality data at the upstream and downstream of river Yamuna at Delhi, India identified 4 groups of parameters (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:

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

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:

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

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.

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 calculated using 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 develop the ground water quality index for drinking and other various purposes.Study area covers the Moth block, Jhansi is located in the Bundelkhand region of central India.

3.1 ABOUT JHANSI DITRICT

Jhansi district in the south western 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 namely Babina, 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 Bundelkhand pediplane zone and Northern highly eroding composite Plain zone.

The climate is sub-humid and it is characterized by a hot dry summer and cold winter. The average annual rainfall is 850.1mm. About 91% of rainfall takes place from June to September. During monsoon surplus water is available for charging to ground water. January is the coldest month of the year when the mean daily maximum temperature is 24.10 °C and the mean daily minimum temperature is 9.2°C, May is the hottest month with mean daily maximum temperature is 42.6°C and means daily minimum temperature is 28.8°C. The mean monthly maximum temperature is 32.6°C and means minimum temperature is 19.2°C. In the summer season the air is very dry and during the monsoon season the moisture content of air is high. The mean monthly relative humidity is 41%. During the post monsoon and winter season winds are light and in the summer and monsoon season the winds strengthen slightly. The mean wind velocity is 4.8 Kmph. The potential evapotranspiration is 1603.3 mm.

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.

The area is comprised of Bundelkhand gneissic complex of Archean age and alluvium of recent age. Physiographically, the area can be divided into two units i.e. Southern Bundelkhand Pedi-plane Province and Northern Highly Eroding Composite Plain Province.

There are 89 no. of government tube wells through which 3806 hectare area is irrigated. Irrigation by private tube well 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.

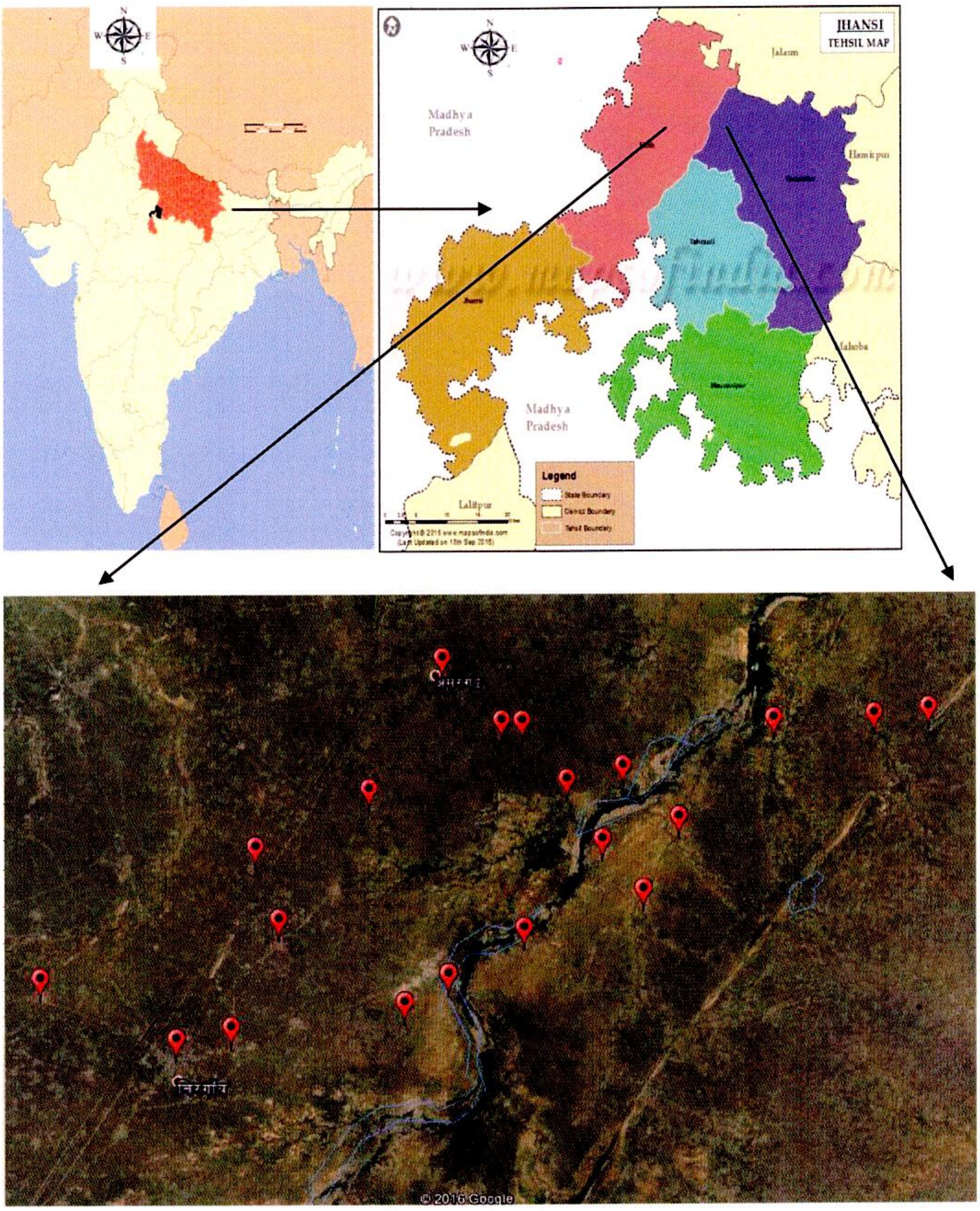


Figure: (A) Location map of Moth block, Jhansi district

CHAPTER 4: GROUNDWATER SCENARIO

4.1HYDROGEOLOGY:

The northern part of the district is occupied by the alluvium of quaternary age. 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 a more or less homogeneous aquifer system. The northern aquifer system yields moderate quantities of ground water through dug wells and tube wells.

In southern parts of the district, the weathered zone of Bundelkhand granite gneissic complex of Archean age and overlying residual soils largely forms the aquifer system. The aquifer system exhibits heterogeneity to some extent due to impervious 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 granitic terrain ground water occurs in fractures and in fine interstices of the weathered rock material.

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 fluctuation varies from 0.85 to 3.65 meters. Shallow water level is observed in canal network area. The deepest water level of about 19.00mgl is observed at Erich in northeastern part 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-constructed up to 150mbgl in hard rock area by CGWB varies from 200 to 600lpm at normal drawdown.

4.1.3 Ground Water Quality:

Ground water of the district is colorless, odorless 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.

4.1.4 Status 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 Betwa river. 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 electric pumpsets is in Mauranipur block i.e. 166 and minimum are in Babina block i.e. 7. Maximum number of State tube wells for irrigation is in Moth block i.e. 38. The area irrigated through state tube-wells and private tube-wells in the district is 3806 & 8678 ha respectively. In three blocks namely 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 tube-wells have been constructed by Central Ground Water Board under exploration program in town area and villages. The yield of tubewells varies from 2001 pm to 6001 pm 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%) and minimum 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 up to 25 meters and tapping 12 to 20 meters of granular zone can be constructed in marginal alluviumplain. In hard rock areas the tube-well may be constructed up to 100 to 150 mbgl after carrying out hydro geological studies. After casing the weathered zone drilling shouldbe carried out in hard rock using different size button bits in telescopic manner (8½",6½" and 6" dia) that will be uncased or naked hole.

4.2.2 Water Conservation Structure & Artificial Recharge:

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, Kamla Sagar and Budhwar Lake. Most of these reservoirs suffer from seepage losses due to fractured nature of Bundelkhand granite and gneisses over these have been constructed.As district is classified into two lithological units 1 (Granite Terrain and Pediplane 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, subsurface dyke 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

Samples were collected in polythene bottles along with GPS coordinates during july2015 – January2016. 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.

TABLE 1: Description of Ground Water Sampling Location in Moth Block

S. No.	Sample ID.	Location of sample	Longitude	Latitude
1.	G-1	Dabra	78.89	25.58
2.	G-2	Ramnagar	78.91	25.59
3.	G-3	Sultanpur	78.83	25.58
4.	G-4	Chirgaonkaral	78.82	25.57
5.	G-5	Simhari	78.77	25.59
6.	G-6	Baral	78.85	25.61
7.	G-7	Nandsiya	78.84	25.63
8.	G-8	semari	78.88	25.65
9.	G-9	Kumariya	78.93	25.66
10.	G-10	Chelra	78.95	25.65
11.	G-11	Nandpura	78.97	25.65
12.	G-12	Kumarivill	78.93	25.66
13.	G-13	Amra	78.91	25.69
14.	G-14	Kolothra	78.93	25.60
15.	G-15	Kukargaon	78.96	25.63
16.	G-16	Phoolkhriya	78.97	25.61
17.	G-17	Dinaura	78.98	25.63
18.	G-18	Baihda	79.02	25.66
19.	G-19	Karguaon	79.05	25.66
20.	G-20	Khallar	79.07	25.66

The samples brought to the laboratory for detailed physicochemical, trace metaland bacteriological analysis. The physicochemical, 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 Hi Media, 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.

5.5 ANALYTICAL 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 overall science 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. At present, approximately thirty five large and small scale industries exists in city, and the number is increasing day by day. 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 analyzed for 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 **bio-accumulate**. 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 the physio-chemical parameters concentration and bacteriological analysis

Sample ID	pH	Tubidity (NTU)	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)
G1	7.37	0.3	4360	2488	2.41	731	626.00	183.00	260.00	280.00	251.00	210.00	4.88	4.88
G2	7.48	0.3	994	717.0	2.12	46	438.00	14.23	21.67	78.90	23.10	91.00	1.25	291.97
G3	7.82	0.5	1305	940.00	1.37	89	628.00	2.97	7.70	15.04	14.55	281.00	2.09	97.26
G4	7.89	0.70	1568	1093.00	2.42	213	482.40	44.49	27.00	112.00	71.06	137.00	4.00	571.36
G5	7.81	2.00	859	455	0.14	63.48	320.00	10.00	56.81	93.00	40.00	28.18	3.57	396.50
G6	7.60	1.70	1183	568	0.46	60.00	403.60	42.00	61.61	63.00	41.00	93.00	5.00	325.60
G7	7.48	10.6	1107	576	2.07	95.00	419.00	25.00	8.02	34.40	47.48	145.92	8.92	280.68
G8	7.70	0.8	1247	702	3.11	70.52	631.20	7.92	0.63	12.83	24.28	263.72	3.43	131.60
G9	7.84	23.7	842	423	1.97	21.13	442.00	2.04	3.29	45.98	34.05	91.41	2.51	254.56
G10	7.42	0.40	1052	519	2.11	10.03	610.00	2.23	3.13	23.41	74.71	96.04	2.34	364.86
G11	7.72	1.00	1032	529	3.19	6.19	562.40	1.26	4.12	23.83	14.21	194.40	1.02	117.81
G12	7.82	0.5	852	425	2.01	21.32	445.25	2.12	3.25	45.82	34.11	91.32	2.41	254.42
G13	7.64	23.7	1042	385	1.86	21.04	388.00	4.31	3.46	41.52	39.29	77.08	2.10	264.87
G14	7.48	7.50	1036	543	2.96	100.99	434.00	6.19	7.60	38.38	40.15	127.99	1.95	260.59
G15	7.25	0.6	963	519	2.83	16.71	506.67	29.40	3.45	43.09	37.73	131.45	1.43	262.42
G16	7.42	0.80	1066	636	3.44	85.17	426.00	78.55	10.00	109.28	15.85	114.32	6.55	338.19
G17	7.39	0.7	950	510	3.18	33.91	347.60	84.70	3.10	82.02	24.27	103.89	0.92	304.58
G18	7.40	0.70	1789	865	3.40	164.35	495.60	83.75	8.00	84.03	37.12	235.05	1.95	362.25
G19	7.31	3.60	2450	1739	5.70	324.26	518.80	551.69	26.20	128.86	129.71	311.20	2.00	853.96
G20	7.45	1.60	975	500	1.90	87.00	369.00	28.08	14.30	132.00	27.64	23.05	1.50	443.34

6.1 PHYSICO-CHEMICAL PARAMETERS& BACTERIOLOGICAL ANALYSIS

6.1.1 pH:pH has no direct impact on the consumers. In spite of this fact, it 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 7.25 to 7.89.

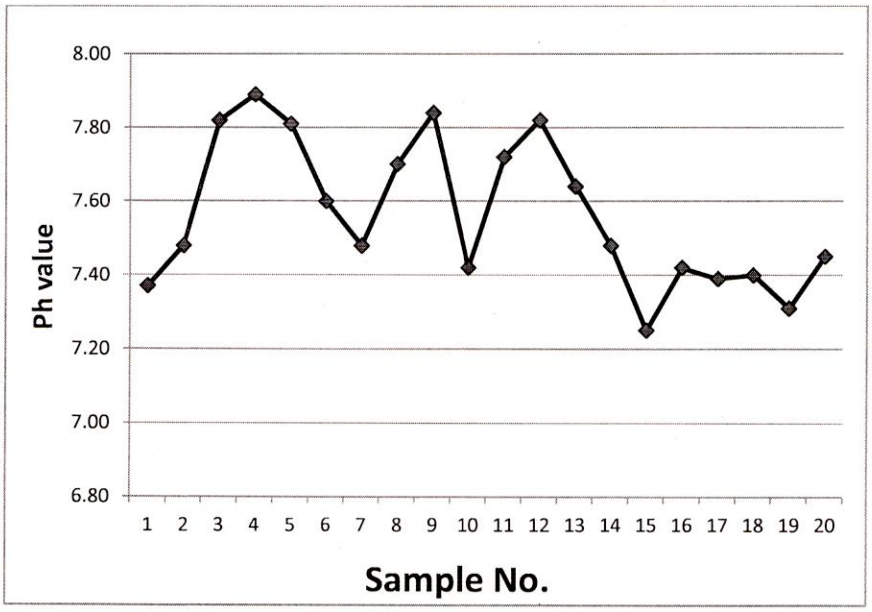


Figure: (a) pH values variations in samples.

6.1.2 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 842 μS/cm to 4360 μS/cm.

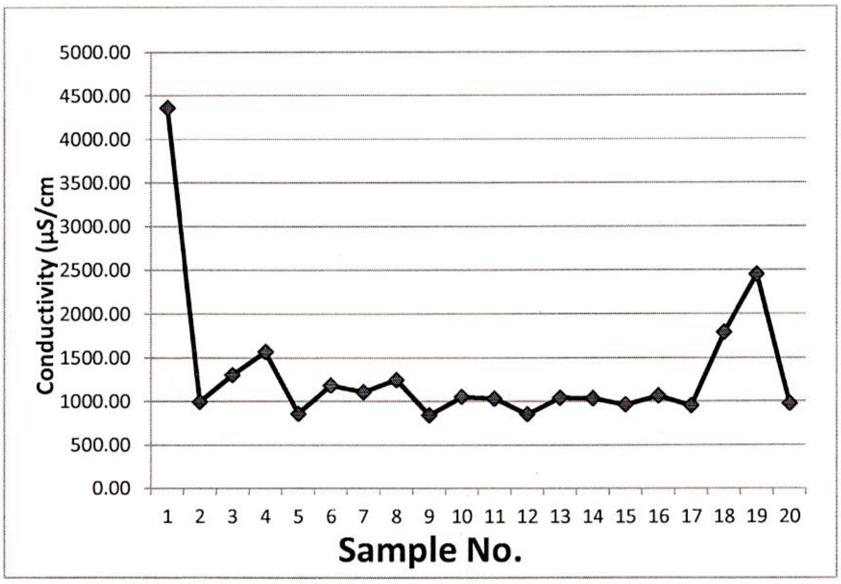


Figure: (b) Electrical conductivity variations of samples

6.1.3 Total Dissolved Solids: Total dissolved solids (TDS) are the term used to describe the inorganic salts and smallamounts of organic matter present in solution 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 385 mg/L to 2488 mg/L. Except four, all samples bearing TDS above 500 mg/L.

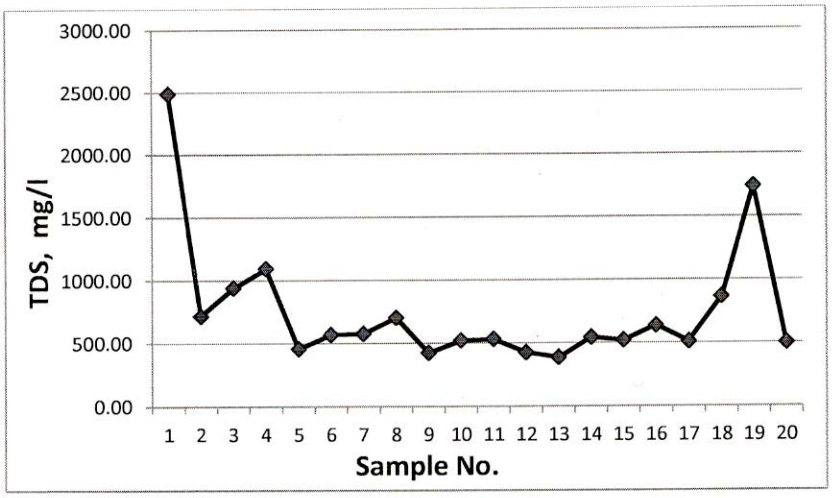


Figure: (c) Total dissolve solid of various samples

6.1.4 Turbidity: Turbidity is a measure of the cloudiness of water. Cloudiness is caused by suspended solids (mainly soil particles) and plankton (microscopic plants and animals) that are suspended in the water column. Moderately low levels of turbidity may indicate a healthy, well-functioning ecosystem, with moderate amounts of plankton present to fuel the food chain. However, higher levels of turbidity pose several problems for stream systems. Turbidity blocks out the light needed by submerged aquatic vegetation. It also can raise surface water temperatures above normal because suspended particles near the surface facilitate the absorption of heat from sunlight.

Suspended soil particles may carry nutrients, pesticides, and other pollutants throughout a stream system, and they can bury eggs and benthic critters when they settle. Turbid waters may also be low in dissolved oxygen. High turbidity may result from sediment bearing runoff, or nutrients inputs that cause plankton blooms.

Turbidity of collected samples varies from 0.3 NTU to 23.7 NTU.

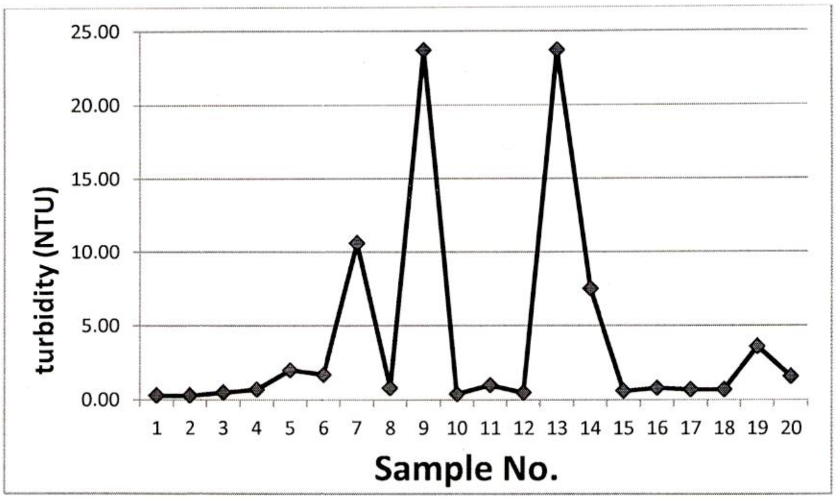


Figure: (d) Turbidity of various samples

6.1.5 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 97.26 to 1729 Figure (e). Only three samples from G1, G4and G19 were exceeded the permissible limit of 600 mg/L and 25% samples were within the acceptable limit of 200 mg/l.

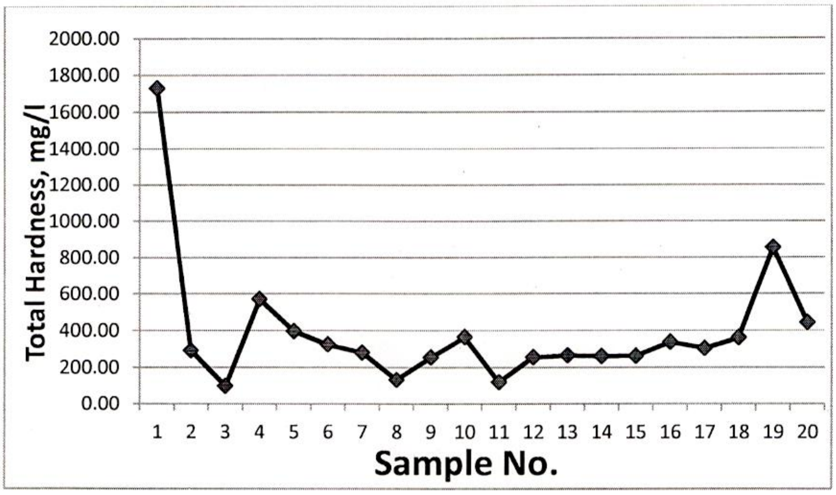


Figure: (e) Total Hardness variations of samples

6.1.6 Calcium: The value of calcium in groundwater samples of the study area ranges between 10.90 to 256.89 mg/l and all values except G1 site were well within the permissible limit of 200 mg/l.

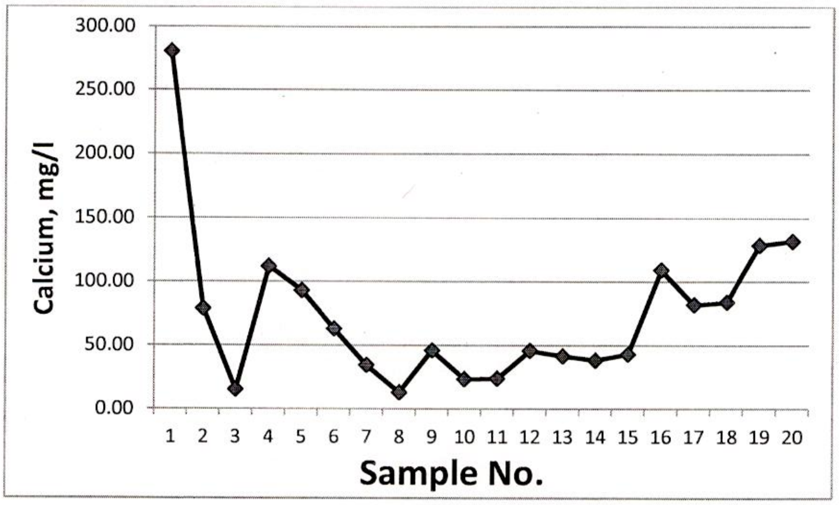


Figure: (f) Calcium values variations of samples

6.1.7 Magnesium: The values of magnesium were in the range 14.21 and 251 mg/l (figure g). About 90% or above samples were having magnesium value within the acceptable limit. However, sample G1 had exceeded the permissible limit.

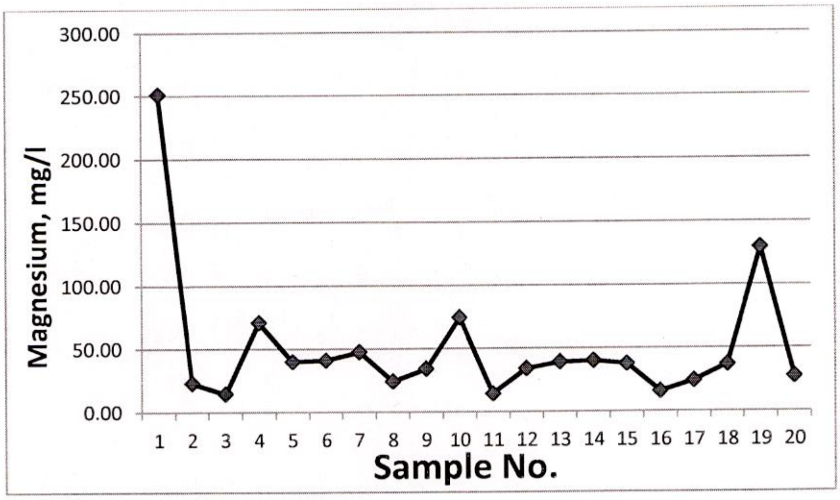


Figure: (g) Magnesium hardness variations of samples

6.1.8 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 23.05 to 281.00mg/l during study period (Figure h). 85% samples were well within the prescribed limit for sodium.

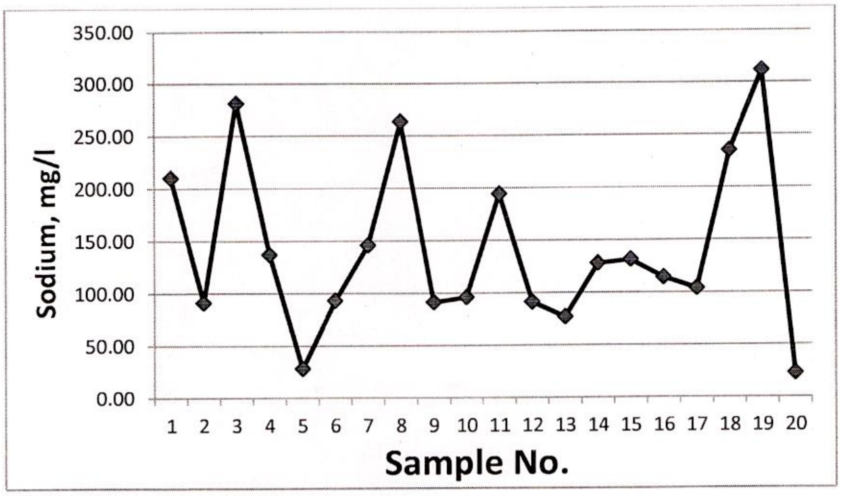


Figure: (h) Sodium variations of samples

6.1.9 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 0.92 to 8.92 mg/l (Figure i). The permissible limit of potassium is 10 mg/l, according to the BIS (2012). Almost every samples were well within the permissible limit.

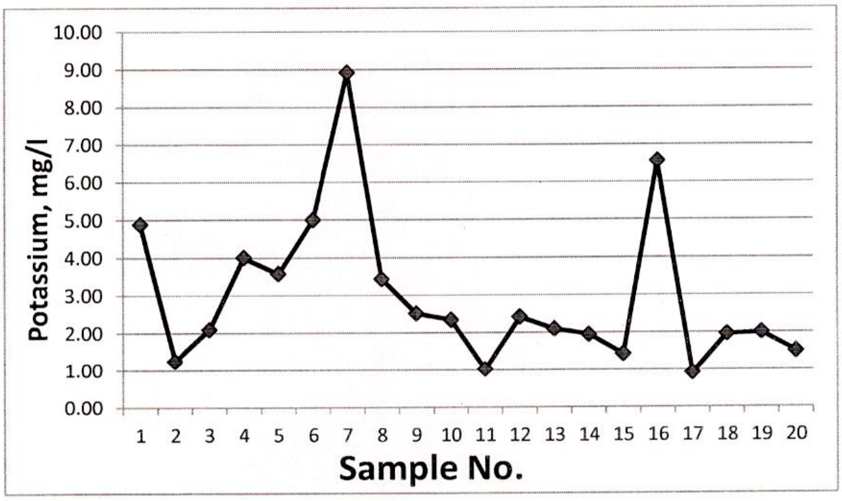


Figure: (i) Potassium variations of samples

6.2.0 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 320 mg/l to 628 mg/l.

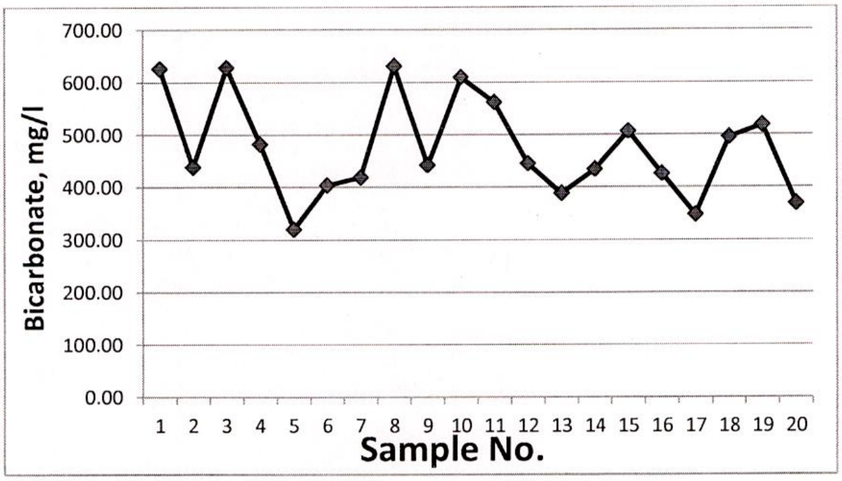


Figure: (j) Bicarbonate variations of samples

6.2.1 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 0.14 to 5.70 mg/l (Figure k). Only 10% of fluoride level was well within the acceptable limit and 15% samples were with within permissible limit. 15 samples exceeded the permissible limit.

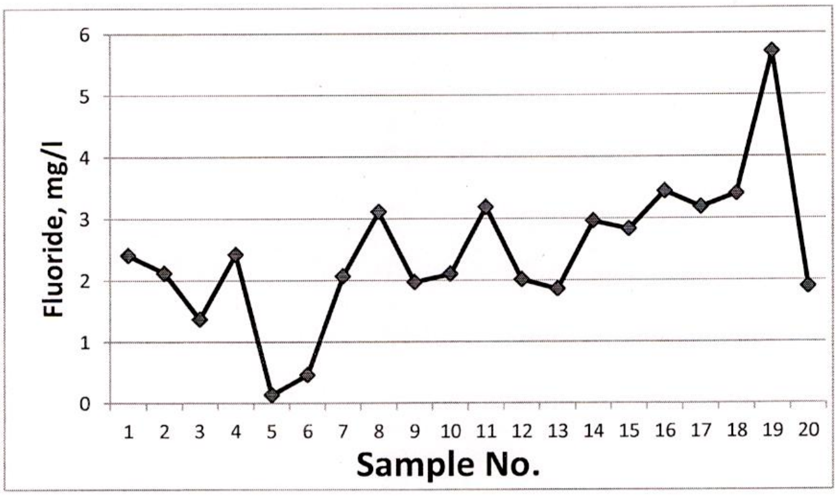


Figure: (k) Fluoride concentration variations of samples

6.2.2Chlorides: 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 6.19 – 731mg/l. Chloride level in 95% samples was well within the acceptable limit.

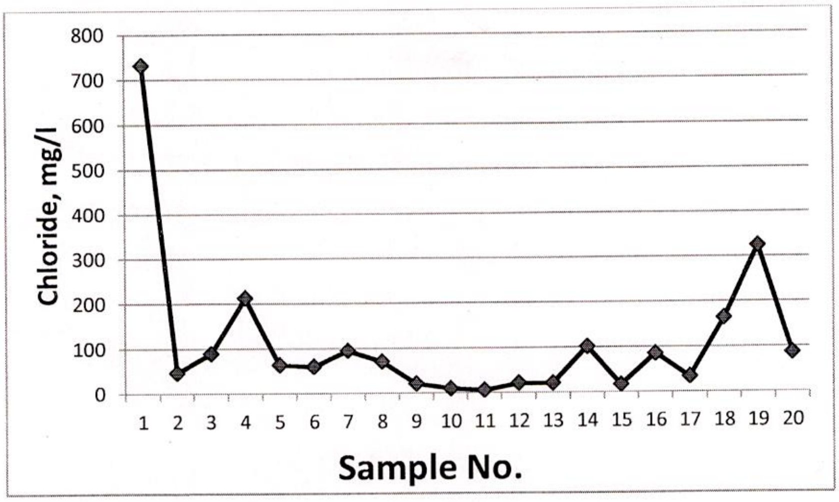


Figure: (m) Chloride concentration variations of samples

6.2.3 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 1.26 mg/l to 551.69 mg/l. Sulphate concentration in all the samples except G-19 were well within the acceptable limit.

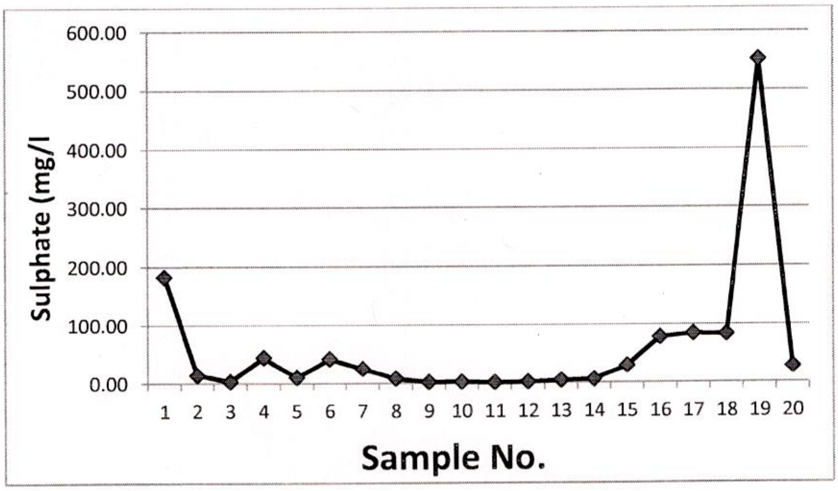


Figure: (n) Sulphate variations of samples

6.2.4 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 0.63 to 260 mg/l Figure (o), and all the samples except station 1were well within the acceptable limit.

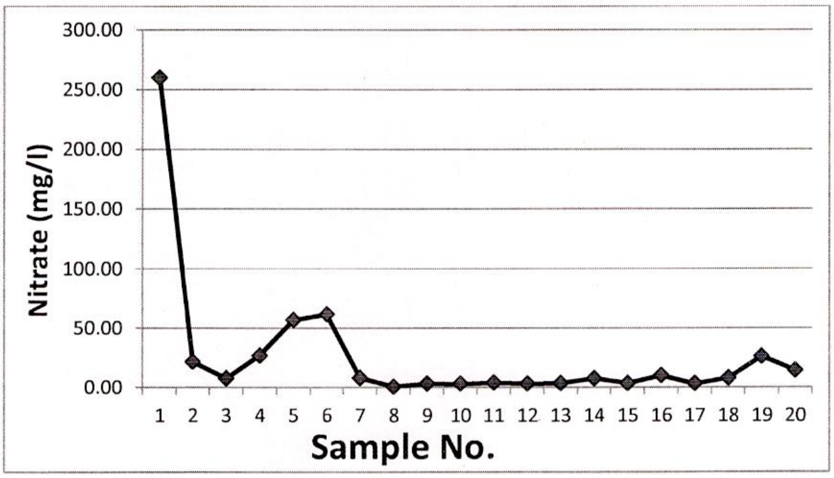


Figure: (o) Nitrate concentration variations samples

6.2.5Trace 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 Are analysed as per standard method.Trace metal is detected with the help Digestion followed by Inductively Coupled Plasma Mass Spectrometry (ICP-MS).

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

	TRACE METALS (CONCENTRATIONS IN PPB)										
Sample ID	Al	As	Cd	Co	Cr	Cu	Fe	Mn	Ni	Pb	Zn
G1	149.72	1.04	0.33	0.55	27.15	2.54	873	22.19	12.51	2.27	20.14
G2	111.45	0.17	0.45	0.53	34.91	6.36	487	21.08	19.23	8.6	664.63
G3	106.38	0.61	0.09	0.46	22.75	3.7	5632	119.08	16.52	6.37	120.8
G4	1396.26	0.75	0.62	1.03	37	4.3	1537	43.12	16.99	2.93	12.92
G5	128.73	0.61	0.18	0.25	17.52	7.22	626	0.14	5.75	4.14	47.4
G6	104.8	2.96	0.42	0.73	28.37	7.6	4260	1181.9	18.31	3.28	52.76
G7	100.75	0.33	0.74	0.5	34.35	5.87	1092	51.62	17.67	4.98	52.48
G8	104.34	0.25	0.95	0.53	30.53	6.93	1517	57..53	17.1	6.88	64.00
G9	68.64	0.62	1.36	0.88	28.43	6.35	498	380.22	15.62	3.13	34.67
G10	98.9	0.21	1.26	0.57	29.79	4.98	1024	41.94	16.26	5.67	39.06
G11	87.98	0.25	1.94	0.62	28.25	5.5	1314	37.58	15.39	4.8	52.81
G12	78.31	0.43	1.65	0.75	28.34	5.92	906	208.9	15.51	3.97	43.74
G13	68.64	0.62	1.36	0.88	28.43	6.35	498	380.22	15.62	3.13	34.67
G14	97.49	2.82	0.56	0.81	34.97	10.95	1142	29.8	17.93	5.98	154.39
G15	70.09	0.25	0.39	0.39	33.06	13.02	642	17.01	15.86	5.14	151.92
G16	134.19	0.39	0.37	0.63	29.39	14.67	882	92.96	14.81	7.63	88.67
G17	51.79	0.21	0.12	0.34	20.57	6.73	1107	67.71	10.9	2.96	24.15
G18	63.54	0.29	0.16	0.14	28.1	9.82	658	30.85	13.21	3.41	31.56
G19	62.75	0.26	0.17	0.45	28.11	10.63	1109	41.19	14.12	4.02	67.06
G20	61.96	0.23	0.18	0.48	28.12	11.43	11559	51.53	15.03	4.62	102.55
Acceptable Limit (ppb)	**30**	**10**	**3**		**50**	**50**	**300**	**100**	**20**	**10**	**5000**
Permissible Limit (ppb)	**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 found that 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 found that all the samples collected from the sources were free 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 obtained data shows that chromium content in all water samples 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 were above the acceptable 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 the water samples analyses except G6, G9 and G13 had less than value below permissible limit.

Nickel: The permissible concentration of nickel in groundwater is 20 ppb. Remaining samples are within the permissible limit. No sample had value above the acceptable 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, all the water samples had value below 10 ppb which is suitable for direct use without further treatment.

Zinc: Zinc is an essential plant and human nutrient. The maximum allowable concentration and permissible concentration of zinc in drinking water are 1500 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 water samples is below 1000 ppb (1 ppm). Hence all the samples collected from all sources are below from maximumpermissible limit for Zinc.

6.2 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 mill equivalent percentages. Total cations and total anions are eachconsidered as 100%. The respective cation and anion locations 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 hydrochemical facies 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 thatgroundwater of the study area is dominated by $Ca-Mg-Na^{+}+K^{+}$ type, whereas anion concentration is dominated by bicarbonate and chloride type.The plot shows that the groundwater samples fall in the field of $Ca-Mg-HCO_3$ types based on hydro-chemical facies.

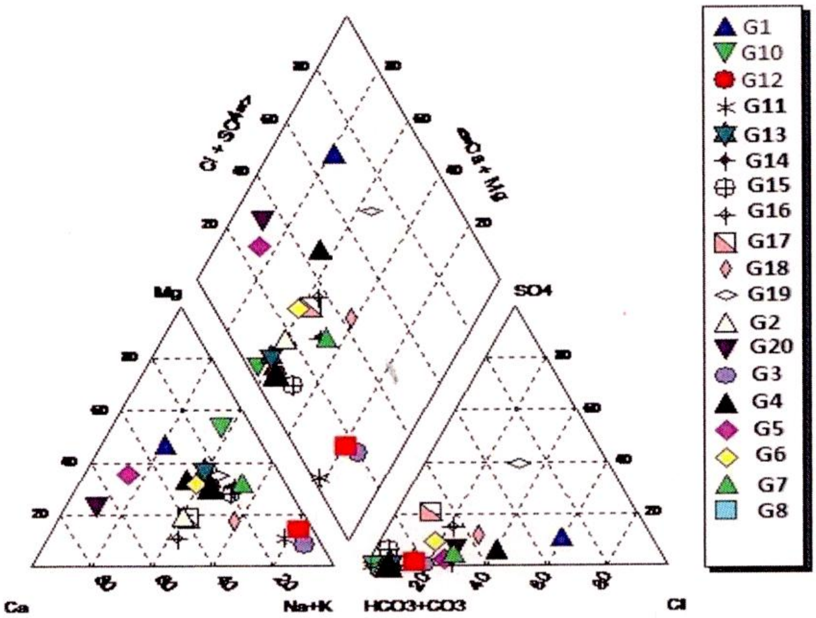


Figure (p) Piper-trilinear plot for the groundwater samples

6.3 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

6.3.1 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:-

$$\text{S.A.R.} = \frac{Na^{+}}{\sqrt{\frac{1}{2}(Ca^{2+} + Mg^{2+})}}$$

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.

6.3.2 Percent sodium (% Na): Percent sodium (% 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	4360	Doubtful	2.20	Low	28.15	Good
G2	994	Permissible	2.32	Low	47.49	Excellent
G3	1305	permissible	12.39	Medium	89.87	Unsuitable
G5	859	permissible	0.62	Low	17.11	Good
G6	1183	Permissible	2.24	Low	46.04	Permissible
G7	1107	permissible	3.79	Low	61.64	Doubtful
G8	1247	Permissible	10.00	Medium	86.68	Unsuitable
G9	842	Permissible	2.49	Low	52.55	Permissible
G10	1052	Permissible	2.19	Low	48.87	Permissible
G11	1032	Permissible	7.79	Low	83.27	Unsuitable
G12	852	Permissible	2.49	Low	52.58	Permissible
G13	1042	permissible	2.06	Low	48.18	Permissible
G14	1036	Permissible	3.45	Low	61.39	Doubtful
G15	963	Permissible	3.53	Low	61.51	Doubtful
G16	1066	Permissible	2.70	Low	46.47	Permissible
G17	950	Permissible	2.59	Low	49.21	Permissible
G18	1789	permissible	5.37	Low	65.63	Doubtful
G19	2450	doubtful	4.63	Low	54.43	Permissible
G20	975	Permissible	0.62	Low	12.51	Excellent

6.3.3 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 low sodicity.

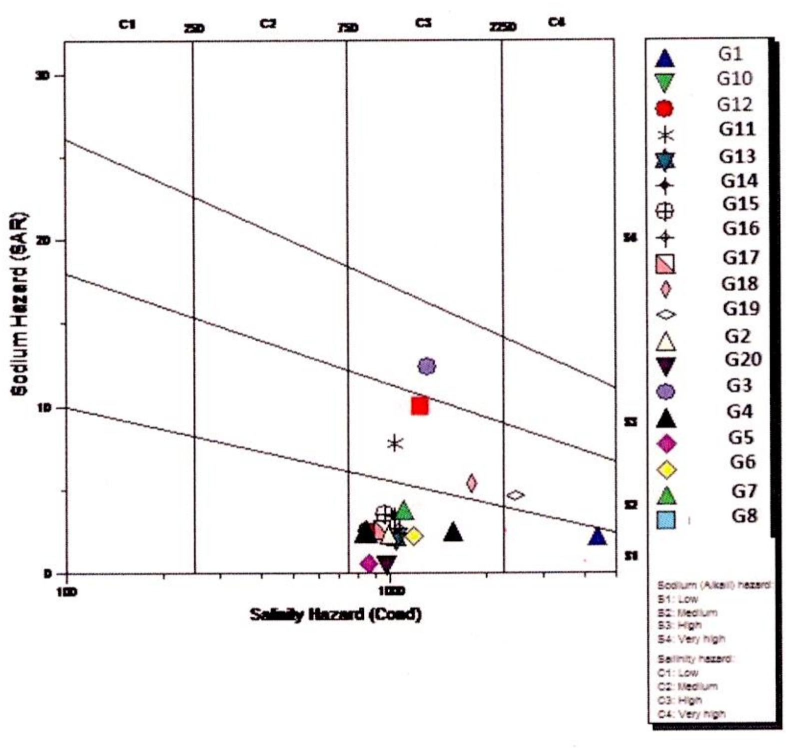


Figure (q) USSL Classification Diagram for Groundwater

6.4 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, CSO_4^-,NO_3^-,magnesium, calcium, Fluoride, Sodium, Bicarbonate and weak positive correlation with potassium. The EC has a strong positivecorrelation with magnesium, TDS, Cl^-, NO_3^-, and sodium and weak correlation with potassium and fluoride. The TDS has a strong positivecorrelation withall the parameterexcept potassium with a weak positive correlation. The Fluoride showed negative correlation with nitrate and positive correlation with sodium and SO_4^-. It shows weak correlation with bicarbonate, calcium magnesium and Cl^-. The Chloride has a strong positive and signification correlation with calcium, magnesium, SO_4^- and NO_3weak correlation withsodium, potassium & bicarbonate. The bicarbonate showed negative weak correlation with potassiumand positive correlation with calcium and NO_3. It showed strong correlation with magnesium and sodium. The sulphate showed max.positivecorrelation with calcium &sodiumand min. with potassium. The nitrate showed strong correlation with Ca^{2+} andMg^{2+} and weak correlation with sodium and potassium.Calcium has positive correlation with all the parameter expect pHhas negative correlation. Sodium also showed positive correlation with all the parameter except pH. Potassium showed negative correlation with sulphate. Potassium has weak correlation with all the parameter.

		PH	EC	TDS	F^-	Cl^-	HCO_3^-	SO_4^{2-}	NO_3^-	Ca^{2+}	Mg^{2+}	Na^+	K^+
PH		1											
turbidity		0.230764											
EC	µS/cm	-0.31423	1										
TDS	mg/l	-0.2781	0.969481	1									
F^-	mg/l	-0.503	0.296815	0.368312	1								
Cl^-	mg/l	-0.27838	0.980415	0.961893	0.254163	1							
HCO_3^-	mg/l	-0.02253	0.476343	0.500663	0.295545	0.370342	1						
SO_4^{2-}	mg/l	-0.44773	0.586119	0.676418	0.686415	0.56705	0.14356	1					
NO_3^-	mg/l	-0.17064	0.862432	0.790024	-0.13569	0.879331	0.24273	0.273842	1				
Ca^{2+}	mg/l	-0.33543	0.81088	0.786882	0.144908	0.869212	0.002308	0.498288	0.835126	1			
Mg^{2+}	mg/l	-0.31752	0.933326	0.896778	0.204835	0.931564	0.567294	0.567294	0.867662	0.795579	1		
Na^+	mg/l	-0.11425	0.512218	0.584469	0.596383	0.423685	0.737473	0.527728	0.117326	0.03884	0.299385	1	
K^+	mg/l	0.014219	0.187385	0.157588	-0.18968	0.252069	-0.06789	-0.00611	0.117326	0.183555	0.21076	-0.0124	1

TABLE 7: Correlation Coefficient Matrix of Water Quality Parameter

The data obtained by chemical analyses were evaluated in terms of its suitability for drinking and general domestic and irrigation uses.

6.5 Suitability for Drinking and General Domestic Uses

To assess the suitability for drinking and public health purposes, the hydrochemical parameters of the groundwater of the Jhansi district area were compared with the prescribed specification of Indian standard for drinking water (IS:10500, 2012). **Table 8** shows that most of the water samples of the study area are marginally suitable for direct uses in drinking and domestic purposes.

pH of the groundwater samples (7.25 – 7.89) are well within the safe limit prescribed for drinking water.

The values of Total Dissolved Solid (TDS) exceeded IS-10500 (2012) desirable drinking water limit (500 mg/l) in 75% of the total samples. However, it is well below the maximum permissible limit of 2000 mg/l, except in 5% groundwater samples. The total hardness (TH) of the analysed sub-surface water of the study area varies between 4.88 mg/l and 853.96 mg/l (Avg. 309.08 mg/l) indicating medium to hard types of groundwater. The analytical data indicate that 40% groundwater samples have hardness higher than 300 mg/l in the study areaand can be categorized as a hard type of water. Hardness value exceeded the maximum permissible limit of 600 mg/l in 5% of the groundwater samples. Hard water prevents formation of lather with soap and increases the boiling point of the water. The high hardness may cause precipitation of calcium carbonate and encrustation on water supply distribution systems. The long term consumption of extremely hard water might lead to an increased incidence of urolithiasis, anencephaly, parental mortality and cardio-vascular disorders.

Fluoride (F^-) is an essential element for maintaining normal development of healthy teeth and bones. However, higher F^- concentration causes dental and skeletal fluorosis such as mottling of teeth, deformation of ligaments and bending of spinal cord. Concentration of F^- exceeds the permissible limit of 1.5 mg/l in about 85% of the groundwater samples of the study area. Concentrations of SO_4^{2-} are also exceeding the drinking water the permissible level of 400 mg/lin 5% of the total 20 analysed samples. Cl^- concentrations are found above the desirable levels of 250 mg/l for drinking water 10% of total samples,no sample has been found above permissible i.e. <1000 mg/l. Concentration of NO_3^- is higher than the recommended level of 45 mg/lfor drinking water 1.5% of total samples of the study area. Excessive NO_3^- in drinking water can cause a number of disorders including methaemoglobinaemia in infants, gastric cancer, goiter, birth malformations and hypertensions.

Calcium is an essentials element for bone, nervous system and cell development. One possible adverse effect from ingesting high concentration of Ca^{2+} for long periods may be an increased risk of kidney stones. Among the cations, Na^{+} is most important ions for human health. A higher sodium intake may cause hypertension, congenial heart diseases, nervous disorder and kidney problems. The guideline value for sodium concentration in drinking water is 200 mg/l. Concentration of Na^{+} exceeds the recommended limit of 200 mg/l only in 20% of the total analysed groundwater samples.

TABLE 8: Statistical summary of measured parameters of Moth block, Jhansi groundwater and its comparison to Indian standards for drinking water (IS-10500, 2012)

Parameters	Min.	Max.	Avg.	*Maximum Desirable*	% Highest permissible Limit	*% Exceeded Desirable Limit*	*Exceeded Permissible Limit*
General Parameters (mg/l)							
pH	7.25	7.89	7.56	6.5-8.5	8.5-9.2	Nil	Nil
EC ($\mu S\ cm^{-1}$)	842	4360	13360	-	-		
Turbidity (NTU)	0.30	23.7	4.09	1	5	20	10
TDS	385	2488	756.69	500	2000	75	5
F^{-}	0.14	5.70	2.43	1.0	1.5	5	85
Cl^{-}	6.19	731	113.01	250	1000	10	-
HCO_3^{-}	320	631.2	474.68	-	-		
SO_4^{2-}	1.26	551.7	60.20	200	400	-	5
NO_3^{-}	0.63	260	26.67	45	NR	1.5	-
Ca^{2+}	12.83	280	74.37	75	200	40	5
Mg^{2+}	14.21	251.0	51.07	30	100	60	10
Na^{+}	23.05	311.20	142.35	-	-	-	-
K^{+}	0.92	8.92	2.99	-	-	-	-

7.0 CONCLUSION

Based on the analysis of Groundwater samples of the Jhansi district, following conclusions are drawn-

1. The groundwater samples were alkaline in nature and medium to highly saline. The spatial differences between the EC and TDS values reflect the wide variations in lithology, surface activities and prevailing hydrological regime.

2. The groundwater chemistry of Jhansi district is dominated by Ca, Mg, Na, and K. The dominance of these ions is in the order Ca> Na > Mg > K. Alkali cations dominate over alkaline earths (Ca and Mg) in many samples and on average Ca alone constitute 43% of the total cations (TZ^+) in the groundwater of the area.

3. The anion chemistry of the analysed samples shows that HCO_3, Cl, NO_3 and$SO_4$are the dominant anions and follows the abundance order of HCO_3>Cl>NO_3>SO_4^->Fin majority of the groundwater samples.

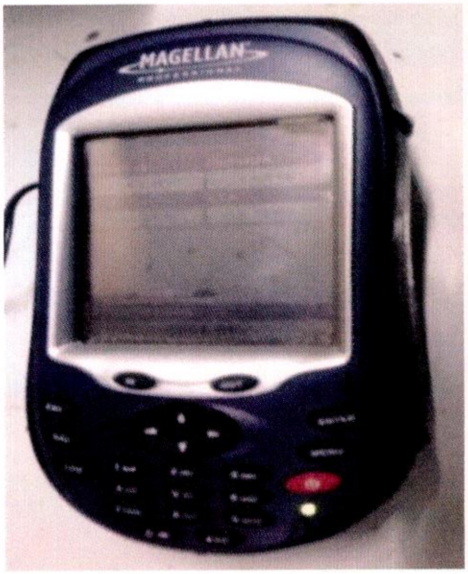
4. The Piper plot of chemical data revealed that the major water types in the studied locations were Ca-Mg-HCO_3, Na-Mg-HCO_3, Na-K-HCO_3 and Na-K-HCO_3-Cl. The facies mapping approach applied to the present study shows that Ca-Mg-HCO_3 is the dominant hydrogeochemical facies and the minor water types are Ca-Mg-SO4-Cl and Na-K-HCO_3.

5. On critical examination of the data, it can be seen that certain major ions concentration in groundwater exceeded the desirable as well as permissible limit recommended for drinking water at many places. Most of the water samples of the study area are marginally suitable for direct uses in drinking purposes.

   Application of Wilcox plot relating electrical conductivity to sodium percent on the analyzed samples, it was concluded that groundwater of the Jhansi district is excellent to permissible quality, which can be used for irrigation purposes except few samples.

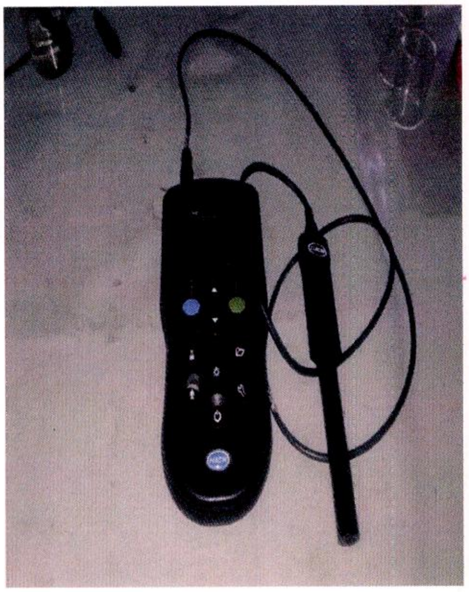
6. Based on US salinity diagram, it can be concluded that most of the water samples fall in the category C3S1, C3S2, C3S3, C4S1 and C4S2 indicating medium to high salinity and low alkalinity.

LABORATORYEQUIPMENT/APPARATUS USED DURNING WATER SAMPLE ANALYSIS

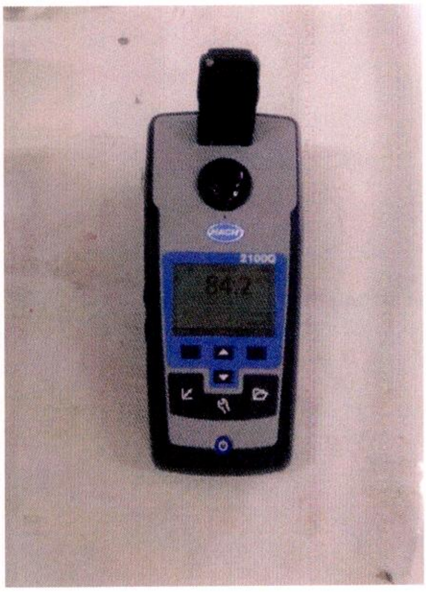


GPS Instruement

Collected Water Samples

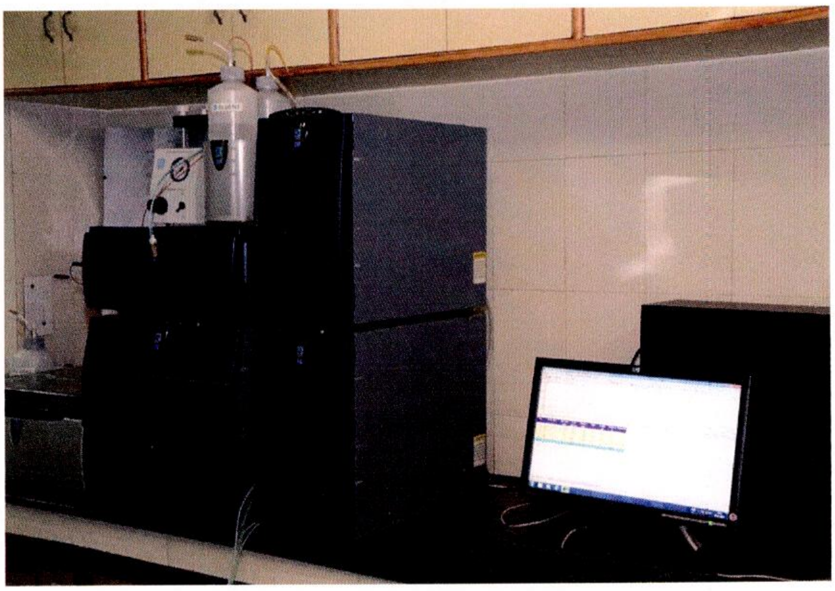


pH and EC Hach-Meter



Turbidity Meter

Filtering of the sample after digesting



Ion Chromatograph (Dionex-ICS 5000)

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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

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