STUDY OF FLUORIDE CONTAMINATED GROUND WATER QUALITY AND HEALTH RISK ASSESSMENT OWING TO BIOACCUMULATION OF FLUORIDE IN CULTIVATED CROPS AND FODDER PLANTS

A Thesis Submitted to
Babu Banarasi Das University
for the Degree of

Doctor of Philosophy
in
Environmental Science

By
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Under the Supervision of
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June, 2018

Certificate of the Supervisor(s)

This is to certify that the thesis, entitled **"Study of Fluoride Contaminated Ground Water Quality and Health Risk Assessment Owing to Bioaccumulation of Fluoride in Cultivated Crops and Fodder plants"** submitted by **Pokhraj Sahu** for the award of **Degree of Doctor of Philosophy** to Babu Banarasi Das University, Lucknow and CSIR- IITR, Lucknow, are record of authentic work carried out by **Pokhraj Sahu** under my supervision. To the best of our knowledge, the matter embodied in this thesis is the original work of the candidate and has not been submitted elsewhere for the award of any other degree or diploma.

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DECLARATION BY THE CANDIDATE

I, hereby, declare that the work presented in this thesis, entitled **"Study of Fluoride Contaminated Ground Water Quality and Health Risk Assessment Owing to Bioaccumulation of Fluoride in Cultivated Crops and Fodder plants"**. in fulfillment of the requirements for the award of Degree of Doctor of Philosophy of Babu Banarasi Das University, Lucknow is an authentic record of my own research work carried out under the supervision of **Dr. Pramod Kumar Singh** (Associate Professor) Department of Environmental Science, Babu Banarasi Das University, Lucknow, India- 226028 and **Dr. Ganesh Chandra Kisku** (Chief Scientist and AcSIR Professor) Environmental Monitoring Laboratory, Environmental Toxicology Group, CSIR-Indian Institute of Toxicology Research (CSIR-IITR), Vishvigyan Bhawan, 31 - MG Marg, Lucknow-226001, India.

I also declare that the work embodied in the present thesis is my original work and has not been submitted by me for any other Degree or Diploma of any university or institution.

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PREFACE

Groundwater is a key source of drinking water among freshwater resources and their need for different purpose is growing day by day due to rapid growth of population, rapid urbanization with change in lifestyle, growing industrialization and agricultural activities, which have deteriorated the surface water and groundwater quality in the last few decades. Arsenic and fluoride containing minerals spread out more than twenty states of the country and both are largely contaminate these precious resource. WHO have reported in 2012, 748 million peoples are yet relied on contaminated drinking water resources worldwide. 200 million peoples are face serious issue of surplus fluoride in drinking water in the region of 27 country across the global and 66.64 million people in India.

The present research work done in Lalganj Tehsil of district Raebareli, UP (India) situated at Indo-Ganga basin. For this study sixty water samples were collected during pre and post-monsoon seasons for two years (2016 and 2017) from three block (Lalganj, Sareni and Khiron) of Lalganj Tehsil of district Raebareli, UP (India). Wheat, Rice, cultivated and fodder crops were collected from each block of Lalganj tehsil for the risk assessment due to total intake of fluoride. Total 24 cultivated crops and fodder plant sample collected during different season from each block.

For the identification of seasonally variation in groundwater, the water sample were collected in pre and post-monsoon (2016 and 2017) continuously. Sampling stations were selected considering the distance from each sampling location, utilization of hand pum and bore well, utilization in drinking purpose. These samples were analyzed for various parameters in the laboratory according to standard procedures of APHA and Indian Standard.

Various hydrochemical parameters such as pH, electrical conductivity (EC), , total dissolved solids (TDS), turbidity, total hardness (TH), total alkalinity (TA), nitrate (NO_3^-), sulphate (SO_4^{2-}), chloride (Cl^-), fluoride (F^-), calcium (Ca^{2+}) magnesium (Mg^{2+}), sodium (Na^+), potassium (K^+) and trace metals such as zinc, iron, nickel, manganese, lead, copper, cobalt, chromium and cadmium were analyzed.

Groundwater forms the major resource of fresh water and provides about 88 % of the drinking water need in rural areas of India. The population has widely dispersed in the rural area where accessibility of infrastructure for the treatment and transportation of surface water dose not possible. Water is an important component and a key factor to the maintenance of a well-balanced environment. The groundwater quality of Lalganj tehsil was diverse among all block with reference hydrochemical data. In this research, groundwater hydrochemical data (hydrochemical and metallic constituent) were compared with **IS (10500)** and **WHO (2011)** drinking water standard for suitability of groundwater to drinking purpose.

In this hydrochemical investigation for the evolution of drinking water quality with respect to physico-chemical parameter following parameter like pH, turbidity, chloride (Cl^-), nitrate (NO_3^-), sulphate (SO_4^{2-}), calcium (Ca^{2+}) magnesium (Mg^{2+}), sodium (Na^+) were found the well within the desirable limits of drinking water standard. But following parameter such as electrical conductivity (EC), total dissolved solids (TDS), total hardness (TH), total alkalinity(TA), fluoride (F^-), potassium (K^+) were exceeded the desirable limits of drinking water standard, in this parameter fluoride can causes significant effect on human health. The elevated concentration of fluoride found in groundwater of Lalganj, Sareni and Khiron block due to occurrence of fluoride bearing minerals in geology of the study area. The elevated concentration of fluoride found in groundwater of Lalganj, Sareni and Khiron block due to occurrence of fluoride bearing minerals in geology of the study area. 75, 42.5 and 45 % groundwater samples of Lalganj, Sareni and Khiron block exposed the concentration is above the guideline limit (1.50 mg/L) of WHO during 2016 while 80, 57.5 and 57.5 % groundwater sample in 2017.

For the evolution of drinking water quality with respect to trace metals such as zinc, nickel, manganese, lead, copper, cobalt, chromium and cadmium, the groundwater of the study area (all block) were well within the prescribe standard of drinking water quality. But with respect to iron in the groundwater samples, of Sareni block were found more than the desirable limits of drinking water standard. Iron may causes to negative health effect on rural inhabitants. Long term consumption of drinking water with high concentration of iron may cause to liver diseases.

Investigation of temporal variation in groundwater quality was done with respect to physico-chemical parameter in groundwater of Lalganj tehsil. The results revels that the concentration observe increasing trends from pre to post-monsoon for pH, electrical conductivity (EC), , total dissolved solids (TDS), turbidity, total hardness (TH), total alkalinity (TA), nitrate (NO_3^-), sulphate (SO_4^{2-}), chloride (Cl^-), fluoride (F^-), calcium (Ca^{2+}) magnesium (Mg^{2+}), sodium (Na^+), potassium (K^+). While the t-test was applied in this physicochemical parameter with respect to pre-monsoon and post-monsoon. Significant variation were found in pH, electrical conductivity (EC), , total dissolved solids (TDS), turbidity, total alkalinity (TA), nitrate (NO_3^-), sulphate (SO_4^{2-}), chloride (Cl^-), calcium (Ca^{2+}). Three proposed process (ion exchange, carbonate reaction and oxidation reduction reaction) are the dominant process that processed in aquifer of the study area and affect the quality of water. Temporal variation of trace elements in groundwater quality was done with respect to physic-chemical parameter in groundwater of Lalganj tehsil. The results revel that the concentration observes decreasing trends from pre to post-monsoon. the results proposed to dilution of trace mental due to recharging of huge amount of rain water during rainy season.

Piper diagram presenting cation the groundwater of the Lalganj, Sareni and Khiron block was sodium type water indicating the cation exchange of $Ca2+$ with $Na+$ while calcium type in control area. More than 75 % sampling locations of Lalganj and Sareni block have observed Na-Mg-HCO3- type of groundwater while sampling locations exceeded from 90% in Khiron block. The groundwater type of control area was found Ca-Mg-HCO3- type water in more than 80 % sampling locations. This is because of the dissolution of limestone in the sampling location.

Statistical approaches conducted for the assessments of groundwater quality such as water quality index (WQI), heavy metal pollution index (HPI), factor analysis/principal component analysis, spearman correlation matrix and hierarchical cluster analysis.

The result of WQI approaches reveals that WQI found ~20 % samples in excellence class, ~75% samples in good class, and ~5% samples in poor class. The result of HPI approaches disclosed that ~95 sample found in low class and ~ 5% samples calculated in Medium class. Principal component analyses (PCA) was conducted to expose the main variable or source identification of highly loaded variables in conducted parameter of groundwater. PCA find out four factors that affected the quality of groundwater during pre-monsoon in all block and in post-monsoon found four factors for groundwater of Lalganj and Sareni block and three factors in Khiron block with respect to physic-chemical variable.

Hierarchical cluster analysis illustrates major 9 clusters to 60 samples of Lalganj block based on similarity and dissimilarity for physic-chemical parameter and 8 cluster for metallic ingredients. Correlation metrics reveals that in pre-monsoon, correlation of fluoride significant at 0.01 levels with EC, TDS, total alkalinity, sulphate and sodium while in post-monsoon, significant with EC, TDS, TA, Cl^-, sulphate and sodium. This parameter shows highly affinity with fluoride.

The study also done to identify the bioaccumulation capacity of fluoride in fodder and cultivated crops. Results shows that maximum F^- found ***46.09***, 43 and 45.70 mg/kg in ***Raphanus sativus*** (Radish) in Lalganj block, Sareni block and Khiron block while 0.34 mg/kg found in control area.

Hazard Index (HI) was calculated for identify the human health risk due to possible intake of fluoride via different dietary sources. HI was calculated with reference to central tedency exposure (CTE) and reasonable maximum exposure (RME) scenario of human age was grouped in 3 class 3-6 years, 7 -18 years and 19-70 years. According to Canada Act Annual Report (2004) If HI >1 than remedial measures should be taken for avoiding of excessive intake of fluoride. Results revel that the HI value found more than the recommended value in all block while below in control area for both CTE and RME scenario.

The noncancerous lifetime hazards ($HI_{cumulative}$) also calculated in population for 3 to 70 years. $HI_{cumulative}$ was found 8.6525, 6.4412 and 10.8020 for Lalganj, Sareni and Khiron block. The population of Lalganj, Sareni and Khiron block exposed to cumulative life time risk, which were 4.26, 3.17 and 5.31 times higher than to inhabitant of Control area in CTE scenario. The population of Lalganj, Sareni and Khiron block exposed to cumulative life time risk, which were 7.06, 4.09 and

15.10 times higher than to inhabitant of Control area in RME scenario.

The water quality and human health are closely linked to each other. In India, The quality of groundwater is mainly contaminated by natural or geogenic contamination. So it is absolutely necessary to determine the quality of water before it is used for human consumption. The water used for drinking purpose should be free from toxic and hazardous elements. Water pollution not only affects water human health, it also have a greater sources for development of economic, and social prosperity. Furthermore water impacts human health; both directly and indirectly.

Continuous using of groundwater for drinking purpose without its amelioration by population of the study area may be exposed to very high fluoride content through drinking water and may suffer from dental fluorosis, skeletal fluorosis and non-skeletal fluorosis. Present examination deal with fluoride containing groundwater quality and possible intake of fluoride via dietary sources. This study could help to generate existing baseline data about groundwater quality of the Ganga basin Lalganj Tehsil, which will bring alertness to people about its purity and quality importance and also help to government of UP for installing the de-fluoridation setup. Proper measures such as amelioration of fluoride before use and rainwater harvesting suggested in this area.

DEDICATED
TO MY
FAMILY AND
TEACHERS

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CHAPTER 1

INTRODUCTION

Water is an elixir for life because it is an essential and greater constituent of all living things. Water resource has played a critical and very important role throughout the history in the growth and development of human civilization. The quality of water is a combination of its physical, chemical, biological and radiological characteristics that make healthful resource for human and all animal. Availability of excellent quality of drinking water is primary right for every animal and human beings. Water is an important component and a key factor to the maintenance of a well-balanced environment **(Ntengwe 2006)**.

Water holds unique chemical characteristic because of its polarity and hydrogen bond, its able to dissolve various compounds, elements e.g. fluoride, arsenic, mercury and toxic metals etc **(Arkoc 2014)**. Because of this nature, it is easily contaminated through natural and man-made activities **(Mendie 2005)** so that water quality assessment is needed to understand its suitability for drinking and different purpose **(Sajil Kumar 2012)**. The main elements of nature is comprises of air, water, soil, flora and fauna, these elements are interconnected and interdependent on each other. Water is abundantly available substances in nature, covers 71% of the Earth's surface. Earth's surface water is largely found in seas and oceans contribute 97%, 2 % Frozen at the poles or in glaciers, both are futile but only 1 % water available for plant and animal uses. The United Nations has announced the years of 2005-2015 as the International Decade for action on "**Water for life**".

In modern times, water resources have critical importance in the economic growth of all contemporary societies. Therefore, water resource assessment and sustainability consideration are of utmost importance, especially, in the developing countries like India where water is commonly of economical and social significance. Access to safe drinking water remains an urgent necessity, as 30% of urban and 90% of rural Indian population still depend completely on untreated surface or groundwater resources **(Kumar et al. 2005).** Water quality plays an important role in promoting agricultural production and standard of human health. While access to drinking water in India has increased over the past decades but the tremendous adverse impact of unsafe water on health continues. The inaccessibility of safe drinking water and scarcity is the major problem in world including India, where ground water is main sources of drinking purpose. It containing dissolved ions (As, Hg, U, F, NO_3^- SO_4^{2-} and heavy metals) beyond the permissible limit is harmful and creates lots of water born disease.

WHO have reported worldwide 748 million peoples are still relied on unimproved drinking water sources in **2012**, almost 27 nations and 200 million people across the global face issues of excess fluoride in drinking water and 66.64 million people in India. India is the 7th biggest, and the second most extremely populated country in the world with a geography of 3.29 million square km with more than 1.04 billion people, serving as a home for a sixth of humanity. Since 2020, total population of India will exceed 1330 million and rate of water consumption is expected to increase 20–40%**.** India enlisted, 16% of the world's population but with just 4% of its water resources **(Planning Commission 1996, 2002)**.

1.1 Groundwater quality

Groundwater is one of the most important, precious renewable natural resources beneath the earth's surface. Groundwater contributes 0.94 % of total water balance and 30 % of world's fresh water resource. It is one of the purest forms of water and completes the requirement of drinking water. Groundwater is a key source of drinking water among freshwater resources and their need for different purpose is growing day by day due to rapid growth of population, rapid urbanization with change in lifestyle, growing industrialization and agricultural activities, which have deteriorated the surface water and groundwater quality in the last few decades **(Gajbhiye et al. 2014; Sharma et al. 2014).** Groundwater is using for drinking water as well as agriculture, industrial and other household activities. Thus it become chief sources for requirement of assorted sectors in this country, it's especially to rural population and plays a very important function in development in India's economy. Groundwater forms the major resource of fresh water and provides about 88 % of the drinking water need in rural areas of India. The population has widely dispersed in the rural area where accessibility of infrastructure for the treatment and transportation of surface water dose not possible **(Jain et al. 2010).** Indian population will exceed 1330 million since 2020 and rate of water consumption is predictable to increase 20–40%. India will contribute sixteen percent of the global population but with just 4% of its water resources **(Planning Commission 1996, 2002)**.

Groundwater quality encompass of a physical, chemical, biological and radiological characteristic that make groundwater to healthful resource for human and another living things. Physical characteristic of water include temperature, turbidity, color, taste, order and total dissolved solid in groundwater. Temperature also affects the dissolution of minerals in groundwater. A very good quality of groundwater contained colorless, tasteless, without order and have dissolve solids up to 500 mg/L. Most of the water born disease caused by biological contamination includes micro-organism, protozoa, algae and fungi, bacteria and viruses. The presence of microbes in groundwater is very common. Nowadays, biotechnologist or hydrologist also increases the population of microbes during bioremediation of contaminated soil and water. Mining and natural occurrence of radio-active element (uranium,) that emitted different types of radiation (α, β and γ radiation) which create abnormalities and it also cause cancer. The best qualities of water have free or without any biological and radiological character. Presence of inorganic and organic constituent in groundwater makes chemical characteristic of water. The present study focused on chemical characteristic of water. Groundwater contain many minerals because of it's a universal solvents properties. Minerals dissolved in groundwater come out from infiltration process when contact with permeable material such as soil particle, mud, sediment and rock. They are referred to as dissolved solid and total mass of dissolved minerals referred as total dissolved solid. Pesticides, insecticides, phenolic compound, glucose, dissolved in water depend on various source are represents organic constituent. Inorganic constituents divided in to three categories (major, minor and trace) based on their concentration of dissolution in groundwater. Major components; elements or inorganic content have greater than 5 mg/L I.e. sodium, calcium, magnesium, chloride, sulphate, bicarbonate, and silica. Minor components; concentration of dissolve minerals have 0.01 to 10.0 mg/L i.e. fluoride, boron, nitrate, iron potassium, strontium and carbonate. Trace contents represents less than 0.01 mg/L i.e. copper, nickel, arsenic, lead, chromium, cobalt, phosphate gold, uranium, cesium, bismuth, scandium, gallium, silver, zinc, zirconium, iodide, bismuth, tin, platinum, thallium, beryllium, barium, germanium etc. the concentration of this major, minor and trace inorganic elements are controlled by accessibility of element in the soil, types of minerals, and geological formation.

Their solubility is depending on rate of geochemical process. Sodium, magnesium, calcium, chloride, bicarbonate and sulphate are major ions that normally consists 90% of the total dissolved solids.

1.2 Groundwater contamination

Groundwater is one of the renewable resources, because of it universal solvents nature it dissolved many minerals. Introducing or dissolution of any undesirable or elevated concentration of physical, chemical, radiological and biological materials into groundwater is called groundwater contamination. Groundwater quality or its contamination largely depends on past geology, rainfall, climate condition, land use and anthropogenic activities like disposal of solid waste and leaking of municipal wastewater, excessive application of fertiliser, and industrialization. Naturals and manmade activities both are contributing to contamination of groundwater. In India, natural weathering is chief source contamination of groundwater in most of the rural area while urban areas because of anthropogenic activities. India occupies 2.4 percent of the total land area of the world, but supports 16.7 percent of the world population. India is largest user of groundwater in the globe and last 20 years most of the aquifer will be in critical condition because of excessive exploitation of these renewable resources.

Arsenic and fluoride containing minerals spread out more than twenty states of the country and both are largely contaminate these precious resource. In India, Arsenic is second most elements that degrade the quality of groundwater and affect larger population of West Bengal, Bihar, Chhattisgarh, Assam, Jharkhand, Manipur, Uttar Pradesh, Punjab, and Haryana. In some part of India, Arsenic mostly found in alluvial aquifer but in Chhattisgarh it's reported in genesis aquifer. Black foot disease is chief symptom of contamination in drinking water because of its carcinogenic in nature. Salinity does not create huge problems as compare to other geogenic contaminants. Salinity observed in Rajasthan, Gujarat, central part of Chhattisgarh, Haryana, coastal regions of southern Indian. Elevated concentration of nitrate in groundwater can directly affected to infant baby. Nitrate came out from biological nitrification of organic compounds. The chief sources of nitrate in groundwater from anthropogenic activities like septic tanks, excessive application of fertilizers. It also depends on thickness of vadose zone, chemical composition of atmosphere, dissolved oxygen.

Iron is common constituents in groundwater in the form of soluble ferrous ions and it came out dissolution from hematite, sulphide and magnetite ore of metamorphic and sedimentary rocks. It is also common constituents in soil. Iron play important role in the formation of haemoglobin in blood. Manganese is also common in groundwater and has similar hydrochemistry with iron. The elevated concentration of manganese found in Uttar Pradesh, Tamil Nadu, Bihar, and Orissa. Chromium is trace elements, because of anthropogenic activities it have been reported in groundwater of industrial region but Chromium in groundwater of Sukinda area of Orissa represents naturals origin from chromites minerals.

However, the problem of environmental pollution has been increases day by day due to rapid exploitation of these precious resources can causes environmental degradation. WHO have reported in 2012, 748 million peoples are yet relied on contaminated drinking water resources worldwide. 200 million peoples are face serious issue of surplus fluoride in drinking water in the region of 27 country across the global and 66.64 million people in India **(WHO 2014)**. Heavy metals present in trace concentration play a most important role in the metabolism and healthy growth of flora and fauna. Certain essential and beneficial elements such as Na, K, Ca, Mg, Fe, Mn, Cu, Co, and Zn are required for growth and strengthens of organisms in precise quantity but their higher concentrations produce several toxicological impacts on organs of human such as kidneys, liver, bones and a lot of severe health disarray **(Jarup 2003; Duruibe et al. 2007; Muhammad 2011)** include hypertension, abdominal pain, headache, intellectual disability, irritability, fatal cardiac arrest, sideroblastic anemia, nerve damages and carcinogenesis. Erosion and weathering of close relative rocks, both process are chief sources for dissolution of heavy metals in the groundwater **(Nouri et al. 2006; Leung and Jiao 2006)**. Many states of India faced problems due to high level of salinity and hardness in groundwater *ie.,* coastal areas of Andhra Pradesh, Tamil Nadu, Gujarat, NCR (National Capital Region of Delhi) and Western Uttar Pradesh. Andhra Pradesh, Jharkhand, Rajasthan, Goa, and Orissa faced the higher concentration of iron and nitrate in groundwater **(Srikanth 2009)**. According to **GCWB (2014)** report, more than 50 % of the districts found elevated concentration of fluoride in Andhra Pradesh, Rajasthan, Tamil Nadu, Gujarat, and Uttar Pradesh. In India, excessive exploitation of groundwater has put 66 million people at risk of a high level of fluoride in 22 states and around 10 million people in 6 states at risk of arsenic **(Ghosh 2007)**.

1.3 Fluoride contamination, occurrence and health outcome

Fluorine, derived from the latin word "*Fluere*" that means "to flow" **(Dolottseva 2016)**. Fluorine is member of the halogen group and is one of the most reactive of all chemical elements. Fluorine and fluoride are interchangeable as generic term and cannot be found free form in nature because of its strongly electronegative. Georgius agrcola a German physician discovered in the early 1500s that fluorine as an element and becauses of its highly negativity, does not occurs in elemental state in nature **(Hong et al. 2016)**. Fluoride is precious element in specific concentration for the developments, protection, and strengthens of teeth and bones. Approximately 96% of fluoride in the human body is found in bones and teeth. Tooth enamel and bones are chiefly built up of calcium phosphate or hydroxyapatite $[Ca_5(PO_4)_3(OH)]$. Fluoroapatite prevents to dental caries, acid release from sugar-consuming bacteria and provide strengthens to tooth and bones. After ingestion of Fluoride through diet and drinking water, F^- ions replaced the hydroxide ions of hydroxyapatite and form stable fluoroapatite $[Ca_5(PO4)_3F]$ due to its hyper electronegative **(Khandare, 2013; Narsimha et al. 2013)**. Fluoride in drinking water has both useful and detrimental effects on human health with only a narrow range between intakes that are associated with these effects. Fluorine has a affluent chemistry, ingredient and domains contents in organic and inorganic compounds. It easily joint with metals, non-metals, metalloids, noble gases and habitually found an oxidation state of -1 **(Riedel and kaupp 2009)**.

1.3.1 Occurrence of fluoride

Fluride is 13 most abounded element and chiefly occurs in the earth's crust where they are found in rocks, coal, clay, and soil are released into the environment naturally through the weathering of minerals, in emissions from volcanic ash and in marine aerosols **(Tylenda 2011)**. Fluoride enrichment in groundwater takes place mainly through leaching and weathering of the Fluoride containing minerals present in past geology **(Shaji et al. 2007; Srinivasamoorthy et al. 2008; Ramachandran et al. 2012; Subba Rao and Rao 2003)**. The release of fluoride to groundwater is dependent on chemical and physical processes that take place between the groundwater and its geological environment containing various fluoride-bearing minerals, e.g., fluorite, hornblende, biotites, topaz, apatite and present in their corresponding host rocks such as granite, syenite, gneists, charnockites, basalt, and khondalites **(Subba Rao 2003; Reddy et al. 2010; Deepu and Shaji 2011; Chidambaram et al. 2013; Manikandan et al. 2014)**, scheelite, fluorspar, cryolite, fluorapatite, fluormica, epidote, and tremolite **(Brindha et al. 2001)**. In India, except geogenic fluoride contamination human activities also contaminate their surrounding environment such as coal based thermal power plant, excessive use of chemical fertilizers in agricultural field **(Srinivasamoorthy et al. 2012; Subba Rao 2014 and Subba Rao et al. 2017)** a few opaque minerals are also present in pockets of sand **(Kumar and Saxena, 2011)**. Dissolution of fluoride is dependend on calcium content, pH conditions where sodium bicarbonate dominates the ground water composition and hydrological properties (e.g., residence time) as well as climatic conditions (e.g., evapo-transpiration, precipitation) and soil conditions (e.g., pH, soil type). Thus fluoride-rich ground waters are often associated with low calcium concentrations due CaF_2 formation, which is poor soluble in water.

1.3.2 Health effect of excessive Fluoride in drinking water

According to **WHO (2011)** the concentration of fluoride deficiency produce dental caries and beyond 1.5 mg/L concentration in drinking water produce kinds of problems or incurable disease (dental and skeletal fluorosis) in human and other livening things. Fluoride consumption within the permitted range of 0.5–1 mg/l was detected to be beneficial in production and maintenance of healthy teeth and bones in human beings. Bureau of Indian standard has suggested the desirable limit of fluoride in drinking water is 1.0 mg/L, which can be extended up to 1.5 mg/L in case of unavailable of alternate sources.

1.3.2.1Dental Caries (Tooth Decay)

Dental caries is the scientific term for tooth decay or cavities. It is an infectious and multifactorial disease, which is characterized by demineralization of inorganic components of teeth and dissolution of organic substance specific types of bacteria. They produce acid (lactic acid, propionic acid and acetic acid) that production by fermentation, which etches away the enamel leaving black spots or cavity on the tooth. The specific bacteria *Sreptococcus mutans* and *Lactobacilli* in dental plaque are the major etiologic factors responsible for this disease **(CDCP 1990-99).**

1.3.2.2 Dental Fluorosis

Dental fluorosis, also called mottling of tooth enamel, is a developmental disturbance of dental enamel caused by the consumption of excess fluoride during tooth development. Dental fluorosis, an irreversible toxic effect on the tooth forming cells, ameloblasts, is an early sign of fluoride attack visible to the naked eye. In dental fluorosis, colour of teeth may steps forward from white, yellow, brown to black. brown spot appears away from the gums on the enamel surface and spread an integral part of the tooth matrix and the enamel will lose its luster and shine **(Susheela 2003)**. **Dean (1934)** has been developed for quantifying the severity of dental fluorosis on the basis of nutritional status of the child. Classifies as a scale of from 0 to 4 as follows: very mild fluorosis (Class 1) symptoms show in opaque white areas irregularly covering about 25% of the tooth surface; mild fluorosis (Class 2) symptoms white areas covering about 50% of the tooth surface; all surfaces affected, with some brown spots and marked wear on surfaces subject to attrition are moderate fluorosis (Class 3); and widespread brown stains and pitting are classifying in Class 4 (severe fluorosis).

1.3.2.3 Skeletal Fluorisis

Skeletal fluorosis is a bone illness caused by excessive accumulation of fluoride in the bones either through water or rarely from foods of endemic areas. The accessibility of fluoride in the bone also varies with age, sex, and specific type of bone such as cancellous bone being more receptive than old or cortical bone **(WHO 2002**). Fluoride is mainly deposited in the joints of the neck, knee, pelvic, and shoulder bones, and once it takes place, it makes movement or walking difficult. Skeletal fluorosis and fracture are considered as the significant outcome due to long-term exposure of excess fluoride in drinking water (**WHO 2002)**. It was observed that approximately 99% of the fluoride in the body is found in bones and teeth (**Husdan et al. 1976; Kaminsky 1990; WHO 2002)** with the remainder distributed in highly vascularized soft tissues and blood.

Crippling skeletal fluorosis is the advanced and severe form of skeletal fluorosis. The prevalence of high levels of fluoride intake and its long-term exposure, malnutrition, strenuous manual labour and impaired renal function leads to severe skeletal fluorosis **(Reddy 1985).**

1.3.2.4 Non skeletal Fluorosis

Excessive exposure of fluoride may causes to degeneration of muscle fibre, abdominal pain, skin rashes, lack of haemoglobin level, neurological manifestation, deformities in RBCs, nervousness, excessive thirst, headache, nausea etc. The intake of elevated fluoride content water may also causes alteration in functional mechanism of liver, respiratory system, central nervous system, kidney, destruction of about 60 enzymes **(Meenakshi and Maheshwari 2006)**. According to **Pratap and Singh (2013)** it also affects on pinal gland, endocrine system, thyroid etc, ill effects on skeletal muscle, gastro-instinal system, erythrocytes, and Fluorosis is irreversible and no treatment exists for it **(CGWB 2014)**. Intake of extremely F^- contaminated plants and fodder was found to create chronic toxicity in grazing animals and humans including bone damage and tooth wear **(Clark and Stewart 1983)** while diets high in fat were confirmed to increase deposition of fluoride in bones and thus enhanced toxicity in humans **(USDHHS 1991)**. **Choi et al 2013** suggested that high exposure of fluoride can cases to decrease the IQ level of children **(NZMA 2013)**. **Gupta et al 2007** studied and concluded that eyeleted concentration of fluoride in drinking water can causes to decrease birth rates.

1.3.3 Effect on plant

The incessant using of water containing high level of fluoride also affects the leaf injury, crop growth, damage to fruits, and decreases the yield **(Yadav et al. 2012)**. Highly bioaccumulation of F^- in flora causes to chlorosis **(Mcnulty and Newman 1961)**, leaf necrosis, leaf tip burn, reduced plant growth **(Elloumi et al. 2005; Zouari et al. 2014)**, decrease the production, damage to fruits, **(Anil and Bhaskara 2008)**, alteration in membrane permeability, inhibited germination, reduced productivities, reduced capacity of photosynthesis capacity, ultra structure malformation **(Gautam et al. 2010)**, and phyto-toxicity **(Liang et al. 1997 ; Clausen et al. 2015)**.

1.3.4 Global scenario of fluoride and Fluorosis

Chief source of fluoride intake by humans is drinking water, especially in areas where fluoride concentrations in groundwater high and according to **Ayoob and Gupta (2006)**, more than 200 million people worldwide rely on drinking water with fluoride concentrations that exceed the WHO guideline of 1.5 mg/l. Fluorosis is widespread in many parts of the world predominantly in mid-latitude regions. Of the 85 million tons of fluoride deposits in the earth crust world-wide **(Teotia and Teotia 1998)**. High fluoride containing groundwater occurs in enormous divisions of Africa, China, the Middle East and Southern Asia (India and Sri Lanka). One of the the most identified high fluoride belts on the earth spread out along the East African Rift from Eritrea to Malawi, another identified fluoride belts on earth that draw out from Syria through Jordan, Algeria, Egypt, Sudan, Libiya, Kenya, and comparable belts in the America and Japan also **(WHO 2005)**. Approximately 200 million people of 27 countries across the world face issues of excess fluoride in drinking water, the greatness and severity of which varies with the environmental settings in terms of their geographical and economical status. China and India both are most fluoride affected region in the world. The foot of high mountains and in areas where the sea has made geological deposits are mostly content high levels of fluoride in water. The highest concentration of fluoride in the water has been found in Kenya (Elementaita 1640 mg/L and Nakuru Lake, 2800 mg/L), followed by in Ethiopia with 177 mg/L and in India with 69.7 mg/L **(Haimanot et al. 1987; and WHO 2006)**.

1.3.5 Indian scenario of fluoride and Fluorosis

Jha and Jha (1982) explain the serious health problem caused by fluoride contamination in groundwater of India and their chief source is natural origin. The occurrence of the fluoride in groundwater is predominantly geogenic. 12 million tons of fluoride deposits in the earth crust are found in India **(Teotia and Teotia 1994)**. Andhra Pradesh is one of the first states in India, where fluoride was first detected in drinking water at Nellore district in 1937 **(Ayoob and Gupta 2006)**. In early 1930's fluorosis was reported only in four states of India, in 1986 it was 13, in 1992 it was 15, in 2002 it was 17 and now it is 19 **(Kundu and Mandal, 2009)**, indicating that endemic fluorosis has been emerging as one of the most alarming public health problem of the country. Among the affected states, Rajasthan, Andhra Pradesh and Gujarat are the three most endemic states **(Planning Commission 2002; Susheela 2003)**. **Susheela (2014)** have mentioned, 230 districts in 18 states and union territories of India, which have been investigated to be endemic for fluorosis and 66 million people have been identified to be at risk, while 25 million people are affected from the condition of dental fluorosis. Majority of the affected people are children who are less than 18 years of age **(Susheela 2002)**. The fluoride concentration in the groundwater is found to be more than 10 mg/L in the eight states of India including Andhra Pradesh, Haryana, Rajasthan, Maharashtra and Madhya Pradesh. It ranged from 5 to 9.9 mg/L in nine states of India namely Assam, Delhi, Gujarat, Karnataka, Kerala, Orissa, Punjab, Tamil Nadu and West Bengal. In the remaining four states of Chhattisgarh, Bihar, Jammu and Kashmir, and Uttar Pradesh, the fluoride concentration ranges from 1.02 to 4.9 mg/L **(WHO 2014)**.

According to **CGWB (2010)**, the groundwater of Agra, Aligarh, Etah, Firozabad, Jaunpur, Kannauj, Mahamaya Nagar, Mainpuri, Mathura, Mau district of Uttar Pradesh having fluoride concentration above 1.5 mg/L. **Saxena and Ahmed (2003)** has been report high fluoride concentration in the Quarternary-Upper tertiary deposits in many parts of UP (Unnao, 2.0 mg/L; Debraspur, 2.1 mg/L; Janghai, 3.2

mg/L; Kulpahar, 3.0 mg/L; Babera, 3.3 mg/L; Karchhana, 2.8 mg/L; Jhansi, 2.8 mg/L, and Etah, 3.0 mg/L) and other researchers also studies at Varanasi **(Ray et al 1983)**, Unnao **(Chanda and Tamta 1999)**, Kanpur, Agra **(Gupta et al. 1999)**, and Mathura **(Misra et al 2006)** Sonebhadra **(Raju et al. 2009)**. **Maurya et al. (2015)** also found the elevated concentration, 8.6 mg/L in Pratapgarh district Uttar Pradesh. **Kanaujia et al. (2013)** was found elevated concentration of fluoride in groundwater of 5 blocks in Raebareli district namely Dalmau block, Amawa block, Deeh block, Sadar block and Unchahar block. According to the report **of Ministry of Environment and Forests, Government of India (2009)** has estimated that fluorosis is prevalent in 19 states of India affecting a population of around 66 million, out of which 6 million are children. It is, therefore, a matter of high concern from the point of view of public health and welfare. the health department of central government (Ministry of Health and Family Welfare) have been released funds under National Programme for Prevention and Control of Fluorosis (NPPCF) of the for 91 districts out of 230 endemic fluorosis districts in India but districts Raebareli is not enlisted in this funds.

1.3.6 Fluoride accumulation in cultivated crops and transfer through dietary product

The sources of fluoride ingestion is not only drinking water, it enter through food, beverages and many others sources i.e. air, drugs, and cosmetics are the foremost sources of fluoride via diet. Almost all the food items contain at least traces amount of organic fluoride but one potentially dangerous source of fluoride is tea. **Jain et al. 2017** reported 4.4 μg/g fluoride concentration in spinach leaves (S. oleracea) in Chhattishgarh, while **Bhargava and Bhardwaj 2009**, spinach leaves tend to accumulate 29.15 ppm and 25.7 ppm fluoride in Rajasthan. Levels of fluoride in vegetables and fruits have low (e.g. 0.1–0.4 mg/kg) and thus normally contribute little to exposure. But, higher levels of fluoride have been investigated in barley and rice (e.g. about 2 mg/kg) and taro, yams and cassava have been found to contain relatively high fluoride levels and the levels of fluoride in meat (0.2–1.0 mg/kg) and fish (2–5 mg/kg). However, fluoride accumulates in bone and the bones of canned fish, such as salmon and sardines, which are eaten, fish protein concentrates may contain up to 370 mg/kg fluoride **(Murray 1986)**. The fluoride in food items depends upon the fluoride contents of the soil and water used for irrigation; therefore, the fluoride content of the food items may vary from place to place. Accumulation of fluoride via root to shoot, when it is in irrigated water or soil, but fluoride ion exposed in air (mostly industrial area), it deposit in leaf **(Gautam et al. 2010)**. Food item contains more than fluoride as compare to groundwater. Fluoride contain in vegetation is highest near industrial area mostly aluminium smelter and phosphate fertilizer. Significant amount of fluoride also found in animal milk resulted from biomagnifications process. The incessant using of water containing high level of fluoride also affects the leaf injury, crop growth, damage to fruits, and decreases the yield **(Yadav et al. 2012)**. The fractional intake of F^- in a huan body though drinking water, food, air and soil needs to be assessed to unreavel the total amount of fluoride accumulation in the body**(Khandare and Rao 2006; Gupta and Banerajee 2001; Pandey and Pandey 2011)**.

Although, the status of groundwater quality with special respect to fluoride contamination were assessed by Kanaujia et al. (2013) in Dalmau block, Amawa block, Deeh block, Sadar block and Unchahar block but lacking for Lalganj, Khiron and Sareni block of Raebareli district Uttar Pradesh. Agricultural land of study area, contaminated with fluoride due to extensively applying or irrigating of fluoride containing groundwater, further plant roots absorb fluoride from contaminate land and transport it to different organ and accumulate at various degree **(Fornasiero 2001; Kalinic et al. 2005; Kozyrenko et al. 2007; Saini et al. 2013)**. Thus, consumption of vegetables, food and fruits become addition potential route of fluoride in food chain can leads to bone and tooth damage of animals and human **(Clark and Stewart 1983; Samal 2015)**. The main objective of present study is to assess the concentrations of fluoride groundwater and assessment to possible heath risk owing to addition exposure via cultivated crops and fodder plant in Lalganj tehsil (Lalganj, Khiron and Sareni block) of Raebareli district Uttar Pradesh.

1.4 AIMS AND OBJECTIVES

Present research work entitled "**Study of Fluoride Contaminated Groundwater Quality and Health Risk Assessment Owing to Bioaccumulation of Fluoride in Cultivated Crops and Fodder plants".** The main objective of present study are to assess the concentrations of fluoride contaminated groundwater of Lalganj tehsil of Raebareli district Uttar Pradesh and to unveil the status of contamination in the region is either natural or anthropogenic origin with following aims and objectives:

- To identify the causes of groundwater pollution and study of special and temporal variation in groundwater quality with an approach of water quality indexing.
- To scrutinize the extent of fluoride content in groundwater with generate thematic map and differentiate area for suitability of drinking purpose.
- To determination of bioaccumulation and biotransformation of fluoride in cultivated crops and fodder plants.
- To assess the potential health risk from additional exposure of fluoride through dietary source.

CHAPTER 2

REVIEW OF LITERATURE

2.1 Review on assessment of groundwater quality

Water is a major constituent of all living things which makes up approximately two-thirds of the human body weight **(Gore, 2006)**. There are about two billion people worldwide who lack access to safe drinking water in current. The main environmental issues today, due to improper and indiscriminate disposal of sewage, industrial and chemical waste to contaminate the underground water **(Obot and Edi 2012)**. Significances of drinking water unsafe, contaminated water are numerous and are still not fully understood **(Onda et al., 2012)**. The WHO has acknowledged the lack of access to clean drinking water as the most critical factor that negatively influences the general health and happiness of populations in developing countries. The critical to first evaluate the quality of ground water before it can be exploited for human consumption. This is, however, not always the case in many developing countries, sometimes due to financial and poor quality control problems **(Hoko 2005)**.

Water pollution is a major global problem which requires ongoing evaluation and revision of water resource policy at all levels. More than 90% rural and just about 30% urban population of India utilized to groundwater for drinking and domestic requirements **(Jaiswal et al. 2003)**, where the population is widely dispersed and the infrastructures required for the treatment and transportation of surface water does not exist **(Jain et al. 2010)**. It has been suggested that it is the leading worldwide cause of deaths and diseases, and that it accounts for the deaths of more than 14,000 people daily. According to WHO organization, about 80% of all the diseases in human beings are caused by water.

Groundwater is a vital source of water supply for about one-third of the world's population **(Nickson et al. 2005)**. Ground water is one of the earth's renewable resources which occur as a part of hydrological cycle. Ground water comes from rain, snow, sleet and hail that socks into the ground. The water that moves down into the ground because of gravity passing between particles of sand, gravel or rock until it reaches a depth where it is filled with water is called saturated zone and the top of this zone is called the water table. The physical and chemical properties of fresh water bodies are characterized by the geochemical, climatic, geo-morphological and pollution condition **(Chaurasia and Pandey, 2007)**.

Contaminants that are mainly related with groundwater pollution include nitrates, pesticides and faecal coliforms and anthropogenically activities such as land use and the interference in the natural flow patterns are often concerned in groundwater pollution **(Schot and Wal 1992)**. Over the 50% of the water requirements of advanced industrialised countries such as United States of America, Germany and Denmark are derived from groundwater resources **(Trauth and Xanthopoulos 1997)**. Groundwater constitutes nearly 90% of the world's readily available freshwater resources, with the remaining 10% from lakes, reservoirs, rivers and wetlands **(Boswinkle (2000)**. According **to Rajmohan et al., (2000) and UNESCO (2000),** the value of groundwater lies not only in its extensive occurrence and availability but also in its reliable good quality. The 40% of the global agricultural production of an estimated the groundwater irrigation of arable lands supports the growth **(DFID 2001)**.

For groundwater, inland salinity and excessive fluoride had become a problem in many districts of Uttar Pradesh including Unnao, Agra, Mathura, Ghaziabad and Aligarh **(CGWB, 2010)**. Long-term taking of contaminated groundwater can pose serious ill effects on human health. Groundwater having low pH can cause gastrointestinal disorders. If $pH < 6.5$, cause corrosion of metal pipes, resulting in the release of toxic metals such as Zn, Pb, Cd, Cu etc**. (Trivedy and Goel, 1986)**. The greater concentration of Cl^- in ground water could be associated with chloride rich minerals **(Karthikeyan et al., 2010)**. The sulphate concentration > 250 mg/l causes gastrointestinal irritation particularly when Mg^{2+} and Na^+ are also present in ground water. The water containing sulphate ions beyond 1000 mg/l have purgative effects **(Singh and Garg, 2012)**.

It is essential requirement for availability of safe and reliable source for sustained population growth and development **(Asonye et al. 2007)**. **Jeevanandam, et al. 2007**, assess the ground water and find out that, developing countries faced serious problem to ground water contamination by industrial effluents, domestic and agricultural activities. This is not the situation in many parts of Ghana, particularly in communities that depend exclusively on boreholes for their water needs where, periodical evaluation of drinking water quality **(Entsua-Mensah et al. 2007a, b)**. Water contamination measures may be misused possibly leading to serious effects on human lives. For example, in a survey of user satisfaction of community water systems in Ghana, respondents expressed concern about possible contamination resulting from equipment corrosion **(Entsua-Mensah et al. 2007a, b)**. If, water twisted have milky after heavy rainfall, suggesting possible contamination by undesirable materials **(Entsua-Mensah et al. 2007a, b)**.

About 35% of the volume of a typical soil consists of air filled pores. The quality of groundwater is worsening rapidly due to industrial and domestic wastes being discharged into the surrounding areas **(Shaji et al. 2009)**. Ground water quality is deteriorating at faster rate due to discharging of industrial wastes into the surrounding areas **(Shaji et al. 2009)**. Comparatively, groundwater contamination is not as common as surface water but once contaminated, treatment is a frequently difficult and time intense **(Agbaire and Oyibo 2009)**.

Many studies carried on groundwater quality at different part of the country **(Guler et al. 2002; Laluraj and Gopinath 2006; Sivasankar and Ramachandramoorthy 2009; Venkataraman et al. 2013; Shekhar and Sarkar2013)**. The public doing ignorance of environment and related concerns, indiscriminate discarding of increasing anthropogenic wastes, unintended uses of agrochemicals, and discharges of inadequately treated sewage have resulted in the deterioration of surface and subsurface water **(Singh and Hasnain 1998; Mitra et al. 2007; Kumar et al. 2008; Ishaku 2011; Ewusi et al. 2013; Kalpana and Elango 2013)**.

It has been estimated that once pollution enters the subsurface environment, it may remain covered for many years, becoming dispersed over wide areas of groundwater aquifer and rendering groundwater supplies unsuitable for consumption and other application **(Nagarajan et al. 2010)**. Many countries, physicochemical and microbiological monitoring of water quality could serve as a suitable tool for investigative potential contamination and to help decision-makers in evaluating the effectiveness of regulatory programmes in managing water resources **(Pusatli et al. 2009; Song and Kim 2009; Sadiq et al. 2010)**. Ghana is a lower middle-income country is opposed with several challenges including the providing of potable water for its growing population to meet the Millennium Development Goals and the Sustainable Development Goals **(Obuobie and Boubacar 2010)**.

Some approaches are recognised by the WHO, guidelines for drinking water quality **(WHO 2011)**. The WHO outlines its health-based targets for many possible water contaminants. **Raju et al. 2011**, assessed the water quality may give clear information about the subsurface geologic environments in which the water presents. Sulphate originates from sedimentary rock sand igneous rocks, is oxidized in soil by bacteria and other organisms to sulphuric acid. Chloride is a major ion in ground water and key element in sea water, atmospheric moisture and mineral halite. The potassium is derived from silicate minerals like orthoclase, microcline, nepheline, leucite and biotite. The F^- content of groundwater can originate from the dissolution of fluorine-bearing minerals in the bedrock. In other words, bedrock mineralogy is, in general, a primary factor for the variations in F^- content of groundwater. Both, quality and quantity of groundwater is important to its owing to the suitability of water for various purposes **(Chidambaram et al. 2011)**.

Quality of groundwater is equally important to its quantity owing to the suitability of water for various purposes **(Chidambaram et al. 2011)**. Hydrological chemistry differs depending on the source of water, the degree to which it has been evaporated, the types of rock and mineral it has encountered, and the time it has been in interaction with reactive minerals **(Plummer et al. 2003; Arshid et al. 2011)**. Valuation of water quality is very important for knowing the suitability for various purposes **(Ifatimehin and Musa 2008; Arshid et al. 2011)**.

The overall, facility of safe drinking water can help to reduce or eliminate preventable deaths (such as those emanating from waterborne diseases) and improve the quality of life for low-income households around the world **(Lawson 2011)**.

Groundwater is the most reliable source of drinking water in sub-Saharan Africa, **(Idiata 2011)**. Water chemistry varies contingent on the source of water, the degree to which it has been evaporated, the types of rock and mineral it has encountered, and the time it has been in contact with reactive minerals **(Plummer et al. 2003; Arshid et al. 2011)**. Valuation of water quality is very vital for knowing the fitness for various purposes **(Ifatimehin and Musa 2008; Arshid et al. 2011)**.

The urban aquifers are the only natural resource for drinking water supply, they are often perceived as of lesser relevance for the drinking water supply, leading to crisis in terms of drinking water scarcity, becoming increasingly polluted thereby decreasing their portability **(Tiwari et al. 2012)**. He gave the information that the urban aquifers are the only natural resource for drinking water supply, they are often perceived as of lesser significance for the drinking water supply, leading to crisis in terms of drinking water scarcity, becoming increasingly polluted thereby decreasing their portability.

These sources of contamination may influence important biological, physical and chemical variables of groundwater **(Sappa et al. 2013)**. The information of hydro-chemistry is vital to evaluate the ground water quality in any area in which the ground water is used for both irrigation and drinking needs **(Srinivas et al. 2013)**. Hydro-chemistry is important to understand for assess the ground water quality in any area in which the ground water is used for both irrigation and drinking purposes **(Srinivas et al. 2013)**. Many water quality studies on have been carried out by numerous researchers in many places in India and most studies on water quality have been agreed out by various researchers in many places in India **(Raju et al. 2011; Srinivasamoorthy et al. 2011; Subramanian 2011; Gnanachandrasamy et al.**

2013; Annapoorna and Janardhanab 2015; Nagaraju et al. 2014; Sajil Kumar et al. 2013).

The investigation of hydro-geochemical for groundwater has been carried out in the coastal aquifers of southern Tamil Nadu, India **(Chandrasekar et al. 2014)**. The groundwater chemistry has been studies in Pratapgarh district in Uttar Pradesh (**Ashwani and Abhay (2014).** According to the WHO, drinking contaminated water is one of the major causes of diarrheal diseases; these diseases make up the second leading cause of child mortality, resulting in the death of about 760,000 children aged <5 years annually **(WHO, 2014)**. Hydro- geochemicalexamination of groundwater has been carried out in the coastal aquifers of southern Tamil Nadu, India **(Chandrasekar et al. 2014)**. **Ashwani and Abhay, 2014**, have studied groundwater chemistry of Pratapgarh district in Uttar Pradesh. Since water is a precious natural resource, for sustaining all life on the earth and due to its manifold benefits and the difficulties created by its excesses, shortage and quality deterioration, water as a resource requires special consideration. More evident challenges have in the northern parts of the country due to the limited number of surface water resources, convincing people to resort to the use of underground water **(Sebiawu et al. 2014)**. Increasing population and development activities continuously increases the water demands and resulted more use of groundwater than surface water resource which has controlled to groundwater reduction **(Krishan et al., 2016).** Any measurable health, water quality or performance variables that are established based on a decision of safety and risk assessments of waterborne hazards for any targets. The health built targets for contaminants deliver a framework for realizing safe drinking water, generating a water safety plan and maintaining water investigation by policymakers. Analyzed results advise that groundwater is a vital natural resource that affects the health and comfort of many people worldwide. Due to this, the quality of this resource should be given a primary research and quality control courtesy. The aim of the study is to evaluate the quality of groundwater and to assess the spatial distribution of various hydro-geochemical characteristics for suitability of groundwater resources in the study area as it is densely populated area and they mostly demand on the groundwater resources.

2.2 Groundwater quality defined via WQI as effective tools

Horten (1965) was first proposed to Water quality index to signify the quality of water. WQI point to a single number such as a grade that expresses the on the whole water quality at a specific location and time based on specific water quality parameter. Numbers of WQI have been developed to assessed water quality data in an easily expressible and understood format **(Couillard and Lefebvre 1985)**

Water quality index is well known methods to express water quality, it is a stable and reproducible unit to measure and communicate information of WQI to the policy makers and concerned people. Hence, it is an crucial parameter for the assessment and management of ground water **(Chauhan et al. 1991; Sahu et al. 1991)**. According to Anonymous (1997), water quality index is reliable method to assessment of water quality trends for management purposes even through it does'nt meant an absolute measure of the degree of pollution or the actual water quality. **Nives (1999)** describe the Water quality index is a mathematical tools for minimize the large quantity of data in to a single number, which represents all over of water quality.

On the basis of calculated water quality indices different sources of water quality has been communicated by **Pradhan et al. (2001)**. According to **Cude**

(2003) WQI was firstly proposed in beginning of 1970s but not accepted or utilized by agencies that monitor water quality. **Tyagi et al. (2003)** carried out the Water quality index in the study of spatial and temporal water quality of the pristine river Kshipra, Madhya Pradesh.

Ahamed et al. (2004) noted that the national Sanitation Foundation (NSF) was incorporated some indices in to water quality indices. Water quality index has been regards as one of the most helpful technique to assess the quality of water and on the basis of calculated water quality indices different sources of water quality has been communicated **(Tiwari and Mishra 1985 and Sinha et al. 2004)**.

Rao et al. (2007) studied the water quality index in the ground water quality assessment in Meghadrigedda watershed, Visakhapatnam, (Andhra Pradesh). **Kakati and Sarma (2007)** has described on his article that WQI reveals a composite influence of fundamental factors on the quality of water for drinking water of Lakhimpur district, Assam.

WQI was used by **Asadi et al. (2005)** in the mapping and assessment of water pollution indices in Municipal Corporation of Hyderabad. **Sinha and Ritesh (2006)**, was calculated WQI for groundwater in 10 location at Hasanpur, JP Nagar and concluded that several groundwater location of the area harshly contaminated. **Stigter et al. (2006)** generated map based on water quality index that revealed the upper aquifer was extremely low category of water quality. For WQI provides beneficial help to the planning of water resource management and land use pattern, according to **Chatterjee et al. (2010)** groundwater quality map is important tfor drinking and irrigation purpose and as precautionary indication of potential environmental health problem.

Mohsen (2007), mentioned on his literature that water quality is common with any other index system, communicated to parameters of water quality into combine into a single number based on chosen method. **Shah et al. 2008** collected groundwater samples from 40 village of Gandhinagar taluka, Gujrat (India) for finding of irrigation awater quality and drinking water suitability. Results revealed that groundwater quality of Gandhinagar taluka was found poor calss as per WQI and suggested that without prior treatment groundwater cannot be used for drinking purpose.

Sahu and Sikdar (2008) calculated a WQI and given a assigned a weight for every physic-chemical parameter based on its important for suitability of drinking purpose. This method is easy way to draw the original qualitative figure of the study area and classified following five categories i.e. <50 excellent water quality, 50 to 100 good water quality, 100 to 200 poor water quality, 200 to 300 very poor water quality and >300 water unsuitable for drinking purpose. assined maximum weight for nitrate because of its foremost important in water quality assessments Similer studied also done by several researchers (**Yakubo et al. 2009; Yidana and Yidana 2010; Srinivasamoorthy et al. 2008)**

Ramakrishnaiah et al. (2009) observed the water quality status based on WQI approach in 12 physico-chemical parameter (pH, TDS, Mg^{2+}, Ca^{2+}, F, TH, HCO_3^-, Cl^-, NO_3^-, SO_4^-,Fe and Fe^-) of groundwater from Tumkur taluk, Karnataka (India).. The water quality of Tumkum taluk was found poor class based on WQI values because of groundwater contain higher value of Fe, Nitrate, Total Hardness, Bicarbonate, Total Dissolve Solid, Mn, and Fluoride.

Rajankar et al. (2009) was calculating WQI in groundwater of Khaperkheda region, Maharashtra (India) during different season applied by WQI calculator given by National Sanitation Foundation (NSF) foundation system. The WQI of that region was fair water quality rating in post-monsoon season but it was slightly changed to medium class in summer and winter. **Rajankar et al. (2009)** further studies to determine the water quality based on water quality index in groundwater of Nagpur region India.

Yakubo et al. (2009) studies om water quality indices to characterized hydrochemistry of groundwater with statistical and predictable graphical method in groundwater of Northen part of the Volta region, Ghana. The results of WQI value point out that groundwater of Volta region was excellent quality for drinking purpose with respect to Na^{+}, Ca^{2+}, Mg^{2+}, Cl^{-}, No_3^{-}, F^{-}, and EC.Yakubo et al. conducted comparative studies between the groundwater quality and suface water quality and results suggested that groundwater quality index is higher than surface water quality indicates that geology of that location had impact on WQI of groundwater in study location. **Yidana and Yidana (2010)** further attempted to find out the dominant factor which plays a significant role in influencing the quality of groundwater from Southern Voltaian sedimentary formation in Ghana, the study was based on WQI. The study reveals three major factors , weathering of silicate mineral, carbonate minerals and reverse cation exchange are the most important process that affecting the hydrochemistry of groundwater.

Vasanthavigar et al. (2010) was studied an assessment of groundwater quality with WQI approaches from groundwater at Thirumanimuttar sub-basin, Tamil Nadu (India). **Vasanthavigar et al. (2011)** further monitored with diverse aim including suitability od drinking, industrial uses and irrigation purpose by **Vasanthavigar et al. (2011)**.

Saeedi et al. (2010) was completed a research based on multivariate analysis with groundwater quality index (GWQI) in groundwater of Qazvin province, west central of Iran and found that two location of the study area was extremely near to mineral water quality. Saeedi et al. also create a map based on GWQI, it provides a comprehensive picture of easily interpretable for regional decision for better planning and groundwater management.

Rita et al. (2011) applied WQI on seasonal variation on water quality of the Sabermati river at Ahmadabad, and results revealed that quality odf water is adversely polluted by discharging of domestic sewage, industrial effluents and agricultural runoff.

Krishan et al (2016) used to WQI developed by Singh et all., (2008) in groundwater of North Goa for suitability of groundwater used to drinking purpose. Similar studied also done in different location with same aims **(Mishra and Patel 2001; Naik and Purohit 2001; Coulibaly and Rodriguez 2004; Sahu and Sikadar 2008; Avvannayar and Shrihari 2008; Samantray et al. 2009; Rajankar et al. 2009; Saeedi et al. 2010).**

2.3 Review on fluoride containing groundwater quality, and associated heath risk.

Fluoride is 13th most abounded elements and widely distributed in earth's crust. It is one of the most essential elements for mineralization of bones and formation of dental enamel when present in low concentration 0.5 – 1.0 mg/L in drinking water

(WHO 2011). According to **Pathak et al. (2012)** Low level of fluoride is required by human system as it is helpful in preventing dental carries but ingestion of excessive amounts of fluoride may cause dental and skeletal fluorosis, joint pain, restriction of mobility, and probably increase the risk of some bone fractures. **Subba Rao (2011)** mentioned in his article most of the villagers of India, suffer health disorders due to occurrences of F^- and As in drinking water and F^- contamination is far more widespread than those of As contamination in the country.

According to **WHO (2005)** fluorosis is widespread in many parts of the world predominantly in mid-latitude regions. **Teotia, and Teotai, M. (1994)** mention ed on his article that 85 million tons of fluoride deposits in the earth crust worldwide, 12 million tons of fluoride found in India. According to **WHO (2005)** High fluoride containing groundwater occurs in enormous divisions of Africa, China, the Middle East and Southern Asia (India and Sri Lanka). One of the the most identified high fluoride belts on the earth spread out along the East African Rift from Eritrea to Malawi, another identified fluoride belts on earth that draw out from Syria through Jordan, Algeria, Egypt, Sudan, Libiya, Kenya, and comparable belts in the America and Japan also.

According to **Ayoob and Gupta (2006)** 200 million peoples are face serious issue of surplus fluoride in drinking water in the region of 25 countries across the global. China and India both are the major affected countries in the world, population of that countries were faced by elevated level of fluoride in drinking water. The major part of both countries still not funded by government under fluororis management programme.

Nouri et al. (2006) studied the groundwater quality of shush aquifer (Khuzestan contry) Iran and found that 40% groundwater samples of study areas is highly affected by eveleted concentration of fluoride. A Study conducted by **Rafique et al., (2009)** in groundwater of Nagar Parkar area of Sindh (Pakistan) and investigation the pH and elevated sodium concentration are geochemical factors controlling the dissolution of fluoride in groundwater.

In this year a study was conducted by **abdelgawad et al. (2009)** for investigation for interaction between the water-rocks in higher fluoride containing groundwater in of Mizunami location, Japan. **Wu et al. (2010)** carried out a investigation on seasonal variation of f^- in groundwater of nearby science park, southern Taiwan. **Fekri and Kasmaei (2011)** was studied and found fluride contamination in Koohbanan rigion of southeastern Iran. Fluoride pollution in soils and waters of Koohbanan region,

Vasquez et al. (2006) studied on F^- in groundwater of Hermosillo city, Sonora (Mexico) the result reveals that geology of the study area associated with granite might be chief source of fluoride in groundwater.

Pillai and Stanley (2002) reported in 20 States of this country reported the concentration of fluoride in groundwater higher than permissible value of drinking water and 150,000 villages is emergence the problem with dental fluorosis and most prominent issue in the states of Andhra Pradesh, Assam, Bihar, Delhi, Gujrat, Hariyana, Karnataka, Madhya Pradesh, Maharatra, Rajasthan, and West Bengal,. According to **CGWB (2010)** the endemic fluorosis is predominant in many states, including Andhra Pradesh, Assam, Rajasthan, Gujarat, Bihar, Chhattisgarh, Delhi, Haryana, Jharkhand, Jammu and Kashmir, Karnataka, Kerala, Madhya Pradesh, Maharashtra, Odisha, Punjab, Tamil Nadu, Telangana, West Bangal, and Uttar Pradesh in the country.

Andhra Pradesh is first state in India **(Ayoob and Gupta 2006)**, where fluoride was earliest noticed in groundwater of Nellore district **(Shortt 1937)** and the groundwater of 195 villages in Prakasam district (Andhra Pradesh) are highly affected with excessive concentration of fluoride **(Eenadu 2013)**. **Gautam et al. (2010)** and **Brindha et al. (2011)** was point out on his studies that the weathering of rocks and leaching of F^- are chief sources of elevated concentration of fluoride in groundwater. **Subba Rao (2017)** also studies fluoride enrichment in groundwater takes place mainly through leaching and weathering of the Fluoride-bearing minerals (fluorite, apatite, biotite, hornblende, etc.) present in hard rock terrains (basalts, granites, gneisses, schists, charnockites, khondalites, etc.) and anthropogenic sources i.e. chemical fertilisers, sewage, sludge.

Soils from vicinity accumulate a large influx of fluoride and metals through atmospheric gravity settling and their dissolution in soil solution percolates and contaminates the ground aquifer **(Subba Rao 2011)**. According to **Gao et al. (2007, 2013),** clay minerals can bind with F^- ions on their surfaces but at high pH, OH^- ions displace F^- ions, which are then released to underground water. **Handa (1975)** noted a general negative correlation between F^- ion and calcium in Indian ground water. The high F^- concentration may, therefore, be expected in ground water in Ca-poor aquifers and in areas where F- rich minerals are common **(Kumar 2012)**. Low calcium and high pH, HCO_3^- and Na^+ favour release of F^- from aquifer matrix into groundwater **(Guo et al. 2007; Salve et al. 2008; Bulusu and Pathak, 1980)**.

Generally, the F- ion concentration and the ground water quality mainly depend on the chemical, physical characteristics of aquifer, well depth, ground water age, hydrologic condition, residence time and geologic structures are important factors which govern the concentration of F- in ground water **(Kim and Jeong 2005)**

Kundu and Mandal (2009) was studied the groundwater quality of West Bangal (India) and found the ranged from 0.01 to 1.8 mg/L while **Suthar et al. (2008)** found maximum up to 86.0 mg/L. **Brindha and Elango (2011)** studied the broad-spectrum of occurrence, cases, implication and mitigation measures of F^- in the groundwater. Rajasthan is one of endemic fluoride zone and is known as “desert state” with acute water crisis **(Jacks et al. 2005)**.

According to **Panday, 2001**, high numbers of rural inhabitants are suffering from deadly incurable disease like fluorosis, which owing due to intake of high level of fluoride from groundwater in many parts of the Indo-Gangetic alluvial region. **Kumar and Saxena (2011)** and **CGWB (1999)** also reported this problem also thinning out in other part of the Ganga basin.

Faisal et al. (2014) also studies the water table depletion and worsening of groundwater quality could be due to the limited rainfall, absence or lack of perennial surface water reserve, rapid civilization, surplus exploitation, unempirical disposal of waste and improper management of groundwater resource. Groundwater of Agra, Aligarh, Etah, Firozabad, Jaunpur, Kannauj, Mahamaya Nagar, Mainpuri, Mathura, Mau district of Uttar Pradesh having fluoride concentration above 1.5 mg/L.

Saxena and Ahmed (2003) has been report high fluoride concentration in the Quarternary-Upper tertiary deposits in many parts of UP (Unnao, 2.0 mg/L; Debraspur, 2.1 mg/L; Janghai, 3.2 mg/L; Kulpahar, 3.0 mg/L; Babera, 3.3 mg/L; Karchhana, 2.8 mg/L; Jhansi, 2.8 mg/L, and Etah, 3.0 mg/L) and other researchers also studies at Varanasi **(Ray et al 1983)**, Unnao **(Chanda and Tamta 1999)**, Kanpur, Agra **(Gupta et al. 1999)**, and Mathura **(Misra et al. 2006)**. **Jha and Jha (1982)** explain the chief source of F^- contamination in the groundwater of India is geogenic or natural origin which causes incurable disease.

Maurya et al. (2015) also studies on fluoride contents in groundwater of Pratapgarh district, Uttar Pradesh and and observed the maximum concentration up to 8.6 mg/L. Dental fluorosis is endemic in 150,000 villages in India with the problem most pronounced in the states of Andhra Pradesh, Bihar, Gujarat, Madhya Pradesh, Punjab, Rajasthan, Tamil Nadu, and Uttar Pradesh **(Pillai and Stanley 2002)**.

Jacks et al. (2005) studied an **e**xcessive F^- in the domestic water supply is reported in at least 10% villages in Rajasthan. Fluoride may also be anthropogenically released into the environment (air, water and soil) through the discharge of wastewater, fumes or solid waste from industrial processes such as phosphate fertilizer, hydrogen fluoride, calcium fluoride, sodium fluoride, fluorosilicic acid, sodium hexafluoro silicate, sulfur hexafluoride, fluorapatite, glass, brick and steel production other than these, possible sources may include pesticides, drinking water fluoridation and coal burning studied**.**

Indian coal is of low grade quality with high ash **(Behera et al. 2016; 2017)** (35-50%), high Fluoride (4-25 mg kg^{-1}) and low calorific value (avg. 2800 kg Kcal). About 82 coal power plants are continuously polluting the environmental components with potentially toxic fluoride, heavy metals and other eco-toxic gases/chemicals.

Dental fluorosis was first related to drinking water in 1925, though several more years before it was shown to be specifically caused by fluoride in drinking water. Dr. Frederick S. McKay is the first to inform the development of an unusual permanent stain or "mottled enamel" on teeth surface and to start research on its relation with fluoride in drinking water. **(Funmilayo and Mojirade 2014)**.

Steel plants use CaF_2, aluminium smelter use Na_3AlF_6 and phosphate fertilizer and phosphoric acid manufacturing plant use $Ca_{10}F_2(PO_4)_6$ **(Tailor and Chandel, 2010)**. Alumina refining Queensland Alumina Limited's plant (QAL) emitted mean annual fluoride about 55,000 kg/yr tons/year and Rio Tinto Yarwun's plant (RTAY) emitted 15,000 kg/yr tons/year during 2007 **(Campin 2010)**.

Divan Junior et al. (2008) studies the fluoride concentration is low in the urban atmosphere but it can increase remarkable around emissions sources. Fluoride concentration in many part of Andhra Pradesh (India) has been studies in Gungtur district by **Subba Rao, (2003)** and Varah River Basin by **Subba Rao, (2008)** Groundwater of coastal area in Andhra Pradesh by **Subba Rao, (2017)**.

Patel et al. (2016) Studied the contamination of surface and groundwater with fluoride around largest coal basin of India and and described possible exposure assessment of fluoride toxicity in animals.

Khandare (2013) studied several factors that supported to high fluoride in environment are longer residence and contact times of waters with fluoride containing minerals, evaporation and excessive and long term irrigation.

2.4 Review on bioaccumulation of fluoride in fodder and cultivated crops.

According to **Mackowiak et al. (2003)** fluoride occurs naturally in soil, is an essential element for human and animal but not for plants. To most plants, fluoride (F) is phytotoxic by influencing a series of metabolisms studied by **Miller (1993)**. **Davison et al. (1985)** found less than 10 mg/kg fluoride is usually found in plants from uncontaminated areas. According to **Ando et al. (1998)** hiper accumulation of fluoride in vegetation can cause to visible leaf injury, damage to fruits and decrease production of yield. While, **Singh et al., (1995)**, studied on okra plant growing in 10 to 120 mg/L fluoride containing irrigation water without showing any effect.

According to **Kabata-Pendias 2001**, the concentration of fluoride in dry mass of plant tissue should not exceeded 30 mg/kg. Fluoride is more soluble in acid soils due to which its uptake by plants is enhanced **(Daines 1952)**. **USDDHS (1991)** studied that high fat containing diets have increase to deposition of fluoride in bone and thus boost toxicity. **Singh et al. (1995)** examined fluoride content in deferent vegetable, 13.24 µg/g in Guafali (*Cyamopsis tetragonaloba*), 13.94 µg/g in Bathua leaves (*Chenopodium alba*), 8.3 µg/g in Pea (*Pisum sativum*) and 13.94 in Kachri (Citrullus melo var. momordica).

Many studies have been conducted to investigate the F concentrations in tea plant so infused tea; it is one of the highly enriched drinks. **(Fung et al. 1999)** Tea plants (*Camellia sinensis L*), nevertheless, can accumulate large amounts of F in mature leaves from soils of normal F availabilities without toxicity symptoms **(Yumada and Hattori 1977; Ruan and Wong 2001; Xie et al. 2001)**. **Ruan et al. (2004)**, observed fluoride accumulation in laboratory condition under deferent pH (4.0 and 5.5) and conclude that significant accumulation of fluoride at pH 5.5.

Further, **Ruan et al. (2004)** conducted a laboratory experiment and found that the concentration of fluoride in leaf decreases with increasing pH 6.5.

Gautam et al. (2010) also studies on bioaccumulation of fluoride in vegetable and cereals from fourteen villages of Nawa tehsil, where fluoride in groundwater above the 1.5 mg/l. **Gautam et al. (2010)** estimated in cereals crops Bajra (1.88 µg/g, Chana (15.88 µg/g). In this area high contents of fluoride found in leafy vegetables, the maximum concentration reported in Spinach (25.7 µg/g), Mustard (24.8 µg/g), Onion (23.92 µg/g) Radish (22.2 µg/g) and Methi(18.24 µg/g) respectively. Similarly studies also conducted by **Gautam et al. (2010)**, in Phagi tehsil (Jaipur), the concentration of fluoride was 38.7 µg/g in *Spinacea oleoracea* (Spinach), 22.7 µg/g in Allium cepa (Onion) 24.06 µg/g in *Amaranthus spinach*, 15.7 µg/g in *Brassica campestris* (Mustard).

Yadav et al. (2012) accumulation of fluoride in agricultural crops is largely depend on the contents of fluoride in the soil and types of soil and estimated the fluoride concentration in tomato and potato from Dausa district, Rajasthan were ranged from 1.10 to 4.6 µg/g and 1.22 to 2.92 µg/g respectively.

Joshi and Bhardwaj (2012) conducted a research on effect of fluoride on growth parameter of Triticum aestivum (Var, Raj 3675) and concluded that chlorophyll contents was reduced 43% at 13 ppm F^- with reduced leaf surface area, number of leaf, fresh and dry weight, number of brance and growth.

Several researchers also studies on fluoride accumulation in plants **(Kusa et al. 2004; Ruan et al. 2004; Singh 2008; Gupta and Banerjee 2011, Pal et al. 2012, Saini et al. 2013; Chakrabarti et al, 2013, Gao et al. 2013)**. **Yadaw et al.**

(2012) studied on effect of fluoride accumulation on growth of crops and vegetables in Dausa district Rajasthan, India and fluoride estimated in Tomato and potato were 1.1 to 4.6 and 1.22 to 9.22 µg/g.

According to **Gomes et al. (2014)** and **Rycewicz-Borechi et al. (2016)**, macrophytes and plants are using in the field of phytoremediation and bioremediation of heavy metals but several researchers **(Ruan et al. 2003; Xie et al. 2007; Gao et al. 2014)** was used to tea plant as a natural accumulater of fluoride while some plants are also sensitive to fluoride toxicity **(Njenga and Kariuki 1994; Arnesen 1997; Kostyshina el al. 2011)**.

Bhattacharya et al. (2017) was carried out risk assessment of developing fluorosis children spacialy in residing in bankura and purulia district of West Bengal by calculating all the possible pathaway of fluoride intake. For this study Bhattacharya et al., was analysed fluoride in drinking water, vegetables, rice, pulses and soil.

Agency for Toxic Substances and Disease Registry was determined the minimal risk level for daily oral F^- uptake to be 0.05 mg $kg^{-1}day^{-1}$ while the estimated human lethal F^- doses showed a wide range of values from 16 to 64 mg kg^{-1} in adults and 3 to 16 mg kg^{-1} in children.

Miller (1993) reported that fluoride in gaseous form enters plant tissues through stomata and creates cell cytotoxicity. **Sant'Anna-Santos et al., (2012)** found that accumulation of rainwater droplets on leaf surface, causing injuries favouring entrance of the pollutant to adjacent inner tissues due to disruption of epicuticular wax. Fluoride may bind with some leachable soil particles / compounds and gradually percolates into the ground aquifer.

2.5 Review on statically studies in groundwater quality

In recent years many studies have been done using principal components analysis in the interpretation and grouping of water quality parameters, **(Gajbhiye 2015)** utilized principal components technique conducted on two-point source of Municipal waste (Urdana Nala and Moti Nala) at Jabalpur, India. **Bhat et al. (2014)** have used this technique for pollution source identification in the sukhnag stream, Kashmir India. Environmental researchers referred that PCA is more highly consistent than factor analysis and it is a mathematical technique without any assumption.

PCA is designed to decrease the number of variables to a small number of indices while endeavouring to keep the relationships between the original data sets. In this study, PCA was used in order to understand and group the water quality parameters. The Euclidean distance usually gives the similarity between two samples, and a distance can be represented by the difference between transformed values of the samples **(Otto et al. 1998).**

Multivariate statistical analyses such as PCA have been used to provide a quantifiable relatedness of water quality data sets, and studies have confirmed the usefulness of multivariate analysis techniques for evaluation and interpretation of groundwater quality parameters **(Singh et al. 2004, 2009)** and identifying critical water quality issues and possible sources of pollution (**Singh et al. 2005; Kumar and Riyazuddin, 2008; Sargaonkar et al. 2008; Rao et al. 2010)**.

The relatively complex setting and geological history of the study area can be distinguished by two proven methods of multivariate analysis namely hierarchical cluster analysis (HCA) and factor analysis (FA). To identify the processes controlling the geochemical evolution of the Veeranam catchment Area, Tamil Nadu groundwater the HCA and FA were applied by **Suvedha et al. (2009)**.

The multivariate statistical interpretation are the suitable technique for a significant data reduction **(Massart et al. 1988)**.

Sajil kumar et al. (2012) studied the groundwater quality by using the heavy metal pollution index (HPI) for Chennai city. In classification of HPI, Cd, Cu, Zn, Pb and Cr were analysed in groundwater and applied for heavy metals pollution indexing.

Information about the status of groundwater quality and their impact on urban and industrial development are available for some districts like Unnao, Ghaziabad, Sonbhadra, Varanasi, and Deoria **(Misra and Mishra 2007; Umar et al. 2006; Singh et al. 2012; Raju et al. 2009, 2011; Bhardwaz and Singh 2011)**.

Therefore, status is lacking for groundwater quality of many districts of Uttar Pradesh including Raebareli district. The present hydro-chemical investigation has an objective to evaluate the quality of groundwater for its protection, management, and quality conservation because it is very important to assess the water quality not only for its present use but also for future consumption or sustainable development.

CHAPTER- 3

MATERIALS AND METHODS

3.1 Raebareli district at glance

I. General Information

- Name of district : Raebareli
- States : Uttar Pradesh
- Administrative division :Lucknow
- Population and (As per census 2011) :3,404,004
- Population density :740/ km^2
- Literacy and sex ratio :70% and 941
- Average annual rain fall : ~1200 mm
- Number of tehsile and blocks :6 and 18
- Basin :Central part of the
- basin Ganga
- Sub-basin :The Gomati-Sai sub-basin

II. Geographical features

- Latitude : 25°49' and 26°36' N
- Longitude : 100°41' and 81°34' E
- Geographical area :4609 km2
- Geological formation :Older and younger alluvium

- Soil types :Sodic soil and sandy loam
- Minerals :Silica

III. Land Use

- Forest area :53.44 km2
- Cultivable area :2541.66 km2
- Barren land :98.63 km2

IV. Irrigation system

- Net irrigated area :1592.08 km2
- Southern part of district irrigated by :Purwa branch canal
- Central part of district irrigated by : Sarda branch canal
- Northern part of district irrigated by :Jaunpur branch canal
- Chief drainage system :Ganga and Sai river

V. Agricultural

- Kharif Crop :Paddy, maize, and Jowar
- Rabi crop :Wheat, barley, pulses, and sugarcane

3.2 Description of the Study area

3.2.1 Physiographic Details

The present study has been carried out in Lalganj tehsil of Raebareli District, Uttar Pradesh (India) to evaluate groundwater quality for drinking purpose. District Raebareli is situated at The Indo-Gangatic belt separated with the Ganga river from District Fatehpur in south part of district, North part joints with Mohanlalganj tehsil of Lucknow is the capital of state. Eastern part of the district connected with tehsil Mussafir Khana of Sultanpur district, south-east connected with Pratapgarh distric and Western part mutual with Unnao district. Raebareli district is part of Lucknow division and the district lies between latitude 25°49' and 26°36’ N and longitude 100°41' and 81°34' E. The altitude varies from about 120.4 to 86.9 meter on top of the sea level in the north-west and south-east.

Total population of the Lalganj tehsil was 4, 98,136 and which males and females population was contributed 2, 57,163 and 2, 40,973 respectively. Population of up to 6 year age groups Children was 60, 320 (India Census 2011). Lalganj tehsil made-up with three blocks Khiron, Sareni and Lalganj, respectively. All blocks located at south-east part of the district and the region belongs to Central Indo-Gangetic belt.

3.2.2 Climate

According to the official site of the district, the area belongs to subtropical climate characterized by hot summer from April to June and very cold and dry winter from December to January. January is the coldest month of the year with the mean daily maximum and minimum temperature of 12 °C and 3-4 °C respectively. May is the hottest month of the year and temperature rich to 40-45° respectively. The average annual rainfall is around 1200 mm mostly depend on the south west monsoon and about 90% of the rainfall takes place from months of mid-June to mid-September.

3.2.3 Geological description

The total sprawl of the district in respect of area is 4609 Square Km. which is 1.56 % of the area of undivided Uttar Pradesh. Lalganj, Sareni and Khiron block spread out in 222.84, 257.61 and 210.04 Square Km respectively. Four types of soils are set up in the district Bhur/Silty sand, Matial/Clay, Dumat/ Loam, and Usar / Alkailine soils. Being the part of the Indo-Gangetic plain the district shows the Geology of older and recent origin and exposes ordinary Gangetic alluvium sediments of quaternary stage. The alluvial of Ganga Basin former consists of sediments which were formed in distant past and are partly undergoing denudation, while the latter is under its process of formation **(Khanna, 1992)**.

The main source of fluoride comes out from the alluvial sediments set down in the ancient times and topography of nearby regions is without hard rock. The type of soil is of mixed variety and varies in different parts of district. It comprises Kachhar, Domat, Matiyar, stiff clay and loam. The surface of soil changes every year and cultivation of Rabi crop is possible here. The downland nearby to Dalmau and Salon is usually a light loam but often the proportion of the sand is very high. To the north of the upland there is belt of stiff clay interspersed with broad and shallow swamps and usar (Reh) lands primarily in the areas of Lalganj, Rohania and Bhela. In the

Ganga upland, the part is inferior and poor where it is impossible to raise rabi without irrigation. The soil in the northern tract of the district is firm or clay.

3.2.4 Hydrological setting

The Ganga, the Sai and their tributaries river are chief drainage system of the district. The superior level of alluvium is composed of clays, silty clay, and sandy loam in changeable proportion with 5 to 16 meter average thickness of this zone. Recent alluvium occupies few part of the district get flooded and forming terraces in the bank of river whereas older alluvium covered a large portion of the district do not get flooded. As per CGWB investigation, the depth of alluvium is above 600 m gbl in the northern division while in the southern and eastern part the width about 487.00 and 487.80 m gbl respectively. According to CGWB, aquifer of district found a 4 stage aquifer system has been recognized down up to depth of 600 m bgl.

Depth of the first aquifer group found 100 to 166.00 mbgl and comprises clay sediment and sand layers in different parts having kankar beds. Saline water found in second aquifer group depth between 100 to 250 mbgl, it does not suitable for domestic uses. Sediment of third aquifer group made up of sand and clay and exists under depth of 140 / 250 mbgl and extends down to 410 / 420 mbgl. The fourth aquifer group exists between 420 to 550/600 mbgl and series of arenaceous to argillaceous sediments spreads out all over the district. The groundwater resource of Laganj, Khiro block was categorized under semi-critical category and Sareni block was under critical category **by Bhargava (2009).** According to **CGWB (2014)**, water level of contour zone of Laganj, Khiro, and Sareni block found between 5 to 10 mbgl in January, 2015.

Table 3.1: Description of the groundwater sampling location of Lalganj block (Lalganj tehsil)

Sample ID	Villages of Lalganj block	Latitude	Longitude	Direction	Sampling Point
L1	Alampur	26°10'30.78"N	80°58'8.83"E	Center	HP
L2	Suddan khera	26°10'07.78"N	80°57'58.57"E	Center	HP
L3	Police station Lalganj	26°09'34.92"N	80°57'56.08"E	Center	BW
L 4	Datuli Lalganj	26° 9'28.91"N	80°58'39.37"E	Center	HP
L 5	Lalganj tehsil	26°10'46.03"N	80°58'39.00"E	North	HP
L 6	Banna mau	26°11'15.22"N	80°59'13.13"E	North	BW
L 7	Huseni	26°16'12.05"N	81° 0'53.82"E	North	HP
L 8	Ekauni	26°14'3.44"N	80°58'29.18"E	North	HP
L 9	Bahai	26° 7'43.65"N	80°59'47.59"E	South	BW
L 10	Semher paha	26° 09'1.84"N	80°56'53.64"E	South	HP
L 11	Lalamau	26° 6'1.12"N	80°55'49.71"E	South	HP
L 12	Chilaula	26° 05'06.53"N	80°57'21.36"E	South	HP
L 13	Aihar	26°11'25.47"N	81° 1'24.81"E	East	HP
L 14	Baras	26°12'47.33"N	81° 3'14.13"E	East	HP
L 15	Bhawani pur	26°11'34.94"N	81° 3'49.95"E	East	HP
L 16	Lodipur utrauwa	26° 9'16.77"N	81° 3'5.58"E	East	BW
L 17	Dhannipur	26° 09'48.53"N	80°56'50.94"E	West	HP
L 18	Pure bhawani	26°10'20.35"N	80°54'21.08"E	West	HP
L 19	Bahara	26°12'16.85"N	80°53'40.63"E	West	HP
L 20	Udwa mau	26°08'45.49"N	80°55'00.23"E	West	BW

Table 3.2: Description of the groundwater sampling location of Sareni block (Lalganj tehsil)

Sample ID	Village of Sareni block	Latitude	Longitude	Direction	Sampling Point
L 21	Sareni police station	26° 9'21.87"N	80°49'037.83"E	Center	HP
L 22	Lakhanapur	26° 09'42.50"N	80°50'15.28"E	Center	HP
L 23	Sareni ganw	26° 09'24.15"N	80°50'09.23"E	Center	HP
L 24	Ghure mau	26°10'07.35"N	80°49'41.34"E	Center	BW
L 25	Ram khera	26°10'41.71"N	80°48'35.66"E	North	HP
L 26	Madai khera	26°10'28.30"N	80°51'12.07"E	North	BW
L 27	Sabji barua	26°11'52.02"N	80°50'00.95"E	North	HP
L 28	Jalalpur	26°12'34.31"N	80°47'58.60"E	North	HP
L 29	Jhampur	26°07'46.36"N	80°50'48.65"E	South	HP
L 30	Madan ganw	26° 6'42.16"N	80°51'19.38"E	South	HP
L 31	Poore chheetu	26° 07'34.99"N	80°48'34.60"E	South	HP
L 32	Bhupganj	26°05'09.28"N	80°49'25.45"E	South	BW
L 33	Dhagaicha	26°09'35.62"N	80°051'07.35"E	East	BW
L 34	Hasanapur	26°09'55.39"N	80°51'46.50"E	East	HP
L 35	Sareni khurmi	26°09'18.67"N	80°52'29.04"E	East	HP
L 36	Champtpur manakhera	26°08'37.75"N	80°52'25.78"E	East	HP
L 37	Rampur khurd	26° 9'27.23"N	80°47'4.07"E	West	HP
L 38	Rasoolpur	26°10'19.47"N	80°47'31.64"E	West	HP
L 39	Bhojpur	26°08'29.56"N	80°45'59.68"E	West	HP
L 40	Samodha	26°12'19.58"N	80°46'16.87"E	West	BW

Table 3.3: Description of the groundwater sampling location of Khiron block (Lalganj tehsil)

Sample ID	Villages of Khiron block	Latitude	Longitude	Direction	Sampling Point
L 41	Hariram khera	26°16'41.28"N	80°56'09.74"E	Center	HP
L 22	Husenabad	26°17'22.85"N	80°54'42.85"E	Center	BW
L 43	Khiron (Health centre)	26°17'15.72"N	80°55'59.13"E	Center	HP
L 44	Sarai mahmood	26°16'24.64"N	80°55'01.55"E	Center	HP
L 45	Haripur mirdaha	26°18'18.33"N	80°54'44.14"E	North	BW
L 46	Paho	26°19'59.68"N	80°56'01.04"E	North	HP
L 47	Atarhar	26°18'48.31"N	80°52'45.97"E	North	HP
L 48	Jeti	26°20'34.60"N	80°52'23.77"E	North	HP
L 49	Dokanha	26°15'26.76"N	80°56'36.65"E	South	HP
L 50	Banai mau	26°14'36.69"N	80°56'25.07"E	South	HP
L 51	Mishra khera	26°14'57.79"N	80°54'58.17"E	South	HP
L 52	Haripur nihasta	26°14'04.60"N	80°54'39.72"E	South	BW
L 53	Rampur majra	26°17'39.84"N	80°58'21.93"E	East	HP
L 54	Jamidar ka purwa	26°18'12.77"N	80°59'01.73"E	East	BW
L 55	Gurbux ganj	26°18'11.96"N	81°01'09.19"E	East	HP
L 56	Chande mau	26°17'21.00"N	81° 00'11.56"E	East	HP
L 57	Akampur	26°16'45.18"N	80°52'12.04"E	West	BW
L 58	Sidhaur	26°13'23.69"N	80°51'9.25"E	West	HP
L 59	Khapura	26°12'18.77"N	80°50'54.20"E	West	HP
L 60	Kanha mau	26°12'51.66"N	80°51'55.83"E	West	HP

Table 3.4: Description of the groundwater sampling location of Bachhrawn block (Control)

Sample ID	Village of Bachhrawan block (Control area)	Latitude	Longitude	Direction	Sampling Point
B 1	Police station Bachhrawan	26°28'12.91"N	81°06'44.53"E	Center	HP
B 2	Malhipur	26°28'33.53"N	81° 05'52.76"E	Center	BW
B 3	Bulkeshwer temple Bachhrawan	26°28'30.57"N	81° 06'47.48"E	Center	HP
B 4	Kundan ganj	26°27'15.83"N	81° 07'11.69"E	Center	HP
B 5	Kundauli	26°30'49.53"N	81°06'49.18"E	North	HP
B 6	Dostpur	26°30'30.18"N	81°05'05.80"E	North	HP
B 7	Tilenda	26°29'40.45"N	81°08'54.66"E	North	BW
B 8	Kasrawan	26°29'17.48"N	81°06'49.23"E	North	HP
B 9	Kadawan	26°25'59.03"N	81°07'10.48"E	South	HP
B 10	Khairhani	26°24'23.85"N	81°07'06.53"E	South	HP
B 11	Bannawa	26°26'30.81"N	81°05'37.01"E	South	BW
B 12	Umar pur	26°25'12.47"N	81°09'26.88"E	South	HP
B 33	Thulendi	26°26'58.43"N	81°09'12.93"E	East	BW
B 14	Bhairampur	26°28'12.65"N	81°10'20.36"E	East	HP
B 15	Pahnasa	26°26'32.06"N	81°11'39.12"E	East	HP
B 16	Ashan jagatpur	26°29'04.91"N	81°12'05.33"E	East	HP
B 17	Rampur sudauli	26°30'23.14"N	81°01'48.46"E	West	HP
B 18	Isia	26°29'24.03"N	81°03'53.29"E	West	BW
B 19	Rahi khera	26°27'14.37"N	81°02'30.45"E	West	HP
B 20	Echauli	26°27'55.74"N	81°01'04.19"E	West	HP

3.3 Selection of sampling location

In this study total three blocks of Lalganj tehsil was selected as a sampling site for assessment of groundwater quality are shown in **table 3.1 to table 3.4**. Further each block was divided in five major parts on the basis of direction (north, south, east, west and centre). Distances between each sampling sites was about 5 km.

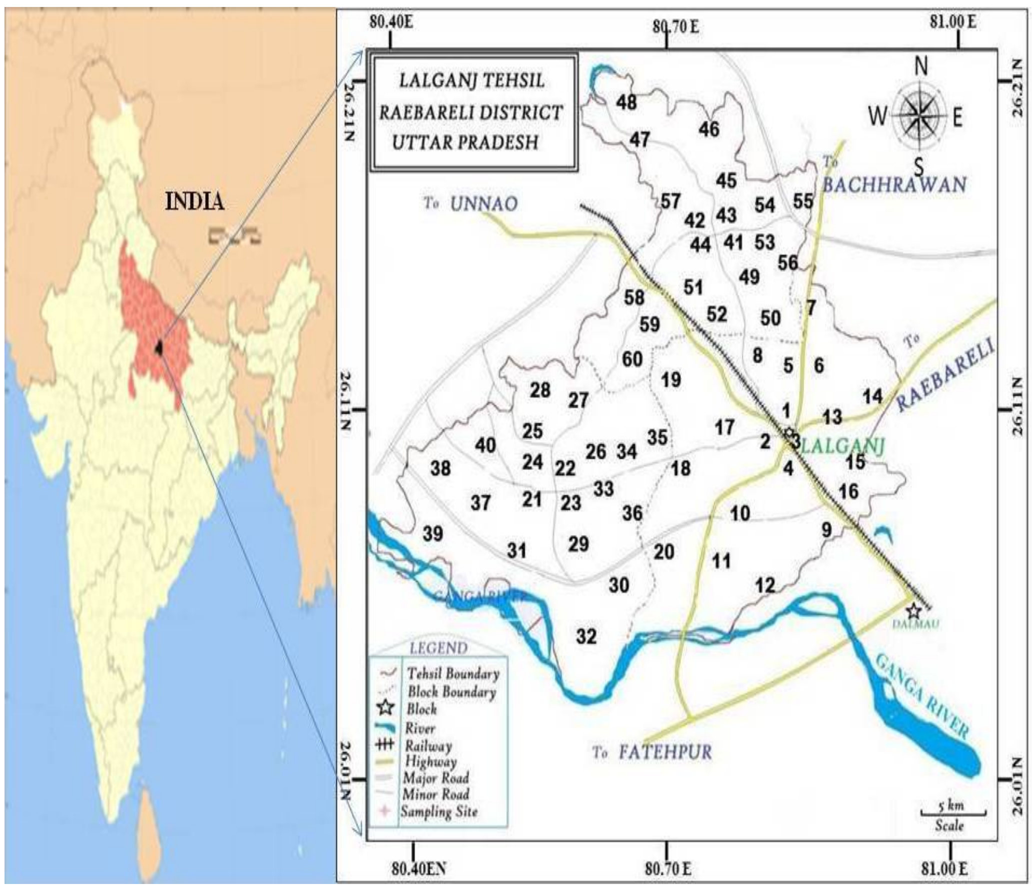


Figure 3.1: Demographic details of from different sampling location of Lalganj tehsil.

3.4 Water Sampling, preservation and analysis

Twenty-twenty groundwater samples were collected randomly from Lalganj tehsil (Lalganj, Khiron and Sareni Block), Raebareli district, Uttar Pradesh (India) during pre and post monsoon season 2016 and 2017, were show in Figure 1 1. Bachhrawan block were taken as a control area which is 30 km remoteness from Khiron and Lalganj. The groundwater samples were collected in pre-washed polyethylene plastic container (1 L capacity). All samples were collected after pumping the hand pump (up to 150 feet) and tube well (more than 250 feet) for 5 minute with rising the bottles for 3 times by water to be sampled, preserved and stored for analysis **(WEF 2012)** as outlined in Standard methods for the Examination of Water and Wastewater. Physico-chemical, fluoride and metallic parameter were analyzed, most of parameters are incorporated in the drinking water standards of **WHO (2011)** and **Indian standard (IS 10500:2012)**. Samples were transported and analyzed in the laboratory of CSIR- Indian Institute of Toxicology Research Lucknow India. Total hardness (TH) as $CaCO_3$, Bicarbonate (BiC) and Chloride (Cl) were analysed by titrimetric method. Electrical conductivity (EC) is measured by ion meter, total dissolve solids (TDS) quantified by gravimetric method and Turbidity (TBDT) was estimated by using Turbidity meter. Sulphate (SO_4^{2}) and nitrate (NO_3^{-}) were analyzed by using spectrophotometer (Dynemica UV-VIS, SB-10). Fluoride was analyzed by Ion Selective Electrode (Orion 4 Star) made by thermo fisher scientific. After analyzed of five samples meter was checked by dipping in standard solution. Sodium, potassium, calcium, and magnesium were measured, using a flame emission mode by AAS (ZEE nit 700). Metals (Zn, Fe, Ni, Mn, Pb, Cu, Cr, Cd and Co) constituent are analyzed in groundwater sample by using atomic absorption spectrophotometer ZEE nit 700 and sodium, potassium, calcium and magnesium had measured, using a flame emission mode. The instrumental condition has decribed in table 6 and hollow cathode lamps were used as a source of light.

Figure 3.2: Showing groundwater samples Collected from different village of Lalganj tehsil.

Table 3.5: physico-chemical and metallic parameter, unit and analytical methods.

S. No.	Parameter	Unit	Analytical method
1.	pH	pH unit	Ion selective electrode
2.	Electrical Conductivity	µS/cm	Electrometric
3.	Turbidity	NTU	Turbidimetric
4.	Alkalinity	mg/L as $CaCO_3$ equivalents	Standard H_2SO_4 titration
5.	Hardness	mg/L as $CaCO_3$ equivalents	EDTA titration
6.	Chloride	mg/L	Titrimetric
7.	TDS,	mg/ L	Gravimetric
8.	Nitrate	mg/ L	UV spectrophotometric
9.	Sulphate	mg/ L	Spectrophotometric
10.	Fluoride	mg/ L	Ion selective electrode
11.	Na^+, K^+, Ca^{2+}, Mg^{2+}	mg/ L	Atomic Emission Photometry
12.	Metals Zn, Fe, Ni, Mn, Pb, Cu, Cr, Cd and Co	mg/ L	Atomic Absorption Photometry

pH (Potential Hydrogenii)

Introduction

pH values from 0 to 7 are diminishing acidic, 7 to 14 increasingly alkaline and 7 is neutral. pH value is governed largely by carbon dioxide/ bicarbonate/carbonate equilibrium. Glass The basic principle of electronic pH measurement is the determination of activity of hydrogen ions by potentiometric measurement using a standard sensing electrode (glass electrode) and a reference electrode (calomel electrode).

Principle

The pH is determined by the measurement of the electromotive force (elf) of a cell compressing of an electrode (an electrode responsive to hydrogen ions such as glass electrode) immersed in the test solution and a reference electrode (usually a calomel electrode). Sensing electrode consists of a thin glass bulb containing a fixed concentration of HCl solution, into which a Ag-AgCl wire is inserted, serving as the electrode with a fixed voltage. Reference electrode consists of a half cell that provides a constant electrode potential. When glass electrode is immersed in a solution, a potential difference develops between the solution in the glass bulb and sample solution. The potential difference E is formulated by Nernst equation:

$$E=RT/nF \{\log (K/M)\}$$

Where,

E= half cell potential, T= Absolute temperature, F= Faraday constant, M= Activity of ions to be measured, R= Gas constant, n= Valence, K= Constant

Since the pH is defined operationally on a potential metric scale, the measuring instrument is also calibrated potentio-metrically with an indicating (glass) electrode and a reference electrode using standard buffers having assigned pH value so that

$$pH= -\log10 [H+]$$

Where, pH = assigned pH of standard buffer.

Equipment and apparatus

pH meter, beaker.

Chemicals

pH Buffer 4, 7 and 9

Procedure

i. The electrode of the pH meter was rinsed with distilled water. It was wiped with a clean tissue paper.
ii. The electrode was dipped in standard solutions having pH values of 4.0, 7.0 and 9.0. This was done for the calibration of the pH meter.
iii. 10 ml sample was taken in a beaker, and the electrode was dipped into the sample in order to measure the pH. The meter reading was allowed to stabilize before noting it down.
iv. The electrode was washed with distilled water before measuring the pH level of another sample.
v. It was kept in mind that the temperatures of all the samples were in the same range.

ALKALINITY

Introduction

Alkalinity is a measure of the capacity of water or any solution to neutralize. The ability to resist change in pH by neutralizing acids or base is called buffering. Carbonate and bicarbonate ions, both are important compound to determine alkalinity in water. Alkalinity is important to aquatic organism because it protects against rapid change in pH. In natural water, most of the alkalinity is caused due to CO_2. The free CO_2 dissolve in water to form carbonic acid (H_2CO_3), which further dissociate in to H^+ and HCO_3^-.The HCO_3^-.thus formed further dissociates in to H^+ and CO_3^-.

Principle

Alkalinity of a sample can be estimated by titrating with standard sulphuric acid titration to pH 8.3 or de-colorization of phenolphthalein indicator will indicate complete neutralization of OH and ½ of CO_3 while to pH 4.5 or sharp change from yellow to pink of methyl orange indicator , that indicate total alkalinity (complete neutralization of OH, CO_3, HCO_3).

Chemical and reagent

Phenolphthalein indicator, H_2SO_4, Methyl orange indicator

Apparatus

Conical flask, Burette stand, Measuring slender, Pipette, Wash bottle

Procedure

i. Suitable volume of sample (100 ml) was taken in a conical flask.
ii. 2-3 drops of phenolphthalein was added to the sample. If no colour appeared, phenolphthalein alkalinity was considered to be absent. If colour turned pink, sample was titrated with standard 0.02 N H_2SO_4 till colour disappeared. The volume of H_2SO_4 required was noted.

iii. 2-3 drops of methyl orange was added and titration was continued till orange colour changed to pink. The volume of H_2SO_4 required was noted.

Calculation

Phenolphthalein alkalinity (mg/l as$CaCO_3$) = (A x 1000) ÷ ml of sample

Methyl orange alkalinity (mg/l as $CaCO_3$) = (B x 1000) ÷ ml of sample

Total alkalinity (mg/l as CaCO3) = (A x B) ÷ ml of sample

CHLORIDE

Introduction

Chloride content in water sample was measured by Argent metric titration method. Chloride is widely distributed as salts of calcium (Ca) Sodium and potassium in water and wastewater in potable water the salty taste produced by chloride concentration invariable and dependent on the chemical composition of water. The major taste producing salts in water are sodium chloride and calcium chloride.

Principle

The amount of chloride present in water can be easily determined by titrating the given water sample with $AgNo_3$. The $AgNO_3$ react with chloride ion according to 1mole of $AgNO_3$ reacts with 1mole of chloride .potassium dichromate use as an indicator and titrated with 0.0141N $AgNO_3$ the end points wine red colour. Note down the ml of $AgNO_3$ required for titrate.

$$AgNO_3 + NaCl \rightarrow AgCl \quad + NaNO_3$$

$$AgCl_{(s)} + Cl^-_{(aq)} \rightarrow AgCl_2^-{}_{(aq)}$$

$$AgCl_{(s)} + 2S_2O_3^{2-}{}_{(aq)} \rightarrow [Ag(S_2O_3)_2]^{3-}{}_{(aq)} + Cl^-_{(aq)}$$

$$AgCl_{(s)} + 2NH_{3(aq)} \rightarrow [Ag(NH_3)_2]^+{}_{(aq)} + Cl^-_{(aq)}$$

$$Ag^+_{(aq)} + Cl^-_{(aq)} \rightarrow AgCl_{(s)}$$

Reagent

Potassium dichromate, Standard AgNO3 0.0141N

Apparatus

Conical flask, Burette Stand, Measuring cylinder, Funnel

Procedure:-

i. Suitable volume of sample (100 ml) was taken in a conical flask.
ii. 2-3 drops of K_2CrO_4 was added.
iii. The sample was titrated with 0.0141 N $AgNO_3$.
iv. At the end point colour change from yellow to wine red was observed.
v. Note down the consume silver nitrate in titration.

Calculation

$$\text{Chloride (Cl}-\text{) (mg/l)} = \frac{A \times \text{N of AgNO3} \times 35.5 \times 1000}{V}$$

Where,

A =Volume of titrant

N = Normality of $AgNO_3$

35.5 =Molecular weight of Cl^{-}1000

V = Volume of sample in (ml)

TOTAL HARDNESS

Introduction

Hardness is caused by the presence of multivalent metallic cat- ions in water. The principle hardness causing cat-ions are divalent Ca^{2+}, $Mg^{2+}$and anions are HCO_3, SO_4, Cl. There are two type of hardness is: carbonate hardness called temporary hardness, because it can be remove by boiling and is caused by dissolved ca and mg bicarbonate and other called non -carbonate hardness (permanent hardness), because it cannot remove by boiling. Non carbonate hardness cat- ions are associated with sulphate, chloride and nitrate ions of ca and mg. Estimated daily intake of mg from water of about 2.3mg and 52. There are following type of hardness:

Classification of hard water

Hardness range (mg/l as $CaCO_3$)	Degree of hardness
0-75	Soft
75-150	moderately hard
150-300	Hard
Above 300	Very hard

Principle

In alkaline condition ethylene diamine tetra acetate (EDTA) acid or its sodium salt (Na_2EDTA) reacts with Ca and Mg to from a soluble cheated complex. Ca and Mg ions develop wine red colour when small amount of dye such as Eriochrome Black-T (EBT) is added under alkaline condition. When EDTA is added as titrant, the Ca and Mg will be complexes with EDTA resulting in sharp change from wine red to blue, which indicates end- point of titration. Hardness expressed as $CaCO_3$.

$$Ca\ (HCO_3) + heat \rightarrow CaCO_3 \downarrow (ppt) + CO_2 + H_2O$$

$$Mg\ (HCO_3)_2 + heat \rightarrow MgCO_3 \downarrow (ppt) + CO_2 + H_2O$$

$$M^+ + \text{Eriochrome Black-T} \rightarrow (\text{M. Eriochrome Blank T})_{complex} \text{Wine red}$$

$$M^{2+} + EDTA \rightarrow [M.EDTA]_{complex}$$

Blue

Chemical and reagent

Ammonium Buffer solution, Eriochrome-black-T indicator, Standard EDTA solution (0.01N)

Glassware ;Burette stand, Measuring slender, 100 ml conical flask,ka

Procedure

i. 100 ml of well mixed sample was taken in a washed conical flask.
ii. 1 ml of ammonium buffer solution was added.
iii. Add about a pinch of EBT (Eriochrome black T) indicator to the sample.
iv. Titrate with standard EDTA (0.01 M). At the end point wine red colour changes to blue.
v. Note down the volume of EDTA required and calculate by following formula.

Figure 3.3: showing hardness analysis in laboratory

Calculation

$$\text{Total Hardness (mg/l)} = \frac{C*D*1000}{V}$$

C = mL of EDTA required by sample for titration

D = mg of $caco_3$ equivalent to 1 ml of EDTA.

V= mL of sample taken for analysis

TOTAL DISSOLVE SOLIDS (TDS)

Introduction

The TDS is combined contents or sum of organic and inorganic substances that are dissolve in water as an ionized (cations and anions), molecular, colloidal, and suspended form. The main source of total dissolved solid in groundwater is natural dissolution and weathering of minerals, rocks, and soil.

Principle

The gravimetric method is measuring the mass of residual or solid content that are dissolve in water by evaporation of liquid media. A well mixed, measured portion of sample is filtered through a standard glass-fibre filter and the filtrate portion is evaporated to dryness at 180±2 ºC and that gives the amount of total dissolved solids. The reason for higher temperature used is to remove all mechanically occluded water. Where organic matter is generally very low in concentration, the losses due to higher drying temperature will be negligible.

Apparatus

Desiccators, Hot oven, Beaker, Evaporating disc.

Procedure

i. Take an evaporating dish or clean beaker and dry it completely. Store the dish/beaker in a desiccator until needed.
ii. Note the initial weight of the dish/beaker.
iii. Put 50 ml sample in the dish/beaker and keep it in a hot air oven at ~100ºC until the sample dries completely.
iv. Cool in a desiccator and note the final weight.

$$\text{TDS (Total dissolve solid) mg/l} = \frac{W_2 - W_1 \times 1000 \times 1000}{\text{Volume of sample}}$$

Where,

W_2= final weight of evaporating dish

W_1= initial weight of evaporating dish

V= volume of sample

FLUORIDE

Introduction

Fluoride ion is minor element but common in groundwater and its dual significant for human being. Beyond the concentration of F^- in drinking water can cause disfigurements of teeth and the concentration below the 0.5 mg/L outcome in dental caries. Hence it is essential to maintain the F- concentration between 0.5 mg/l to 1.0 mg/L in drinking water. Measurement of fluoride in drinking water through ion selective electrode is an approved by Environment Protection Agency.

Principle

When a Fluoride ion-selective electrode comes into contact with an aqueous solution containing fluoride ions, a potential difference develops between the measuring electrode and the reference electrode. The value of this potential difference is proportional to the logarithm of the fluoride ion activity in accordance with the Nernst equation.

$$F^- + H^+ \rightarrow HF$$

This neutralization reaction from Hydrogen fluoride (HF) the conjugate acid of fluoride.

$$F- + H_2O \rightleftharpoons HF + HO^-$$

Instrument and apparatus; Ion-selective Electrode or Fluoride meter, plastic beaker

Figure 3.4: Showing fluoride analysis in groundwater samples in the laboratory

Chemicals

TISAB-III, sodium fluoride, fluoride electrode filling solution,

Preparation of standard fluoride solution

Stock solution (1000 ppm F^-)

Accurately weighted 2.2101 gm of Sodium fluoride after desiccated. 1000 mL capacity of volumetric flask was taken and dissolved with distilled water.

Working solution

100 ppm F^-

10 mL of Stock solution was taken in 100 ml capacity of volumetric flask and make up with 100 mL distilled water.

10 ppm F^- solution

10 mL of 100 ppm F^- solution was taken in 100 ml capacity of volumetric flask and make up with 100 mL distilled water.

1 ppm F^- solution

10 mL of 10 ppm F^- solution was taken in 100 ml capacity of volumetric flask and make up with 100 mL distilled water.

0.1 pm F^- solution

10 mL of 1 ppm F^- solution was taken in 100 ml capacity of volumetric flask and make up with 100 mL distilled water.

Procedure:

i. The electrode of the fluoride meter was rinsed with distilled water and wiped dry with a clean tissue.
ii. Electrode was filled with fluoride filling solution.

iii. The electrode was dipped in a beaker containing 10 ml standard solution having a value of 0.1 ppm along with 1 ml of TISAB (Total Ionic Strength Adjustment Buffer) solution. The meter was calibrated to read 0.1 ppm.

iv. The step was repeated with two more standards having values of 1 and 10 ppm respectively.

v. Instruments has calibrated through above process and slope show between 55 to 60.

vi. After the calibration ,10 ml sample was taken in a beaker, 1 ml TISAB solution was added to it and the fluoride level was read by dipping the electrode into it.

vii. The electrode was washed again with distilled water before measuring the fluoride level of another sample.

viii. It was kept in mind that the temperatures of all the samples were in the same range.

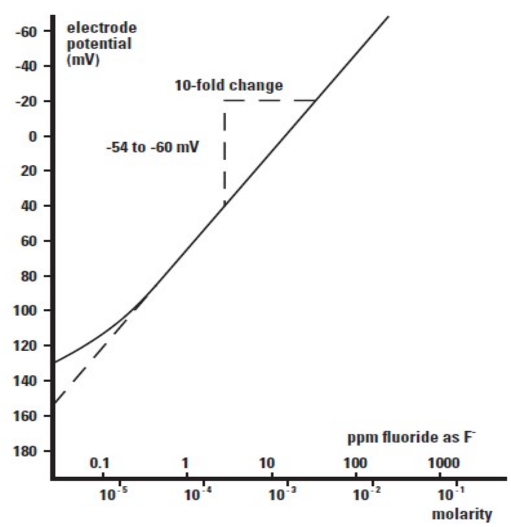


Figure 3.5 Typical Calibration Curve for fluoride analysis

NITRATE

Introduction

Nitrate and nitrites are nitrogen oxygen chemical units which combine with various organic and inorganic compounds. The greatest use of nitrates is as fertilizer once taken in to the body nitrates are converted in to nitrites. Nitrate is an important plant nutrient and cause eutrophication in receiving water bodies. High concentration in drinking water (<40mg/l) may cause “Blue baby disease”. The major source of nitrates in drinking water is runoff of from fertilizer use, leaking from septic tanks, sewage. The following treatment methods (s) have proven to be effective for removing nitrate to below 10mg/l or 10ppm from ion exchange, rivers osmosis.

Principle

Nitrate test in water sample determined by (UV) Spectrophotometric method. An ultraviolet technique measures the absorbance of nitrate at 220 nm, If organic matters dissolved in water then it absorbed at 220 nm after that second measurement was taken at 275 nm. Second measurement was taken to correct the nitrate value (because 275 nm is not absorbed by nitrate).

Reagent; 1N HCL

Apparatus; Spectrophotometer, Beaker

Procedure

i. 50 ml sample was taken in clean and dry 100ml beaker.
ii. 1ml 1N HCL was added.

iii. Check absorbance of distilled water and set it at zero absorbance.

iv. Use spectrophotometer to set 220nm to obtain NO_3-N reading.

v. Another to set wavelength 275nm to determine interference due to dissolve organic matter.

vi. Note down the reading and calculated by nitrate graph.

Calculation

The concentration is calculated followed by the standard calibration curve and below formula.

$$X = \frac{Y-C}{M}$$

Y= difference between absorbance of sample at 275 nm and 220 nm

M= Intercept (0.013), C = slope (0.039), X = Concentration of Nitrate

Table 3.6 Spectro-photometric absorption of nitrate standard for nitrate calculation

Sl. Nos.	Concentration of standard	Absorbance of standard (A)	Absorbance of Blank (B)	Net absorbance (B-A)
1	0	0	0	0
2	1	0.025	0	0.025
3	2	0.052	0	0.052
4	4	0.104	0	0.104
5	6	0.158	0	0.158
6	8	0.204	0	0.204

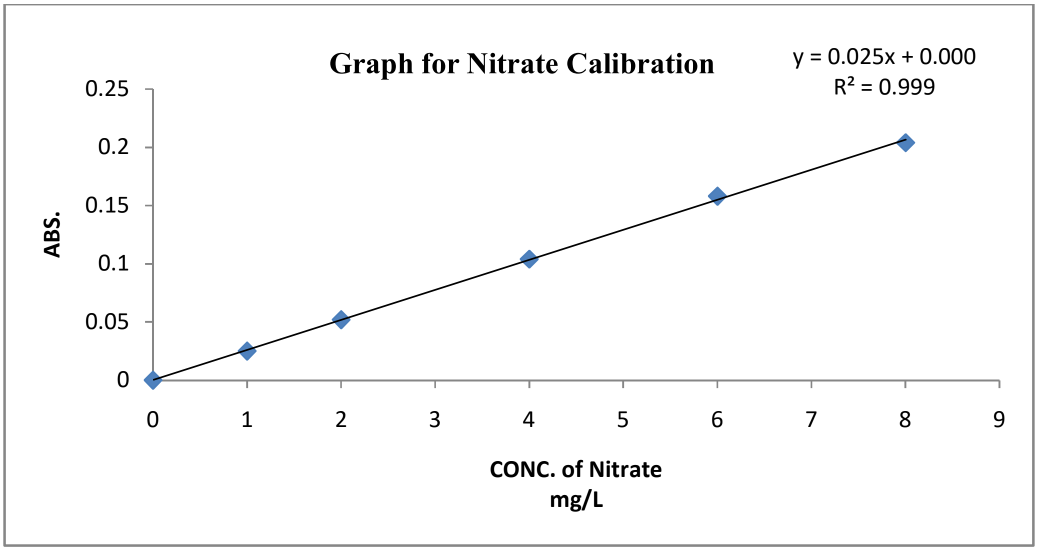


Figure 3.6: Calibration graph for Nitrate determination.

SULPHATE

Introduction

Sulphate in water sample can be estimated by Gravimetric method in which sulphate is precipitated as barium sulphate. Sulphate are naturally occurs in numerous minerals, including barite ($BaSO_4$), epsomite ($MgSO_4$. $7H_2O$), gypsum $CaSO_4.2H_2O$ (Greenwood and Earns haw,1984). Sulphate ions are precipitated in hydrochloride acid and medium as barium sulphate $BaSO_4$ by the addition of barium chloride BaCl. The precipitation is carried out, after a period of digestion the precipitate is filtered, washed with water and free of chloride.

Principle

Sulphate ion (SO_4^{2-}) is precipitated in an acetic acid medium with barium chloride ($BaCl_2$) so as to form barium sulphate ($BaSO_4$) crystals of uniform size.

$$\mathbf{BaCl_2\ (excess) + SO_4^{2-} \rightarrow BaSO_4\ (precipitate)}$$

The crystal formation is enhanced in the presence of an acetic acid buffer solution containing magnesium chloride, potassium nitrate, sodium acetate and acetic acid.

Reagent

Conditioning reagent, $BaCl_2$

Apparatus

Magnetic stirrer, Spectrophotometer

Procedure

i. Set the wavelength to 420 nm. Use the blank to set the zero absorbance.
ii. Take 50ml sample in clean acid washed 100 mL beaker.
iii. Add 10ml Buffer solution.
iv. Add pinch of $BaCl_2$, appear precipitate of $BaSO_4$.
v. Use Magnetic stirrer to constant speed and mixed the whole precipitate of $BaSO_4$.
vi. After mixing of solution, using spectrophotometer took the absorbance at 420nm.
vii. Reading was noted and calculated by calibration graph.

Calculation

The concentration is calculated followed by the standard calibration curve and below formula.

$$X = \frac{Y-C}{M}$$

Y= absorbance of sample at 420 nm

M= Intercept (0.006)

C = slope (0.000)

X = Concentration of Sulphate

Table 3.7 Factor analysis for sulphate determination

Sl. Nos.	Concentration of standard (A)	Absorbance of standard At 420 nm	Absorbance of Blank	Net absorbance (B)	Factors (A/B)
1	0	0	0	0	
2	5	0.029	0	0.029	172.4138
3	10	0.058	0	0.058	172.4138
4	15	0.09	0	0.09	166.6667
5	20	0.12	0	0.12	166.6667
6	25	0.15	0	0.15	166.6667
				average	168.9655

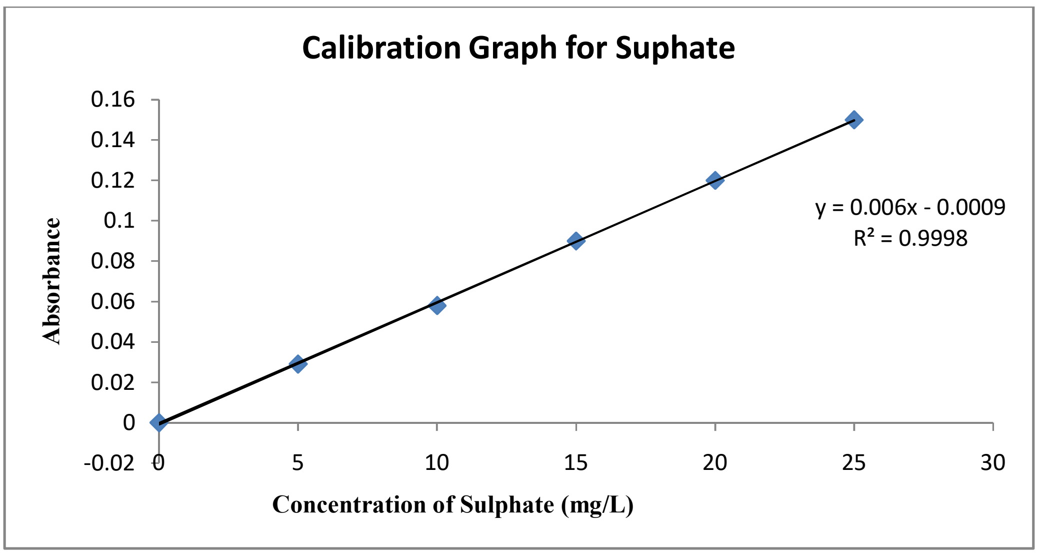


Figure 3.7: Calibration graph for Sulphate determination.

Figure 3.8: Determination of sulphate through spectrophotometer.

TURBIDITY

Introduction

Turbidity is caused by wide variety of suspended and colloidal materials. Run off from barren areas during rain is the most natural contributor of turbidity, particularly silt and clay. The discharge of untreated industrial and domestic effluents also adds great quantity of turbidity. Organic material reaching water bodies serves as food for bacteria, resulting the enhancements of bacteria and other microorganisms feed upon bacteria.

Principle

Turbidity is an expression of the optical property that causes light to be scattered and absorbed rather than transmitted in straight lines through the sample. Higher the intensity of scattered lights higher the turbidity. The standard method for the determination of turbidity has been based on the Jackson candle turbidity meter.

Apparatus

Turbidity meter or Nephelometer, weight balance.

Chemicals

Hydrazine sulphate solution

Dissolved 1.00 gm Hydrazine sulphate in 100 mL volumetric flask, then makeup up to mark with distilled water.

Hexamethylene tetramine solution

Dissolved 10.00 gm Hexamethylene tetramine in 100 mL volumetric flask, then makeup up to mark with distilled water.

Stock Solution (40 NTU)

5 ml of both solutions were taken in 100 mL volumetric flask, and stored at 25±3°C for 24 hours after that makeup up to mark with distilled water.

Procedure

Samples were store in room for some time at constant temperature, and then mixed the sample. Sample was poured into turbidity tube, and waited for disappearing of air bubble after that taken directly from reading from Nephelometer. If reading appear continues 40 or above needed for dilution of sample below 40 NTU.

Figure 3.9: Determination of turbidity by turbidity meter.

CONDUCTIVITY

Introduction

Conductivity is the capacity of water to carry an electrical current and varies both with number and types of ions in the solutions, which in turn is related to the concentration of ionized substances in the water. Most dissolved inorganic substances in water are in the ionized form and hence contribute to conductance. Conductivity measurement gives rapid and practical estimate of the variations in the dissolved mineral contents of a water body.

Principle

Conductivity is a numerical expression of the ability of a water sample to carry an electrical current and varies with the number and types of ions the solution contains. Most dissolved organic substances in water are in the ionized form and hence contribute to conductance.

Conductance G is defined as the reciprocal of resistance R.

G=1/R where R is in Ohm and G is in Ohm^{-1}(sometimes written as Mho).

Conductance of a solution is a measure between two spatially fixed chemically inert electrodes. To avoid polarization at the electrode surface the conductance measurement is made with an alternating current signal. The conductance (G) of a solution is directly proportional to the surface area (A, cm^2) and inversely proportional to the distance between the electrodes (L, cm).The constant of proportionality (k) is such that

G= k A/L

k is called "conductivity" (also specific conductance). The unit of k is 1/ohm-cm or mho per centimeter. It can be defined as the conductance of a conductor 1 cm in length and $1cm^2$ in cross sectional area. The specific conductance depends on the nature of the conductor (the solution between the electrodes), the ion concentration and pressure.

Apparatus

Conductivity meter

Procedure:

i. The electrode of the conductivity meter was rinsed with distilled water. It was wiped dry with a clean tissue paper and rinsed again with the sample whose conductivity was to be measured.

ii. The electrode was dipped in a beaker containing the sample.

iii. The conductivity of the sample was noted from the screen of the meter.

iv. The electrode was washed again with distilled water and sample before measuring the conductivity of another sample.

v. It was kept in mind that the temperatures of all the samples were in the range of 25±1º C.

Figure 3.10: Ion Meter For measurement of Electrical conductivity

METALIC INGREDIENT

Introduction:-

Metals constitute an important portion of drinking water and waste water. The concentration of metals re easily determined by atomic absorption spectrophotometer. Metals with specific gravity greater than 5 or often more are termed as heavy metals .the term used to denote that are toxic. The most important route for elimination of metals is via kidney. In fact kidney can be considered to be complex filter whose primary purpose is to eliminate toxic substances from the body.

- **Heavy Metals like:** Cd, Cr, Cu, Mn, Pb, and Zn.
- **Others:** Na, K, Ca, Mg, Fe

Principle

The atomic absorption uses essentially monochromatic radiation to excite vaporized atoms from their ground state. The instrument consists of a specific light source, a cell (consisting of the aspirated sample), a monochromator and a detection system. The light source, usually a hollow cathode tube, emits essentially line radiation of the same wavelength as that being absorbed by the element under study. This is accomplished by making the source out of the sample element.

Apparatus; AAS, Hot plate, Conical flask, Volumetric flask (500 ml)

Reagent; Nitric acid, (HNO_3), Perchlorice acid ($HClO_4$), Mix standard.

Procedure

i. 500 ml sample was taken in a conical flask of suitable capacity and 10 ml of 4:1 digestion mixture (1 parts perchloric acid and 4 part nitric acid) was added to it.
ii. The sample was allowed to digest on a hotplate until volume got reduced considerably and dense white fumes appeared.

iii. The sample was removed from the hotplate and allowed to cool.

iv. The volume was made upto 20 ml with 0.1 N HNO_3 and sample was then filtered using a 41 or 42 pore size filter paper.

v. The filtered sample was then subjected to analysis using atomic absorption spectroscopy.

Figure 3.11 Atomic absorption spectrophotometer

Table 3.8: Operating conditions of instrumental during analysis of selected element.

Elements	Air (L/m)	Acetylene (L/m)	Lamp (nm)	Limit of detection (ppm)
Zn	2	17	213.9	0.008
Fe	2	17	248.3	0.050
Ni	2	17	232.0	0.040
Mn	2	17	279.5	0.020
Pb	2	17	217.0	0.060
Cu	2	17	224.8	0.025
Cr	2	17	257.9	0.050
Cd	2	17	228.8	0.009
Co	2	17	240.7	0.050

3.5 Collection and Analysis of fluoride in cultivated crops, Fodder plant and rhizospheric soil samples

For this study, 24 no. of plant samples and their rhizoshepheric soil were collected from Lalganj tehsil (all block) during 2016 (USDA Method). Plants and their rhizospheric soil samples were collected and stored in plastic zipper bags with proper labeling. samples were transported in CSIR-IITR (Council of Scientific and Industrial Research- Indian Institute of Toxicology Research) for further processing and analysis. The plants samples were thoroughly washed, chopped into small pieces, air dried for 2 days and then oven dried at 105 °C. The dried samples were then milled to pass through 70 mesh sieve to get homogenized representative powder sample and kept for fluoride determination. The soil samples were immediately sun dried and later dried in a hot air oven at 105 °C for 72 h. The dried soil samples were then grinded by cautiously disaggregating in a mortar and screened through 70 mesh sieve to get homogenized representative powder sample. Finally the samples were stored in airtight polyethylene bags at room temperature for fluoride analysis. Necessary precaution was taken at each step to minimize any contamination. All reagents and calibration standards use for the experiment will analytical grade chemicals. Fluoride was analyzed through alkali NaOH fusion method by using Ion Selective Electrode **(McQuaker and Gumey 1977)**. 0.5 g prepared or stored samples was taken in 100 mL nickel crucible then moistened softly with ultrapure water (Milli-Q water). Samples were placed in oven for about one hour at 150 °C after adding of 6 mL of 16.75 N NaOH solutions, this process solidify to NaOH solution in given time period. Thereafter samples were placed into muffle furnace at 300 °C, swiftly raised the temperature up to 600°C and samples were fused at this temperature for half an hour. After 30 minute, samples were removed from furnace and cooled at normal room temperature. Solidify sodium hydroxide was dissolved by slightly heated to samples after adding of 10 mL Milli-Q water. For the adjustment of pH to 8-9, approximately 8 mL of concentrated HCl was added. Whole sample was poured in to 100 mL plastic volumetric flask, then, made up to volume with Milli-Q water and filtered with whatman filter paper (No. 40). Fluoride was measured through potentiomentrically after taken 10 mL of digested sample in plastic beaker and added 1 mL TISAB-III solution. Ion selective electrode (Orion 4 star) made by Thermo Scientific and EPA approved ISE test procedure for standard test method ASTM D 1179-04-B and 4500-F-C (21st edition). The average recoveries based on the spiked samples at two different levels of fluoride were 94±5-99±4%.

3.5.1 Determination of Moisture contents

The freshly collected vegetables and others plants samples 50 g were air dried for two days. After that dried at 70 ºC temperature in a hot air oven for 3 days then cooled in decicator for 24 Hours. The moisture contents were calculated by following equation**.**

$$\text{Moisture contents } \% = \frac{(W_1 - W_2)}{W_1} * 100$$

Here,

W_1 fresh weight of plants samples

W_2 dry weight of plants samples **(bhatacharya et al., 2017).**

Fig. 3.12: Cultivated, Fodder crops, and soil samples collected from different location of Lalganj tehsil.

Table 3.9: Description of collected cultivated crops sample

Sl.No.	Scientific Name	English Name	Local Name	Edible Parts
1	***Oryza Sativa L***	Rice	Chawal	Seed
2	***Triticum vulgaris***	Wheat	Ghehun	Seed
3	***Cajanus cajan***	Pigeon pea	Arhar	Seed
4	***Vigna mungo***	Black gram	Urad	Seed
5	***Lycopersicon esculentum***	Tomato	Tamatar	Fruit
6	***Capsicum annuam***	Chilli	Mirch	fruit
7	***Solanum tuberosum***	Potato	Alu	Root
8	***Abelmoschus esculentus***	Okra	Bhindi	Fruit
9	***Brassica oleraceabotrytis***	Cauliflower	Fulgobhi	Flower
10	***Luffa aegyptiaca***	Sponge gourd	Taroi	Fruit
11	***Coriandrum sativum***	Coriander	Dhaniya	Leaf
12	***Trichosanthes dioica***	Pointed gourd	Parwal	Fruit
13	***Allium cepa***	Onion	Pyaj	Stem
14	***Chenopodium album***	Pigweed	Bathua	Leaf
15	***Brassica oleracea capitata***	Cabbage	Patta gobhi	Leaf
16	***Momordica Charntia***	Bitter melon	Karela	Fruit
17	***Spinacea oleracea***	Spinach	Palak	Leaf
18	***Raphanus sativus***	Radish	Muli	Stem
19	***Trigonella foenum-graecum***	Fenugreek	Methi	Leaf
20	***Lagenaria siceraria***	Bottle Gourd	Loucky	Fruit
21	***Solanum melongena***	Brinjal	Bhanta	Fruit
22	***Vicia faba***	Broad bean	Sem	Fruit
23	***Daucus carota***	Wild carrot	Soya	Leaf
24	***Amaranthus spinosus***	Chaulai	Chaulai	Leaf

Table 3.10: Description of collected plant sample that are used as a fodder for animal

Sl.No.	Scientific Name	English Name	Local Name	Edible Parts
1	***Oryza Sativa L***	Rice	Chawal	Stem+Leaf
2	***Vigna mungo***	Black gram	Urad	Stem+Leaf
3	***Triticum vulgaris***	Wheat	Ghehun	Stem+Leaf
4	***Sorghum bicolor***	Sorghum	Chari	Stem+Leaf
5	**Zea mays**	Maize	Makka	Stem+Leaf

3.6 Quality control and quality assurance

Analytical grade chemicals (Merck, and Sigma-Aldrich, Germany) were used during study. The glassware's were cleaned through 1 N nitric acid, analysis of blank samples, calibrated equipment, and NABL categories of glassware were used for quality assurance procedure. All reagents and calibration standards for analysis were prepared using milliqui water. All analyses were carried out with triplicate samples, and the recoveries of metal were found 75 to 95% through the spiked sample method. All samples were performed in triplicate with blank sample and standard solution was preserved at 4 °C before its use for analysis.

3.7 Statistical analysis

3.7.1 Water quality index (WQI)

Water Quality index (WQI) is defined as a technique of ranking which affords the composite influence of individual water quality parameter on the overall quality of water. WQI is one of the powerful tools to assess the status of drinking water suitability for human consumption. The average means concentration of the thirteen physico-chemical parameters such as pH, TDS, Turbidity, TA, TH, Cl^-, NO_3^-, SO_4^{2-}, F^-, Ca^{2+}, Mg^{2+}, Na^+, and K^+ was used for the calculation of WQI. The cumulative effects of different parameters can be calculated to evaluate the drinking water quality of an area. The critical pollution index considered unacceptable is 100. The steps are as follows:

In the first step,

The permissible values of different parameters as per Indian standard and WHO standard were observed to select the parameters for calculating the WQI. Then among the total analyzed parameter, 13 parameters has been selected for assigned a weight (wi) according to its relative importance in the overall quality of water for drinking purposes (Table 4.3). The maximum weight of 5 has been assigned to the parameter like TDS, Cl^-, SO_4^{2-}, NO_3^- and F^- due to their major importance and these parameters are the mainly pollution indicating parameters and TA, TH and K^+ which are given the minimum weight of 3 as these parameters are itself may not be harmful than previous ones.

In the second step,

The relative weight (Wi) is computed from the following equation

Wi = wi / ∑wi .... Eq. (1)

Where,

wi =assigned a weight

∑wi = sum of the weights of all the parameters considered in relative weight calculation table.

In the third step,

a quality rating scale, Qi, was computed for each parameter using following equation:

Qi = (Ci / Si) x100 .... Eq. (2)

Here

Ci =the concentration of parameters present in the samples

Si= acceptable limits of WHO and Indian standard for each parameter, in mg/L.

Si Value for pH is considered as 7.

In the fourth step, the water quality sub index, SI_i was then calculated for each parameter using Eq. (3).

SI_i = Wi x Qi .... Eq. (3)

In ending step, WQI values Computed by means of-

WQI = $\sum SI_i$ .... Eq. (4)

Computed WQI values are usually classified into five categories as follows **(Sahu and Sikdar 2008)**: ≤50 excellent water, 50–100 good water, 100–200 poor water, 200–300 very poor water, >300 water unsuitable for drinking.

Table 3.11: Groundwater quality parameters with their unit weights for WQI calcution.

Sl.No.	Parameter	Standard (Si)	Weight (Wi)	Relative Weight (Wi/∑Wi)
1	pH	7	4	0.074
2	TDS	500	5	0.093
3	Turbidity	5	4	0.074
4	TA	200	3	0.056
5	TH	200	3	0.056
6	Cl^-	250	4	0.074
7	NO_3^-	45	5	0.093
8	SO_4^{2-}	250	5	0.093
9	F^-	1	5	0.093
10	Ca^{2+}	75	5	0.093
11	Mg^{2+}	30	4	0.074
12	Na^+	200	4	0.074
13	K^+	10	3	0.056
			∑Wi 54	∑1.000

3.7.2 Heavy metal Pollution Index (HPI)

The HPI calculate to entire quality of water with on the basis of heavy metals contaminations. It was developed by assigning rating (Wi) value betwen zero and one. Zinc, iron, manganese, nickel, lead, copper, cadmium, and chromium have been monitored for the model index application. Permissible value (Si) and desirable value (Ii) were taken from national drinking water specifications (Indian Standard 2012) for each heavy metal **(Prasad et al 2014)**. The HPI is determined according to **Mohan et al. 1996** and equation is given below:

$$HPI = \frac{\sum_{i=1}^{n} WiQi}{\sum_{i=1}^{n} Wi} \text{......................eq (1)}$$

Where,

Wi = The unit weight,

Qi = The sub-index of the (i) parameter, and

n = The number of considered parameters.

The sub-index Qi of the parameter is described using:

$$Qi = \sum_{i=1}^{n} \frac{\{Mi(-)Ii\}}{Si-Ii} * 100 \text{...........eq (2)}$$

Where as,

Mi = Observed concentration of heavy metal of the i^{th} parameter.

Si = Standard value (Maximum acceptable limit) of drinking water in the absence of other water sources.

Ii = Ideal value (highest desirable value) for the same heavy metals.

The sign (-) indicates the numerical difference of two values and algebraic sign does not take into account. The index is anticipated for the rationale of drinking water and the critical or significant pollution index score for drinking water is 100 **(Mehrabi et al. 2015)**.

3.7.3 Factor Analysis/Principal Component Analysis

The Principal component or factor analysis is performed to extract the most important factors affecting the water quality which was described by 14 physicochemical parameters from each block of the study area. Due to the complex associations between physicochemical parameters, it was tough to draw clear conclusions but principal component analysis extracts the information and explains the variables. this new latent variables which are orthogonal and uncorrelated to each other**.** Hydrochemical data was generally normalized to drop misclassification due to the diverse order of magnitude and range of variation of the analytical parameter. The rotation of the factors was executed by the Varimax with Kaiser Normalization. 14 physicochemical parameters during both seasons were selected for FA.

3.7.4 Spearman Correlation Matrix

Spearman correlation matrix was applied for finding the relation within the physicochemical parameter and metallic contents. The two-tailed bivariate correlation (significant at 0.05 and 0.01 level) was carried out to investigate the relationship within physicochemical parameters and metallic contents .

3.7.5 Hierarchical Cluster Analysis

HCA is a powerful data mining technique, which classifies variables into clusters on the basis of similarities within a group and dissimilarities between different groups. HCA is advantageous technique, which allows the assembling of objects based on their similarity. HCA classifies water quality parameters into groups so that variables within a cluster starting with the most similar pair of variables and forming higher clusters step by step. The dendrogram can be fragmented at dissimilar levels to yield different clusters of the data set and provides a visual summary of the cluster through a picture of the groups and their proximity with a dramatic reduction in dimensionality of the original data. In this study, the the Ward's method with squared Euclidean distance uses the minimum variance approach to evaluate distance between clusters.

3.7.6 T-test

T-test was performed through SPSS software where computed value of test significance at 5% level and test was conducted for testing significant variation between means of pre-monsoon data (physicochemical parameter) during 2016 and 2017 in groundwater of Lalganj tehsil with respect post-monsoon data, The degree of freedom and the t- test is given by following equation:

$$\text{Degree of freedom} = (n_1 - n_2 - 2)$$

$$t = \frac{(\bar{x}_1 - \bar{x}_2)}{\sqrt{s^2 \left(\frac{1}{n_1} + \frac{1}{n_2}\right)}}$$

Where $\bar{x}_1$ is the means of pre-monsoon data , $\bar{x}_2$ is means of post-monsoon data, s^2 is the variance of combined sample, n_1 and n_2 is numeral of observations on variable of pre-monsoon and post-monsoon data of Lalganj tehsil.

If computed value (t-value) is less than critical value ($p = 0.05$), there are similarity between means. Otherwise, the difference is significant.

3.8 Risk characterization from exposure of fluoride via dietary intake

3.8.1 Study of the nutrition pattern of fluoride

The survey completed with the help of randomly selected permanents residents of Three hundred male and Three hundred female from Lalganj tehsil (100 male and 100 female each block). The survey of the nutrition patter was categorized according to age i.e. children (3-6 years), teenagers (7-18 years) and adults (19-70 years) and their weight were 19, 52 and 80 kg taken as per **US EPA 2011** from "The Exposure Factor Handbook". The survey evaluating according to National Institute of Nutrition (India) based on daily diets, quantity of eating and frequency of rice, wheat, vegetables and pulses **(Thimmayamma and Rau, 1987)**.

3.8.2 Estimated daily intake of fluoride (EDI)

Daily intake of fluoride intake was calculation from developed equation by US EPA, 1992;

$$\text{EDI} = \frac{C * IR * EF * ED * AF * CF}{BW * AT}$$

Where,

EDI = Estimated Daily Intake (mg/kg/day)

C = Concentration of F^- in Diet (mg/kg or mg/L)

IR = Intake or Ingation Rate (mg/day)

EF = Exposure Frequency (days/year) i.e. how many day taken in year.

ED = Exposure Duration or length of time (year)

AF = Absorption Factor (without unit)

CF = Conversion Factor (10^{-6} kg/mg)

BW = Body weight of children, teenage and adult (kg)

AT = Average Time (days)

EDI was calculated by applying the above equation, where based on the absorption efficiency (75 to 100 %) in the gastro-intestinal tract **(ASTDR 2001)**. Two values (Central tendency exposure and Reasonable maximum exposure) were taken for calculation of risk characterization **(USEPA 1989; Erdal and Buchanan 2005)**. In central tendency exposure (CTE) scenarios, absorption factor (AF) was taken 0.75 because of average absorption (75%) in the gastro-intestinal tract and Reasonable maximum exposure (RME) calculation; absorption factor (AF) was taken 1 for wrost-case exposure (100%) in the gastro-intestinal tract.

For complete risk characterization, ingestion of fluoride via diets (drinking water and consumption of wheat, rice, vegetables and pulses) are taken for cumulative EDI calculation;

$$EDI_{Cumulative} = EDI_{Rice} + EDI_{Wheat} + EDI_{vegitables} + EDI_{drinking\ water}$$

The Hazard Index (HI) was calculated to characterized the risk owing to exposure of fluoride in various age groups of local inhabitant.

$$HI = \frac{EDI_{cumulative}}{RfD}$$

The reference dose (RfD) was calculated from following equation

$$RfD = \frac{NOAEL}{UF * MF}$$

Where NOAEL is No observed adverse effect level, UF is uncertainity factor and MF is modifying factor. The RfD **USEPA 2003** recommended **0.06 mg/kg** fluoride and found from Integrated Risk Information System (IRIS) published by **USPA 1987**.

According to (USEPA 2003) and Grzeti and (Ghariani 2008) the cumulative non-cancerous lifetime risk for 3 to 70 years age groups was estimated to fluoride vulnerability for the entire life.

$$HI_{Cumulative} = HI_{3-6\ years} + HI_{7-18\ years} + HI_{19-70\ years}$$

3.8.3 Exposure dose assessments of fluoride through drinking water

Exposure dose (ED) was evaluated by following equation developed by **Jha et al., (2009).**

$$\mathbf{ED} = \frac{\mathbf{C}}{\mathbf{WB}} * \boldsymbol{WI}$$

Where,

ED is Exposure dose of fluoride (mg/kg/day), C is fluoride concentration (mg/L), WB is body weight of person (kg) and WI is water intake (L/day).

Table 3.12: Consumption pattern of cultivated crops and vegetables for 3 to 6 years age groups

Scientific Name	3 to 6 years age groups	
	Intake Frequency (gfwt/day)	**Exposure Frequency (Day/Year)**
Oryza Sativa L	50 (daily)	365 (12 months)
Triticum vulgaris	50 (daily)	365 (12 months)
Cajanus cajan	25 (thrice in a week)	156 (12 months)
Vigna mungo	25 (once in a week)	52 (12 months)
Lycopersicon esculentum	10 (daily)	365 (12 months)
Capsicum annuam	1 (daily)	366 (12 months)
Solanum tuberosum	25 (daily)	365 (12 months)
Abelmoschus esculentus	100 (once in a week)	26 (6 months)
Brassica oleraceabotrytis	25 (Once in a week)	17 (4 months)
Luffa aegyptiaca	25 (Once in a week)	17 (4 months)
Coriandrum sativum	15 (daily)	365 (12 months)
Trichosanthes dioica	25 (Once in a week)	17 (4 months)
Allium cepa	5 (daily)	365 (12 months)
Chenopodium album	25 (Once in week)	8 (2 months)
Brassica oleracea capitata	30 (Once in a week)	17 (4 months)
Momordica Charntia	25 (thrice in a month)	12 (4 months)
Spinacea oleracea	30 (Once in a week)	34 (8 months)
Raphanus sativus	25 (twice in a week)	34 (4 months)
Trigonella foenum-graecum	30 (Once in a week)	17 (4 months)
Lagenaria siceraria	30 (twice in a week)	34 (4 months)
Solanum melongena	25 (thrice in a week)	121 (12 months)
Vicia faba	25 (5 time in a month)	20 (4 months)
Daucus carota	30 (twice in a week)	34 (4 months)
Amaranthus spinosus	25 (twice in a week)	34 (4 months)

Table 3.13: consumption pattern of cultivated crops and vegetables for 7 to 18 years age groups

Scientific Name	7 to 18 years age groups	
	Intake Frequency (gfwt/day)	**Exposure Frequency (Day/Year)**
Oryza Sativa L	250 (daily)	365 (Daily)
Triticum vulgaris	150 (daily)	365 (12 months)
Cajanus cajan	50 (thrice in week)	156 (12 months)
Vigna mungo	50 (once in a week)	52 (12 months)
Lycopersicon esculentum	15 (daily)	365 (12 months)
Capsicum annuam	2 (daily)	366 (12 months)
Solanum tuberosum	75 (daily)	365 (12 months)
Abelmoschus esculentus	150 (once in a week)	26(6 months)
Brassica oleraceabotrytis	50 (Once in a week)	17 (4 months)
Luffa aegyptiaca	75 (Once in a week)	17 (4 months)
Coriandrum sativum	15 (daily)	365 (12 months)
Trichosanthes dioica	75 (Once in a week)	17 (4 months)
Allium cepa	20 (daily)	365 (12 months)
Chenopodium album	50 (Once in week)	8 (2 months)
Brassica oleracea capitata	50 (Once in a week)	17 (4 months)
Momordica Charntia	75 (thrice in a month)	12 (4 months)
Spinacea oleracea	75 (Once in a week)	34 (8 months)
Raphanus sativus	50 (twicein a week)	34 (4 months)
Trigonella foenum-graecum	50 (Once in a week)	17 (4 months)
Lagenaria siceraria	50 (twice in a week)	34 (4 months)
Solanum melongena	50 (thrice in a week)	121 (12 months)
Vicia faba	50 (5 time in a month)	20 (4 months)
Daucus carota	50 (twice in a week)	34 (4 months)
Amaranthus spinosus	50 (twice in a week)	34 (4 months)

Table 3.14: consumption pattern of cultivated crops and vegetables for 19 to 70 years age groups

Scientific Name	**19 to 70 years age groups**	
	Intake Frequency (gfwt/day)	**Exposure Frequency (Day/Year)**
Oryza Sativa L	350 (daily)	365 (Daily)
Triticum vulgaris	200 (daily)	365 (12 months)
Cajanus cajan	75 (thrice in week)	156 (12 months)
Vigna mungo	75 (once in a week)	52 (12 months)
Lycopersicon esculentum	20 (daily)	365 (12 months)
Capsicum annuam	3 (daily)	366 (12 months)
Solanum tuberosum	100 (daily)	365 (12 months)
Abelmoschus esculentus	200 (once in a week)	26 (6 months)
Brassica oleraceabotrytis	75 (Once in a week)	17 (4 months)
Luffa aegyptiaca	100 (Once in a week)	17 (4 months)
Coriandrum sativum	15 (daily)	365 (12 months)
Trichosanthes dioica	100 (Once in a week)	17 (4 months)
Allium cepa	25 (daily)	365 (12 months)
Chenopodium album	75 (Once in week)	8 (2 months)
Brassica oleracea capitata	75 (Once in a week)	17 (4 months)
Momordica Charntia	100 (thrice in a month)	12 (4 months)
Spinacea oleracea	100 (Once in a week)	34 (8 months)
Raphanus sativus	75 (twice in a week)	34 (4 months)
Trigonella foenum-graecum	75 (Once in a week)	17 (4 months)
Lagenaria siceraria	100 (twice in a week)	34 (4 months)
Solanum melongena	75 (thrice in a week)	121 (12 months)
Vicia faba	75 (5time in a month)	20 (4 months)
Daucus carota	100 (twice in a week)	34 (4 months)
Amaranthus spinosus	75 (twice in a week)	34 (4 months)

CHAPTER 4

RESULTS

To understanding of current status of groundwater quality of Lalganj tehsil, with special reference to fluoride concentration in groundwater and an assessment of potential health risk associated with excessive intake of fluoride through diet. A sincere attempt was conducted to aware local people of the same so that corrective measures could be taken timely. Physic-chemical and trace constituent were analyzed in collected 60 groundwater samples are presented in this chapter during pre-monsoon and post-monsoon season of last two year from different villages of the tehsil. fluoride also analyzed in groundwater, cultivated crops, fodder plant and diet was described in this chapter. The collection of samples and method used for water quality analysis are described in previous chapter "materials and methods" section. In this chapter, the analyzed results are presented in following different section.

4.1 Hydrochemical facies and trace constituents in groundwater

4.1.1 Hydrochemical facies in groundwater

4.1.1.1 The pH

The pH of groundwater were ranged from 7.02 to 8.61 (7.81±0.06) for Lalganj block, 7.00 to 8.23 (7.67±0.05) for Sareni block and 7.26 to 8.34 (7.80±0.06) for Khiron block during 2016 and 7.55 to 8.21 (7.90±0.03) for Lalganj block, 7.55 to 8.21 (7.92±0.02) for Sareni block and 7.64 to 8.21 (7.99±0.04) for Khiron block during year of 2017 are shown in **Table** 4.11. Maximum pH were found, 8.61 at L13 of Lalganj block, 8.23 at L30 of Sareni block and 8.34 at L53 of

Khiron block while minimum was recorded 7.02 at L17 of Lalganj block, 7.00 at L27 of Sareni block and 7.26 at L44 of Khiron block during 2016. During 2017, Minimum pH was 7.55 recorded at L25, L27, L32, L38 of Lalganj block, and maximum pH found 8.21 at L13 of Lalganj block, L33 of Sareni block and L51 of Khiron block.

4.1.1.2 Turbidity

The turbidity of groundwater were ranged from BDL to 6.0 NTU (2.0±0.24) for Lalganj block, BDL to 8.0 NTU (4.0±0.05) for Sareni block and BDL to 6.0 NTU (2.0±0.23) for Khiron block during 2016 and 1.0 to 5.0 NTU (3.0±0.21) for Lalganj block, 2.0 to 7.0 NTU (4.0±0.20) for Sareni block and 1.0to 6.0 NTU (3.0±0.18) for Khiron block during year of 2017 are shown in **Table** 4.11.

4.1.1.3 Total Hardness

The Total hardness (TH) was varied from 26 to 736 mg/L and 36 to 782 mg/L in all block of Lalganj tehsil for during the year of 2016 and 2017 (**Table** 5.1). In the year of 2016, the maximum value of 736 mg/L was observed in groundwater source in Sareni block while the lowest value of 26 mg/L was found in groundwater sample of Lalganj Block. In the year of 2017, the maximum value of 782 mg/L observed in groundwater source in Sareni block while the lowest value of 36 mg/L found in groundwater sample of Lalganj Block. The average concentration of total hardness was reported 282±19.45, 323±22.28, and 209±12.67 mg/L during 2016 and 310±19.02, 352±22.42, and 235±13.20 mg/L in Lalganj, Sareni and Khiron block during 2017.

Table 4.1: Groundwater sample belong to category of water based on hardness

Range of Hardness mg/l	Category of water	Percent of groundwater sample					
		Lalganj block		Sareni block		Khiron block	
		2016	2017	2016	2017	2016	2017
0 – 75	Soft	5%	5%	-	-	5%	5%
75 – 150	Moderately hard	7.5%	-	-	-	20%	7.5%
150 – 300	Hard	50%	52.5%	62.5%	50%	67.5%	70%
>300	Very hard	37.5%	42.5%	37.5%	50%	7.5%	17.5%

In groundwater, 95 % of water made up from only seven solutes; calcium, magnesium, sodium, potassium, chloride, sulphate, and bicarbonate.

4.1.1.4 Calcium

Results indicated that the mean concentration of calcium in the groundwater of the Lalganj, Sareni and Khiron block during 2016 were found 46±3.44 , 49±3.14 and 35±2.48 mg/L. Calcium content in the groundwater of the Lalganj, Sareni and Khiron block ware found 51±3.22, 52±1.98 and 40±1.76 mg/L during 2017. The mean concentration of calcium were found within the suibable limits of IS and WHO standards precise in **Table 5.1**. Maximum Calcium were found, 115 mg/L at Bahara village of Lalganj block, 133 mg/L at Jalalpur village of Sareni block and 66 mg/L at Jamidar ka purwa village of Khiron block while minimum was recorded 7 mg/L at Aihar of Lalganj block, 13 mg/L at near police station of Sareni and 5 mg/L at Dokanha village of Khiron block during 2016. During 2017, Minimum value of Ca^{2+} was recorded 14 mg/L at Aihar village of Lalganj block, 30 mg/L at near police station of Sareni and 16 mg/L at Kanha mau village of Khiron block and maximum

Calcium found 120 mg/L at L13 of Lalganj block, 92a mg/L L33 of Sareni block and L51 of Khiron block.

4.1.1.5 Magnesium

IS suggested the acceptable value of Mg^{2+} in drinking water is 30 mg/L and in the study part average concentration during 2016 found more than the IS value in Lalganj block (66±5.71 mg/L), Sareni block (80±6.76 mg/L) and Khiron block (53±3.80 mg/L). In 2017, value of Mg^{2+} noted that Lalganj block was 69±4.08 mg/L, Sareni block was 85±7.25 mg/L and Khiron block was 63±3.36 mg/L. control area (Bachhrawan block) was found 44±3.29 mg/L and 53±3.72 mg/L for year of 2016 and 2017.

4.1.1.6 Sodium

Excessive intake of sodium can increase blood pressure, infection and confusion while deficiency may cause muscle paralysis, decreased growth, dehydration. The value of sodium in the groundwater samples of Lalganj, Sareni and Khiron block 189±8.81, 179±8.29 and 182±10.37 mg/L during year of 2016 while 205±8.50, 200±8.45 and 197±9.84 mg/L in 2017.

4.1.1.7 Potassium

The value of potassium varied between 5 to 46 mg/L in Lalganj block, 8 to 56 mg/L in Sareni block and 4 to 22 mg/L in Khiron block with the mean values were found 18±1.76, 23±1.96 and 12± 0.74 mg/L in Lalganj, Sareni and Khiron block during 2016. The concentration of potassium in 2017, ranged from 6 to 45 mg/L, 9 to 46 mg/L and 5 to 23 mg/L with average concentration were calculated

15±1.73 mg/L, 20± 1.62 mg/L, and 13±0.70 mg/L for Lalganj, Sareni and Khiron block.

4.1.1.8 Total Alkalinity or Bicarbonates (T-Alk)

Results point out that the mean concentration of bicarbonates in the groundwater of the Lalganj, Sareni and Khiron block during 2016 were found 419±13.98 , 400±18.53 and 407±33.45 mg/L. Bicarbonates content in the groundwater of the Lalganj, Sareni and Khiron block ware found 474±15.70, 446±19.34 and 490±39.24 mg/L during 2017. The mean concentration of bicarbonates was found within the permissible limits (600 mg/L) of Indian standards but higher than acceptable limit (200 mg/L) precise in **Table 5.1**. Maximum bicarbonates were found, 628 mg/L at Lalamau village of Lalganj block, 756 mg/L at Sabji barua village of Sareni block and 1146 mg/L at Khapura village of Khiron block during 2016 and 672 mg/L at Lalamau of Lalganj block, 761 mg/L at Sabji barua village of Sareni block and 1234 mg/L at Khapura village of Khiron block during 2017. Concentrations of bicarbonate in groundwater samples of control area were found 354±10.68 and 414±14.19 mg/L for 2016 and 2017.

4.1.1.9 Chloride

Results indicated that the mean concentration of chloride in the groundwater of the Lalganj, Sareni and Khiron block were found 75±11.85 , 167±26.96 and 73±10.04 mg/L during 2016 and 82±13.57, 193±26.66 and 80±9.71 mg/L during 2017. The mean concentration of chloride were found within the suitable limits of IS and WHO standards precise in **Table** 5.1. Maximum chloride were found, 375 mg/L near Lalganj tehsil of Lalganj block, 658 mg/L at Hasanapur village of Sareni block and 288 mg/L at Kanha mau village of Khiron block during 2016. During 2017, the maximum value of chloride found 380 mg/L at Lalganj tehsil of Lalganj block, 624 mg/L at Hasanapur village of Sareni block and 294 mg/L at Kanha mau village of Khiron block during 2017.

4.1.1.10 Sulphate

The concentration of Sulphate in groundwater were ranged from 1 to 451 mg/L (121±18.70) for Lalganj block, 1 to 400 mg/L (104±14.90) for Sareni block and BDL to 266 mg/L (81±11.41) for Khiron block during 2016 and 12 to 421 mg/L (139±18.98) for Lalganj block, 13 to 395 mg/L (116±14.33) for Sareni block and 10 to 266 mg/L (93 ±10.68) for Khiron block during year of 2017 are shown in **Table** 4.11. The mean value of sulphate in water samples of region is within the limit 200 mg/L.

4.1.1.11 Nitrate

Results point out that the mean concentration of nitrate in the groundwater of the Lalganj, Sareni and Khiron block during 2016 were found 21±3.51, 13±1.57 and 7±1.06 mg/L. In 2017, nitrate content in the groundwater of the Lalganj, Sareni and Khiron block ware found 24±3.43, 15±1.46 and 10±1.01 mg/L. The mean concentration of nitrate was found within the permissible limits (45 mg/L) of Indian standards but precise in **Table** 5.1. Maximum nitrate were found, 84 mg/L at Bahara village of Lalganj block, 52 mg/L at Hasanapur village of Sareni block and 32 mg/L at Haripur mirdaha village of Khiron block during 2016 and 82 mg/L at Lalganj tehsil of Lalganj block, 50 mg/L at Hasanapur village of Sareni block and 30 mg/L at Haripur mirdaha village of Khiron block during 2017. Concentrations of nitrate in groundwater samples of control area were found 13±1.30 and 16±2.10 mg/L for 2016 and 2017.

4.1.1.12 Fluoride

F^-concentration in groundwater of Lalganj, Sareni and Khiron block ranged from 0.61 to 4.63, 0.64 to 2.99 and 0.44 to 17.20 respectively, while 0.26 to 1.43 mg/L in Bachharawan block (control area) during 2016. In 2017, F^-concentration in groundwater of Lalganj, Sareni and Khiron block ranged from 0.59 to 4.72, 0.89 to 3.10 and 0.46 to 16.20 respectively, while 0.26 to 1.46 mg/L in Bachharawan block (control area). The mean value of fluoride in water samples of Lalganj, Sareni and Khiron block were 2.16, 1.45 and 2.84 mg/L during 2016 and 2.25, 1.60 and 2.94 mg/L which exceeded maximum limit of drinking water of Indian Standard and WHO.

4.1.1.13 Total Dissolve Solid (TDS)

Total dissolve solid is a sum of all dissolved organic and inorganic constituent. The main contributors to water are: chloride (Cl^-), Fluoride (F^-), sodium (Na^+), nitrate (NO_3^-), calcium (Ca^{+2}), magnesium (Mg^{+2}), bicarbonate (HCO_3^-), and sulphate (SO_4^{-2}). The Total dissolve solid (TDS) was varied from 617 to 1848 mg/L, 547 to 2254 mg/L and 459 to 1927 mg/L in Lalganj, Sareni and Khiron block for during the year of 2016 and 657 to 1939 mg/L, 611 to 2309 mg/L and 548 to 2075 mg/L in 2017 (**Table** 5.1). The average concentration of Total dissolve solid was reported 978±49.62, 1036±65.25, and 871±57.33 mg/L during 2016 and 1076±50.67, 1141±62.95, and 994±61.99 mg/L during 2017.

Table 4.2.Results of physico-chemical facies in groundwater of Lalganj block, during the year of 2016

Sample ID	Season	pH	EC µS/cm	TDS mg/l	Turbidity NTU	Alkalinity mg/l	TH mg/l	Cl^- mg/l	NO_3^- mg/l	SO_4^{2-} mg/l	F^- mg/l	Ca^{2+} mg/l	Mg^{2+} mg/l	Na^+ mg/l	K^+ mg/l
L1	Pre	7.68	1070	787	BDL	312	133	72	1	56	2.33	18	35	255	16
L2	Pre	7.02	1229	892	2	417	312	77	26	83	2.00	70	54	135	13
L3	Pre	7.02	969	719	BDL	342	253	52	21	21	1.25	38	64	140	18
L 4	Pre	7.94	1115	834	2	368	344	48	6	78	1.36	49	88	147	13
L 5	Pre	7.63	2100	1508	BDL	512	490	162	82	362	4.22	18	179	154	16
L 6	Pre	7.32	975	705	BDL	352	292	21	1	42	1.29	74	42	130	16
L 7	Pre	7.46	1006	732	1	352	303	18	1	52	1.53	45	76	135	21
L 8	Pre	7.77	816	617	2	299	232	37	5	1	2.64	39	54	120	23
L 9	Pre	7.49	921	683	1	356	236	11	7	21	1.61	49	46	162	9
L 10	Pre	8.23	951	688	1	412	158	31	1	5	2.59	37	26	131	19
L 11	Pre	7.71	1444	1078	2	456	242	48	5	236	2.53	15	82	200	14
L 12	Pre	7.63	1096	833	2	456	242	46	17	11	1.88	44	52	156	13
L 13	Pre	8.11	1080	794	1	396	28	30	7	16	4.54	7	5	263	46
L 14	Pre	7.35	966	699	1	341	142	67	8	5	1.89	30	27	180	15
L 15	Pre	7.62	1753	1223	2	524	344	72	5	209	2.65	56	82	230	12
L 16	Pre	8.2	865	651	1	312	216	32	3	29	1.43	46	40	131	21
L 17	Pre	7.02	1276	931	2	523	130	35	25	47	2.00	31	21	201	25
L 18	Pre	7.53	1818	1314	BDL	484	476	22	24	259	0.96	48	143	264	46
L 19	Pre	7.45	2292	1580	3	500	452	243	31	232	2.20	97	85	344	21
L 20	Pre	7.41	1381	1007	4	300	430	62	30	180	0.86	55	110	195	38
L1	Post	8.10	1219	869	1	350	158	102	5	90	2.74	23	41	231	15

Table continue…

L2	Post	8.01	1415	1006	4	452	340	121	48	99	2.38	74	62	131	10
L3	Post	7.9	1108	788	2	359	272	80	32	40	1.32	34	74	145	10
L 4	Post	8.11	1287	865	2	362	260	98	23	79	1.80	44	60	168	11
L 5	Post	8.01	2657	1790	1	510	480	375	83	451	4.63	59	133	159	5
L 6	Post	8.02	1106	810	2	396	288	45	6	86	1.22	78	38	140	9
L 7	Post	8.06	1064	785	2	360	330	32	6	82	1.66	53	79	136	20
L 8	Post	8.02	908	696	1	242	286	56	15	86	2.31	36	55	176	10
L 9	Post	8.04	1039	675	1	338	246	13	7	39	1.88	53	45	162	5
L 10	Post	7.96	1091	811	2	456	242	46	17	11	2.88	44	52	156	15
L 11	Post	8.17	1802	1279	5	628	254	73	4	263	2.83	26	76	187	9
L 12	Post	8.05	1348	973	3	484	257	40	15	123	0.91	40	62	178	12
L 13	Post	8.61	1191	863	3	394	26	28	7	21	4.42	16	45	296	41
L 14	Post	8.07	1051	785	3	344	204	97	30	22	1.63	48	34	189	7
L 15	Post	8.17	1873	1293	4	558	365	73	9	263	2.83	66	80	217	9
L 16	Post	8.19	1180	1040	5	421	210	69	25	145	2.56	38	48	254	19
L 17	Post	7.95	1480	1051	4	540	155	64	55	85	1.62	36	56	188	16
L 18	Post	7.74	1851	1350	1	508	490	39	21	319	0.61	49	147	211	43
L 19	Post	7.68	2510	1848	6	541	497	302	84	377	2.87	115	85	316	14
L 20	Post	7.99	1722	1251	5	498	475	68	40	202	1.66	52	96	242	33

BDL –Below detection limit Turbidity (<1NTU)

Table 4.3: Results of physico-chemical facies in groundwater of Sareni block during the year of 2016

Sl.No.	Season	pH	EC µS/cm	TDS mg/l	Turbidity NTU	Alkalinity mg/l	TH mg/l	Cl^- mg/l	NO_3^- mg/l	SO_4^{2-} mg/l	F^- mg/l	Ca^{2+} mg/l	Mg^{2+} mg/l	Na^+ mg/l	K^+ mg/l
L 21	Pre	7.44	1076	813	2	380	204	21	3	59	1.21	13	69	212	34
L 22	Pre	7.5	1372	985	2	312	301	255	9	87	1.84	38	83	166	14
L 23	Pre	7.3	1011	746	3	288	231	105	4	55	0.82	45	56	136	26
L 24	Pre	8.01	980	722	2	288	231	102	1	54	0.80	39	53	132	24
L 25	Pre	7.52	1416	1043	4	348	310	107	11	151	1.59	22	102	258	23
L 26	Pre	7.42	827	604	2	299	232	37	5	1	0.64	39	54	120	24
L 27	Pre	7	2864	2053	2	725	499	512	6	302	2.21	48	151	250	26
L 28	Pre	7.62	1862	1397	3	342	688	200	15	252	0.86	133	86	321	26
L 29	Pre	7.4	1001	739	2	408	270	12	5	16	0.94	41	67	140	29
L 30	Pre	7.6	1269	905	4	526	238	20	10	31	2.12	53	42	169	28
L 31	Pre	7.39	997	746	3	298	222	128	7	28	1.20	39	50	111	54
L 32	Pre	8.21	816	617	2	299	232	37	5	1	0.64	39	54	120	25
L 33	Pre	7.01	1553	1125	5	425	366	254	5	30	1.02	39	108	189	56
L 34	Pre	7.21	2604	1813	BDL	523	652	584	25	202	1.24	61	200	165	28
L 35	Pre	7.19	1407	991	2	420	356	44	10	142	1.91	49	93	175	25
L 36	Pre	7.62	1544	1135	5	352	394	166	26	184	2.00	62	95	184	27
L 37	Pre	7.21	823	614	5	312	196	25	5	5	1.01	22	56	154	13
L 38	Pre	7.34	742	547	2	254	213	21	9	2	1.11	46	40	137	13
L 39	Pre	7.12	1066	784	2	410	201	55	2	15	1.88	57	24	180	20
L 40	Pre	7.5	1230	903	7	484	286	20	12	89	0.94	41	73	134	13
L 21	Post	7.92	1345	977	5	394	226	51	10	58	1.68	28	63	342	20

Table continue…

L 22	Post	8.1	1583	1181	3	342	321	345	27	136	2.19	43	89	177	10
L 23	Post	7.92	1132	841	3	333	250	159	6	68	1.23	48	52	139	20
L 24	Post	8.08	1248	1054	4	366	260	189	16	125	1.59	35	69	223	15
L 25	Post	7.99	1493	1149	6	364	248	216	14	168	1.69	36	63	267	9
L 26	Post	7.89	835	659	3	312	286	56	10	16	0.85	48	67	130	9
L 27	Post	7.68	4025	2254	3	756	561	587	20	400	2.99	61	164	231	18
L 28	Post	7.85	1856	1344	5	548	365	186	19	204	1.74	46	88	228	13
L 29	Post	8.08	1177	913	5	454	218	30	13	151	1.08	42	45	151	15
L 30	Post	8.23	1354	1012	5	556	284	48	25	98	2.00	49	64	149	8
L 31	Post	7.86	1024	780	4	242	268	212	2	19	1.61	45	62	128	52
L 32	Post	8.07	1181	912	3	403	276	86	11	81	1.63	48	68	175	20
L 33	Post	7.59	1950	1454	8	460	442	379	11	160	1.25	50	127	203	52
L 34	Post	7.89	2669	2006	2	536	736	658	52	265	1.45	73	221	160	26
L 35	Post	7.62	1514	1108	5	352	394	166	26	184	2.00	62	95	184	21
L 36	Post	7.79	1885	1488	6	521	556	301	27	186	1.50	96	123	191	23
L 37	Post	7.99	959	760	6	352	216	84	16	37	1.24	42	45	161	11
L 38	Post	7.99	908	618	6	256	240	54	16	25	1.33	48	48	147	10
L 39	Post	7.88	1128	878	4	451	214	94	6	25	1.44	62	54	160	15
L 40	Post	7.88	1395	759	5	324	256	58	16	68	1.44	52	43	167	12

BDL –Below detection limit (<1NTU)

Table 4.4: Results of physico-chemical facies in groundwater of Khiron block during the year of 2016

Sl.No.	Season	pH	EC µS/cm	TDS mg/l	Turbidity NTU	Alkalinity mg/l	TH mg/l	Cl^- mg/l	NO_3^- mg/l	SO_4^{2-} mg/l	F^- mg/l	Ca^{2+} mg/l	Mg^{2+} mg/l	Na^+ mg/l	K^+ mg/l
L 41	Pre	7.64	919	681	BDL	328	118	14	1	1	2.49	20	27	255	12
L 22	Pre	7.26	808	587	1	276	276	27	1	22	0.60	53	58	121	9
L 43	Pre	7.44	1348	978	2	421	240	121	6	106	1.11	41	56	189	22
L 44	Pre	7.26	814	616	1	276	276	27	1	22	1.22	53	58	121	21
L 45	Pre	7.34	908	673	2	292	240	16	9	35	0.77	50	46	188	17
L 46	Pre	7.48	715	528	1	276	140	20	9	1	0.90	33	23	127	14
L 47	Pre	7.56	783	558	1	287	168	12	1	BDL	1.70	25	43	157	16
L 48	Pre	7.56	683	526	3	198	162	29	4	34	0.88	21	44	147	13
L 49	Pre	7.42	601	459	BDL	213	42	7	BDL	20	1.56	5	12	172	8
L 50	Pre	7.32	780	600	2	156	121	25	2	211	1.56	34	14	130	6
L 51	Pre	7.43	695	514	1	211	152	24	2	21	1.20	21	40	151	12
L 52	Pre	7.86	1015	742	4	242	268	212	2	19	0.61	45	62	128	7
L 53	Pre	7.32	831	620	2	265	200	54	8	24	1.25	41	39	160	8
L 54	Pre	7.4	1219	867	1	488	224	63	1	50	1.00	46	43	145	9
L 55	Pre	7.6	1183	864	1	526	238	20	10	31	1.22	53	42	139	12
L 56	Pre	8.24	834	630	2	231	185	48	7	69	1.22	41	33	154	9
L 57	Pre	7.69	1484	1106	2	580	121	77	3	101	2.10	8	40	254	20
L 58	Pre	7.39	1949	1484	4	692	268	140	3	208	4.62	5	103	294	12
L 59	Pre	7.75	1890	1436	1	648	140	79	6	204	16.20	12	44	396	10

Table continue…

L 60	Pre	7.34	1573	1202	6	480	368	288	8.95	60	10.88	39	108	155	16
L 41	Post	8.14	920	733	BDL	398	122	24	7	33	3.54	25	30	197	6
L 22	Post	7.89	872	682	3	285	300	89	12	19	0.78	50	81	127	9
L 43	Post	8.01	1613	1152	5	462	253	184	12	201	1.67	47	54	161	20
L 44	Post	8.04	1149	1090	2	395	242	154	13	168	1.66	39	65	224	12
L 45	Post	7.92	1330	967	4	440	266	42	32	103	0.94	50	57	217	15
L 46	Post	7.87	902	546	2	237	181	45	13	30	1.29	39	34	120	17
L 47	Post	8.27	844	636	2	326	215	48	3	13	1.96	28	58	141	10
L 48	Post	8.06	943	747	3	312	226	48	17	74	0.44	33	64	169	12
L 49	Post	8.25	844	553	1	260	60	12	1	51	1.24	12	16	187	5
L 50	Post	8.04	831	535	3	236	190	35	4	43	1.61	28	48	125	4
L 51	Post	8.24	841	641	2	231	185	48	7	69	1.22	41	66	154	9
L 52	Post	8.19	1234	660	2	246	155	33	9	64	1.46	45	84	159	7
L 53	Post	8.34	1008	734	5	287	253	97	13	66	1.11	50	51	152	7
L 54	Post	7.99	1378	1099	3	612	436	74	1	84	0.85	66	109	136	6
L 55	Post	8.13	1546	1022	2	566	284	48	25	98	1.56	49	64	142	12
L 56	Post	8.14	1320	968	4	466	330	69	16	86	1.44	55	79	168	10
L 57	Post	8.12	1757	1231	4	618	132	121	7	151	2.78	32	44	226	20
L 58	Post	7.78	2612	1710	3	874	254	156	7	266	5.46	23	96	259	12
L 59	Post	8.22	2829	1927	4	1146	138	143	6	173	17.20	19	37	366	10
L 60	Post	8.14	2354	1551	4	779	175	145	8	215	12.48	11	62	286	14

BDL –Below detection limit Turbidity (<1NTU), Nitrate and Sulphate (<1)

Table 4.5: Results of physico-chemical facies in groundwater of Control area (Bachhrawan) during 2016.

Sl.No.	Season	pH	EC µS/cm	TDS mg/l	Turbidity NTU	Alkalinity mg/l	TH mg/l	Cl^- mg/l	NO_3^- mg/l	SO_4^{2-} mg/l	F^- mg/l	Ca^{2+} mg/l	Mg^{2+} mg/l	Na^+ mg/l	K^+ mg/l
B 1	Pre	7.8	963	626	BDL	319	264	24	10	124	0.32	45	37	41	6
B 2	Pre	7.89	1050	672	BDL	396	256	40	15	68	0.30	44	35	54	4
B 3	Pre	7.53	1609	1014	BDL	484	476	52	24	132	0.56	48	87	164	9
B 4	Pre	7.58	719	446	BDL	246	265	54	10	16	0.67	30	46	23	2
B 5	Pre	7.26	758	463	BDL	277	276	27	9	22	0.60	53	35	21	2
B 6	Pre	7.59	809	526	1	317	244	53	9	10	0.37	68	18	18	13
B 7	Pre	7.68	1659	1062	1	312	554	133	26	186	0.27	110	68	206	6
B 8	Pre	7.59	699	440	2	244	172	74	8	4	0.87	34	35	23	3
B 9	Pre	7.22	945	605	BDL	378	234	41	16	36	0.43	54	24	36	4
B 10	Pre	7.21	760	479	BDL	312	196	25	5	5	1.01	22	34	54	6
B 11	Pre	7.58	981	608	BDL	378	234	41	16	36	0.43	54	24	36	4
B 12	Pre	7.53	1664	1015	1	386	476	22	24	259	0.76	48	87	164	9
B 13	Pre	7.52	1074	666	BDL	359	333	95	1	32	0.36	53	49	56	3
B 14	Pre	7.52	956	583	1	299	305	53	1	39	0.31	62	37	72	4
B 15	Pre	7.02	1069	674	BDL	443	253	52	21	21	1.25	38	39	40	5
B 16	Pre	7.9	1181	768	BDL	459	272	80	32	40	0.92	34	45	45	10
B 17	Pre	7.66	945	605	BDL	312	260	114	1	47	0.57	56	29	22	8
B 18	Pre	7.66	828	522	BDL	284	233	78	5	8	0.32	62	19	40	11
B 19	Pre	7.58	836	518	BDL	351	226	33	5	10	0.61	36	33	29	3
B 20	Pre	7.66	770	469	1	256	255	52	8	12	0.43	76	16	19	14

Table continue…

B 1	Post	8.17	1147	711	1	310	284	30	15.52	190	0.33	42	44	54	8
B 2	Post	8.25	1262	770	BDL	384	282	78	21.08	99	0.47	62	31	73	5
B 3	Post	7.64	1808	1175	1	569	490	89	29	175	0.61	49	89	111	43
B 4	Post	8.24	1376	880	1	410	356	75	23	159	0.58	52	56	78	12
B 5	Post	7.79	866	546	1	287	300	89	12	19	0.77	39	49	27	9
B 6	Post	7.88	926	574	2	300	296	63	15	29	0.59	84	21	26	17
B 7	Post	7.56	2087	1273	3	342	688	200	15	252	0.26	133	86	221	7
B 8	Post	7.84	1287	836	2	315	438	127	15	125	0.64	88	57	81	7
B 9	Post	7.99	1001	651	1	355	216	84	16	37	1.24	30	34	61	11
B 10	Post	7.84	1056	676	1	380	284	62	25	40	0.47	64	30	53	6
B 11	Post	7.74	1817	1145	2	458	490	39	21	319	1.21	49	89	111	43
B 12	Post	7.86	1386	859	1	412	350	65	22	135	1.43	57	61	76	12
B 13	Post	7.82	1139	729	1	360	348	105	9	53	0.46	42	59	79	6
B 14	Post	7.6	1122	696	4	310	354	84	2	62	0.35	55	53	104	8
B 15	Post	7.9	1181	768	BDL	459	272	80	32	40	0.92	34	45	45	10
B 16	Post	7.72	1201	733	3	366.33	330	93	13	62	0.86	44	53	77	8
B 17	Post	7.64	1178	719	2	376	268	128	1	67	0.90	58	30	30	12
B 18	Post	7.77	981	638	1	332	266	101	9	18	0.39	68	24	48	17
B 19	Post	7.95	924	591	BDL	402	252	35	8	16	0.91	41	36	33	4
B 20	Post	7.78	1028	648	2	360	268	89	9	36	0.78	57	33	39	10

BDL –Below detection limit Turbidity (<1NTU)

Table 4.6: Results of physico-chemical facies in groundwater of Lalganj block, during the year of 2017

Sl.No.	Season	pH	EC µS/cm	TDS mg/l	Turbidity NTU	Alkalinity mg/l	TH mg/l	Cl^- mg/l	NO_3^- mg/l	SO_4^{2-} mg/l	F^- mg/l	Ca^{2+} mg/l	Mg^{2+} mg/l	Na^+ mg/l	K^+ mg/l
L1	Pre	8.00	1320	1050	1	552	162	89	4	85	2.54	25	39	236	7
L2	Pre	8.01	1463	1058	3	562	346	98	36	84	2.26	65	59	136	9
L3	Pre	8	1130	750	3	361	284	60	22	36	1.42	33	68	150	8
L 4	Pre	8.06	1403	785	2	371	266	21	18	72	1.63	45	58	172	8
L 5	Pre	8.01	2681	1686	2	516	488	317	66	420	4.52	55	123	169	6
L 6	Pre	8.02	1111	780	1	401	290	20	5	77	1.32	75	36	145	8
L 7	Pre	8.1	1078	760	2	368	336	10	5	69	1.56	56	77	142	16
L 8	Pre	7.98	912	657	1	252	289	18	12	75	2.23	40	52	180	8
L 9	Pre	8.04	915	714	1	351	250	32	4	29	1.78	56	56	168	6
L 10	Pre	8	1089	816	2	469	249	26	13	12	2.86	55	53	159	14
L 11	Pre	8.02	1773	1274	4	641	259	70	2	253	2.79	30	66	189	10
L 12	Pre	7.98	1296	960	4	491	261	21	12	114	1.10	39	65	184	15
L 13	Pre	8.21	1155	861	2	399	39	18	6	19	4.52	14	54	300	36
L 14	Pre	7.98	1061	762	3	352	209	74	25	18	1.72	43	36	192	8
L 15	Pre	8.06	1855	1265	5	562	370	70	6	245	1.81	60	72	226	7
L 16	Pre	8.09	1517	983	4	432	216	18	20	132	2.45	36	46	262	17
L 17	Pre	8	1495	1042	3	562	162	50	45	77	1.60	35	52	193	16
L 18	Pre	7.77	1860	1324	3	512	493	29	16	300	0.59	42	132	236	45
L 19	Pre	7.66	2680	1748	5	551	498	252	69	351	2.78	101	72	316	20
L 20	Pre	7.88	1738	1213	5	501	476	36	36	186	1.53	48	86	264	36

Table continue…

L1	Post	8.15	1582	1123	2	576	172	112	7	91	2.72	28	45	242	9
L2	Post	8.16	1618	1158	2	588	356	126	50	92	2.43	79	62	142	10
L3	Post	7.6	1185	858	4	412	310	84	40	42	1.42	34	72	152	9
L 4	Post	8.16	1432	936	3	410	288	99	22	76	1.82	49	68	184	8
L 5	Post	7.75	2739	1814	2	536	490	380	82	421	4.72	62	135	175	8
L 6	Post	7.85	1177	877	2	425	300	60	9	82	1.36	80	45	156	7
L 7	Post	7.55	1138	855	2	389	352	36	9	86	1.77	62	88	152	16
L 8	Post	7.66	976	762	2	263	310	77	16	88	2.41	42	59	188	9
L 9	Post	7.79	960	744	3	359	267	25	8	42	1.92	56	62	172	8
L 10	Post	7.58	1150	871	2	482	256	52	16	13	2.99	52	63	162	16
L 11	Post	7.89	1842	1326	5	672	294	74	5	251	2.94	36	71	192	12
L 12	Post	7.75	1436	1051	5	512	284	45	14	135	1.21	42	76	193	15
L 13	Post	7.87	1238	915	3	412	36	29	9	26	4.62	23	65	301	35
L 14	Post	7.78	1227	922	3	456	215	88	31	25	1.72	58	42	199	9
L 15	Post	7.7	1914	1340	5	582	412	85	10	253	3.25	62	84	236	10
L 16	Post	7.8	1609	1132	5	452	325	76	24	162	2.63	42	56	284	15
L 17	Post	7.6	1572	1132	3	582	265	72	53	94	1.74	43	57	201	18
L 18	Post	7.75	1977	1457	4	562	510	51	23	325	0.65	52	142	245	44
L 19	Post	7.93	2767	1939	5	574	516	321	80	388	2.94	120	82	336	22
L 20	Post	7.76	1813	1333	4	512	504	56	42	231	1.72	56	96	282	38

Table 4.7: Results of physico-chemical facies in groundwater of Sareni block during the year of 2017

Sl.No.	Season	pH	EC µS/cm	TDS mg/l	Turbidity NTU	Alkalinity mg/l	TH mg/l	Cl^- mg/l	NO_3^- mg/l	SO_4^{2-} mg/l	F^- mg/l	Ca^{2+} mg/l	Mg^{2+} mg/l	Na^+ mg/l	K^+ mg/l
L 21	Pre	7.64	919	681	BDL	328	118	14	1	1	2.49	20	27	255	12
L 22	Pre	7.26	808	587	1	276	276	27	1	22	0.60	53	58	121	9
L 23	Pre	7.44	1348	978	2	421	240	121	6	106	1.11	41	56	189	22
L 24	Pre	7.26	814	616	1	276	276	27	1	22	1.22	53	58	121	21
L 25	Pre	7.34	908	673	2	292	240	16	9	35	0.77	50	46	188	17
L 26	Pre	7.48	715	528	1	276	140	20	9	1	0.90	33	23	127	14
L 27	Pre	7.56	783	558	1	287	168	12	1	BDL	1.70	25	43	157	16
L 28	Pre	7.56	683	526	3	198	162	29	4	34	0.88	21	44	147	13
L 29	Pre	7.42	601	459	BDL	213	42	7	BDL	20	1.56	5	12	172	8
L 30	Pre	7.32	780	600	2	156	121	25	2	211	1.56	34	14	130	6
L 31	Pre	7.43	695	514	1	211	152	24	2	21	1.20	21	40	151	12
L 32	Pre	7.86	1015	742	4	242	268	212	2	19	0.61	45	62	128	7
L 33	Pre	7.32	831	620	2	265	200	54	8	24	1.25	41	39	160	8
L 34	Pre	7.4	1219	867	1	488	224	63	1	50	1.00	46	43	145	9
L 35	Pre	7.6	1183	864	1	526	238	20	10	31	1.22	53	42	139	12
L 36	Pre	8.24	834	630	2	231	185	48	7	69	1.22	41	33	154	9
L 37	Pre	7.69	1484	1106	2	580	121	77	3	101	2.10	8	40	254	20
L 38	Pre	7.39	1949	1484	4	692	268	140	3	208	4.62	5	103	294	12
L 39	Pre	7.75	1890	1436	1	648	140	79	6	204	16.20	12	44	396	10

Table continue…

L 40	Pre	7.34	1573	1202	6	480	368	288	8.95	60	10.88	39	108	155	16
L 21	Post	8.14	920	733	BDL	398	122	24	7	33	3.54	25	30	197	6
L 22	Post	7.89	872	682	3	285	300	89	12	19	0.78	50	81	127	9
L 23	Post	8.01	1613	1152	5	462	253	184	12	201	1.67	47	54	161	20
L 24	Post	8.04	1149	1090	2	395	242	154	13	168	1.66	39	65	224	12
L 25	Post	7.92	1330	967	4	440	266	42	32	103	0.94	50	57	217	15
L 26	Post	7.87	902	546	2	237	181	45	13	30	1.29	39	34	120	17
L 27	Post	8.27	844	636	2	326	215	48	3	13	1.96	28	58	141	10
L 28	Post	8.06	943	747	3	312	226	48	17	74	0.44	33	64	169	12
L 29	Post	8.25	844	553	1	260	60	12	1	51	1.24	12	16	187	5
L 30	Post	8.04	831	535	3	236	190	35	4	43	1.61	28	48	125	4
L 31	Post	8.24	841	641	2	231	185	48	7	69	1.22	41	66	154	9
L 32	Post	8.19	1234	660	2	246	155	33	9	64	1.46	45	84	159	7
L 33	Post	8.34	1008	734	5	287	253	97	13	66	1.11	50	51	152	7
L 34	Post	7.99	1378	1099	3	612	436	74	1	84	0.85	66	109	136	6
L 35	Post	8.13	1546	1022	2	566	284	48	25	98	1.56	49	64	142	12
L 36	Post	8.14	1320	968	4	466	330	69	16	86	1.44	55	79	168	10
L 37	Post	8.12	1757	1231	4	618	132	121	7	151	2.78	32	44	226	20
L 38	Post	7.78	2612	1710	3	874	254	156	7	266	5.46	23	96	259	12
L 39	Post	8.22	2829	1927	4	1146	138	143	6	173	17.20	19	37	366	10
L 40	Post	8.14	2354	1551	4	779	175	145	8	215	12.48	11	62	286	14

BDL –Below detection limit Turbidity (<1NTU), Nitrate and Sulphate (<1)

Table 4.8: Results of physico-chemical facies in groundwater of Khiron block during the year of 2017

Sl.No.	Season	pH	EC µS/cm	TDS mg/l	Turbidity NTU	Alkalinity mg/l	TH mg/l	Cl^- mg/l	NO_3^- mg/l	SO_4^{2-} mg/l	F^- mg/l	Ca^{2+} mg/l	Mg^{2+} mg/l	Na^+ mg/l	K^+ mg/l
L 41	Pre	8.09	979	735	1	402	132	20	5	23	3.44	30	32	202	8
L 22	Pre	7.77	900	662	4	298	310	54	8	14	0.75	52	78	136	11
L 43	Pre	7.98	1636	1098	5	475	262	154	9	162	1.62	42	56	168	22
L 44	Pre	7.99	1198	945	3	403	251	45	10	123	1.66	40	62	229	13
L 45	Pre	7.89	1341	935	3	436	269	39	26	85	1.10	48	50	224	16
L 46	Pre	7.64	924	559	2	263	192	20	8	26	1.32	41	36	134	18
L 47	Pre	8.2	881	631	2	335	220	25	6	10	1.89	32	56	145	12
L 48	Pre	7.92	950	709	2	326	230	26	10	52	0.52	30	62	171	13
L 49	Pre	8.06	886	597	2	284	64	9	6	42	1.32	26	20	193	6
L 50	Pre	7.99	995	548	3	251	193	25	5	36	1.52	30	52	129	8
L 51	Pre	8.21	871	611	2	241	189	26	9	52	1.12	38	60	162	7
L 52	Pre	8.02	1245	718	2	256	162	97	7	49	1.36	40	80	168	8
L 53	Pre	8.11	1026	706	4	294	258	82	10	48	1.23	45	52	159	5
L 54	Pre	7.88	1496	1277	3	715	442	166	5	64	0.95	62	100	145	9
L 55	Pre	8.1	1564	1004	2	588	291	36	25	74	1.59	44	63	146	11
L 56	Pre	8.06	1334	929	3	482	336	30	13	69	1.56	52	78	172	13
L 57	Pre	8.06	1772	1182	3	624	142	87	9	123	2.65	36	42	230	18
L 58	Pre	7.65	2631	1663	2	891	261	121	6	241	5.23	24	88	262	13
L 59	Pre	8.2	2847	1898	4	1153	152	118	8	152	15.26	20	34	374	14
L 60	Pre	8.06	2361	1558	3	792	182	294	5	184	10.30	16	52	293	12

Table continue…

L 41	Post	7.88	1002	792	2	412	142	32	8	36	3.56	33	36	212	9
L 22	Post	7.98	1020	804	5	362	325	92	14	26	0.82	56	88	145	10
L 43	Post	7.9	1699	1230	4	501	281	186	12	212	1.62	45	66	175	23
L 44	Post	8	1530	1174	4	436	261	162	15	175	1.69	43	72	236	15
L 45	Post	7.96	1515	1110	5	526	284	52	30	125	1.10	52	62	235	17
L 46	Post	7.82	1036	692	6	321	201	51	14	36	1.23	51	42	145	19
L 47	Post	7.66	935	716	5	362	230	53	6	20	1.95	36	65	149	15
L 48	Post	7.8	1025	825	4	342	251	56	18	84	0.46	36	69	188	14
L 49	Post	8	1021	671	2	310	68	16	3	54	1.36	35	33	201	8
L 50	Post	8.15	905	608	3	261	213	36	6	50	1.68	36	62	136	9
L 51	Post	7.83	876	684	3	249	210	52	8	76	1.23	39	68	168	8
L 52	Post	8	1295	723	2	284	203	36	10	65	1.56	41	88	175	10
L 53	Post	7.6	1075	738	4	288	274	82	12	69	1.21	46	59	165	6
L 54	Post	7.69	1727	1250	4	732	456	76	2	80	0.92	63	121	155	10
L 55	Post	7.55	1616	1085	3	612	312	52	24	92	1.62	49	75	152	12
L 56	Post	7.73	1445	1072	3	513	352	84	15	85	1.52	58	94	188	15
L 57	Post	7.88	1863	1321	3	652	162	132	9	153	2.85	42	56	245	19
L 58	Post	7.89	2786	1740	3	865	274	162	8	266	5.52	29	95	282	15
L 59	Post	7.69	3275	2075	4	1234	164	152	6	182	16.20	28	45	386	16
L 60	Post	7.79	2456	1501	5	814	192	153	9	216	13.20	26	56	301	13

Table 4.9: Results of physico-chemical facies in groundwater of Control area during the year of 2017

Sl.No.	Season	pH	EC µS/cm	TDS mg/l	Turbidity NTU	Alkalinity mg/l	TH mg/l	Cl^- mg/l	NO_3^- mg/l	SO_4^{2-} mg/l	F^- mg/l	Ca^{2+} mg/l	Mg^{2+} mg/l	Na^+ mg/l	K^+ mg/l
B 1	Pre	8.15	1011	672	1	321	288	25	12	152	0.36	51	40	60	11
B 2	Pre	8.16	1138	743	BDL	392	289	66	15	88	0.46	67	33	76	6
B 3	Pre	7.6	1741	1112	1	574	496	70	26	152	0.62	63	78	112	36
B 4	Pre	8.16	1288	853	1	423	362	68	21	132	0.52	65	52	80	11
B 5	Pre	7.75	809	533	1	294	312	77	10	14	0.72	51	44	32	10
B 6	Pre	7.85	883	572	2	312	302	56	13	19	0.56	95	26	32	18
B 7	Pre	7.55	1810	1191	3	352	692	153	10	212	0.36	138	84	236	6
B 8	Pre	7.66	1185	774	2	321	452	110	8	103	0.54	84	52	86	9
B 9	Pre	7.87	928	618	1	362	230	55	10	34	1.12	43	32	69	12
B 10	Pre	7.78	1030	674	1	388	291	52	22	36	0.36	77	33	59	7
B 11	Pre	7.7	1743	1113	2	465	499	36	17	302	1.06	59	78	118	37
B 12	Pre	7.8	1248	826	1	423	361	45	12	126	1.35	67	58	78	16
B 13	Pre	7.79	1102	710	1	375	351	92	6	36	0.52	56	55	81	8
B 14	Pre	7.58	999	665	4	315	366	64	6	49	0.61	65	49	106	10
B 15	Pre	7.89	1133	740	BDL	462	284	75	16	29	0.82	47	43	56	11
B 16	Pre	7.75	1129	726	3	375	341	84	14	56	1.10	55	48	84	9
B 17	Pre	7.6	1072	701	2	388	271	110	3	56	0.89	67	27	35	14
B 18	Pre	7.75	963	621	1	345	273	84	5	17	0.46	77	26	52	15
B 19	Pre	7.93	898	599	BDL	412	261	30	7	12	0.84	51	34	46	6
B 20	Pre	7.76	972	637	2	374	276	75	6	29	0.88	65	33	42	12

Table continue…

B 1	Post	8.09	1222	772	2	352	300	35	17	188	0.36	57	45	66	12
B 2	Post	7.77	1322	821	1	421	298	80	22	101	0.38	71	36	82	8
B 3	Post	7.98	1838	1210	3	586	501	92	30	182	0.62	68	82	134	35
B 4	Post	7.99	1506	949	2	454	384	80	22	162	0.59	74	56	88	12
B 5	Post	7.89	959	600	2	325	314	88	BDL	32	0.82	61	55	26	12
B 6	Post	7.64	949	632	3	325	215	62	16	36	0.62	103	34	36	19
B 7	Post	8.2	2110	1323	4	362	712	198	14	256	0.26	150	91	245	7
B 8	Post	7.92	1414	878	3	354	463	132	13	126	0.65	94	59	89	10
B 9	Post	8.11	1157	732	2	402	252	86	19	42	1.20	51	42	75	14
B 10	Post	7.88	1234	767	3	413	286	84	26	45	0.45	83	39	69	8
B 11	Post	8.1	1817	1196	3	485	452	56	22	321	1.23	64	84	128	35
B 12	Post	8.06	1483	934	2	462	362	66	24	142	1.46	71	62	88	18
B 13	Post	8.06	1216	806	2	386	362	124	10	58	0.52	67	61	88	11
B 14	Post	7.99	1256	793	5	384	377	86	6	67	0.42	73	53	112	12
B 15	Post	8.21	1357	843	2	492	294	82	36	52	0.82	57	51	59	13
B 16	Post	8.02	1217	806	4	410	352	94	14	69	0.87	61	53	94	10
B 17	Post	8.06	1321	821	3	421	285	135	2	72	0.92	73	38	63	16
B 18	Post	7.65	1061	704	2	365	284	121	6	20	0.43	84	36	56	16
B 19	Post	8.2	1079	684	2	452	276	36	9	26	0.92	57	38	58	7
B 20	Post	8.06	1218	758	3	425	286	94	10	45	0.82	71	46	50	16

BDL –Below detection limit Turbidity (<1NTU),

Table 4.10: Descriptive statistics of chemical composition of groundwater of Lalganj tehsil for 2016 and 2017

		pH	EC	TDS	Turbidity	BiC	TH	Cl^-	NO_3^-	SO_4^{2-}	F^-	Ca^{2+}	Mg^{2+}	Na^+	K^+
Lalganj block	Mean	7.81	1351	978	2	419	282	75	21	121	2.16	46	67	189	18
2016	Min	7.02	816	617	BDL	2242	26	11	1	1	0.61	7	5	120	5
	Max	8.61	2657	1848	6	628	497	375	84	451	4.63	115	179	344	46
	SEM	0.06	72.56	49.62	0.24	13.98	19.45	11.85	3.51	18.70	0.16	3.44	5.71	8.81	1.74
2017	Mean	7.90	1522	1076	3	474	310	82	24	139	2.25	51	69	205	15
	Min	7.55	912	657	1	252	36	10	2	12	0.59	14	36	136	6
	Max	8.21	2767	1939	5	672	516	380	82	421	4.72	120	142	336	45
	SEM	0.03	79.42	50.67	0.21	15.70	19.02	13.57	3.43	18.98	0.16	3.22	4.08	8.50	1.73
Sareni block	Mean	7.67	1428	1036	4	400	323	167	13	104	1.45	49	80	179	23
2016	Min	7.00	742	547	BDL	242	196	12	1	1	0.64	13	24	111	8
	Max	8.23	4025	2254	8	756	736	658	52	400	2.99	133	221	342	56
	SEM	0.05	103.26	65.25	0.27	18.53	22.28	26.96	1.57	14.90	0.08	3.14	6.76	8.29	1.96
2017	Mean	7.92	1625	1141	4	446	352	193	15	116	1.60	52	85	200	20
	Min	7.55	872	611	2	246	219	25	2	13	0.89	30	45	136	9
	Max	8.21	4275	2309	7	761	782	624	50	395	3.10	92	235	362	46
	SEM	0.02	116.64	62.95	0.20	19.34	22.42	26.66	1.46	14.33	0.06	1.98	7.25	8.45	1.62
Khiron block	Mean	7.80	1204	871	2	407	209	73	7	81	2.84	35	53	182	12
2016	Min	7.26	601	459	BDL	156	42	7	BDL	BDL	0.44	5	12	120	4
	Max	8.34	2829	1927	6	1146	436	288	32	266	17.20	66	109	396	22
	SEM	0.06	84.20	57.33	0.23	33.45	12.67	10.04	1.06	11.41	0.64	2.48	3.80	10.37	0.74
2017	Mean	7.92	1449	994	3	490	235	80	10	93	2.94	40	63	197	13
	Min	7.55	871	548	1	241	64	9	2	10	0.46	16	20	129	5
	Max	8.21	3275	2075	6	1234	456	294	30	266	16.20	63	121	386	23
	SEM	0.03	99.14	61.99	0.18	39.24	13.20	9.71	1.01	10.68	0.61	1.76	3.36	9.84	0.70

SEM *Standard Error Mean, Data in mg/L except for* **EC** *(µS/cm),* **Turbidity** *(NTU)* ***BDL*** *–Below detection limit Turbidity* ***(<1NTU),*** *Nitrate and Sulphate* ***(<1)***

Table 4.11: Results of metallic ingredients in groundwater of Lalganj block during the year of 2016.

Sl.No.	Sl.No.	Season	Unit	Zn	Fe	Ni	Mn	Pb	Cu	Co	Cr	Cd
L1	B 1	Pre	ppb	71.54	191.38	1.16	BDL	BDL	15.42	3.4	0.91	0.76
L2	B 2	Pre	ppb	11.5	162.59	2.3	6.4	1.23	BDL	3.2	BDL	BDL
L3	B 3	Pre	ppb	55.8	412.86	9.71	55.36	BDL	1	6.2	BDL	BDL
L 4	B 4	Pre	ppb	39.45	195	7.35	7.5	1.23	3	6.3	1.2	BDL
L 5	B 5	Pre	ppb	136.87	224.16	2.3	9.47	6.45	0.75	18.3	BDL	0.89
L 6	B 6	Pre	ppb	11.56	221.97	5.48	28.07	BDL	22.15	2.1	BDL	BDL
L 7	B 7	Pre	ppb	25.98	14.97	3.6	5.52	BDL	1.25	1.2	1.1	BDL
L 8	B 8	Pre	ppb	158.94	314.76	4.25	11.97	BDL	1.94	2.14	BDL	1.3
L 9	B 9	Pre	ppb	86.52	166.71	2.6	18.32	2.25	BDL	BDL	0.95	BDL
L 10	B 10	Pre	ppb	9.84	92.39	1.5	4.07	1.3	0.95	4.05	0.77	BDL
L 11	B 11	Pre	ppb	59.86	421.41	5.6	5.5	2.54	18.69	2.48	BDL	BDL
L 12	B 12	Pre	ppb	19.86	269.48	3.18	9.32	1.96	1.01	9.6	2.54	2.41
L 13	B 13	Pre	ppb	116.37	946.34	3.1	9.55	BDL	2.85	BDL	BDL	1.1
L 14	B 14	Pre	ppb	57.64	692.31	2.3	9.25	1.4	2.41	BDL	BDL	BDL
L 15	B 15	Pre	ppb	85.19	73.26	1.1	0.49	9.52	5.53	2.79	BDL	BDL
L 16	B 16	Pre	ppb	126.9	89.63	5.55	24.75	3	1.65	4.65	0.84	BDL
L 17	B 17	Pre	ppb	86.42	1.11	8.03	18.91	0.93	1.1	8.7	BDL	0.86
L 18	B 18	Pre	ppb	3.94	192.51	24.93	5.5	8.2	3.32	6.22	BDL	BDL
L 19	B 19	Pre	ppb	71.96	333.36	11.82	21.19	15.86	4.24	11.7	BDL	BDL
L 20	B 20	Pre	ppb	4.23	101.96	1.08	10.09	2.3	4.22	BDL	1.12	0.88
L1	B 1	Post	ppb	67.20	189.60	1.52	2.10	BDL	13.22	3.10	0.56	0.62
L2	B 2	Post	ppb	9.21	152.30	2.62	8.62	1.12	BDL	2.31	BDL	BDL
L3	B 3	Post	ppb	50.30	408.60	10.01	60.21	BDL	0.64	5.62	BDL	BDL
L 4	B 4	Post	ppb	36.20	188.00	8.20	8.62	1.14	2.61	5.32	1.02	BDL
L 5	B 5	Post	ppb	130.20	220.40	3.02	12.31	5.23	0.70	12.30	BDL	0.68
L 6	B 6	Post	ppb	10.20	218.00	6.21	30.54	BDL	18.36	1.56	BDL	BDL
L 7	B 7	Post	ppb	20.60	13.50	4.23	7.23	BDL	1.05	2.31	0.92	BDL
L 8	B 8	Post	ppb	156.30	310.50	4.62	12.35	BDL	1.75	2.35	BDL	1.20
L 9	B 9	Post	ppb	80.60	160.60	3.21	19.24	2.14	BDL	BDL	0.88	BDL
L 10	B 10	Post	ppb	7.80	90.50	1.90	6.21	1.12	0.88	3.63	0.62	BDL
L 11	B 11	Post	ppb	52.30	418.60	5.50	7.62	2.06	16.34	2.31	BDL	BDL
L 12	B 12	Post	ppb	16.30	260.60	3.64	11.20	1.56	1.21	8.63	2.21	2.31
L 13	B 13	Post	ppb	112.60	936.50	3.86	13.20	BDL	2.64	BDL	BDL	0.99
L 14	B 14	Post	ppb	55.30	665.00	3.60	12.30	1.15	2.31	BDL	BDL	BDL
L 15	B 15	Post	ppb	83.20	70.50	2.80	2.10	7.50	5.12	2.02	BDL	BDL
L 16	B 16	Post	ppb	122.30	87.60	7.00	26.31	2.89	1.45	3.98	0.66	BDL
L 17	B 17	Post	ppb	82.60	2.12	9.20	21.61	1.13	1.02	6.32	BDL	0.74
L 18	B 18	Post	ppb	3.60	182.42	25.60	7.11	7.90	3.02	5.23	BDL	BDL
L 19	B 19	Post	ppb	68.20	312.30	14.60	23.10	14.80	4.06	9.85	BDL	BDL
L 20	B 20	Post	ppb	3.20	99.90	2.13	11.32	2.20	4.11	BDL	0.98	0.62

Table 4.12 Results of metallic ingredients in groundwater of Sareni block during the year of 2016.

Sl.No.	Sl.No.	Season	Unit	Zn	Fe	Ni	Mn	Pb	Cu	Co	Cr	Cd
L 21	B 1	Pre	ppb	288.43	375.36	2.1	4.83	BDL	0.77	BDL	BDL	1.2
L 22	B 2	Pre	ppb	154.88	118.74	8.6	15.9	3.58	1.18	2.5	BDL	BDL
L 23	B 3	Pre	ppb	110.32	336.21	5.5	40.3	5.2	BDL	1.02	1.22	BDL
L 24	B 4	Pre	ppb	124.88	354.72	5.4	42.8	4.58	BDL	1.01	1.12	BDL
L 25	B 5	Pre	ppb	129.73	259.94	1.5	11.27	12.24	2.14	2.99	BDL	0.95
L 26	B 6	Pre	ppb	158.94	314.76	4.25	11.97	BDL	1.94	2.14	BDL	BDL
L 27	B 7	Pre	ppb	156.48	426.71	29.76	62.38	9.52	8.94	8.4	BDL	BDL
L 28	B 8	Pre	ppb	242.76	428.19	2.57	22.238	5.42	15.03	4.8	BDL	3.8
L 29	B 9	Pre	ppb	112.84	537.12	2	1.1	BDL	2.25	1.54	1.3	1.1
L 30	B 10	Pre	ppb	114.6	892.76	7.24	9.95	BDL	8.97	9.1	BDL	BDL
L 31	B 11	Pre	ppb	112.87	189.74	2.1	9.53	BDL	2.21	1.24	BDL	BDL
L 32	B 12	Pre	ppb	158.94	314.76	4.25	11.97	BDL	1.94	2.14	1.1	BDL
L 33	B 13	Pre	ppb	112.88	329.71	1.6	11.63	BDL	4.09	BDL	BDL	1.11
L 34	B 14	Pre	ppb	213.79	182.47	7.62	1.2	12.77	2.41	8.82	BDL	1.3
L 35	B 15	Pre	ppb	112.57	442.56	1.3	1.1	8.87	BDL	1.75	1.2	BDL
L 36	B 16	Pre	ppb	198.53	645.22	19.48	15.05	4.8	3.01	6.21	BDL	BDL
L 37	B 17	Pre	ppb	112.24	52.97	11.98	11.1	BDL	BDL	2.1	4	0.71
L 38	B 18	Pre	ppb	58.96	786.53	1.9	43.85	BDL	BDL	1.5	1.1	BDL
L 39	B 19	Pre	ppb	24.78	258.89	8.73	32.17	BDL	1.54	BDL	BDL	BDL
L 40	B 20	Pre	ppb	157.05	751	6.89	42.39	11.85	6.48	5.63	2.14	BDL
L 21	B 1	Post	ppb	280.5	370.6	3.2	6.23	BDL	0.67	BDL	BDL	1.01
L 22	B 2	Post	ppb	150.3	111.3	9.6	17.2	3.38	1.02	2.31	BDL	BDL
L 23	B 3	Post	ppb	119.5	342.6	6.5	44.3	4.42	BDL	1.32	1.01	BDL
L 24	B 4	Post	ppb	118.6	343.6	5.5	45.3	3.95	BDL	1.36	1.32	BDL
L 25	B 5	Post	ppb	125.3	252.6	2.3	13.6	10.2	1.98	2.56	BDL	0.88
L 26	B 6	Post	ppb	158.94	310.5	5.5	15.2	BDL	1.63	1.56	BDL	BDL
L 27	B 7	Post	ppb	151.5	420.5	35.6	66.2	8.22	7.25	6.54	BDL	BDL
L 28	B 8	Post	ppb	240.5	420.5	3.4	23.24	4.22	14.23	2.68	BDL	3.21
L 29	B 9	Post	ppb	108.6	530.2	3.6	1.6	BDL	2.22	1.06	1.02	0.89
L 30	B 10	Post	ppb	108.6	882.6	8.6	11.2	BDL	8.54	7.69	BDL	BDL
L 31	B 11	Post	ppb	108.3	187.02	3.2	12.3	BDL	2.36	1.68	BDL	BDL
L 32	B 12	Post	ppb	155.6	308.08	4.56	14.2	BDL	1.84	2.61	1.12	BDL
L 33	B 13	Post	ppb	110.8	322.44	2.3	15.6	BDL	4.22	BDL	BDL	0.99
L 34	B 14	Post	ppb	208.6	172.52	8.9	3.2	10.7	2.34	7.61	BDL	1.03
L 35	B 15	Post	ppb	109.6	432.52	1.9	2.5	7.89	BDL	1.42	1.32	BDL
L 36	B 16	Post	ppb	190.2	640.14	18.6	16.9	4.23	3.21	5.36	BDL	BDL
L 37	B 17	Post	ppb	109.5	50.27	15.6	12.3	BDL	BDL	3.12	3.21	0.88
L 38	B 18	Post	ppb	55.3	780.5	2.8	50.6	BDL	BDL	1.62	0.89	BDL
L 39	B 19	Post	ppb	20.6	254.8	9.4	33.9	BDL	1.33	BDL	BDL	BDL
L 40	B 20	Post	ppb	150.6	749	7.6	46.5	10.5	6.21	3.62	1.65	BDL

Table 4.13: Results of metallic ingredients in groundwater of Khiron block during the year of 2016.

Sl.No.	Season	Unit	Zn	Fe	Ni	Mn	Pb	Cu	Co	Cr	Cd
L 41	Pre	ppb	94.52	58.86	1.28	5.54	1.24	BDL	0.80	BDL	0.86
L 22	Pre	ppb	34.85	156.9	4.37	35.48	2.36	1.67	1.50	0.89	BDL
L 43	Pre	ppb	12.59	423.86	15.34	49.6	10.82	8.90	1.21	BDL	0.75
L 44	Pre	ppb	34.85	156.9	4.37	35.48	2.36	1.67	1.50	BDL	0.84
L 45	Pre	ppb	33.87	193.56	1.21	9.84	0.84	BDL	1.26	0.76	BDL
L 46	Pre	ppb	74.76	86.41	3.68	9	BDL	1.54	1.50	0.78	BDL
L 47	Pre	ppb	98.64	196.55	1.29	17.84	2.5	BDL	2.36	BDL	BDL
L 48	Pre	ppb	35.87	123.68	2.51	1.54	5.9	BDL	6.50	BDL	0.97
L 49	Pre	ppb	19.36	86.51	1.2	19.74	2.54	BDL	BDL	1.00	BDL
L 50	Pre	ppb	15.72	63.75	1.16	1.2	14.5	BDL	BDL	BDL	BDL
L 51	Pre	ppb	52.38	100.52	5.32	68.4	3.52	1.01	2.13	BDL	BDL
L 52	Pre	ppb	168.81	695.94	11.37	16.19	0	6.11	6.42	BDL	1.72
L 53	Pre	ppb	86.42	26.98	5.48	27.61	4.21	1.21	2.54	0.95	BDL
L 54	Pre	ppb	95.8	196.57	7.39	83.46	7.2	1.13	5.20	BDL	BDL
L 55	Pre	ppb	112.8	106.84	1.18	53.87	5.58	1.21	BDL	BDL	BDL
L 56	Pre	ppb	193.42	186.95	12.97	92.54	6.24	2.44	4.58	BDL	0.92
L 57	Pre	ppb	16.7	119.8	11.97	26.47	4.58	10.45	2.41	BDL	BDL
L 58	Pre	ppb	116.78	105.51	1.62	84.6	23.15	19.58	7.15	4.21	BDL
L 59	Pre	ppb	76.21	156.37	11.98	9.8	10.83	1.53	75.84	BDL	BDL
L 60	Pre	ppb	193.54	557.13	2.21	19.73	5.4	23.15	5.40	2.15	3.15
L 41	Post	ppb	91.3	52.8	2.6	6.5	1.05	BDL	0.62	BDL	0.86
L 22	Post	ppb	33.3	150.29	5.6	40.23	2.08	1.55	1.32	0.77	BDL
L 43	Post	ppb	10.62	419.8	16.2	51.3	9.89	8.23	1.02	BDL	0.75
L 44	Post	ppb	32.3	150.2	5.6	41.2	2.06	1.36	1.32	BDL	0.84
L 45	Post	ppb	31.33	183.5	1.8	12.6	1.1	BDL	1.06	0.56	BDL
L 46	Post	ppb	70.77	85.4	4.5	12.3	BDL	1.44	1.25	0.59	BDL
L 47	Post	ppb	96.3	190.36	2.6	2.36	2.32	BDL	2.00	BDL	BDL
L 48	Post	ppb	33.6	118.6	3.4	2.51	4.89	BDL	4.62	BDL	0.97
L 49	Post	ppb	17.6	80.52	3.3	20.31	2.2	BDL	BDL	0.94	BDL
L 50	Post	ppb	14.3	59.52	2.6	2.6	13.9	BDL	BDL	BDL	BDL
L 51	Post	ppb	49.9	98.58	6.5	74.3	3.56	1.23	2.01	BDL	BDL
L 52	Post	ppb	160.6	682.96	12.3	20.3	BDL	5.62	4.32	BDL	1.72
L 53	Post	ppb	82.6	22.62	6.8	30.8	4.12	1.06	2.34	0.84	BDL
L 54	Post	ppb	92.3	190.51	8.8	94.2	6.87	1.00	3.66	BDL	BDL
L 55	Post	ppb	108.6	100.6	2.6	64.2	5.23	1.05	BDL	BDL	BDL
L 56	Post	ppb	188.6	180.3	14.3	104.6	5.98	2.04	4.02	BDL	0.92
L 57	Post	ppb	15.7	112.6	12.8	36.2	4.38	9.44	2.36	BDL	BDL
L 58	Post	ppb	112.30	101.23	2.6	98.21	20.1	16.30	7.77	4.01	BDL
L 59	Post	ppb	74.0	142.6	12.4	13.6	10.8	1.35	50.20	BDL	BDL
L 60	Post	ppb	186.55	546.3	2.9	30.5	5.32	18.60	3.66	2.31	3.15

Table 4.14: Results of metallic ingredients in groundwater of control block during the year of 2016.

Sl.No.	Season	Unit	Zn	Fe	Ni	Mn	Pb	Cu	Co	Cr	Cd
B 1	Pre	ppb	3.21	596.5	BDL	5.687	BDL	5.56	5.56	BDL	BDL
B 2	Pre	ppb	15.3	251.423	BDL	18.6475	2.26	6.69	2.23	BDL	0.86
B 3	Pre	ppb	3.941	192.51	BDL	5.5	8.41	3.32025	6.25	BDL	BDL
B 4	Pre	ppb	50.08	286.4	6.5	65.84	BDL	3.284	6.3	BDL	BDL
B 5	Pre	ppb	34.85	156.9	4.365	35.48	2.35	1.67	3.5	BDL	BDL
B 6	Pre	ppb	15.32	432.8	1.158	22.576	1.36	7.836	2.4	BDL	BDL
B 7	Pre	ppb	253.9	295.47	BDL	96.584	7.69	7.74	1.3	BDL	BDL
B 8	Pre	ppb	65.35	402.95	7.35	19.5	3	1	5.6	BDL	BDL
B 9	Pre	ppb	175.92	625.7	BDL	68.971	BDL	5.968	6.2	BDL	BDL
B 10	Pre	ppb	146.2	863.74	BDL	9.987	BDL	0.98	18.6	BDL	BDL
B 11	Pre	ppb	55.8	412.86	9.009	55.36	4.56	1	6.2	BDL	BDL
B 12	Pre	ppb	54.8	409.6	10.2	59.64	3.52	1.2	5.6	BDL	BDL
B 13	Pre	ppb	22.6	396.12	2.63	66.98	1.36	3.66	1.16	BDL	BDL
B 14	Pre	ppb	112.244	52.971	9.8	11.097	BDL	BDL	2.1	0.3998	BDL
B 15	Pre	ppb	22.6	396.12	2.63	66.98	1.36	3.66	1.16	BDL	BDL
B 16	Pre	ppb	3.941	192.51	2.493	5.5	9.52	3.32025	8.2175	BDL	BDL
B 17	Pre	ppb	123.3	366.65	6.23	25.69	BDL	BDL	5.32	BDL	BDL
B 18	Pre	ppb	76.8	398.647	0.921	18.659	BDL	5.541	5.976	1.64	BDL
B 19	Pre	ppb	423.81	116.87	3.33	99.86	3.34	4.45	1.98	0.98	0.87
B 20	Pre	ppb	16.32	456.8	1.76	46.78	4.5	9.8	5.6	BDL	BDL
B 1	Post	ppb	2.91	588.6	BDL	8.23	BDL	5.23	5.21	BDL	BDL
B 2	Post	ppb	13.6	241.6	1.2	21.3	2.01	6.21	2.01	BDL	0.86
B 3	Post	ppb	3.21	182.3	0.52	8.61	7.21	3.21	5.1	BDL	BDL
B 4	Post	ppb	48.08	280.6	7.1	71.35	BDL	3.01	4.3	BDL	BDL
B 5	Post	ppb	32.05	150.6	5.6	41.3	2.21	1.42	2.1	BDL	BDL
B 6	Post	ppb	14.12	423.6	2.6	27.6	1.09	6.24	2.6	BDL	BDL
B 7	Post	ppb	222.2	288.6	0.92	102.2	6.92	7.56	1.6	BDL	BDL
B 8	Post	ppb	60.35	397.6	8.2	23.6	2.84	1.02	4.9	BDL	BDL
B 9	Post	ppb	170.92	620.6	1.2	73.6	BDL	5.22	4.3	BDL	BDL
B 10	Post	ppb	142.2	852.42	1.2	12.35	BDL	0.78	12.3	BDL	BDL
B 11	Post	ppb	54.8	409.6	10.2	59.64	3.52	1.2	5.6	BDL	BDL
B 12	Post	ppb	20.6	382.6	11.3	71.64	1.25	3.22	1.02	BDL	BDL
B 13	Post	ppb	102.6	42.9	12.1	13.64	BDL	BDL	1.06	0.55	BDL
B 14	Post	ppb	20.5	366.9	3.5	77.6	1.26	3.24	1.04	BDL	BDL
B 15	Post	ppb	3.621	172.6	3.3	8.6	8.62	3.02	6.33	BDL	BDL
B 16	Post	ppb	90.2	426.3	3.4	37.6	5.32	7.54	5.97	2.31	0.85
B 17	Post	ppb	119.9	34.6	7.5	29.4	BDL	BDL	4.36	BDL	BDL
B 18	Post	ppb	74.6	372.3	1.2	21.6	BDL	5.32	5.01	1.02	BDL
B 19	Post	ppb	419.6	110.6	4.1	102.6	3.3	4.21	2.12	0.72	0.87
B 20	Post	ppb	15.63	406.3	2.3	51.3	4.26	7.65	3.64	BDL	BDL

Table 4.15: Results of metallic ingredients in groundwater of Lalganj block during the year of 2017.

Sl.No.	Sl.No.	Season	Unit	Zn	Fe	Ni	Mn	Pb	Cu	Co	Cr	Cd
L1	B 1	Pre	ppb	70.20	192.30	1.56	2.34	BDL	14.62	4.20	0.62	0.66
L2	B 2	Pre	ppb	12.30	153.60	2.65	8.56	1.32	BDL	2.35	BDL	BDL
L3	B 3	Pre	ppb	52.30	412.30	11.23	60.24	BDL	0.67	6.20	BDL	BDL
L 4	B 4	Pre	ppb	37.60	166.20	9.52	8.96	1.23	2.51	5.37	1.12	BDL
L 5	B 5	Pre	ppb	136.50	223.60	4.36	11.20	5.36	1.02	12.64	BDL	0.62
L 6	B 6	Pre	ppb	15.30	220.30	7.21	29.60	BDL	19.50	1.87	BDL	BDL
L 7	B 7	Pre	ppb	23.60	14.60	5.63	8.20	BDL	1.34	2.54	1.10	BDL
L 8	B 8	Pre	ppb	155.60	312.00	5.24	11.60	BDL	1.85	2.85	BDL	1.32
L 9	B 9	Pre	ppb	86.30	158.60	4.25	18.90	2.31	BDL	BDL	1.20	BDL
L 10	B 10	Pre	ppb	9.40	92.30	2.34	7.20	1.32	0.89	3.76	0.68	BDL
L 11	B 11	Pre	ppb	56.30	425.30	6.31	8.20	2.36	16.24	2.45	BDL	BDL
L 12	B 12	Pre	ppb	19.60	262.30	4.35	12.30	2.50	1.32	8.24	2.31	2.23
L 13	B 13	Pre	ppb	110.30	825.00	4.36	14.30	BDL	2.53	BDL	BDL	1.10
L 14	B 14	Pre	ppb	56.80	652.00	6.32	13.20	1.95	2.36	BDL	BDL	BDL
L 15	B 15	Pre	ppb	84.60	73.60	3.24	3.10	8.21	5.16	2.01	BDL	BDL
L 16	B 16	Pre	ppb	129.60	89.60	6.24	15.30	2.95	1.62	4.21	0.67	BDL
L 17	B 17	Pre	ppb	86.40	3.50	8.62	20.10	1.34	1.23	6.54	BDL	0.82
L 18	B 18	Pre	ppb	5.60	162.30	24.30	8.20	7.26	3.56	5.62	BDL	BDL
L 19	B 19	Pre	ppb	68.60	315.20	26.30	20.30	13.20	4.62	9.84	BDL	BDL
L 20	B 20	Pre	ppb	6.34	120.40	3.60	14.20	2.13	5.26	BDL	1.20	0.72
L1	B 1	Post	ppb	66.20	172.60	2.20	3.26	BDL	12.60	3.60	0.55	0.55
L2	B 2	Post	ppb	8.20	126.40	3.10	10.23	1.21	BDL	2.10	BDL	BDL
L3	B 3	Post	ppb	42.30	385.60	12.34	62.30	BDL	0.52	5.60	BDL	BDL
L 4	B 4	Post	ppb	28.60	123.60	11.21	9.26	1.12	2.13	5.10	0.92	BDL
L 5	B 5	Post	ppb	110.00	201.30	5.12	12.60	5.10	0.89	10.20	BDL	0.60
L 6	B 6	Post	ppb	8.30	199.60	7.89	30.20	BDL	16.20	1.62	BDL	BDL
L 7	B 7	Post	ppb	16.50	10.30	6.10	9.30	BDL	1.02	2.30	0.99	BDL
L 8	B 8	Post	ppb	121.30	289.60	5.98	12.30	BDL	1.63	2.40	BDL	1.20
L 9	B 9	Post	ppb	56.30	123.40	4.68	19.20	2.23	BDL	BDL	1.10	BDL
L 10	B 10	Post	ppb	8.60	72.30	3.12	8.60	1.21	0.75	3.40	0.55	BDL
L 11	B 11	Post	ppb	45.60	384.20	7.24	9.12	2.25	15.60	2.20	BDL	BDL
L 12	B 12	Post	ppb	14.30	203.10	5.62	14.20	2.14	1.23	6.20	2.00	2.10
L 13	B 13	Post	ppb	188.60	512.30	6.23	15.60	BDL	2.33	BDL	BDL	0.99
L 14	B 14	Post	ppb	42.30	456.20	8.24	14.90	1.82	2.13	BDL	BDL	BDL
L 15	B 15	Post	ppb	54.60	52.30	4.36	4.10	8.00	4.25	1.80	BDL	BDL
L 16	B 16	Post	ppb	110.30	55.60	7.38	16.20	2.56	1.52	3.89	0.57	BDL
L 17	B 17	Post	ppb	66.40	2.60	9.21	22.30	1.23	1.10	5.84	BDL	0.76
L 18	B 18	Post	ppb	3.20	121.30	26.20	9.89	6.25	3.20	4.96	BDL	BDL
L 19	B 19	Post	ppb	52.30	278.60	28.30	21.30	10.60	4.12	7.88	BDL	BDL
L 20	B 20	Post	ppb	4.60	110.30	6.20	16.50	1.98	4.98	BDL	1.10	0.66

Table 4.16 Results of metallic ingredients in groundwater of Sareni block during the year of 2017.

Sl.No.	Sl.No.	Season	Unit	Zn	Fe	Ni	Mn	Pb	Cu	Co	Cr	Cd
L 21	B 1	Pre	ppb	282.3	380.2	4.2	6.8	BDL	0.78	BDL	BDL	1.21
L 22	B 2	Pre	ppb	156.3	112.3	10.3	16.2	3.32	1.02	2.12	BDL	BDL
L 23	B 3	Pre	ppb	118.2	352.6	7.6	43.6	4.36	BDL	1.32	0.98	BDL
L 24	B 4	Pre	ppb	116.4	345.2	6.2	46.2	4.21	BDL	1.25	1.42	BDL
L 25	B 5	Pre	ppb	128.6	256.1	3.3	12.5	10.8	2.14	2.62	BDL	0.92
L 26	B 6	Pre	ppb	154.6	312.2	6.4	16.9	BDL	1.95	1.45	BDL	BDL
L 27	B 7	Pre	ppb	156.3	415.6	36.5	67.1	7.94	7.68	6.87	BDL	BDL
L 28	B 8	Pre	ppb	247.5	425.3	3.8	23.32	5.21	15.21	2.98	BDL	3.12
L 29	B 9	Pre	ppb	112.4	529.1	4.3	2.6	BDL	3.21	1.25	1.21	0.88
L 30	B 10	Pre	ppb	114.3	862.1	9.21	11.01	BDL	8.29	7.64	BDL	BDL
L 31	B 11	Pre	ppb	109.5	194.2	4.2	12.3	BDL	26.26	1.84	BDL	BDL
L 32	B 12	Pre	ppb	150.6	312.4	5.6	13.4	BDL	2.1	2.94	1.31	BDL
L 33	B 13	Pre	ppb	111.3	326.1	3.6	14.2	BDL	4.01	BDL	BDL	0.92
L 34	B 14	Pre	ppb	214.2	184.2	9.7	3.2	10.62	2.68	7.88	BDL	1.12
L 35	B 15	Pre	ppb	105.6	436.1	2.9	4.2	7.65	BDL	1.56	1.42	BDL
L 36	B 16	Pre	ppb	178.6	654.2	16.4	15.3	4.23	3.64	5.68	BDL	BDL
L 37	B 17	Pre	ppb	112	56.8	14.6	14.2	BDL	BDL	3.94	3.22	0.87
L 38	B 18	Pre	ppb	56.3	784.2	3.6	56.3	BDL	BDL	1.87	0.95	BDL
L 39	B 19	Pre	ppb	26.4	263.2	9.6	30.2	BDL	1.62	BDL	BDL	BDL
L 40	B 20	Pre	ppb	152.3	751.4	8.4	42.6	10.95	6.54	3.84	1.62	BDL
L 21	B 1	Post	ppb	213	345.6	5.62	7.8	BDL	0.65	BDL	BDL	1
L 22	B 2	Post	ppb	123.6	89.6	12.3	18.6	3.22	0.85	1.88	BDL	BDL
L 23	B 3	Post	ppb	88.2	299.5	8.21	44.6	4.1	BDL	1.21	0.88	BDL
L 24	B 4	Post	ppb	89.4	345.2	7.62	47.6	3.89	BDL	1.1	1.2	BDL
L 25	B 5	Post	ppb	99.2	201.3	5.21	13.6	9.2	1.98	1.36	BDL	0.85
L 26	B 6	Post	ppb	114.8	299.3	8.21	17.5	BDL	1.75	1.22	BDL	BDL
L 27	B 7	Post	ppb	121.5	386.2	37.26	69.2	6.2	5.99	5.6	BDL	BDL
L 28	B 8	Post	ppb	198.5	362.4	4.35	25.6	3.2	12.3	2.3	BDL	2.9
L 29	B 9	Post	ppb	98.9	456.2	5.23	4.9	BDL	3.1	1.1	1.1	0.63
L 30	B 10	Post	ppb	87.6	756.6	10.21	12.9	BDL	7.98	6.2	BDL	BDL
L 31	B 11	Post	ppb	87.9	154.2	6.21	13.8	BDL	24.2	1.5	BDL	BDL
L 32	B 12	Post	ppb	123.8	388.6	6.21	15.9	BDL	2	2.4	1.15	BDL
L 33	B 13	Post	ppb	79.8	297.2	4.32	16.7	BDL	3.98	BDL	BDL	0.86
L 34	B 14	Post	ppb	189.6	152.3	10.2	4.5	8.2	2.36	6.89	BDL	0.98
L 35	B 15	Post	ppb	88.4	386.7	3.6	4.6	5.1	BDL	1.2	1.21	BDL
L 36	B 16	Post	ppb	134.7	550.5	18.2	16.7	4.2	3.33	4.96	BDL	BDL
L 37	B 17	Post	ppb	92.5	29.6	17.2	15.6	BDL	BDL	3.3	2.9	0.77
L 38	B 18	Post	ppb	36.4	654.1	5.3	56.6	BDL	BDL	1.32	0.86	BDL
L 39	B 19	Post	ppb	19.5	201.5	11.54	32.4	BDL	1.52	BDL	BDL	BDL
L 40	B 20	Post	ppb	126.4	654.3	9.24	43.2	8.2	4.98	3.33	1.42	BDL

Table 4.17: Results of metallic ingredients in groundwater of Khiron block during the year of 2017.

Sl.No.	Season	Unit	Zn	Fe	Ni	Mn	Pb	Cu	Co	Cr	Cd
L 41	Pre	ppb	99.6	54.6	3.6	7.6	1.23	0.62	0.72	BDL	0.85
L 22	Pre	ppb	36.4	152.3	6.4	39.5	2.2	4.62	1.42	0.75	BDL
L 43	Pre	ppb	12.6	423.4	17.8	52	9.65	8.35	1.35	BDL	0.72
L 44	Pre	ppb	36.4	154.2	6.5	42.1	2.12	1.61	1.42	BDL	0.83
L 45	Pre	ppb	33.6	177.6	2.6	13.4	2.14	BDL	1.32	0.62	BDL
L 46	Pre	ppb	77.5	86.4	6.4	13.2	BDL	1.55	1.33	0.74	BDL
L 47	Pre	ppb	86.5	175.6	2.7	2.63	2.36	BDL	2.25	BDL	BDL
L 48	Pre	ppb	36.4	123.4	6.3	2.61	4.95	BDL	4.67	BDL	0.92
L 49	Pre	ppb	20.5	84.6	4.5	22.3	2.62	BDL	BDL	0.85	BDL
L 50	Pre	ppb	16.4	65.31	3.6	2.8	14.2	BDL	BDL	BDL	BDL
L 51	Pre	ppb	52.6	99.2	8.4	75.6	3.64	1.25	2.12	BDL	BDL
L 52	Pre	ppb	152.6	623.4	13.2	21.3	BDL	5.75	4.36	BDL	1.70
L 53	Pre	ppb	84.3	32.1	8.5	31.2	4.35	1.23	2.66	0.94	BDL
L 54	Pre	ppb	94.6	191.2	9.4	93.6	7.12	1.24	3.84	BDL	BDL
L 55	Pre	ppb	119.4	105.6	4.2	65.4	5.36	1.02	BDL	BDL	BDL
L 56	Pre	ppb	182.6	170.3	15.2	111.3	6.12	2.04	4.23	BDL	0.98
L 57	Pre	ppb	26.3	132.6	11.4	38.2	5.36	9.06	2.63	BDL	BDL
L 58	Pre	ppb	105.3	112.4	2.3	78.2	21.6	15.89	7.88	3.60	BDL
L 59	Pre	ppb	84.3	136.4	13.4	16.2	11.3	1.37	50.20	BDL	BDL
L 60	Pre	ppb	156.7	532.6	3.5	28.3	6.2	17.20	3.55	3.10	3.02
L 41	Post	ppb	75.6	36.2	5.2	7.9	1.12	0.52	0.62	BDL	0.69
L 22	Post	ppb	26.9	121.3	8.1	41.2	1.98	4.21	1.10	0.70	BDL
L 43	Post	ppb	8.9	389.6	19.2	52.6	7.36	7.23	1.11	0.00	0.62
L 44	Post	ppb	29.4	138.7	7.2	43.6	1.89	1.42	1.21	0.00	0.75
L 45	Post	ppb	27.8	122.3	4.1	15.6	1.88	BDL	1.20	0.56	BDL
L 46	Post	ppb	59.8	56.4	7.2	14.2	BDL	1.23	1.00	0.65	BDL
L 47	Post	ppb	66.2	165.2	3.6	3.4	2.13	BDL	1.90	BDL	BDL
L 48	Post	ppb	30.2	88.2	8.2	3.3	4.21	BDL	3.80	BDL	0.86
L 49	Post	ppb	12.6	56.4	5.6	23.6	1.98	BDL	BDL	0.74	BDL
L 50	Post	ppb	14.2	48.6	5.2	3.8	12.3	BDL	BDL	BDL	BDL
L 51	Post	ppb	46.9	78.6	10.2	76.2	3.21	1.11	2.00	BDL	BDL
L 52	Post	ppb	127.5	523.6	15.3	26.2	BDL	4.62	4.10	BDL	1.50
L 53	Post	ppb	66.9	26.9	9.4	33.2	4.12	1.03	2.30	0.86	BDL
L 54	Post	ppb	75.6	156.8	10.6	96.3	6.2	1.02	3.30	BDL	BDL
L 55	Post	ppb	88.7	78.6	5.6	62.2	3.99	0.89	BDL	BDL	BDL
L 56	Post	ppb	162.3	164.2	16.3	110.2	5.1	1.88	3.90	BDL	0.78
L 57	Post	ppb	20.6	120.1	12.5	39.6	4.88	7.65	2.20	BDL	BDL
L 58	Post	ppb	79.8	97.6	4.3	79.5	20.1	13.60	5.90	3.30	BDL
L 59	Post	ppb	64.8	110.2	15.2	17.6	9.99	1.22	41.60	BDL	BDL
L 60	Post	ppb	113.6	486.2	4.5	29.3	4.89	12.60	3.20	2.90	2.80

Table 4.18: Results of metallic ingredients in groundwater of Bachhrawan block during the year of 2017.

Sl.No.	Season	Unit	Zn	Fe	Ni	Mn	Pb	Cu	Co	Cr	Cd
B 1	Pre	ppb	3.61	532.1	2.3	9.21	BDL	5.36	5.74	BDL	BDL
B 2	Pre	ppb	14.03	264.2	2.3	22.3	2.13	6.39	2.62	BDL	0.82
B 3	Pre	ppb	4.36	184	1.2	9.61	8.12	3.33	5.21	BDL	BDL
B 4	Pre	ppb	52.3	263.1	8.6	72.1	BDL	3.26	4.54	BDL	BDL
B 5	Pre	ppb	36.4	156.2	5.2	42.5	2.36	1.52	2.61	BDL	BDL
B 6	Pre	ppb	16.4	432.1	2.9	28.6	1.32	6.62	2.74	BDL	BDL
B 7	Pre	ppb	202	299.5	1.2	106.4	5.98	7.68	1.94	BDL	BDL
B 8	Pre	ppb	60.35	399.2	7.6	24.3	2.64	1.25	5.2	BDL	BDL
B 9	Pre	ppb	159.6	625.4	2.1	75.4	BDL	6.21	4.6	BDL	BDL
B 10	Pre	ppb	144.6	735.6	2.3	14.2	BDL	0.84	12.4	BDL	BDL
B 11	Pre	ppb	56.4	406.3	11.2	60.1	3.62	1.35	5.7	BDL	BDL
B 12	Pre	ppb	26.4	482.6	12.3	72.1	2.31	3.54	1.32	BDL	BDL
B 13	Pre	ppb	118.3	45.6	14.2	12.3	BDL	BDL	1.2	0.52	BDL
B 14	Pre	ppb	24.6	387.4	4.6	75.6	1.34	3.24	1.4	BDL	BDL
B 15	Pre	ppb	4.65	182.3	4.5	9.6	8.9	3.28	6.22	BDL	BDL
B 16	Pre	ppb	92.4	436.1	4.2	38.6	6.32	7.62	5.84	2.12	0.95
B 17	Pre	ppb	117.6	36.4	7.9	30.2	BDL	BDL	4.36	BDL	BDL
B 18	Pre	ppb	58.6	375.6	2.4	22.3	BDL	5.34	5.11	1	BDL
B 19	Pre	ppb	412.5	123.5	5.4	111.2	3.61	5.61	2.01	0.72	0.99
B 20	Pre	ppb	14.6	406.4	3.2	52.2	5.2	7.85	3.52	0.65	BDL
B 1	Post	ppb	1.56	420.6	3.8	10.2	BDL	4.62	3.6	BDL	BDL
B 2	Post	ppb	10.3	244.3	4.1	23.6	2	5.23	2.2	BDL	0.62
B 3	Post	ppb	5.36	156.4	3.2	10.3	6.8	3.1	3.9	BDL	BDL
B 4	Post	ppb	42.3	230.2	9.2	73.6	BDL	2.9	3.8	BDL	BDL
B 5	Post	ppb	28.6	136.1	5.9	43.6	2.1	1.32	2.1	BDL	BDL
B 6	Post	ppb	14.3	398.5	3.2	29.3	1.1	5.8	2.3	BDL	BDL
B 7	Post	ppb	152	266.5	3.1	104.2	4.89	5.6	1.6	BDL	BDL
B 8	Post	ppb	38.4	3.52.2	9.1	26.3	2	1.1	4.9	BDL	BDL
B 9	Post	ppb	120.6	545.5	3.9	78.6	BDL	5.2	4.1	BDL	BDL
B 10	Post	ppb	123.4	654.2	3.3	15.6	BDL	0.77	10.3	BDL	BDL
B 11	Post	ppb	45.6	388.8	12.3	62.3	3.22	1.2	4.6	BDL	BDL
B 12	Post	ppb	20.1	422.2	15.6	75.6	1.88	3.2	1.1	BDL	BDL
B 13	Post	ppb	88.5	39.9	16.2	13.6	BDL	BDL	0.9	0.32	BDL
B 14	Post	ppb	21.3	342.2	5.6	76.8	1.22	3.1	1.2	BDL	BDL
B 15	Post	ppb	3.2	169.8	5.9	10.3	7.2	2.9	5.3	BDL	BDL
B 16	Post	ppb	67.8	400.2	4.8	40.3	4.9	6.5	3.9	2.1	0.84
B 17	Post	ppb	91.3	30.1	8.9	31.2	BDL	BDL	3.86	BDL	BDL
B 18	Post	ppb	38.6	325.1	3.6	23.2	BDL	5	4392	1	BDL
B 19	Post	ppb	354.6	103.6	6.2	113.6	2.9	5.21	2	0.62	0.77
B 20	Post	ppb	12.3	388.7	4.9	56.5	3.6	5.88	3.2	0.55	BDL

Table 4.19: Descriptive statistics of metallic composition of groundwater of Lalganj tehsil for 2017 (n=20)

		Zn	**Fe**	**Ni**	**Mn**	**Pb**	**Cu**	**Co**	**Cr**	**Cd**
Lalganj block	Mean	60.21	252.64	5.76	14.11	2.75	4.30	4.25	0.43	0.38
2016	Min	3.20	1.11	1.08	BDL	BDL	BDL	BDL	BDL	BDL
	Max	158.94	946.34	25.60	60.21	15.86	22.15	18.30	2.54	2.41
	SEM	7.30	35.40	0.87	2.01	0.61	0.92	0.64	0.10	0.10
2017	Mean	56.79	218.91	7.96	15.43	2.53	4.06	3.74	0.42	0.36
	Min	3.20	2.60	1.56	2.34	BDL	BDL	BDL	BDL	BDL
	Max	188.60	825.00	28.30	62.30	13.20	19.50	12.64	2.31	2.23
	SEM	7.42	28.25	1.06	1.96	0.50	0.83	0.49	0.10	0.09
Sareni block	Mean	140.95	397.02	7.34	21.37	3.66	3.05	2.93	0.62	0.48
2016	Min	20.60	50.27	1.30	1.10	BDL	BDL	BDL	BDL	BDL
	Max	288.43	892.76	35.60	66.20	12.77	15.03	9.10	4.00	3.80
	SEM	9.29	34.95	1.17	2.82	0.69	0.59	0.42	0.15	0.13
2017	Mean	125	374	9.17	23.36	3.12	4.10	2.60	0.57	0.43
	Min	20	30	2.90	2.60	BDL	BDL	BDL	BDL	BDL
	Max	282	862	37.26	69.20	10.95	26.26	7.88	3.22	3.12
	SEM	8.71	32.54	1.19	2.91	0.58	0.95	0.36	0.13	0.12
Khiron block	Mean	76.76	186.72	5.95	35.67	5.49	3.80	5.55	0.52	0.46
2016	Min	10.62	22.62	1.16	1.20	BDL	BDL	BDL	BDL	BDL
	Max	193.54	695.94	16.20	104.60	23.15	23.15	75.84	4.21	3.15
	SEM	8.81	26.69	0.73	4.88	0.83	0.95	2.19	0.16	0.13
2017	Mean	67.82	167.47	8.19	38.42	5.25	3.33	4.41	0.51	0.43
	Min	8.90	26.90	2.30	2.61	BDL	BDL	BDL	BDL	BDL
	Max	182.60	623.40	19.20	111.30	21.60	17.20	50.20	3.60	3.02
	SEM	7.28	23.61	0.73	4.97	0.78	0.73	1.56	0.15	0.12
Control area	Mean	82.70	351.37	3.90	41.73	2.58	3.80	4.55	0.19	0.11
2016	Min	2.91	34.60	BDL	5.50	BDL	BDL	BDL	BDL	BDL
	Max	423.81	863.74	12.10	102.60	9.52	9.80	18.60	2.31	0.87
	SEM	15.95	30.63	0.55	4.79	0.45	0.43	0.53	0.16	0.05
2017	Mean	72.50	318.88	5.96	45.19	2.44	3.72	3.84	0.24	0.12
	Min	1.56	30.10	1.20	9.21	BDL	BDL	0.90	BDL	BDL
	Max	412.50	735.60	16.20	113.60	8.90	7.85	12.40	2.12	0.99
	SEM	14.06	28.13	0.62	5.02	0.41	0.37	2.34	0.082	0.048
Standard IS		5000	300	20	100	10	50	-	50	3
EPA 2013		5000	300	-	-	15	1300	-	100	5
WHO 2011		3000	300	-	100	10	2000	-	50	3

Data in ppb or µg/L except SEM (Standard Error Mean)

4.1.2 Metallic constituent in groundwater

The Descriptive statistics of metals in groundwater of Lalganj, Sareni and Khiron were given in **Table 4.19**.

4.1.2 .1 Zinc (Zn)

The concentration of Zn in groundwater varied from 3.0 to 158.94, 20.60 to 288.43 and 10.62 to 193.54 ppb for Lalganj, Sareni and Khiron block while 3.20 to 188.60, 20.0 to 282.0 and 8.90 to 182.60 ppb, respectively for 2017. The average value of Zinc found 60.21±7.30, 140.95±9.29 and 76.76±8.81 ppb for Lalganj, Sareni and Khiron block during year of 2016. In 2017, the mean concentration of Zn in groundwater observed 56.79±7.42, 125±8.71 and 67.82±7.28 ppb for Lalganj, Sareni and Khiron block. The average concentration of Zn in the control area obseved 82.70±15.95 and 72.50± 14.06 during 2016 and 2017.

4.1.2 .2 Iron (Fe)

The concentration of iron in groundwater varied from 1.11 to 946.34 ppb with mean value 252.64±35.40 ppb for Lalganj block, 50.27 to 892.76 ppb with mean value 397.02±34.95 ppb for Sareni block and 22.62 to 695.94 ppb with mean value 186.72±26.69 ppb for Khiron block during 2016 while 2.60 to 825.0 ppb with mean value 218.91±28.25 ppb for, 30 to 862 ppb with mean value 374±32.54 ppb for Sareni block and 26.90 to 623.40 ppb with mean value 167.47±23.61 ppb for Khiron block, respectively for the year of 2017.

4.1.2 .3 Nickel (Ni)

The mean concentrations of nickel was found 5.76±0.87, 7.34±1.17, 5.95±0.73 and 3.90±0.55 ppb with range from 1.08 to 25.60, 1.30 to 35.60, 1.16 to 16.20 and BDL to 12.10 ppb for Lalganj, Sareni, Khiron and Bachhrawan block during 2016. In 2017, the concentration was ranged from 1.56 to 28.30, 2.90 to 37.26, 2.30 to 19.20 and 1.20 to 16.20 ppb for Lalganj, Sareni, Khiron and Bachhrawan block with mean value 7.96±1.06, 9.17±1.19, 8.19±0.73 and 5.96±0.62 ppb for Lalganj, Sareni, Khiron and Bachhrawan block during 2017.

4.1.2 .4 Manganese (Mn)

In this investigation, the concentration of Manganese in groundwater varied from BDL to 60.21, 1.10 to 66.20, 1.20 to 104.60 and 5.50 to 102.60 ppb for Lalganj, Sareni, Khiron and control area (Bachhrawan block) during 2016, while 2.34 to 62.20, 2.60 to 69.20, 2.61 to 111.30 and 9.21 to 113.60 ppb, respectively for 2017. The average value of Manganese found 14.11±2.01, 21.37±2.82, 35.67±4.88 and 41.73±4.79 ppb for Lalganj, Sareni, Khiron and control area (Bachhrawan block) during year of 2016. In 2017, the mean concentration of Manganese in groundwater observed 15.43±1.96, 23.36±2.91, 38.42±4.97 and 45.19±5.02 ppb for Lalganj, Sareni, Khiron and Bachhrawan block.

4.1.2 .5 Lead (Pb)

The concentration of lead in groundwater varied from BDL to 15.86 ppb with mean value 2.75±0.61 ppb for Lalganj block, BDL to 12.77 ppb with mean value 3.66±0.69 ppb for Sareni block and BDL to 23.15 ppb with mean value 5.49±0.83

ppb for Khiron block during 2016 while BDL to 13.20 ppb with mean value 2.53±0.50 ppb for Lalganj, BDL to 10.95 ppb with mean value 3.12±0.58 ppb for Sareni block and BDL to 21.60 ppb with mean value 5.25±0.78 ppb for Khiron block, respectively for the year of 2017. The concentration of lead in groundwater of control area varied from BDL to 9.52 with mean value 2.58±0.45 ppb for 2016 and BDL to 8.90 ppb with average value 2.44±0.41 ppb for 2017.

4.1.2 .6 Copper (Cu):

The mean concentrations of Copper was found 4.30±0.92, 3.05±0.59, 3.80±0.95 and 3.80±0.43 ppb with range from BDL to 22.15, BDL to 15.03, BDL to 23.15 and BDL to 9.80 ppb for Lalganj, Sareni, Khiron and Bachhrawan block during 2016. In 2017, the concentration was ranged from BDL to 19.50, BDL to 26.26, BDL to 17.20 and BDL to 7.85 ppb for Lalganj, Sareni, Khiron and Bachhrawan block with mean value 4.06±0.83, 4.10±0.95, 3.33±0.73 and 3.72±0.37 ppb for Lalganj, Sareni, Khiron and Bachhrawan block during 2017.

4.1.2 .7 Cobalt (Co)

The concentration of Co in groundwater samples of study were ranged from BDL to 18.30 ppb with mean value 4.25±0.64 ppb for Lalganj block, BDL to 9.10 ppb with mean value 2.93±0.42 ppb for Sareni block, BDL to 75.84 ppb with mean value 5.55±2.19 for Khiron block and BDL to 18.60 ppb with mean value 4.55±0.53 for control area during 2016. The concentration of Co in groundwater samples of study during 2017 were ranged from BDL to 12.64 ppb with mean value 3.74±0.49 ppb for Lalganj block, BDL to 7.88 ppb with mean value 2.60±0.36 ppb for Sareni block, BDL to 50.20 ppb with mean value 4.41±1.56 for Khiron block and 0.90 to 18.60 ppb with mean value 3.84±2.34 for control area during 2017.

4.1.2 .8 Chromium (Cr)

In this research, the concentration of Chromium in groundwater varied from BDL to 2.54, BDL to 4.0, BDL to 4.21 and BDL to 2.31 ppb for Lalganj, Sareni, Khiron and control area (Bachhrawan block) during 2016, while BDL to 2.31, BDL to 3.22, BDL to 3.60 and BDL to 2.12 ppb, respectively for 2017. The average value of Chromium found 0.43±0.10, 0.62±0.15, 0.52±0.16 and 0.19±0.16 ppb for Lalganj, Sareni, Khiron and control area (Bachhrawan block) during year of 2016. In 2017, the mean concentration of Chromium in groundwater observed 0.42±0.10, 0.57±0.13, 0.51±0.15 and 0.24±0.08 ppb for Lalganj, Sareni, Khiron and Bachhrawan block.

4.1.2 .9 Cadmium (Cd)

In this investigation, the concentration of cadmium in groundwater varied from BDL to 2.41 ppb with mean value 0.38±0.10 ppb for Lalganj block, BDL to 3.80 ppb with mean value 0.48±0.13 ppb for Sareni block and BDL to 3.15 ppb with mean value 0.46±0.13 ppb for Khiron block during 2016 while BDL to 2.33 ppb with mean value 0.36±0.09 ppb for, BDL to 3.12 ppb with mean value 0.43±0.12 ppb for Sareni block and BDL to 3.02 ppb with mean value 0.43±0.12 ppb for Khiron block, respectively for the year of 2017. The concentration of cadmium in groundwater of control area varied from BDL to 0.87 with mean value 0.11±0.05 ppb for 2016 and BDL to 0.99 ppb with average value 0.12±0.05 ppb for 2017.

4.2 Spatial and temporal variation in groundwater quality

4.2.1 Spatial and temporal variation physicochemical variable

In the study area, pH was found alkaline in nature. The mean pH values were 7.58, 7.43 and 7.52 recorded in pre-monsoon and 8.04, 7.92 and 7.52 in Lalganj Sareni and Khiron block during post-monsoon 2016. The pH of groundwater was 7.99, 7.84 and 7.99 in pre-monsoon and 7.80, 7.99 and 7.84 in post-monsoon 2017 for Lalganj, Sareni, and Khiron. pH of groundwater during post-monsoon was higher as compare to pre-monsoon during both year, because of dissolution of ion increase the pH of water. Spatial and temporal variations in groundwater sample with sampling location are given in Figure 4.2.1.

The mean concentration of TDS (914, 964 and 784 mg/L in Lalganj, Sareni and Khiron block) and EC (1256, 1323 and 1052 µS/cm in Lalganj, Sareni and Khiron block) during pre-monsoon 2016 and both are increase in post-monsoon, TDS (1041, 1107 and 959 mg/L in Lalganj, Sareni and Khiron block) and EC (1445, 1533 and 1356 µS/cm in Lalganj, Sareni and Khiron block). EC totally depends on TDS and TDS depend on all dissolved ions. Concentration of TDS in post-monsoon was found higher than pre-monsoon due to minerals dissolve during monsoon and affect the water quality.

The mean value of turbidity in groundwater samples during pre-monsoon season (2016 and 2017), was observed in Lalganj block (1 and 3 NTU), Sareni block (3 and 4 NTU) and Khiron block (2 and 3 NTU) and post-monsoon season it was observed in Lalganj block (3 and 3 NTU), Sareni block (5 and 5 NTU) and Khiron block (3 and 4NTU). The turbidity in groundwater samples during post-monsoon found more than pre-monsoon due to dissolution of clay particles from soil during percolation of rain water.

Total Hardness in pre-monsoon 2016 ranged from 28 to 490 mg/L with mean value 273±28.0 mg/L for Lalganj block, 196 to 688 mg/L with mean value 316±32.14 mg/L for Sareni block and 42 to 368 mg/L with mean value 197±17.5 mg/L for Khiron block, while the concentration was increased in post-monsoon season were ranged from 26 to 497 mg/L with mean value 292±27.62 mg/L for Lalganj block, 214 to 736 mg/L with mean value 331±31.60 mg/L for Sareni block and 60 to 436 mg/L with mean value 220±18.84 mg/L for Khiron block. The mean value of TH during pre-monsoon 2017, it was observed 297±27.26 mg/L with ranged from 39 to 489 mg/L for Lalganj block, 337±31.60 mg/L with ranged from 219 to 742 mg/L for Sareni block and 227±18.73 mg/L with ranged from 64 to 442 mg/L for Khiron block, while the concentration was increased in post-monsoon season were ranged from 36 to 516 mg/L with mean value 323±26.90 mg/L for Lalganj block, 236 to 782 mg/L with mean value 367±32.27 mg/L for Sareni block and 68 to 456 mg/L with mean value 243±18.91 mg/L for Khiron block.

4.2.2 Spatial and temporal variation in cations of groundwater

Among the cations (Na^{2+}, K^{+}, Ca^{2+} and Mg^{2+}) ions ranged from 120 to 344, 9 to 46, 7 to 97 and 5 to 179 mg/L with mean value 1 84, 21, 43 and 66 mg/L during pre-monsoon 2016 for Lalganj block and the concentration observed in post-monsoon ranged from 131 to 316, 5 to 43, 16 to 105, and 34 to 147 mg/L with mean value 194, 16, 49 and 68 mg/L respectively. The mean concentration of Na^{2+}, K^{+}, Ca^{2+} and Mg^{2+} in pre-monsoon 2017 was 201, 15, 48, and 65 while in post-monsoon, it was 210, 16, 54 and 74 mg/L in Lalganj block. The mean value of Na^{2+}, K^{+}, Ca^{2+} and Mg^{2+} ions in Sareni block was observed 173, 26, 46 and 78 mg/L during pre-monsoon 2016 and in post-monsoon 2016, it was 186, 19, 51 and 83, mg/L respectively. The mean value 195, 19, 50 and 81 mg/L during pre-monsoon 2017 in groundwater of Sareni block and the concentration observed in post-monsoon 2017, it was found 205, 20, 54 and 89 mg/L.

The average concentration of Na^{2+}, K^{+}, Ca^{2+} and Mg^{2+} ions in Khiron block was analyzed 179, 13, 32 and 47 mg/L during pre-monsoon 2016 and in post-monsoon 2016, it was 186, 11, 37 and 60 mg/L respectively. The mean value 192, 12, 37 and 58 mg/L during pre-monsoon 2017 in groundwater of Sareni block and the concentration observed in post-monsoon 2017, it was found 202, 13, 42 and 68 mg/L respectively. The data of cations (Na^{2+}, Ca^{2+} and Mg^{2+}) showing increasing trends in pre-monsoon to post-monsoon season. The concentration of all cations was found in following decreasing order (Na^{2+}> Mg^{2+} >Ca^{2+} >K^{+}) in Lalganj, Sareni and Khiron block while the order change in control area (Na^{2+} >Ca^{2+} > Mg^{2+} >K^{+}) due to elevated concentration of fluoride form insoluble CaF_2 and decease the concentration of Calcium.

4.2.3 Spatial and temporal variation in anions of groundwater

The anionic concentration ($HCO_3^{-,}$ Cl^{-}, NO_3^{-} $SO_4^{2-}$and F^{-}) in groundwater during pre-monsoon 2016, it was ranged from 299 to 524, 11 to 243, 1 to 82, 1 to 362 and 0.86 to 4.54 mg/L for Lalganj block, 254 to 725, 12 to 584, 1 to 26, 1 to 302 and 0.64 to 2.21 mg/L for Sareni block and 156 to 692, 7 to 288, BDL to 10, BDL to 211 and 0.60 to 16.20 mg/L for Khiron block, while the concentration was increased in post-monsoon season were ranged from 242 to 628, 13 to 375, 4 to 84, 11 to 451, and 0.61 to 4.63 mg/L for Lalganj block, 242 to 756, 30 to 658, 2 to 52 and 0.85 to 2.99 mg/L for Sareni block and 231 to 1146, 12 to 184, 4 to 84, 11 to 451, and 0.44 to 17.20 mg/L for Khiron block.

The mean anionic concentration ($HCO_3^{-,}$ Cl^-, NO_3^- $SO_4^{2-}$and F^-) in groundwater during pre-monsoon 2016 were 401±17.5, 59±12.1, 15±4.2, 97±24.0, 2.09±0.2 mg/L for Lalganj block, 385±25.22, 135±36.05, 9±1.49, 85±20.18 and 1.30±0.12 mg/L for Sareni block and 385±25.22, 135±36.05, 9±1.49, 85±20.18 and 1.30±0.12 mg/L for Khiron block. While during post-monsoon 2016, the mean anionic concentration ($HCO_3^{-,}$ Cl^-, NO_3^- $SO_4^{2-}$and F^-) in groundwater were437 ±21.45, 91±20.08, 27±5.45, 144±28.31, 2.24±0.23 mg/L for Lalganj block, 416±27.35, 198±39.75, 17±2.44, 124±21.57 and 1.60±0.10 mg/L for Sareni block and 459±55.02, 81±11.61, 11±1.74, 100±16.03 and 3.03±0.95 mg/L for Khiron block.

In pre-monsoon 2017, The anionic concentration ($HCO_3^{-,}$ Cl^-, NO_3^- $SO_4^{2-}$and F^-) in groundwater were ranged from 252 to 641, 10 to 317, 2 to 69, 12 to 420 and 0.59 to 4.52 mg/L for Lalganj block, 246 to 761, 25 to 594, 2 to 41, 13 to 362 and 0.89 to 2.10 mg/L for Sareni block and 241 to 1153, 9 to 294, 5 to 26, 10 to 241 and 0.52 to 15.26 mg/L for Khiron block, while the concentration was increased in post-monsoon season were ranged from 263 to 672, 25 to 380, 5 to 82, 13 to 421, and 0.65 to 4.72 mg/L for Lalganj block, 265 to 756, 36 to 624, 6 to 50, 19 to 395, and 0.192 to 3.10 mg/L for Sareni block and 249 to 1234, 16 to 186, 2 to 30, 20 to 266, and 0.46 to 16.20 mg/L for Khiron block.

The mean anionic concentration ($HCO_3^{-,}$ Cl^-, NO_3^- $SO_4^{2-}$and F^-) in groundwater during pre-monsoon 2017 were 460±22.38, 66±17.82, 21±4.45, 133±26.71, 2.15±0.23 mg/L for Lalganj block, 425±27.21, 175±37.57, 13±1.86, 105±19.44 and 1.53±0.07 mg/L for Sareni block and 475±55.68, 74±15.69, 10±1.32, 81±14.06 and 2.82±0.82 mg/L for Khiron block. While in post-monsoon 2017, the mean anionic concentration ($HCO_3^{-,}$ Cl^-, NO_3^- $SO_4^{2-}$and F^-) in groundwater were 488 ±22.16, 97±20.34, 28±5.23, 146±27.59, 2.35±0.23 mg/L for Lalganj block, 467±27.32, 210±38.39, 17±2.19, 127±21.26 and 1.66±0.11 mg/L for Sareni block and 504±56.55, 86±11.72, 11±1.52, 105±15.99 and 3.07±0.93 mg/L for Khiron block.

Table 4.20: Descriptive statistics for season-wise chemical composition of groundwater of Lalganj tehsil for 2016 (n=20)

		pH	EC	TDS	Turbidity	BiC	TH	Cl^-	NO_3^-	SO_4^{2-}	F^-	Ca^{2+}	Mg^{2+}	Na^+	K^+
Lalganj block	Mean	7.58	1256	914	1	401	273	59	15	97	2.09	43	66	184	21
Pre-monsoon	Min	7.02	816	617	BDL	299	28	11	1	1	0.86	7	5	120	9
	Max	8.23	2292	1580	4	524	490	243	82	362	4.54	97	179	344	46
	SEM	0.1	94.2	64.0	0.2	17.5	28.0	12.1	4.2	24.0	0.2	4.8	9.5	13.5	2.4
Post- monsoon	Mean	8.04	1445	1041	3	437	292	91	27	144	2.24	49	68	194	16
	Min	7.68	908	675	1	242	26	13	4	11	0.61	16	34	131	5
	Max	8.61	2657	1848	6	628	497	375	84	451	4.63	115	147	316	43
	SEM	0.04	108.65	74.76	0.36	21.45	27.62	20.08	5.45	28.31	0.23	4.95	6.67	11.60	2.47
Sareni block	Mean	7.43	1323	964	3	385	316	135	9	85	1.30	46	78	173	26
Pre-monsoon	Min	7.00	742	547	BDL	254	196	12	1	1	0.64	13	24	111	13
	Max	8.21	2864	2053	7	725	688	584	26	302	2.21	133	200	321	56
	SEM	0.07	126.47	88.39	0.36	25.22	32.14	36.05	1.49	20.18	0.12	5.36	9.14	11.92	2.55
Post- monsoon	Mean	7.92	1533	1107	5	416	331	198	17	124	1.60	51	83	186	19
	Min	7.59	835	618	2	242	214	30	2	16	0.85	28	43	128	8
	Max	8.23	4025	2254	8	756	736	658	52	400	2.99	96	221	342	5
	SEM	0.04	163.15	95.52	0.33	27.35	31.60	39.75	2.44	21.57	0.10	3.33	10.17	11.65	2.80
Khiron block	Mean	7.52	1052	784	2	354	197	65	4	62	2.65	32	47	179	13
Pre-monsoon	Min	7.26	601	459	BDL	156	42	7	BDL	BDL	0.60	5	12	121	6
	Max	8.24	1949	1484	6	692	368	288	10	211	16.20	53	108	396	22
	SEM	0.053	89.96	68.51	0.33	35.78	17.05	16.51	0.75	15.46	0.88	3.70	5.39	15.67	1.05
Post- monsoon	Mean	8.09	1356	959	3	459	220	81	11	100	3.03	37	60	186	11
	Min	7.78	831	535	BDL	231	60	12	1	13	0.44	11	16	120	4
	Max	8.34	2829	1927	5	1146	436	184	32	266	17.20	66	109	366	20
	SEM	0.03	136.25	89.39	0.29	55.02	18.84	11.61	1.74	16.03	0.95	3.31	5.08	13.96	1.03

SEM *Standard Error Mean, Data in mg/L except for* **EC** *(µS/cm),* **Turbidity** *(NTU) and pH.*

Table 4.21: Descriptive statistics season-wise (2017) chemical composition of groundwater of Lalganj tehsil (n=20)

		pH	EC	TDS	Turbidity	BiC	TH	Cl^-	NO_3^-	SO_4^{2-}	F^-	Ca^{2+}	Mg^{2+}	Na^+	K^+
Lalganj block	Mean	7.99	1477	1024	3	460	297	66	21	133	2.15	48	65	201	15
Pre-monsoon	Min	7.66	912	657	1	252	39	10	2	12	0.59	14	36	136	6
	Max	8.21	2681	1748	5	641	498	317	69	420	4.52	101	132	316	45
	SEM	0.03	113.37	69.73	0.30	22.38	27.26	17.82	4.45	26.71	0.23	4.28	5.63	11.81	2.52
Post- monsoon	Mean	7.80	1568	1127	3	488	323	97	28	146	2.35	54	74	210	16
	Min	7.55	960	744	2	263	36	25	5	13	0.65	23	42	142	7
	Max	8.16	2767	1939	5	672	516	380	82	421	4.72	120	142	336	44
	SEM	0.04	113.24	73.48	0.27	22.16	26.90	20.34	5.23	27.59	0.23	4.81	5.91	12.46	2.42
Sareni block	Mean	7.84	1574	1077	4	425	337	175	13	105	1.53	50	81	195	19
Pre-monsoon	Min	7.55	872	611	2	246	219	25	2	13	0.89	30	45	136	9
	Max	8.15	4083	2201	7	761	742	594	41	362	2.10	82	214	356	46
	SEM	0.03	165.28	91.99	0.27	27.21	31.60	37.57	1.86	19.44	0.07	2.74	9.96	11.87	2.36
Post- monsoon	Mean	7.99	1676	1204	5	467	367	210	17	127	1.66	54	89	205	20
	Min	7.66	938	750	2	265	236	36	6	19	0.92	33	52	142	10
	Max	8.21	4275	2309	6	756	782	624	50	395	3.10	92	235	362	46
	SEM	0.03	168.12	85.91	0.29	27.32	32.27	38.39	2.19	21.26	0.11	2.84	10.72	12.23	2.27
Khiron block	Mean	7.99	1392	948	3	475	227	74	10	81	2.82	37	58	192	12
Pre-monsoon	Min	7.64	871	548	1	241	64	9	5	10	0.52	16	20	129	5
	Max	8.21	2847	1898	5	1153	442	294	26	241	15.26	62	100	374	22
	SEM	0.04	133.86	87.66	0.22	55.68	18.73	15.69	1.32	14.06	0.82	2.60	4.48	13.87	0.98
Post- monsoon	Mean	7.84	1505	1040	4	504	243	86	11	105	3.07	42	68	202	13
	Min	7.55	876	608	2	249	68	16	2	20	0.46	26	33	136	6
	Max	8.15	3275	2075	6	1234	456	186	30	266	16.20	63	121	386	23
	SEM	0.03	148.63	88.69	0.25	56.55	18.91	11.72	1.52	15.99	0.93	2.30	4.86	14.24	0.99

SEM *Standard Error Mean, Data in mg/L except for* **EC** *(μS/cm),* **Turbidity** *(NTU) and pH.*

Table 4.22: Descriptive statistics of metallic composition of groundwater of Lalganj tehsil for 2016 (n=20)

		Zn	Fe	Ni	Mn	Pb	Cu	Co	Cr	Cd
Lalganj block	Mean	62.02	255.91	5.35	13.06	2.91	4.57	4.65	0.47	0.41
Pre-monsoon	Min	3.94	1.11	1.08	BDL	BDL	BDL	BDL	BDL	BDL
	Max	158.94	946.34	24.93	55.36	15.86	22.15	18.30	2.54	2.41
	SEM	10.5	51.1	1.2	2.8	0.9	1.4	1.0	0.2	0.1
Post- monsoon	Mean	58.41	249.38	6.17	15.17	2.60	4.02	3.84	0.39	0.36
	Min	3.20	2.12	1.52	2.10	BDL	BDL	BDL	BDL	BDL
	Max	156.30	936.50	25.60	60.21	14.80	18.36	12.30	2.21	2.31
	SEM	10.36	50.27	1.26	2.93	0.83	1.21	0.76	0.13	0.14
Sareni block	Mean	142.82	399.92	6.74	20.14	3.94	3.15	3.14	0.66	0.51
Pre-monsoon	Min	24.78	52.97	1.30	1.10	BDL	BDL	BDL	BDL	BDL
	Max	288.43	892.76	29.76	62.38	12.77	15.03	9.10	4.00	3.80
	SEM	13.40	50.12	1.57	3.93	1.06	0.87	0.66	0.23	0.21
Post- monsoon	Mean	139.07	394.11	7.93	22.60	3.39	2.95	2.71	0.58	0.44
	Min	20.60	50.27	1.90	1.60	BDL	BDL	BDL	BDL	BDL
	Max	280.50	882.60	35.60	66.20	10.70	14.23	7.69	3.21	3.21
	SEM	13.20	50.02	1.76	4.14	0.91	0.81	0.53	0.19	0.18
Khiron block	Mean	78.39	189.98	5.40	33.40	5.69	4.08	6.42	0.54	0.46
Pre-monsoon	Min	12.59	26.98	1.16	1.20	BDL	BDL	BDL	BDL	BDL
	Max	193.54	695.94	15.34	92.54	23.15	23.15	75.84	4.21	3.15
	SEM	12.792	38.437	1.057	6.503	1.253	1.481	3.69	0.232	0.181
Post- monsoon	Mean	75.13	183.46	6.51	37.94	5.29	3.51	4.68	0.50	0.46
	Min	10.62	22.62	1.80	2.36	BDL	BDL	BDL	BDL	BDL
	Max	188.60	682.96	16.20	104.60	20.10	18.60	50.20	4.01	3.15
	SEM	12.433	38.029	1.032	7.404	1.128	1.225	2.435	0.225	0.181
Control area	Mean	83.81	365.18	3.42	40.27	2.66	3.83	5.06	0.15	0.09
Pre-monsoon	Min	3.21	52.97	BDL	5.50	BDL	BDL	1.16	BDL	BDL
	Max	423.81	863.74	10.20	99.86	9.52	9.80	18.60	1.64	0.87
	SEM	23.26	42.23	0.79	6.80	0.67	0.63	0.86	0.09	0.06
Post- monsoon	Mean	81.58	337.56	4.37	43.19	2.49	3.77	4.03	0.23	0.13
	Min	2.91	34.60	0.00	8.23	BDL	BDL	1.02	BDL	BDL
	Max	419.60	852.42	12.10	102.60	8.62	7.65	12.30	2.31	0.87
	SEM	22.47	45.08	0.85	6.94	0.61	0.57	0.59	0.13	0.07

Data in ppb except SEM (Standard Error Mean)

Table 4.23: Descriptive statistics of metallic composition of groundwater of Lalganj tehsil for 2017 (n=20)

		Zn	Fe	Ni	Mn	Pb	Cu	Co	Cr	Cd
Lalganj block	Mean	61.16	243.75	7.38	14.80	2.67	4.32	4.03	0.45	0.37
Pre-monsoon	Min	5.60	3.50	1.56	2.34	BDL	BDL	BDL	BDL	BDL
	Max	155.60	825.00	26.30	60.24	13.20	19.50	12.64	2.31	2.23
	SEM	10.35	46.13	1.48	2.78	0.76	1.26	0.77	0.15	0.14
Post- monsoon	Mean	52.43	194.06	8.54	16.07	2.39	3.81	3.45	0.39	0.34
	Min	3.20	2.60	2.20	3.26	BDL	BDL	BDL	BDL	BDL
	Max	188.60	512.30	28.30	62.30	10.60	16.20	10.20	2.00	2.10
	SEM	10.82	32.89	1.54	2.82	0.65	1.11	0.62	0.13	0.13
Sareni block	Mean	140.19	397.68	8.52	22.61	3.46	4.36	2.85	0.61	0.45
Pre-monsoon	Min	26.40	56.80	2.90	2.60	BDL	BDL	BDL	BDL	BDL
	Max	282.30	862.10	36.50	67.10	10.95	26.26	7.88	3.22	3.12
	SEM	13.18	49.29	1.70	4.18	0.92	1.43	0.54	0.20	0.18
Post- monsoon	Mean	110.69	350.55	9.81	24.12	2.78	3.85	2.34	0.54	0.40
	Min	19.50	29.60	3.60	4.50	BDL	BDL	BDL	BDL	BDL
	Max	213.00	756.60	37.26	69.20	9.20	24.20	6.89	2.90	2.90
	SEM	10.711	43.109	1.703	4.156	0.725	1.279	0.462	0.175	0.159
Khiron block	Mean	75.73	181.66	7.50	37.87	5.63	3.64	4.80	0.53	0.45
Pre-monsoon	Min	12.60	32.10	2.30	2.61	BDL	BDL	BDL	BDL	BDL
	Max	182.60	623.40	17.80	111.30	21.60	17.20	50.20	3.60	3.02
	SEM	11.22	35.33	1.02	7.16	1.18	1.16	2.43	0.23	0.18
Post- monsoon	Mean	59.92	153.29	8.88	38.98	4.87	3.01	4.02	0.49	0.40
	Min	8.90	26.90	3.60	3.30	BDL	BDL	BDL	BDL	BDL
	Max	162.30	523.60	19.20	110.20	20.10	13.60	41.60	3.30	2.80
	SEM	9.23	31.92	1.04	7.08	1.06	0.93	2.01	0.21	0.16
Control area	Mean	80.99	338.68	5.28	44.44	2.69	4.01	4.21	0.25	0.14
Pre-monsoon	Min	3.61	36.40	1.20	9.21	BDL	BDL	1.20	BDL	BDL
	Max	412.50	735.60	14.20	111.20	8.90	7.85	12.40	2.12	0.99
	SEM	21.70	41.38	0.86	7.17	0.64	0.59	0.57	0.12	0.08
Post- monsoon	Mean	64.01	298.05	6.64	45.94	2.19	3.43	222.84	0.23	0.11
	Min	1.56	30.10	3.10	10.20	BDL	BDL	0.90	BDL	BDL
	Max	354.60	654.20	16.20	113.60	7.20	6.50	4392.00	2.10	0.84
	SEM	18.24	38.45	0.90	7.21	0.51	0.47	219.43	0.12	0.06

Data in ppb except SEM (Standard Error Mean)

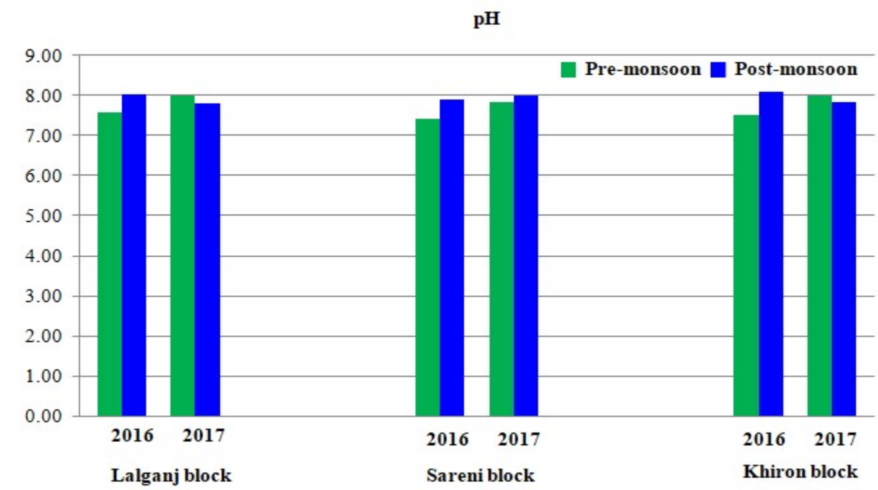


Figure 4.1: Seasonal variation of pH in different block of Lalganj tehsil for the year of 2016-17

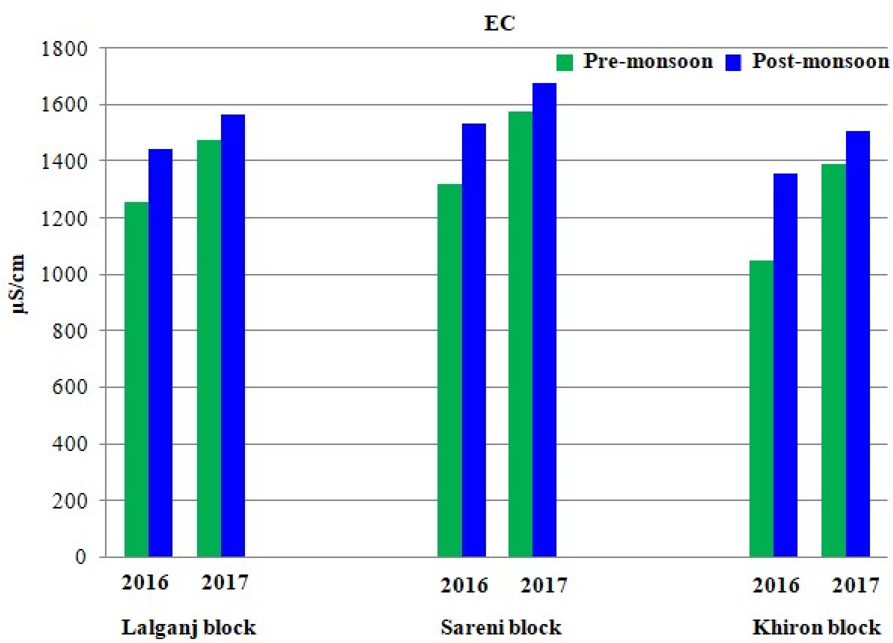


Figure 4.2: seasonal variation of EC in different block of Lalganj tehsil for the year of 2016-17

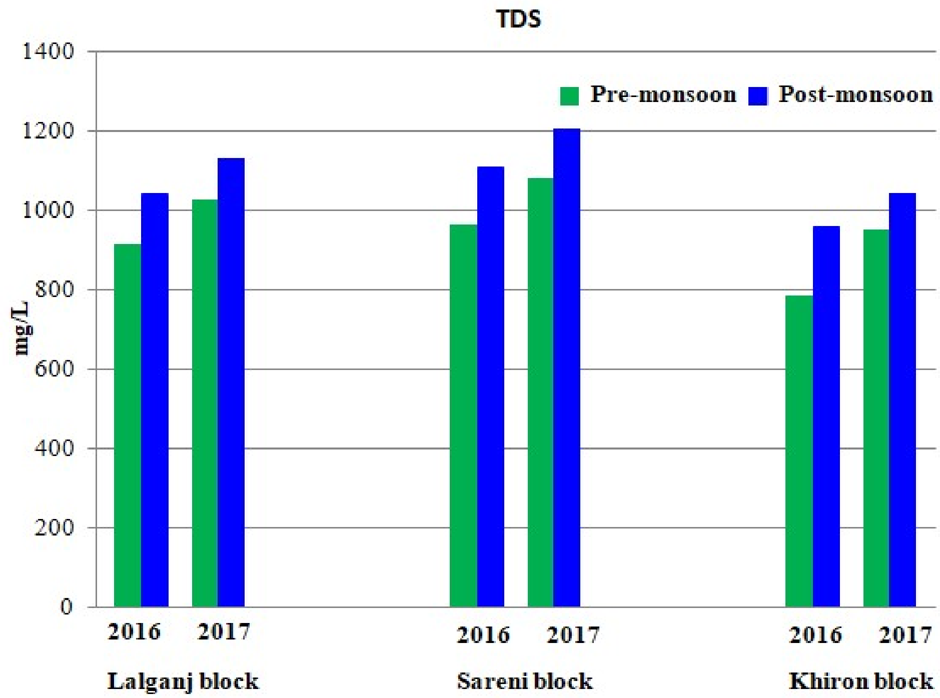


Figure 4.3: Seasonal variation of TDS in different block of Lalganj tehsil for the year of 2016-17

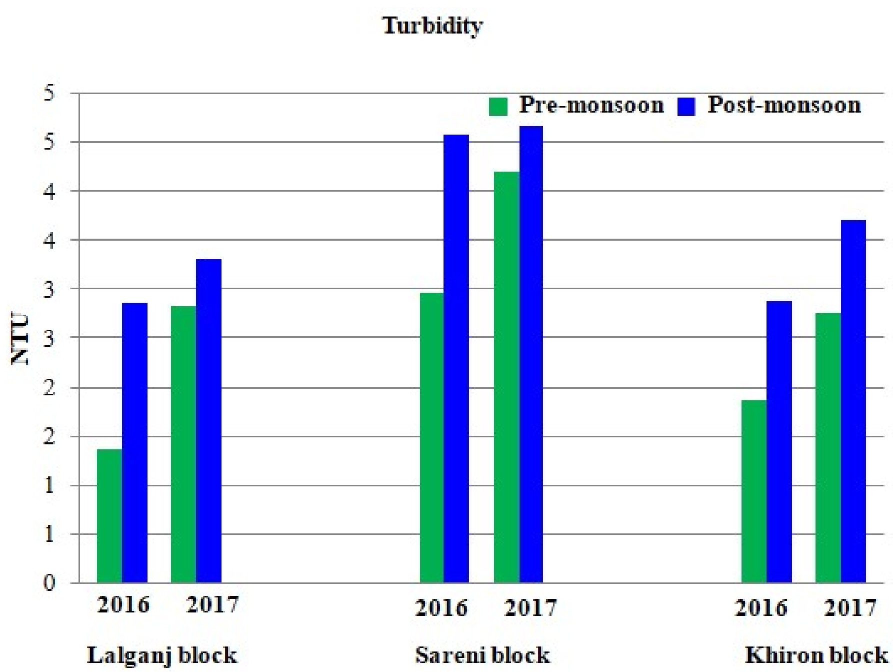


Figure 4.4: Seasonal variation of turbidity in different block of Lalganj tehsil for the year of 2016-17

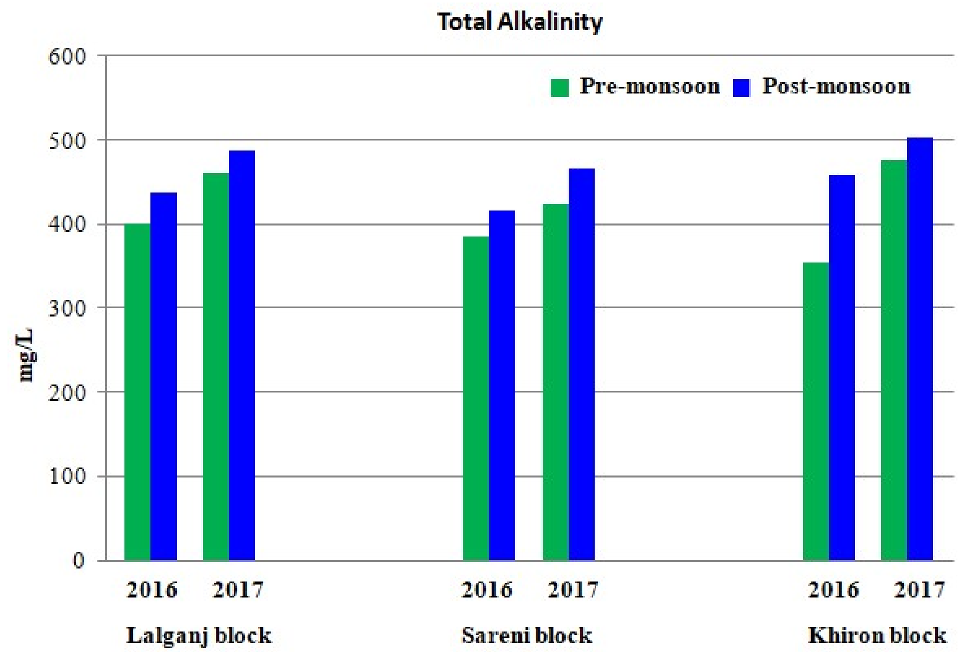


Figure 4.5: Seasonal variation of total alkalinity in different block of Lalganj tehsil for the year of 2016-17

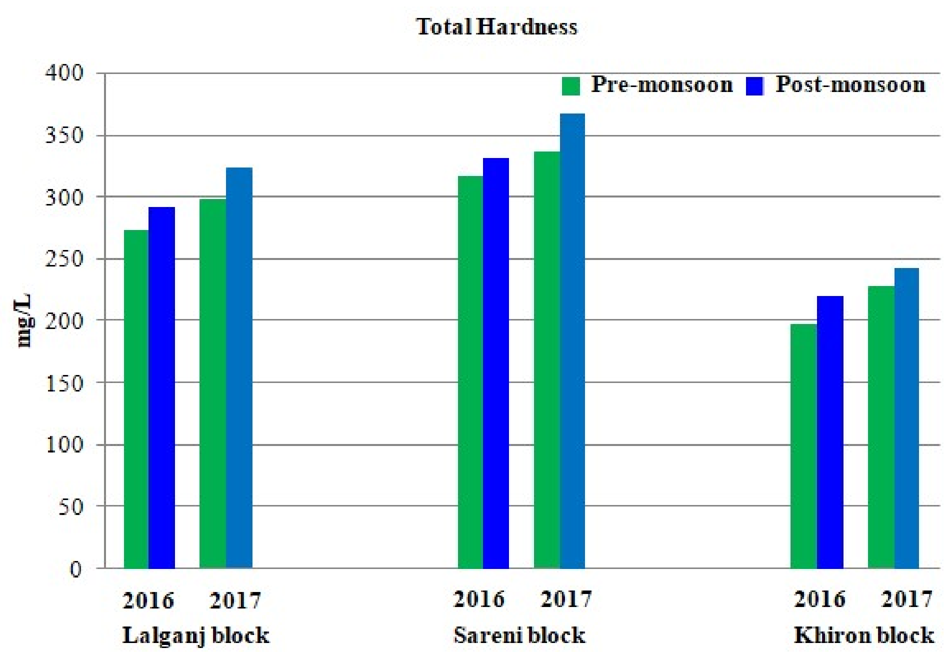


Figure 4.6: Seasonal variation of total hardness in different block of Lalganj tehsil for the year of 2016-17

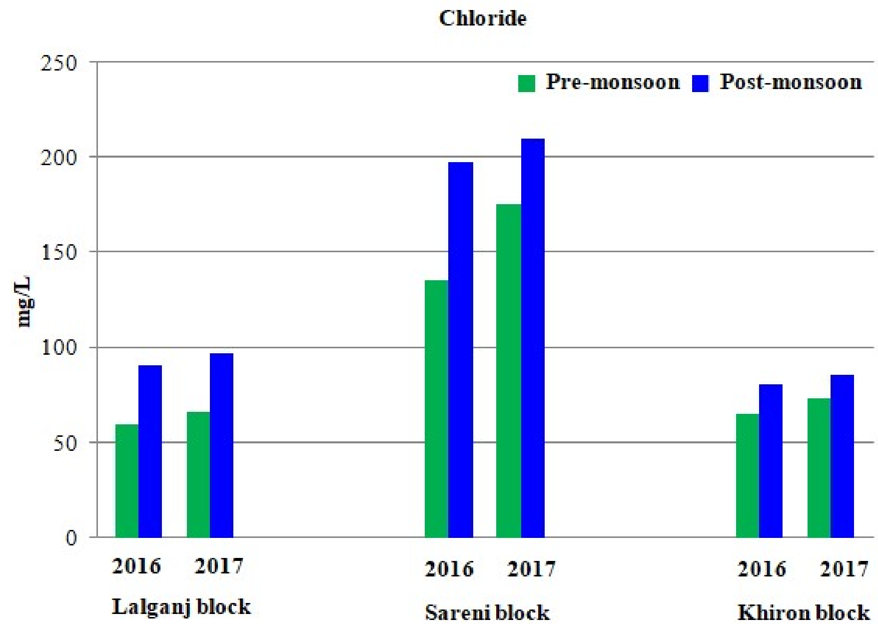


Figure 4.7: Seasonal variation of chloride in different block of Lalganj tehsil for the year of 2016-17

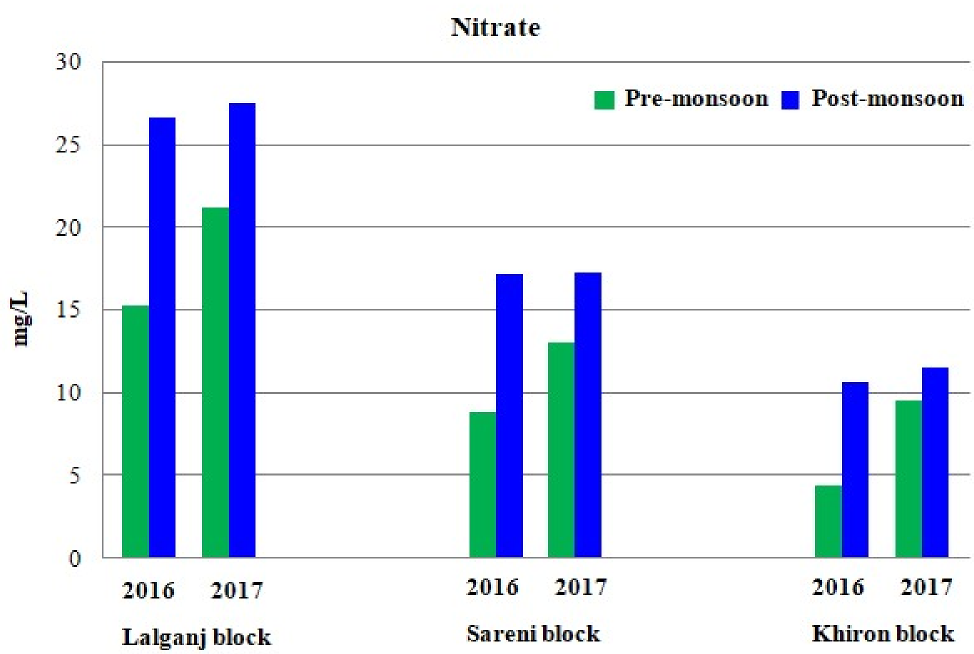


Figure 4.8: Seasonal variation of nitrate in different block of Lalganj tehsil for the year of 2016-17

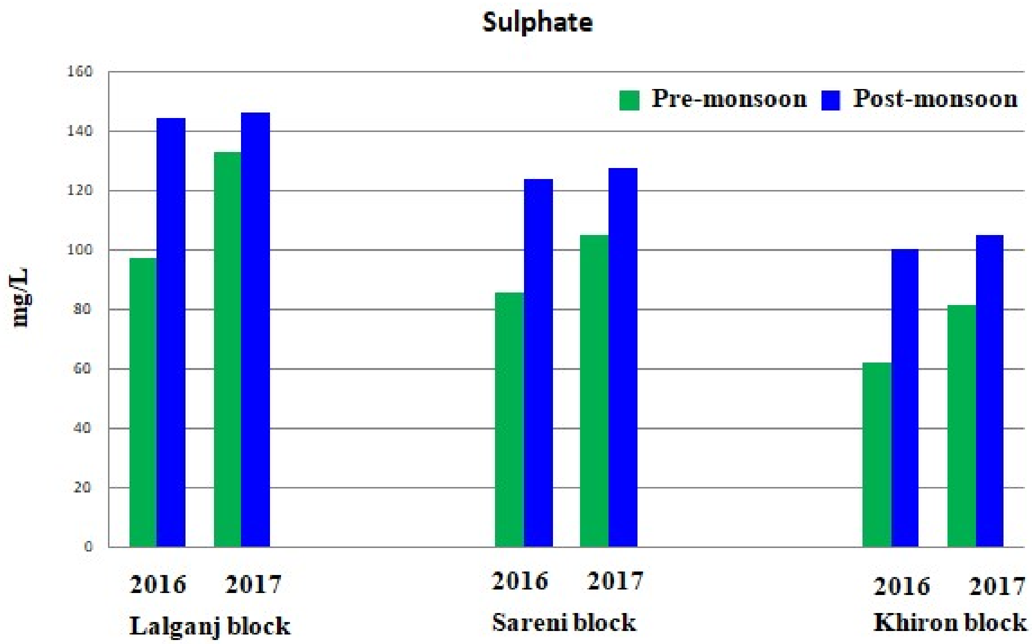


Figure 4.9: Seasonal variation of sulphate in different block of Lalganj tehsil for the year of 2016-17

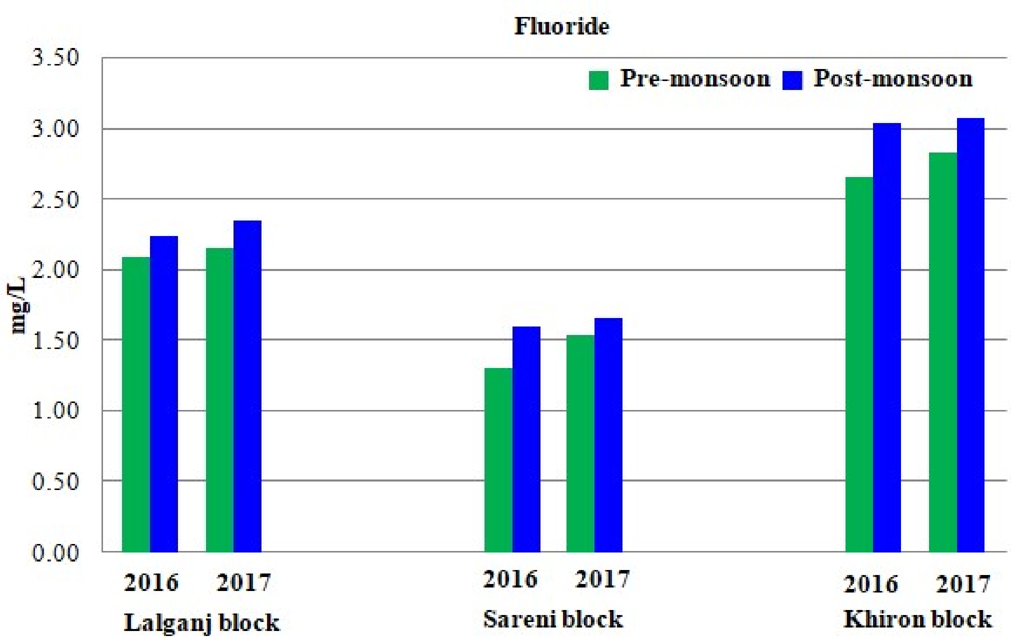


Figure 4.10: Seasonal variation of fluoride in different block of Lalganj tehsil for the year of 2016-17

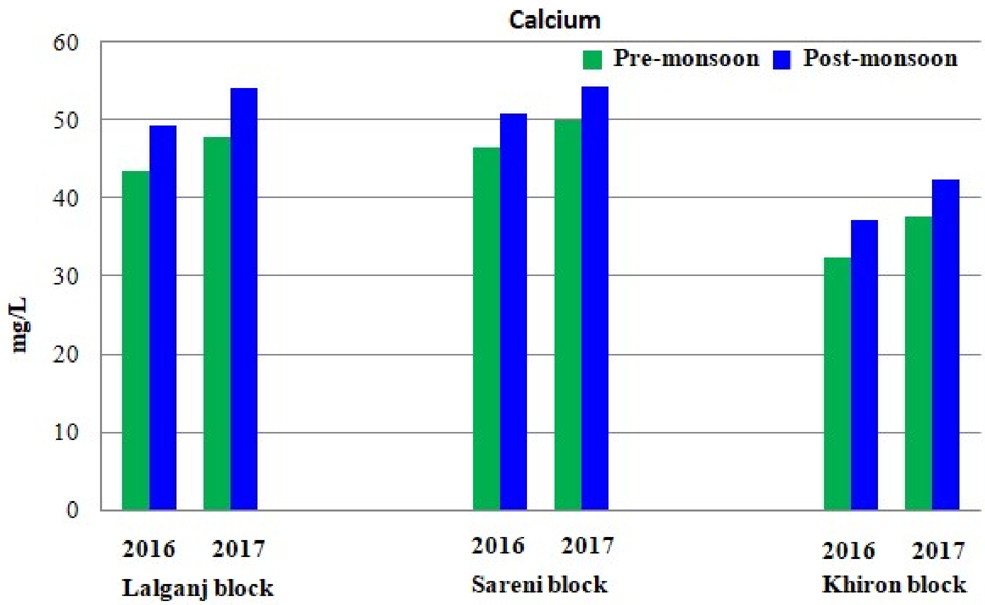


Figure 4.11: Seasonal variation of calcium in different block of Lalganj tehsil for the year of 2016-17

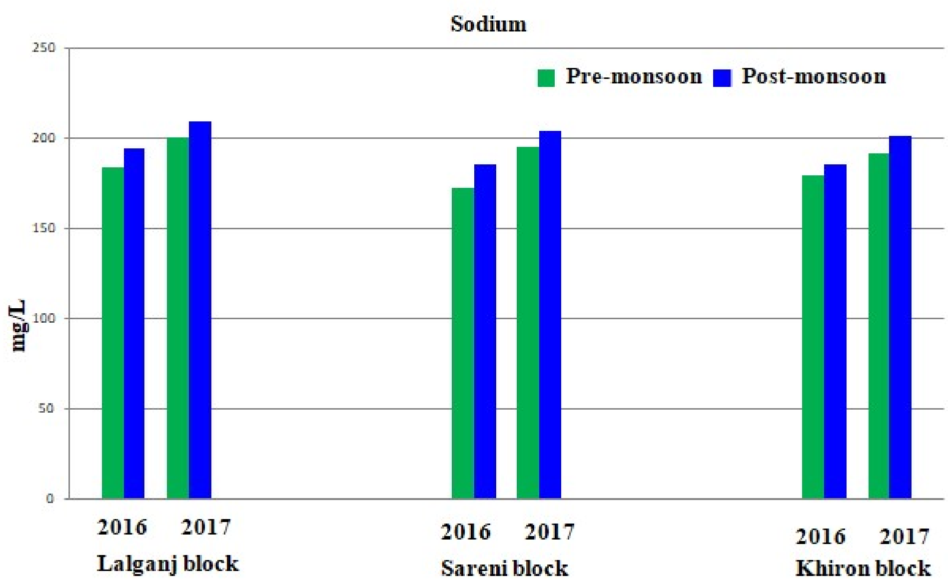


Figure 4.12: Seasonal variation of sodium in different block of Lalganj tehsil for the year of 2016-17

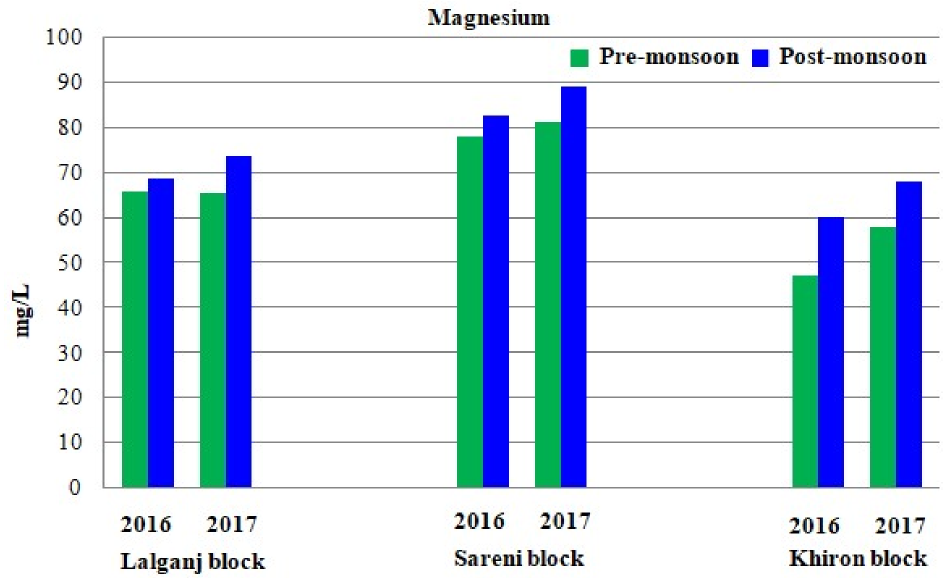


Figure 4.13: Seasonal variation of magnesium in different block of Lalganj tehsil for the year of 2016-17

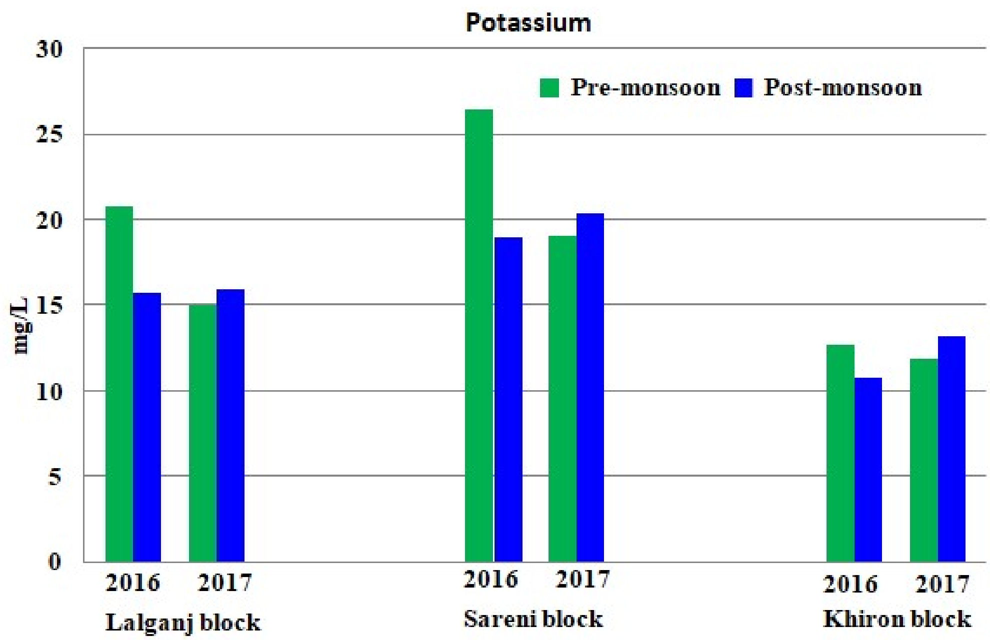


Figure 4.14: Seasonal variation of potassium in different block of Lalganj tehsil for the year of 2016-17

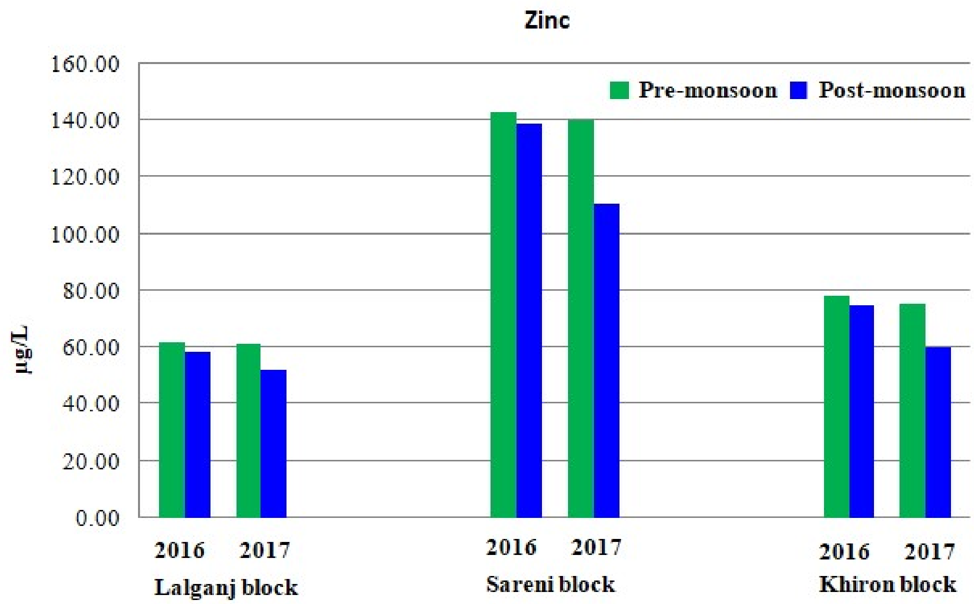


Figure 4.15: Seasonal variation of zinc in different block of Lalganj tehsil for the year of 2016-17

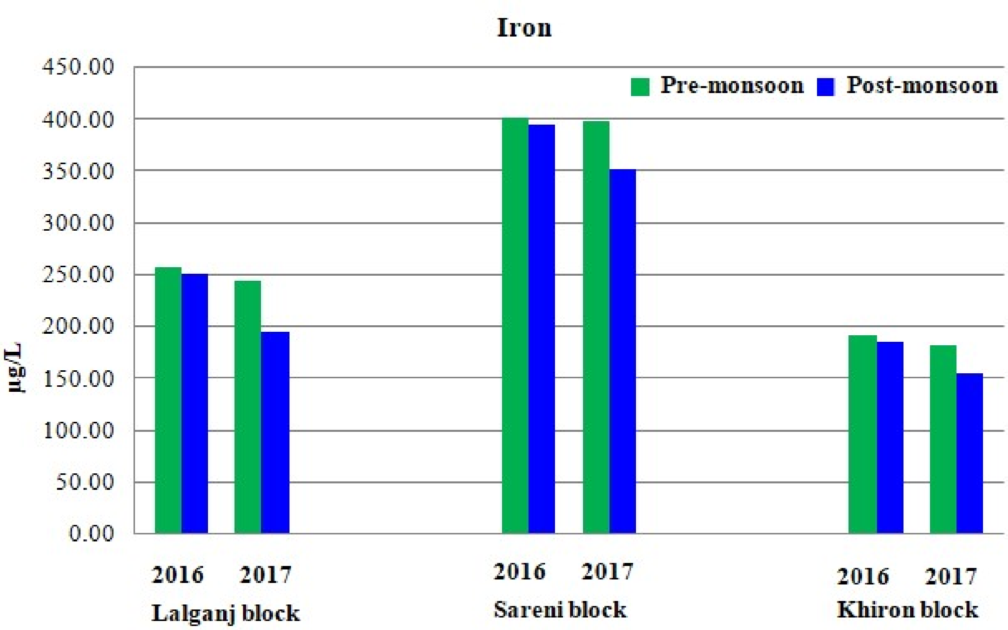


Figure 4.16: Seasonal variation of iron in different block of Lalganj tehsil for the year of 2016-17

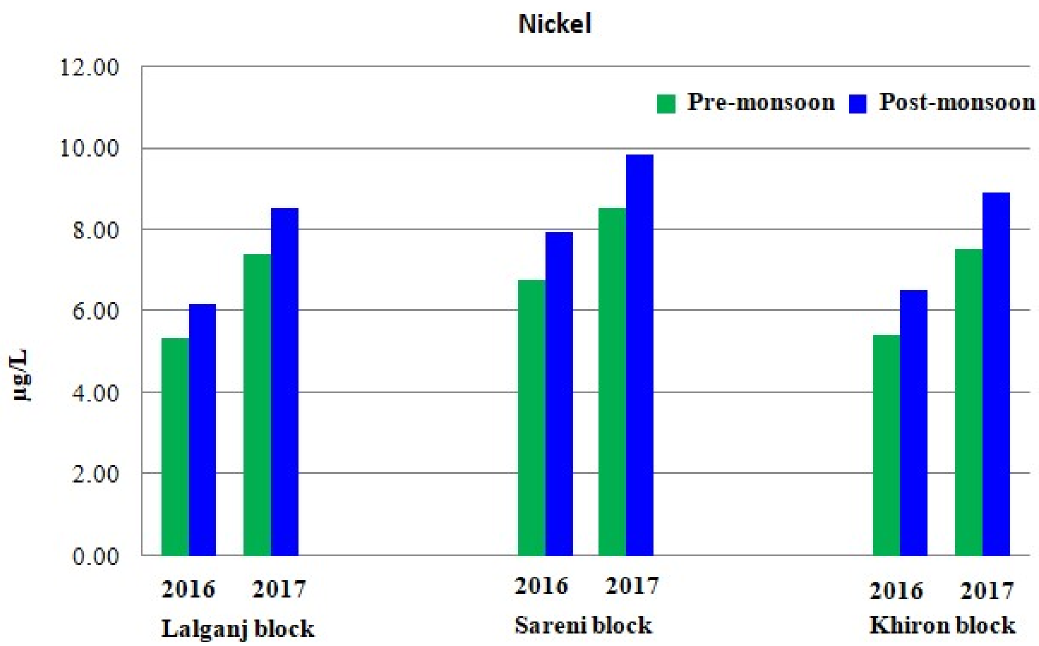


Figure 4.17: Seasonal variation of nickel in different block of Lalganj tehsil for the year of 2016-17

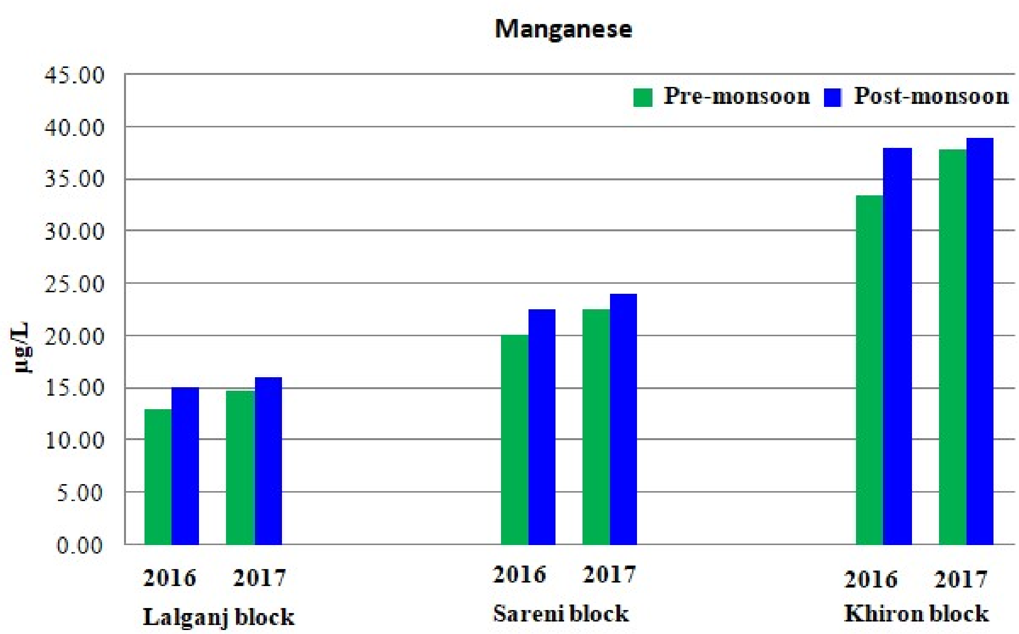


Figure 4.18: Seasonal variation of manganese in different block of Lalganj tehsil for the year of 2016-17

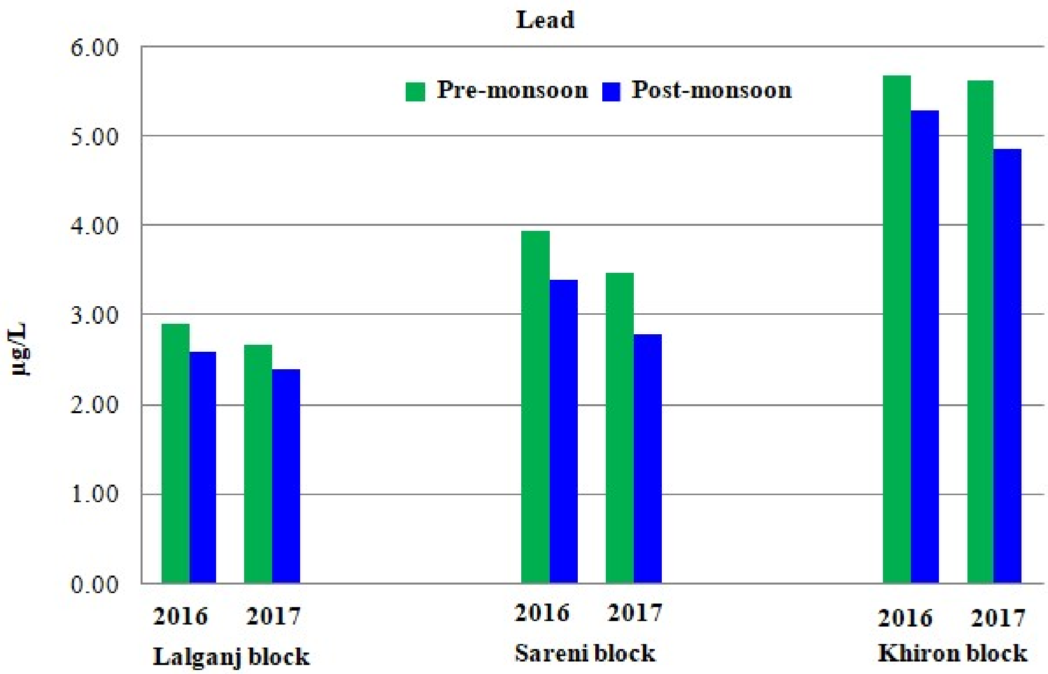


Figure 4.19: Seasonal variation of lead in different block of Lalganj tehsil for the year of 2016-17

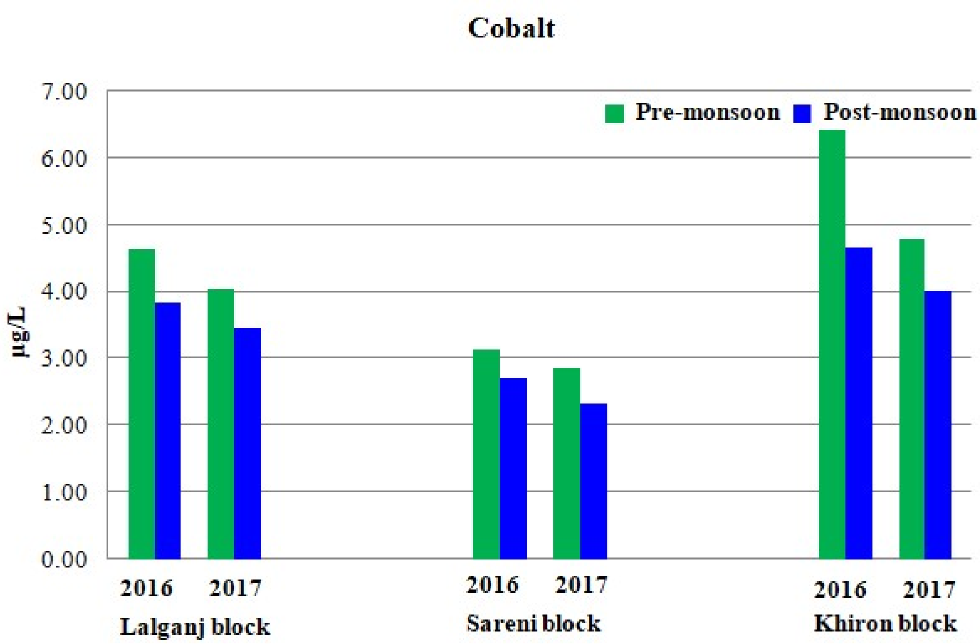


Figure 4.20: Seasonal variation of cobalt in different block of Lalganj tehsil for the year of 2016-17

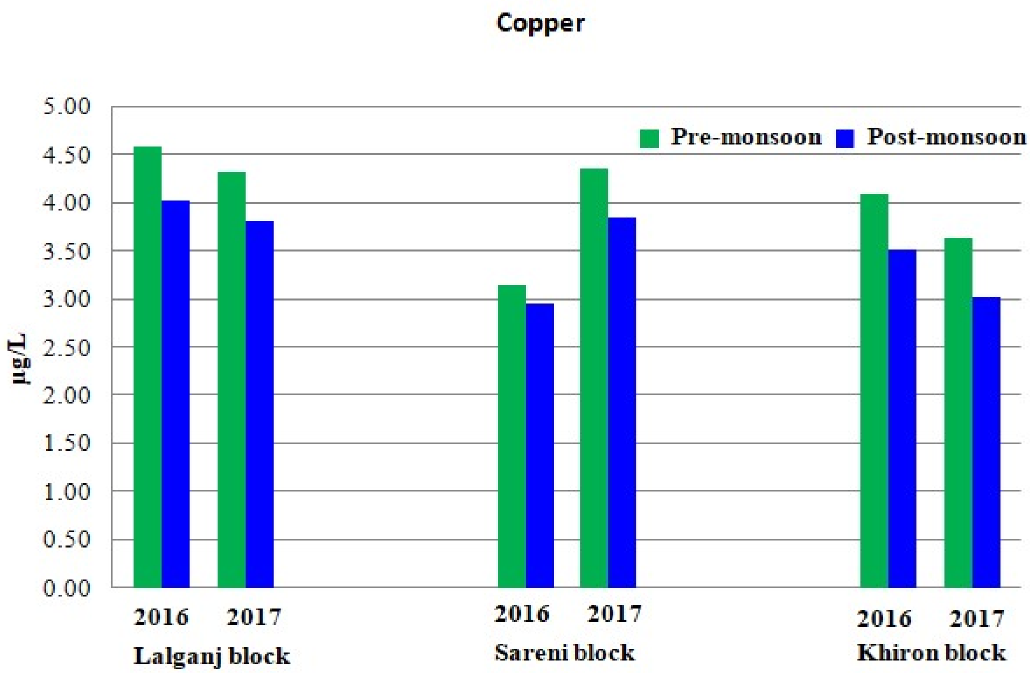


Figure 4.21: Seasonal variation of copper in different block of Lalganj tehsil for the year of 2016-17

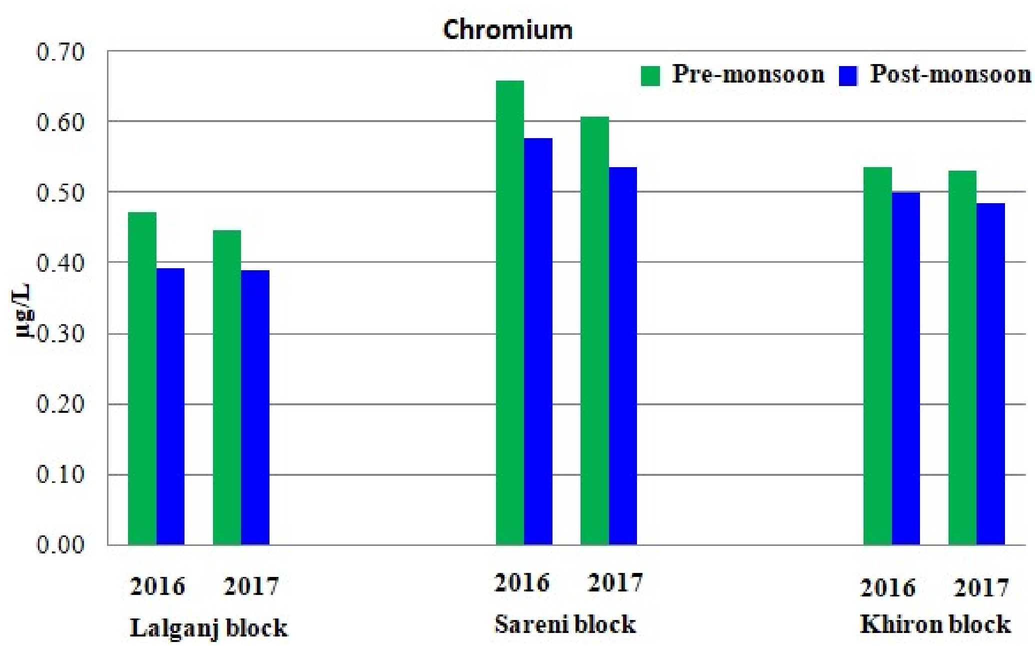


Figure 4.22: Seasonal variation of chromium in different block of Lalganj tehsil for the year of 2016-17

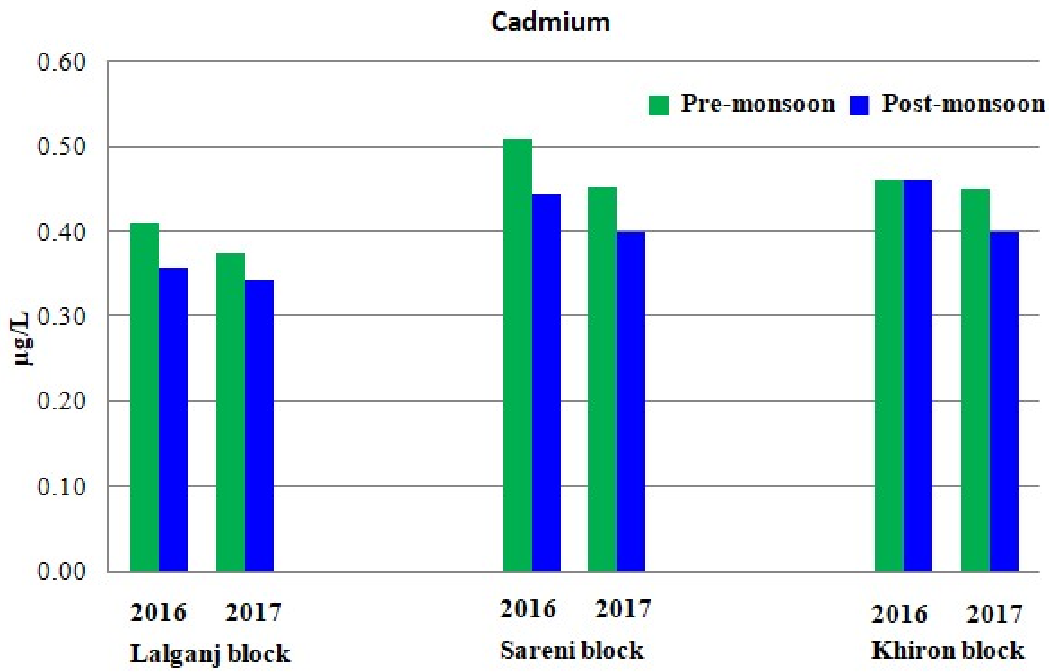


Figure 4.23: Seasonal variation of cadmium in different block of Lalganj tehsil for the year of 2016-17

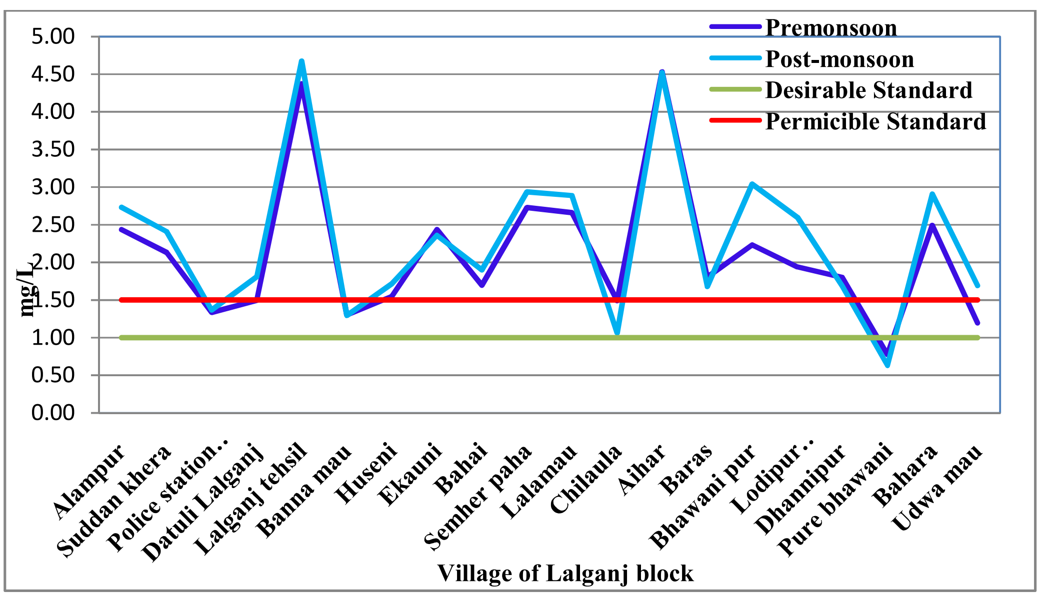


Figure 4.24: Spatio-temporal variation of F^- in Lalganj block for the years of 2016-17

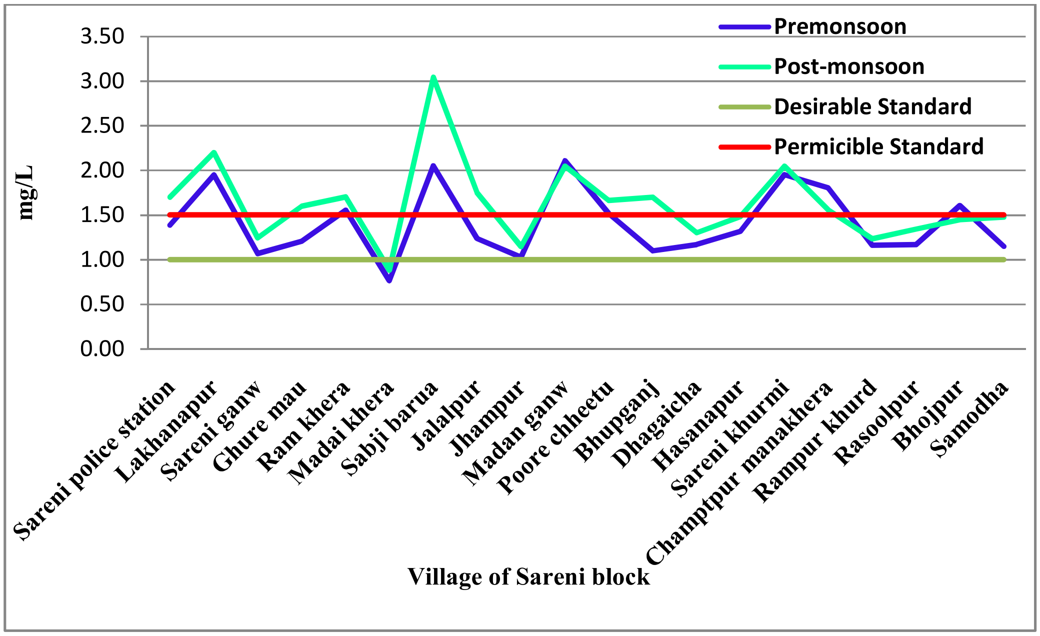


Figure 4.25: Spatio-temporal variation of F^- in Sareni block for the years of 2016-17

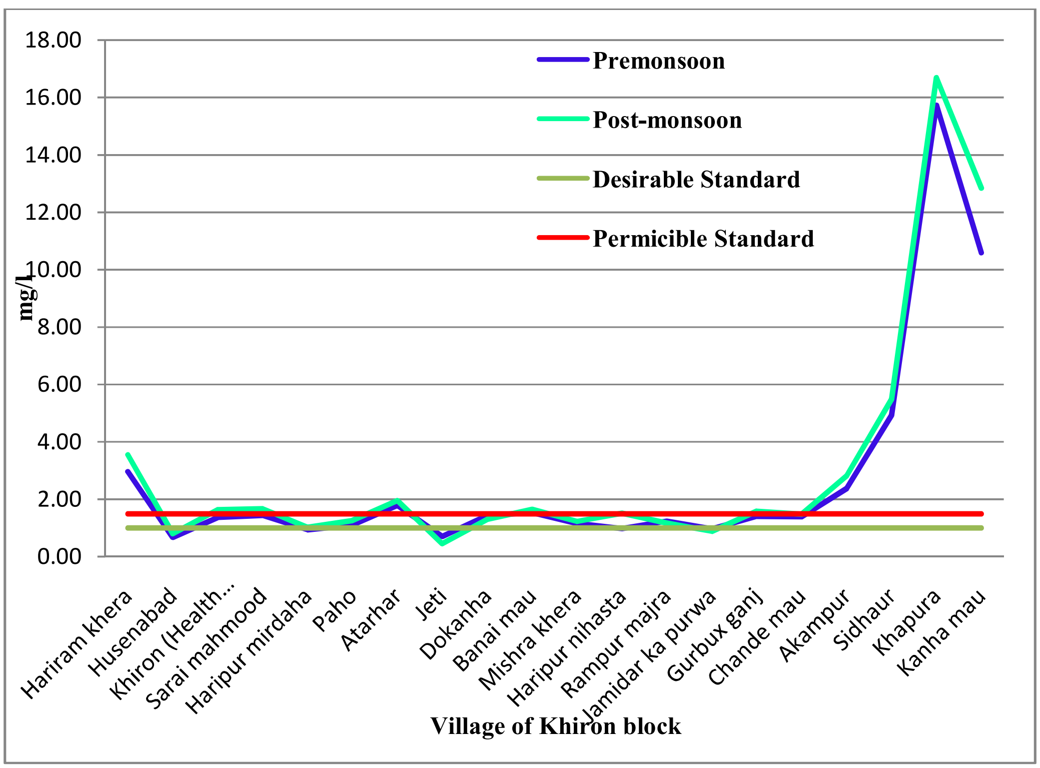


Figure 4.26: Spatio-temporal variation of F^- in Khiron block for the years of 2016-17

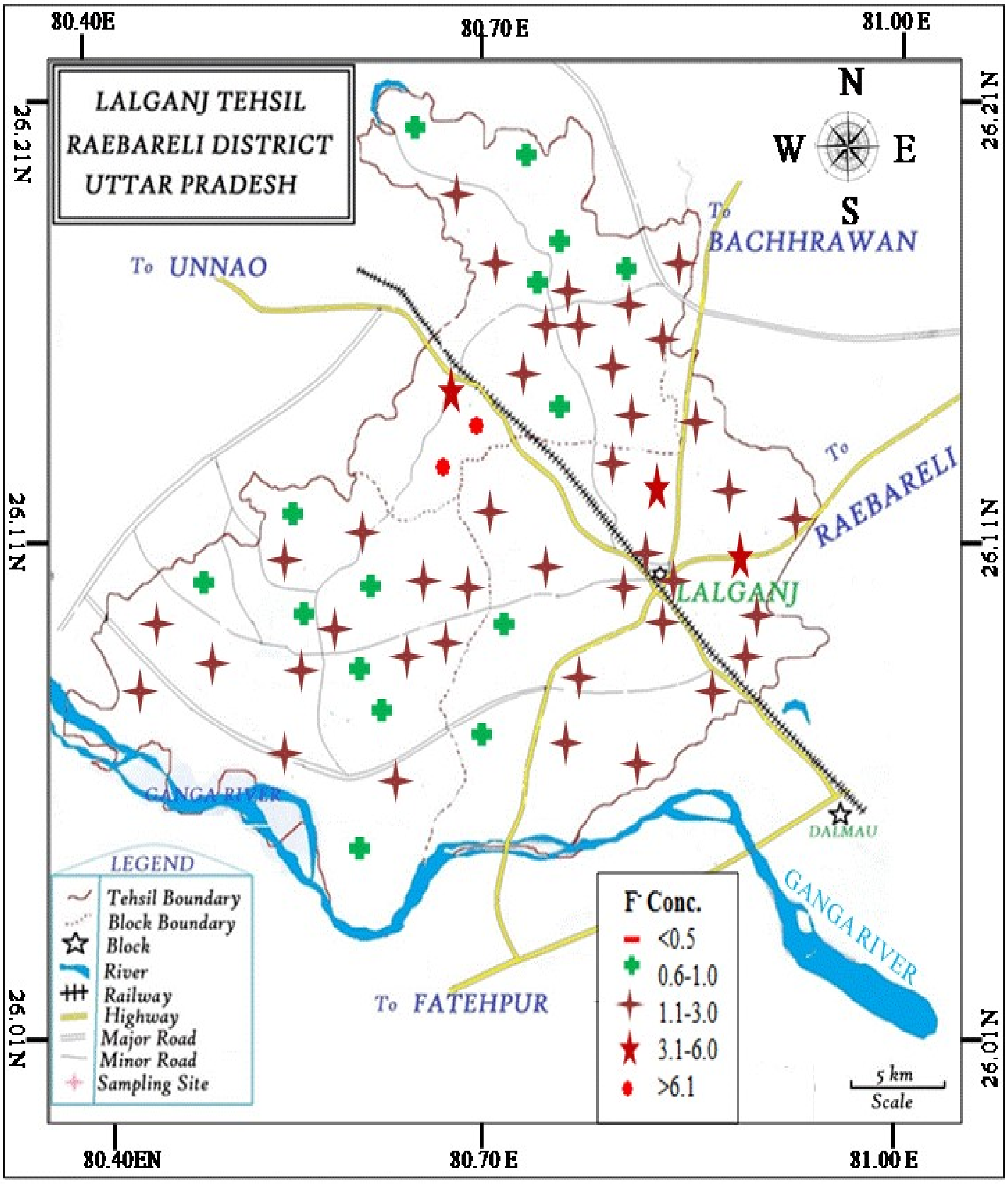


Figure 4.27 Spatial distribution of F^- in groundwater of Lalganj tehsil during pre-monsoon 2016

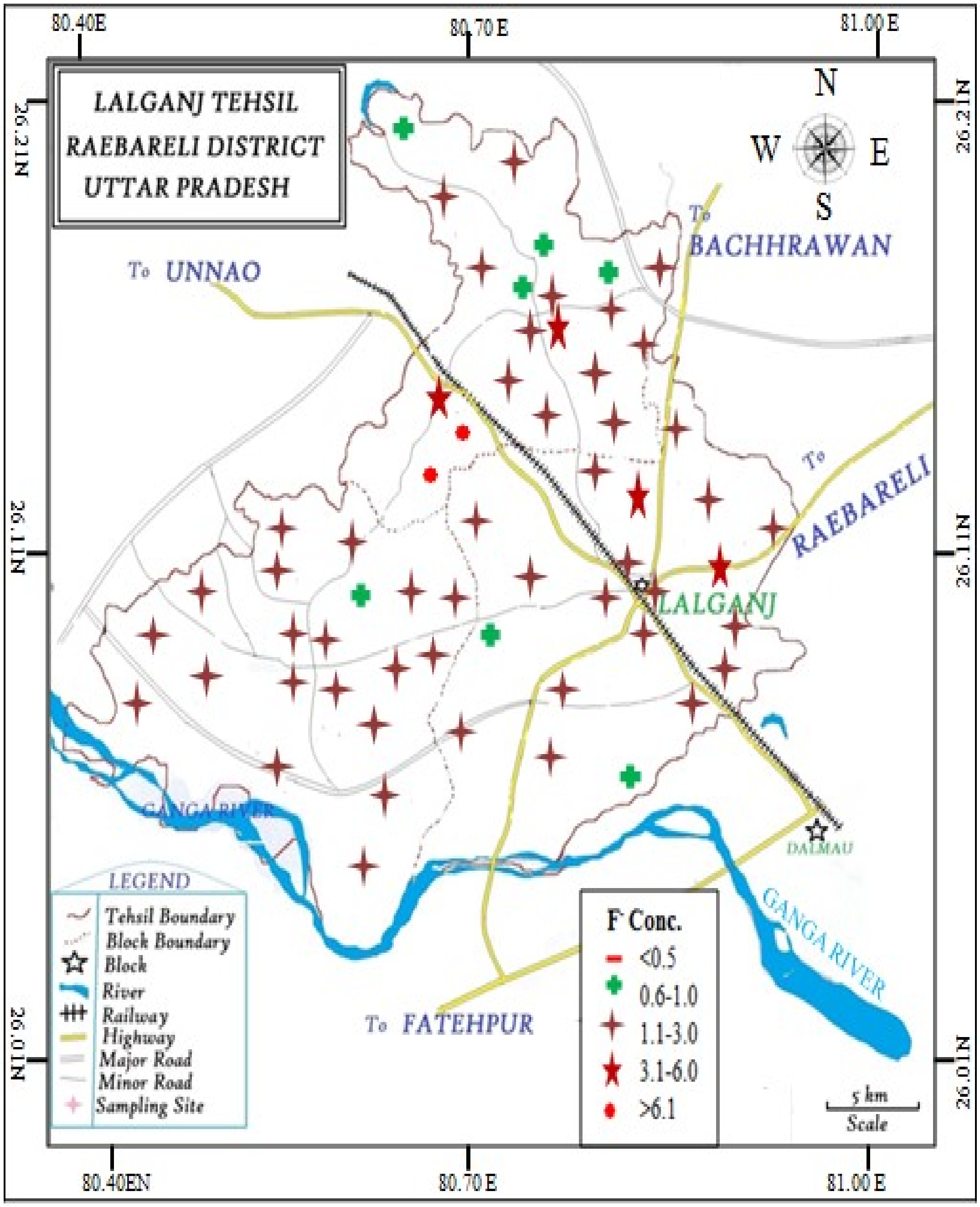


Figure 4.28: Spatial distribution of F^- in groundwater of Lalganj tehsil during post-monsoon 2016

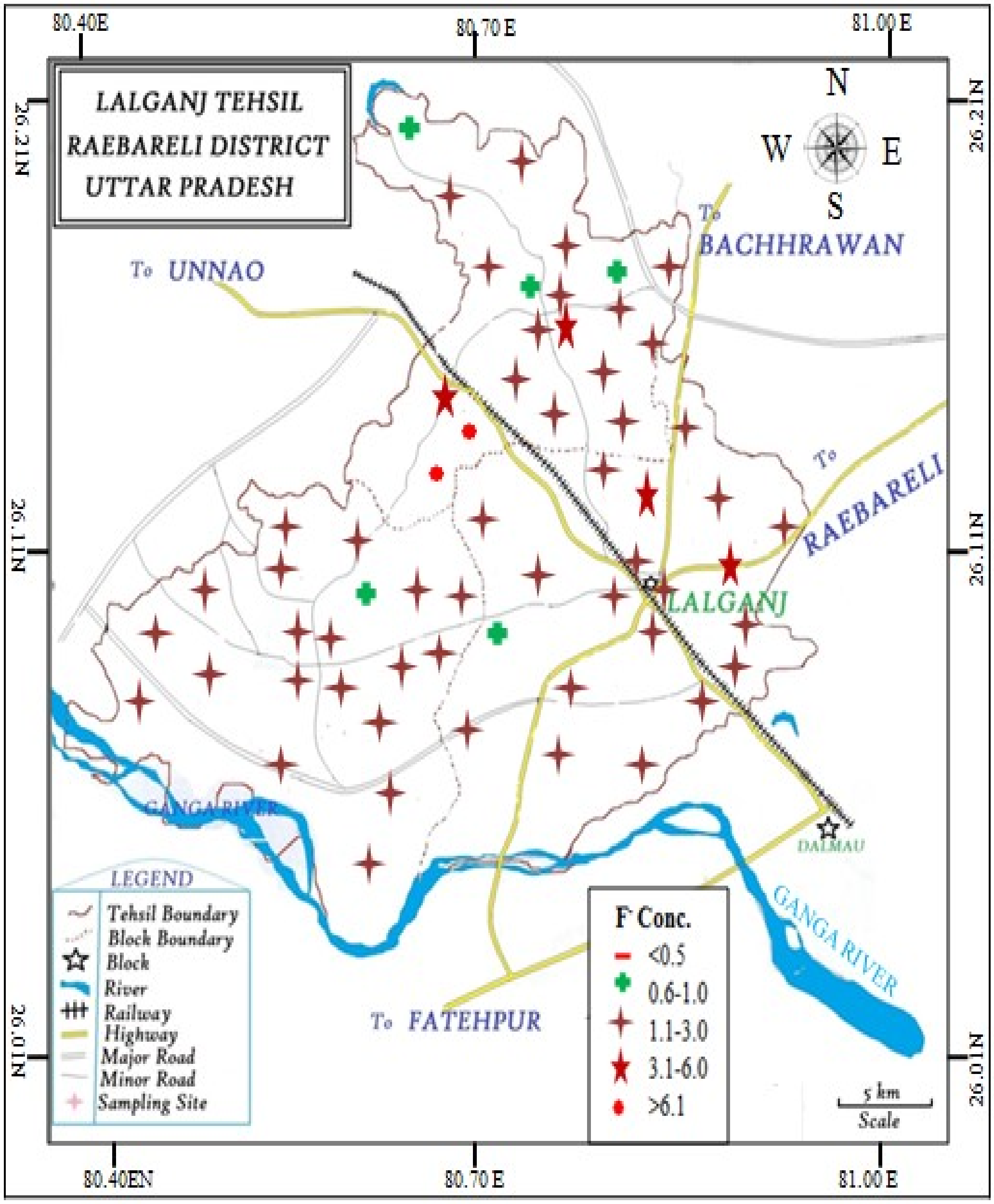


Figure 4.29:Spatial distribution of F^-in groundwater of Lalganj tehsil during pre-monsoon 2017

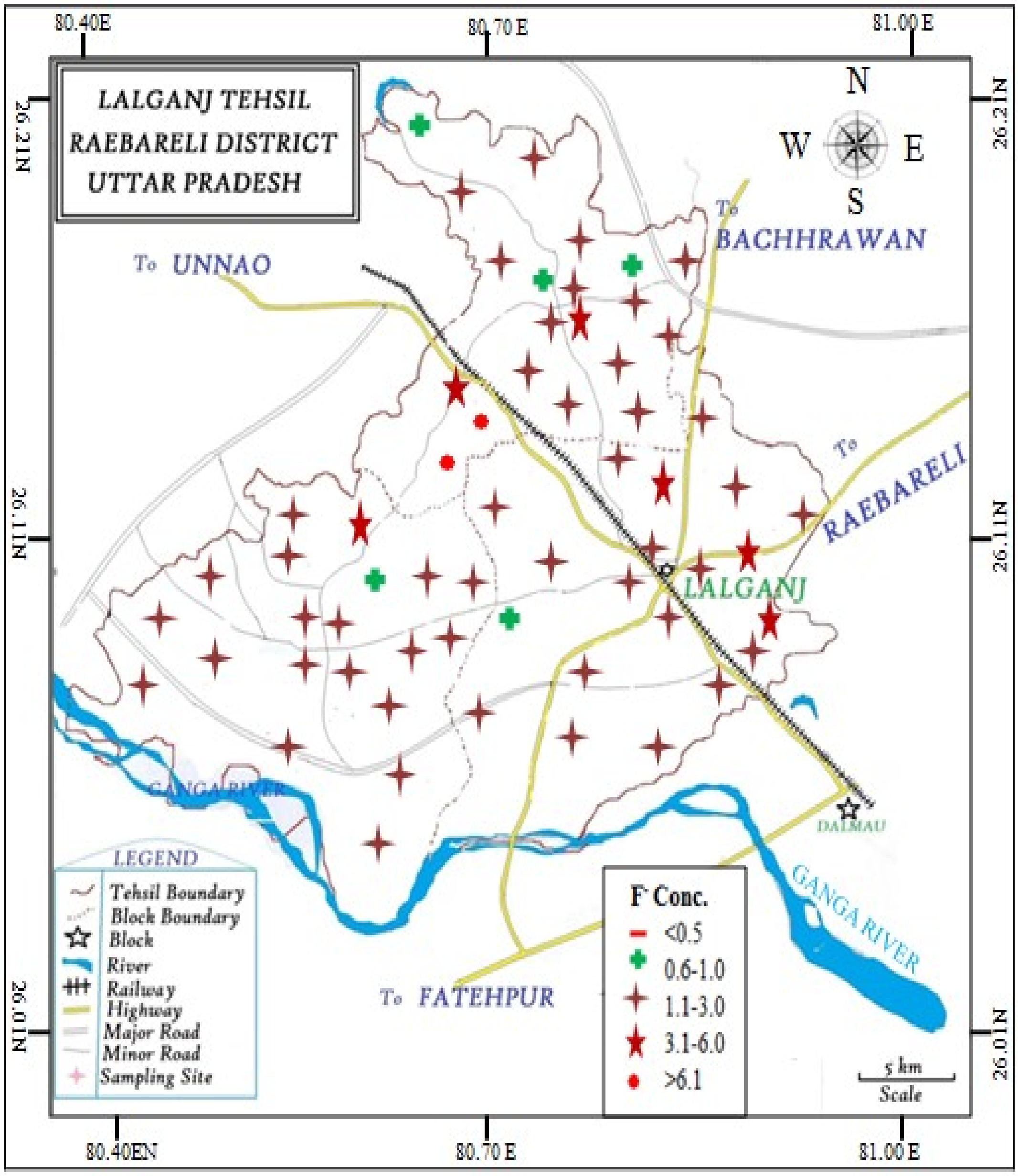
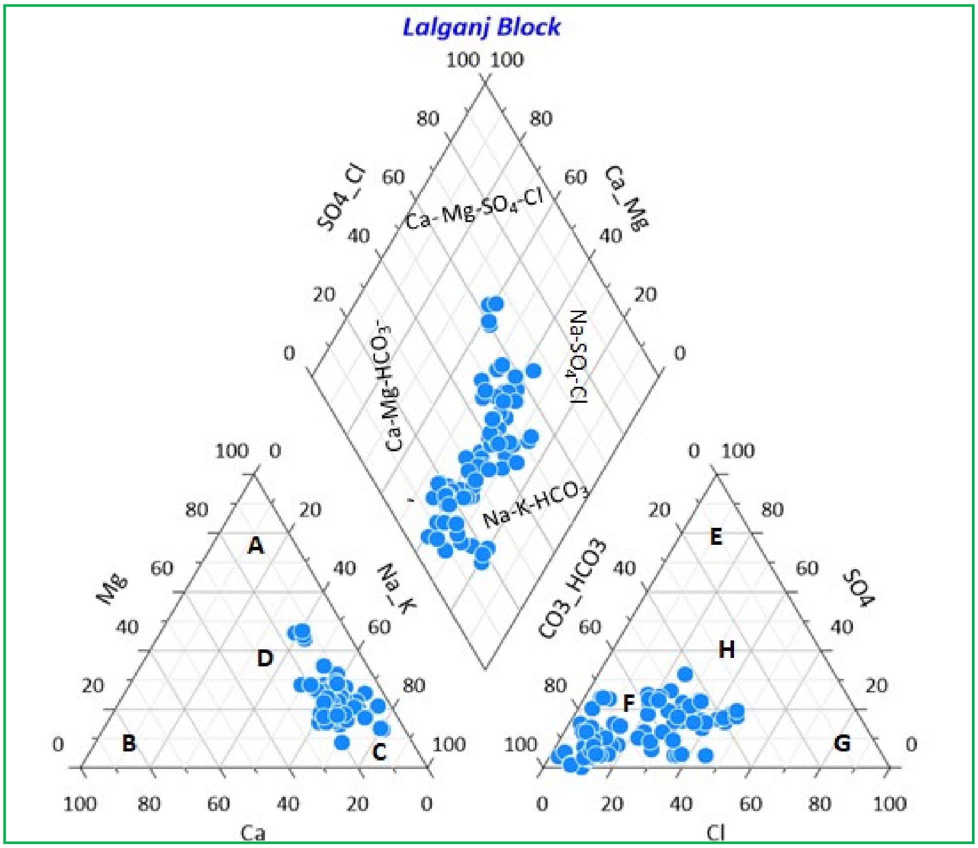


Figure 4.30: Spatial distribution of F⁻in groundwater of Lalganj tehsil during post-monsoon 2017

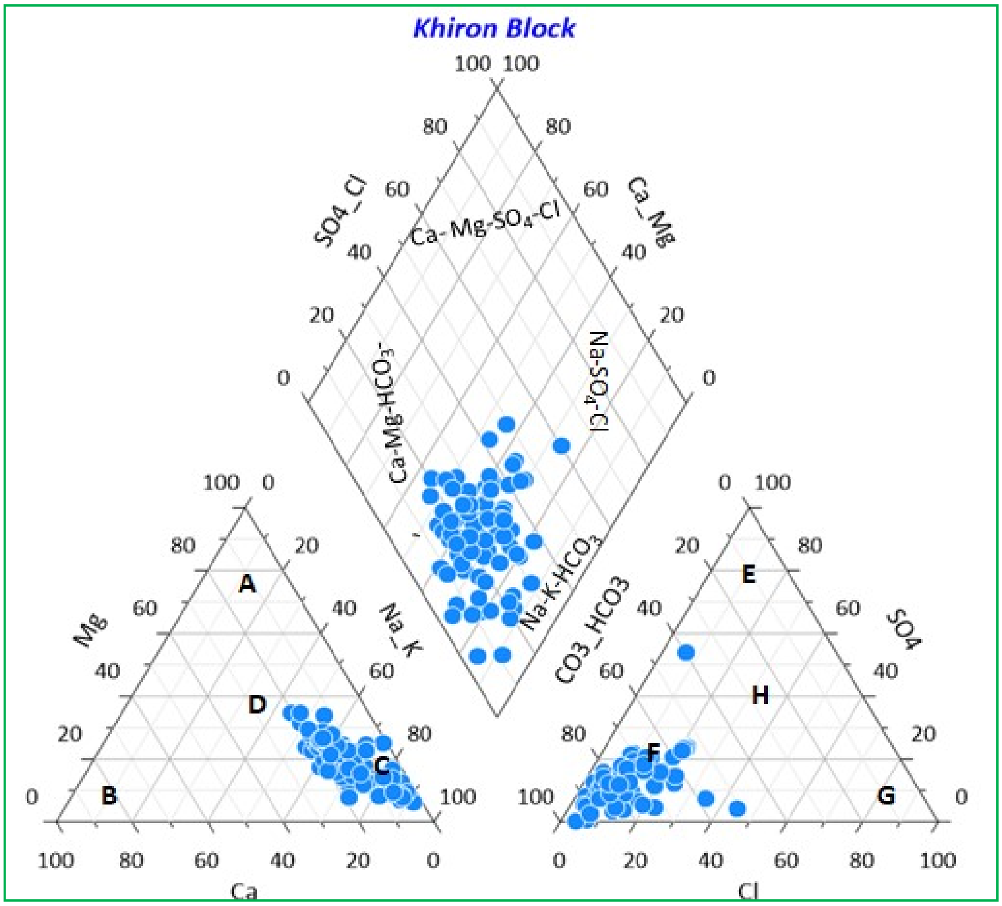


Cations **Anions**

A. Magnesium type **C.** Sodium type **E.** Sulphate type **G.** Chloride type

B. Calcium type **D.** No dominant type **F.** Bicarbonate type **H.** No dominant type

Figure 4.31: Piper trilinear diagram showing in for major ions in groundwater of the Lalganj block

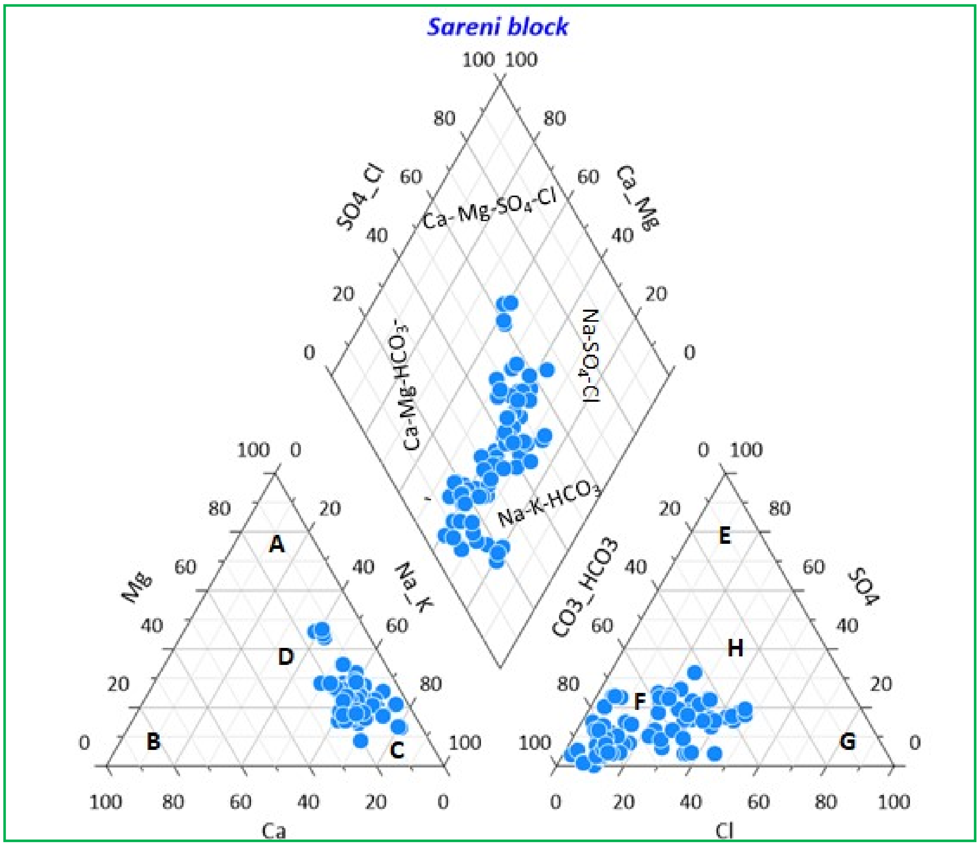


Cations **Anions**

A. Magnesium type **C.** Sodium type **E.** Sulphate type **G.** Chloride type

B. Calcium type **D.** No dominant type **F.** Bicarbonate type **H.** No dominant type

Figure 4.32: Piper trilinear diagram showing in for major ions in groundwater of the Khrion block

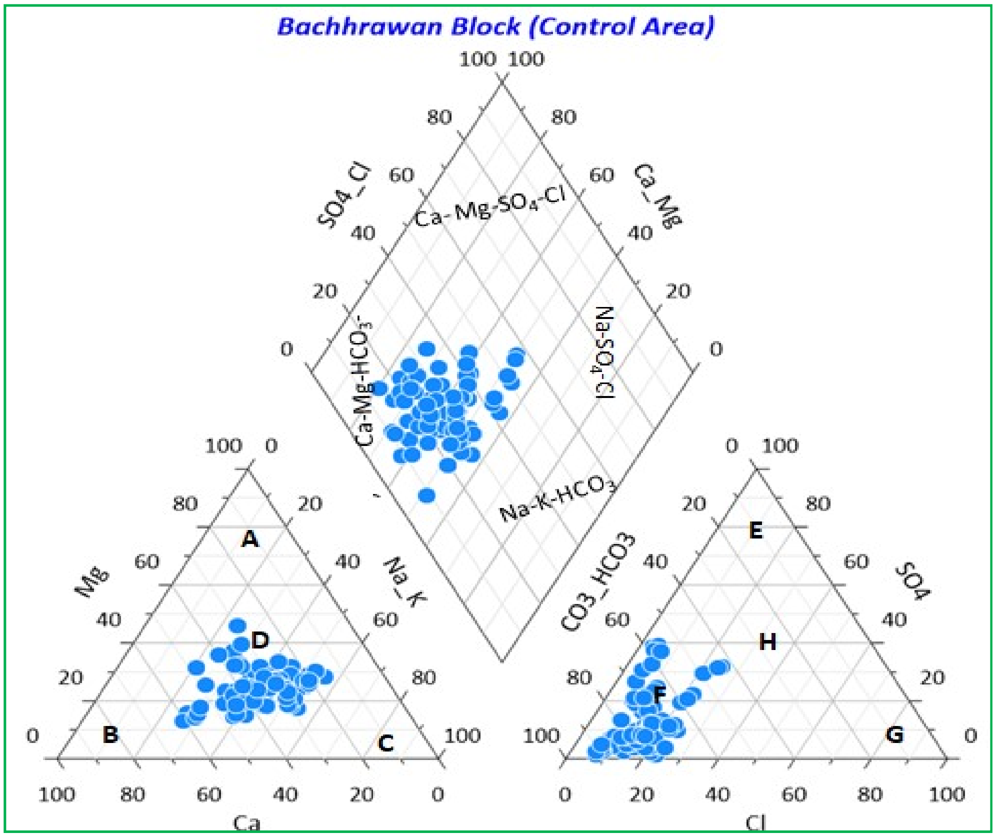


Cations **Anions**

A. Magnesium type **C.** Sodium type **E.** Sulphate type **G.** Chloride type

B. Calcium type **D.** No dominant type **F.** Bicarbonate type **H.** No dominant type

Figure 4.33: Types of groundwater in the Sareni block showing in Piper diagram



Cations **Anions**

A. Magnesium type **C.** Sodium type **E.** Sulphate type **G.** Chloride type

B. Calcium type **D.** No dominant type **F.** Bicarbonate type **H.** No dominant type

Figure 4.34: Types of groundwater in the Bachhrawan block showing in Piper diagram

4.3 Identification of groundwater type

Piper diagram performed for identification of groundwater type in the study area (Piper, 1944) and applied in analyzed cations and anions of 80 groundwater samples (20 samples X 2 seasons X 2 years) of Lalganj, Sareni Khiron and Control area during pre-monsoon and post-monsoon for 2016 and 2017. Ionic balance was computed according to (Huh et al., 1998) for precision ±5% in cation and anion analysis as 100*****(cations-anions)/(cations+anions).

4.4 Statistical analysis

4.4.1 Water quality index (WQI)

WQI value of groundwater for Lalganj tehsil during pre-monsoon and post-monsoon 2016 was given in **Table 4.25** and during pre-monsoon and post-monsoon 2017 in **Table 4.26**. Acoording to **Sahu and Shekher, 2008**. WQI was classified into five class were presented in **Table 4.27**. Lower rates of WQI conform that the water is free from pollutant or impurities and suitable for drinking purpose. The mean values of WQI calculated for Lalganj, Sareni and Khiron block were 64.45, 66.35 and 58.71 respectively. It was ranged from 44.37 to 111.76, 40.19 to 119.62, and 28.75 to 155.24 for Lalganj block, Sareni block and Khiron block during 2016. In 2017, the mean WQI values calculated for Lalganj, Sareni and Khiron block were 68.90, 71.23 and 65.62 respectively with ranged from 47.67 to 114.80 for Lalganj block, 46.58 to 124.66 for Sareni block and 35.71 to 157.44 for Khiron block. The average value was observed below 100 for all block, which shows that the status of water quality of the study area is good.

Spatio-temporal variation in WQI during pre-monsoon and post-monsoon are calculated during both years and presented in **Table 4.25** and **able 4.26** It is observed from the results that WQI mean value in pre-monsoon and post-monsoon was found 61.21 and 67.70 for Lalganj block, 62.92 and 69.77 for Sareni block, 53.68 and 63.73 in Khiron block during 2016. The maximum temporal variation found in Khiron block and minimum in Lalganj block.

Table 4.24 WQI value of groundwater for Lalganj tehsil during pre-monsoon and post-monsoon 2016.

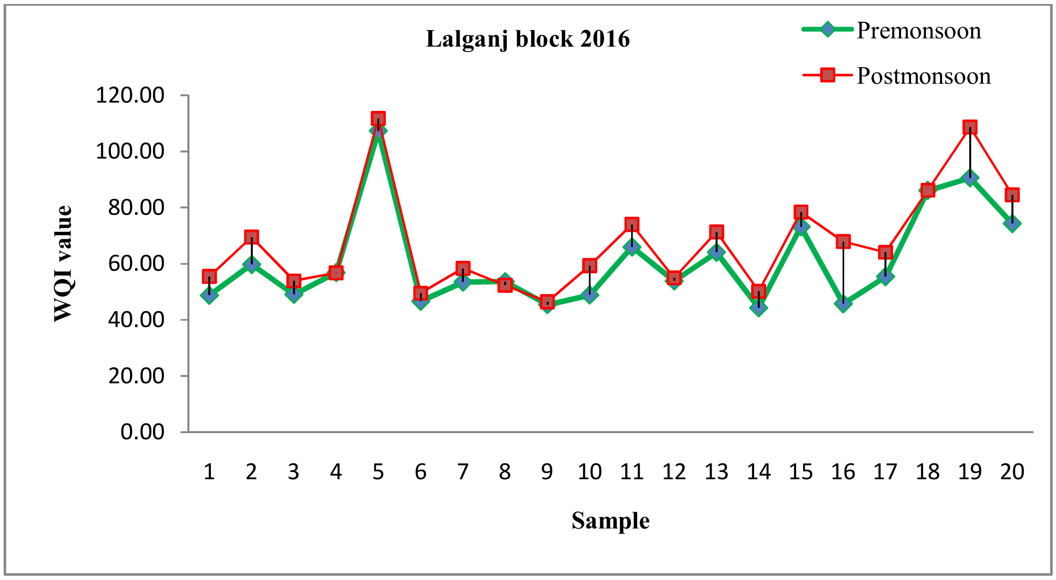
Premonsoon 2016						Postmonsoon 2016					
Sample ID	**Lalganj WQI**	**Sample ID**	**Sareni WQI**	**Sample ID**	**Khiron WQI**	**Sample ID**	**Lalganj WQI**	**Sample ID**	**Sareni WQI**	**Sample ID**	**Khiron WQI**
L1	48.77	L 21	55.15	L 41	44.34	L1	55.49	L 21	62.17	L 41	50.63
L2	59.78	L 22	61.96	L 42	39.42	L2	69.54	L 22	72.20	L 22	48.85
L3	49.12	L 23	50.13	L 43	56.28	L3	53.93	L 23	53.63	L 43	67.05
L 4	56.87	L 24	47.56	L 44	46.42	L 4	56.76	L 24	63.48	L 44	61.54
L 5	107.33	L 25	68.83	L 45	44.72	L 5	111.76	L 25	65.64	L 45	58.73
L 6	46.69	L 26	43.63	L 46	34.49	L 6	49.55	L 26	46.21	L 46	41.41
L 7	53.54	L 27	106.63	L 47	41.58	L 7	58.35	L 27	119.53	L 47	47.21
L 8	53.66	L 28	85.00	L 48	37.42	L 8	52.35	L 28	76.76	L 48	46.34
L 9	45.49	L 29	52.30	L 49	28.75	L 9	46.48	L 29	54.52	L 49	31.38
L 10	48.89	L 30	61.65	L 50	37.14	L 10	59.38	L 30	64.23	L 50	40.57
L 11	66.01	L 31	59.00	L 51	36.05	L 11	74.07	L 31	64.77	L 51	45.16
L 12	53.93	L 32	44.51	L 52	45.77	L 12	55.00	L 32	60.44	L 52	48.48
L 13	64.13	L 33	78.93	L 53	41.00	L 13	71.35	L 33	95.58	L 53	49.24
L 14	44.37	L 34	104.67	L 54	45.94	L 14	50.18	L 34	119.62	L 54	64.41
L 15	73.22	L 35	68.19	L 55	48.95	L 15	78.44	L 35	76.74	L 55	60.93
L 16	45.80	L 36	78.72	L 56	40.79	L 16	67.93	L 36	92.83	L 56	61.85
L 17	55.44	L 37	43.99	L 57	58.70	L 17	64.11	L 37	51.02	L 57	69.46
L 18	86.13	L 38	40.19	L 58	89.93	L 18	86.18	L 38	48.32	L 58	99.83
L 19	90.59	L 39	50.05	L 59	136.08	L 19	108.64	L 39	55.23	L 59	155.24
L 20	74.34	L 40	57.68	L 60	119.90	L 20	84.54	L 40	52.44	L 60	126.22
Mean	**61.21**	**Mean**	**62.94**	**Mean**	**53.68**	**Mean**	**67.70**	**Mean**	**69.77**	**Mean**	**63.73**
Min	**44.37**	**Min**	**40.19**	**Min**	**28.75**	**Min**	**46.48**	**Min**	**46.21**	**Min**	**31.38**
Max	**107.33**	**Max**	**106.63**	**Max**	**136.08**	**Max**	**111.76**	**Max**	**119.62**	**Max**	**155.24**

Table 4.25: WQI value of groundwater for Lalganj tehsil during pre-monsoon and post-monsoon 2017.

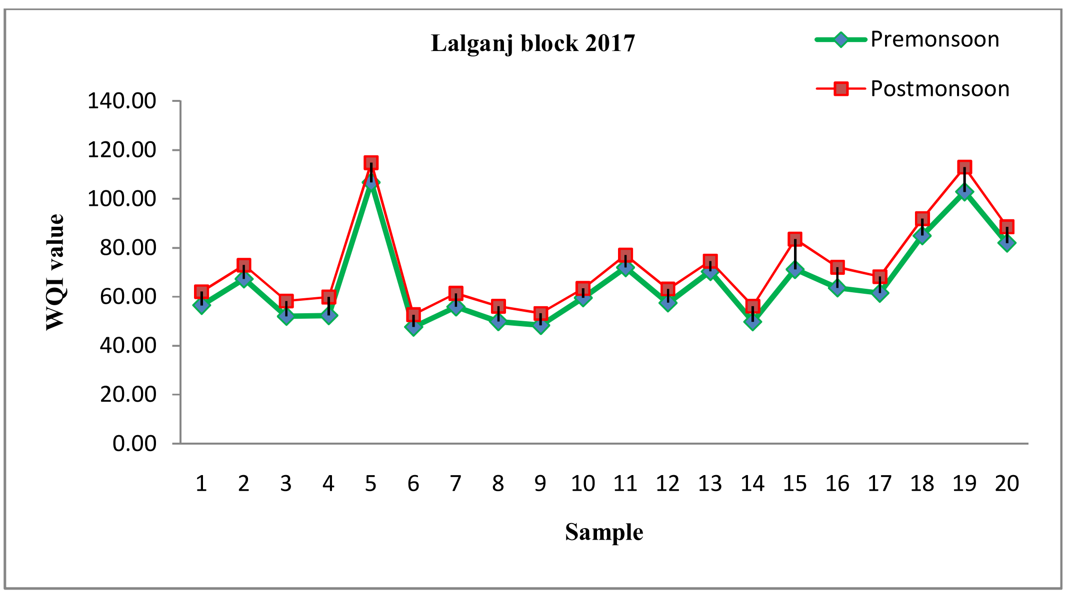
Premonsoon 2017						Postmonsoon 2017					
Sample ID	Lalganj WQI	Sample ID	Sareni WQI	Sample ID	Khiron WQI	Sample ID	Lalganj WQI	Sample ID	Sareni WQI	Sample ID	Khiron WQI
L1	56.53	L 21	60.87	L 41	52.03	L1	62.10	L 21	65.43	L 41	56.19
L2	67.35	L 22	70.24	L 42	49.05	L2	72.94	L 22	74.94	L 42	55.92
L3	52.04	L 23	53.23	L 43	65.62	L3	58.32	L 23	56.69	L 43	70.59
L 4	52.37	L 24	62.23	L 44	58.20	L 4	59.95	L 24	67.80	L 44	67.86
L 5	106.75	L 25	63.04	L 45	56.69	L 5	114.80	L 25	70.89	L 45	65.50
L 6	47.67	L 26	46.58	L 46	42.33	L 6	52.69	L 26	50.87	L 46	50.86
L 7	55.92	L 27	112.58	L 47	47.74	L 7	61.43	L 27	124.66	L 47	54.63
L 8	49.92	L 28	76.09	L 48	44.31	L 8	56.14	L 28	77.03	L 48	51.24
L 9	48.34	L 29	53.19	L 49	35.71	L 9	53.25	L 29	59.84	L 49	40.18
L 10	59.61	L 30	62.45	L 50	42.29	L 10	63.44	L 30	69.58	L 50	46.97
L 11	71.96	L 31	63.36	L 51	42.78	L 11	77.02	L 31	70.11	L 51	47.42
L 12	57.54	L 32	59.04	L 52	48.84	L 12	63.20	L 32	62.08	L 52	52.46
L 13	70.34	L 33	90.28	L 53	47.33	L 13	74.57	L 33	97.18	L 53	49.46
L 14	49.82	L 34	114.92	L 54	69.34	L 14	56.23	L 34	122.35	L 54	71.99
L 15	71.20	L 35	75.89	L 55	59.79	L 15	83.55	L 35	84.29	L 55	64.77
L 16	63.65	L 36	90.10	L 56	60.87	L 16	72.15	L 36	96.72	L 56	67.48
L 17	61.51	L 37	50.52	L 57	66.41	L 17	68.27	L 37	63.44	L 57	73.61
L 18	84.97	L 38	47.54	L 58	95.93	L 18	91.90	L 38	55.91	L 58	102.53
L 19	102.86	L 39	52.31	L 59	146.11	L 19	113.01	L 39	56.47	L 59	157.44
L 20	81.98	L 40	51.68	L 60	115.10	L 20	88.56	L 40	66.93	L 60	131.44
Mean	65.62	Mean	67.81	Mean	62.32	Mean	72.18	Mean	74.66	Mean	68.93
Min	47.67	Min	46.58	Min	35.71	Min	52.69	Min	50.87	Min	40.18
Max	106.75	Max	114.92	Max	146.11	Max	114.80	Max	124.66	Max	157.44

Table 4.26: Classification of groundwater quality of the Lalganj tehsil based on WQI (Sahu and Sikdar 2008).

Rating of WQI	Water Quality Status	Number of Sampling Location					
		2016			2017		
		Lalganj	Sareni	Khiron	Lalganj	Sareni	Khiron
≤50	Excellent	9	7	24	4	2	13
50–100	Good	28	30	12	32	34	22
100–200	Poor	3	3	4	4	4	5
200–300	Very poor	-	-	-	-	-	-
>300	Unsuitable for drinking	-	-	-	-	-	-

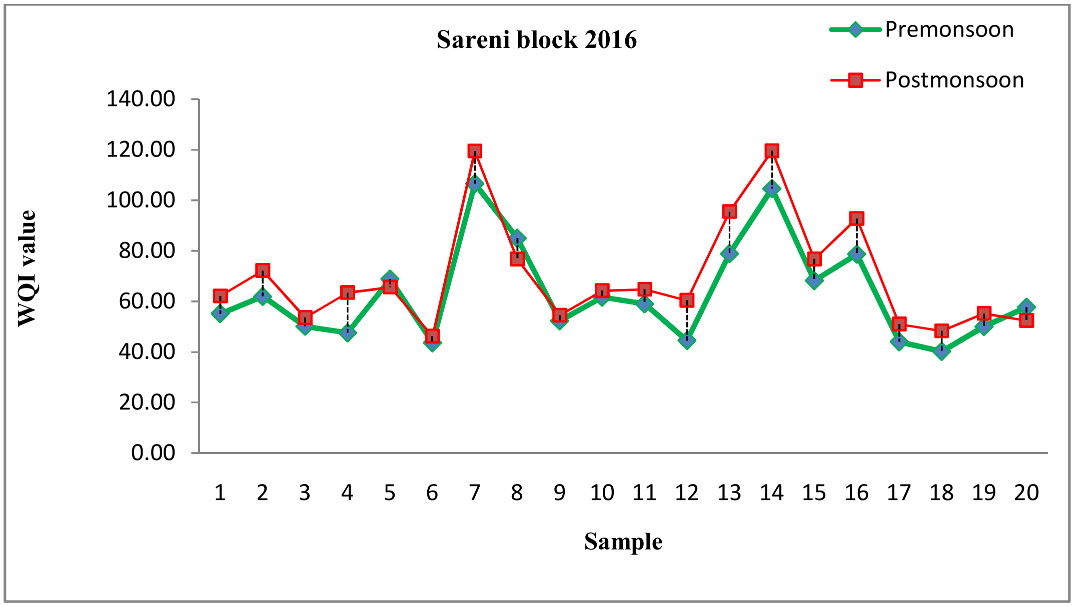


(I)



(II)

Figure 4.35: Temporal variation in WQI value in groundwater of Lalganj block (I and II)



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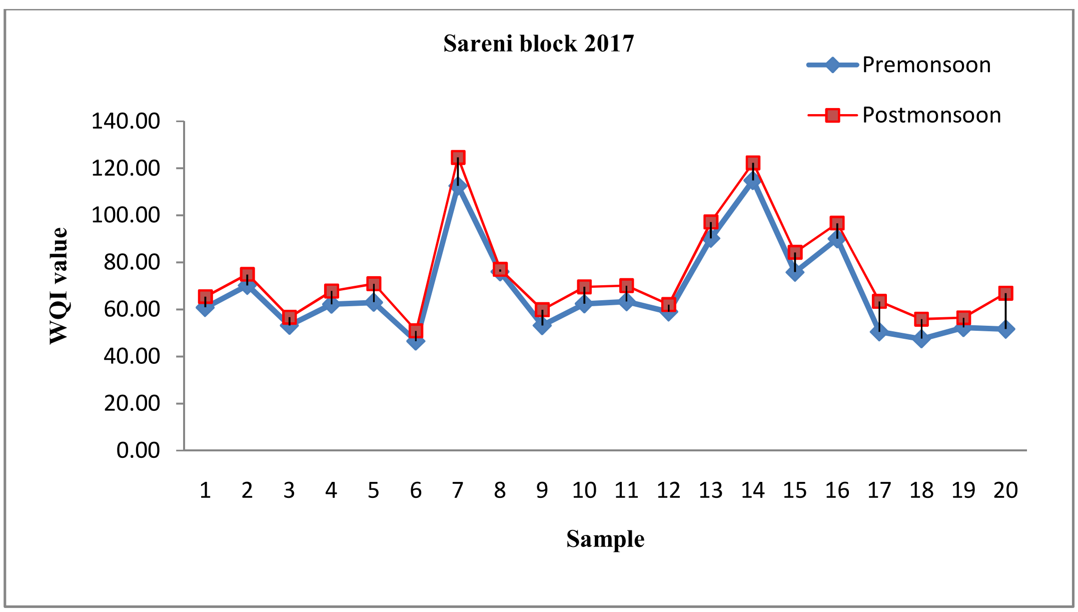
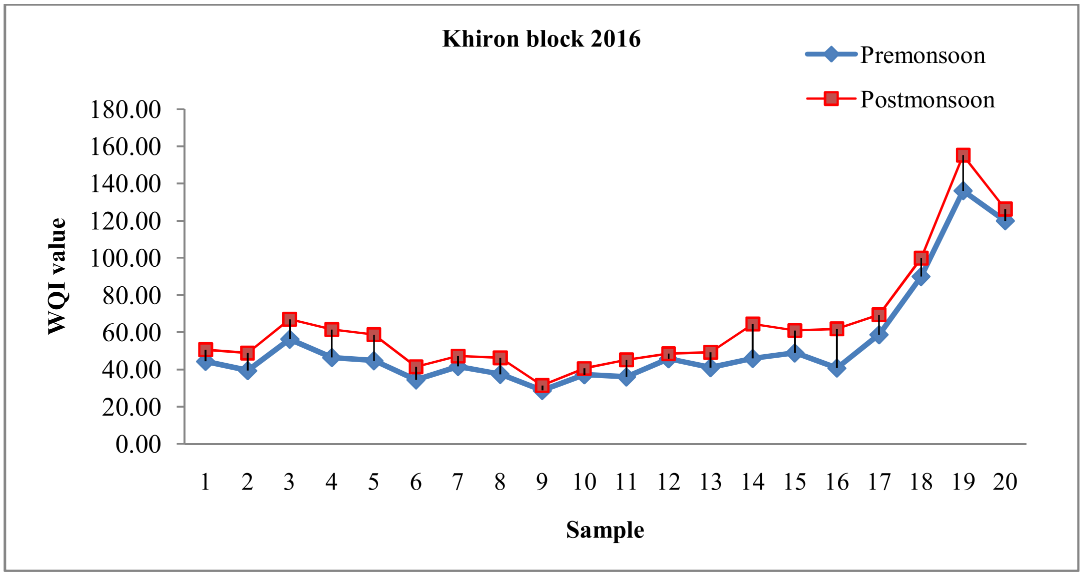
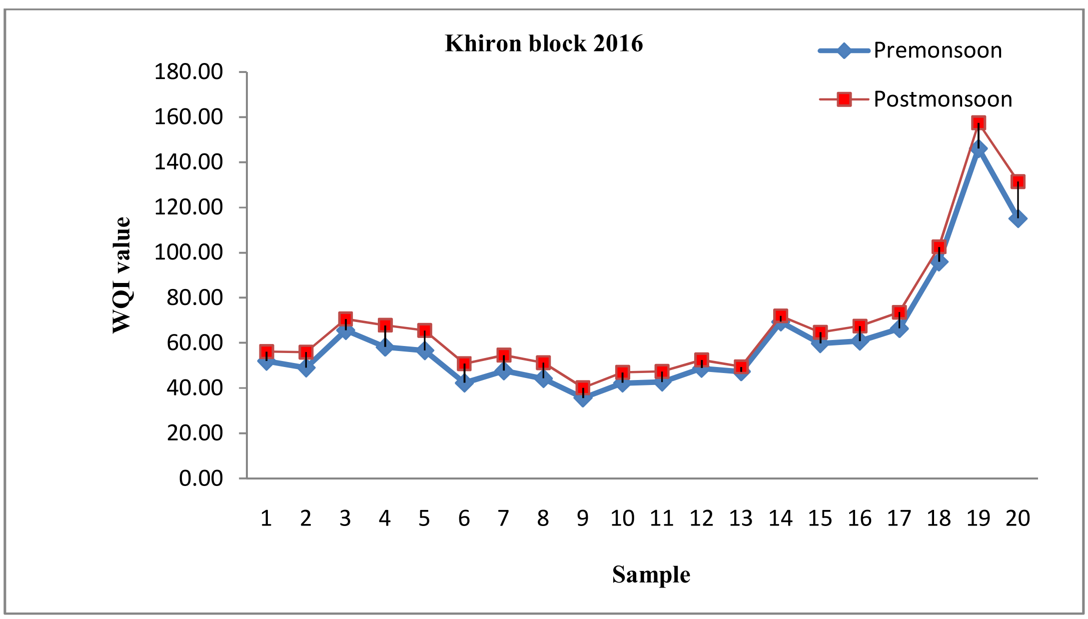


(II)

Figure 4.36: Temporal variation in WQI value in groundwater of Sareni block (I and II)



(I)



(II)

Figure 4.37: Temporal variation in WQI value in groundwater of Khiron block (I and II)

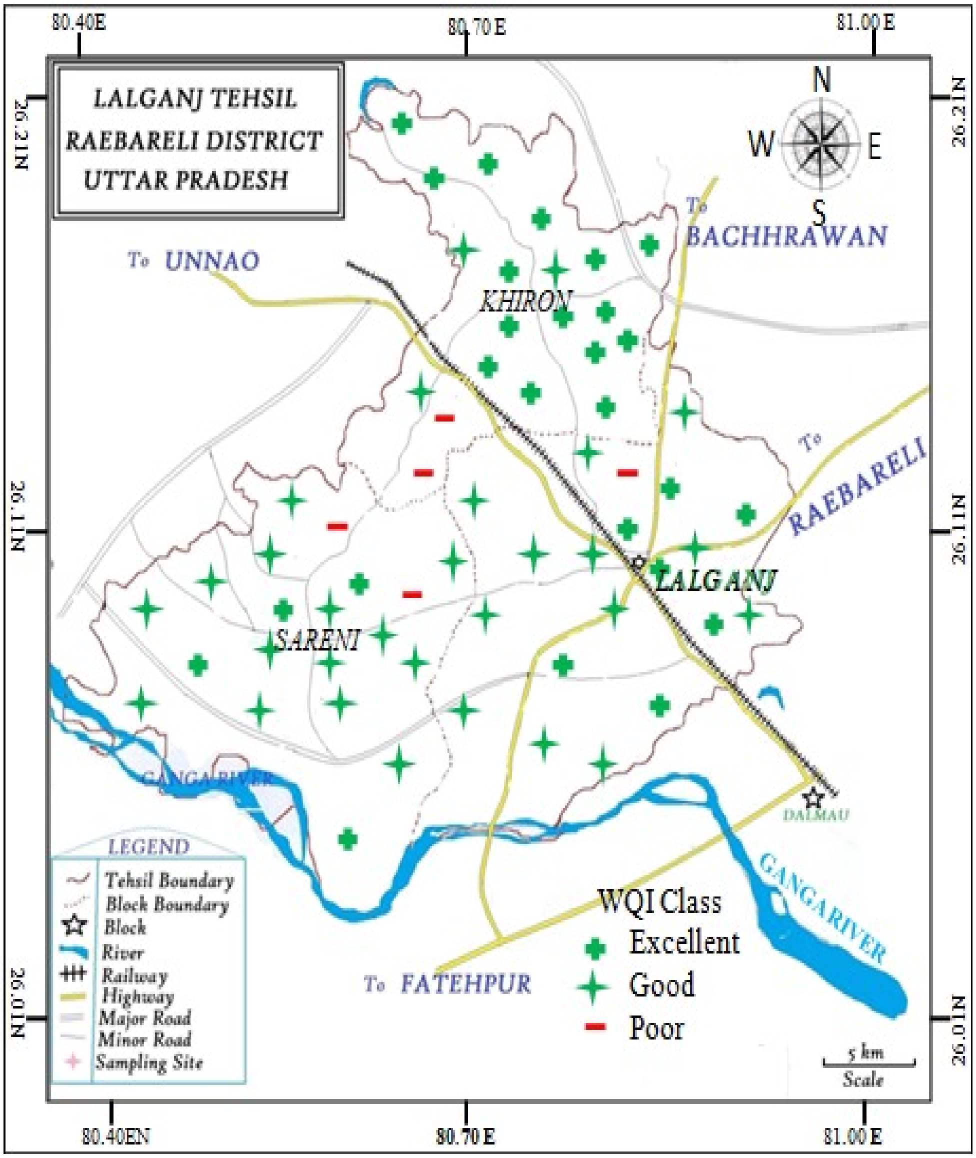


Figure 4.38: Spatial variation in WQI value in Lalganj tehsil during pre-monsoon 2016

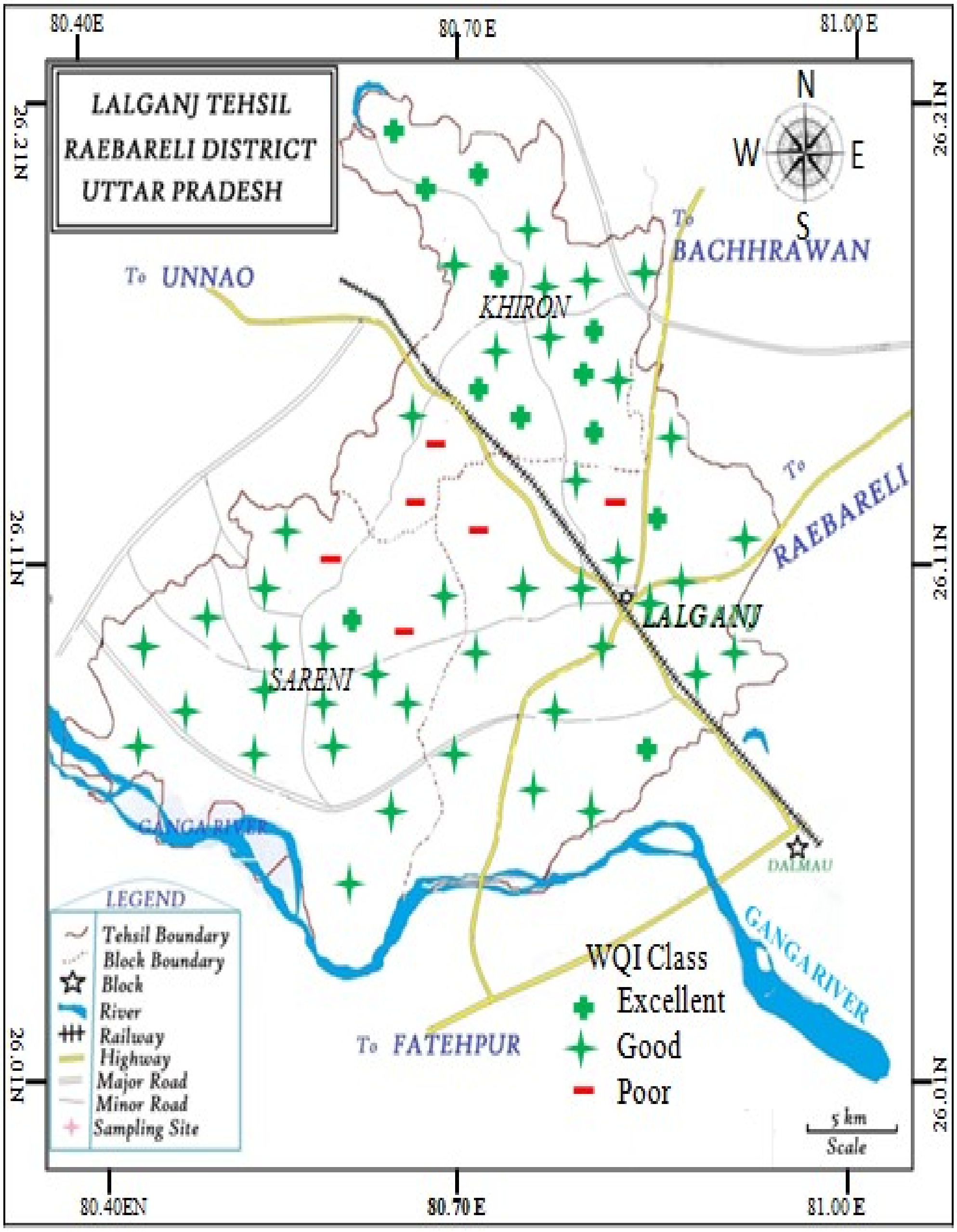


Figure 4.39: Spatial variation in WQI value in Lalganj tehsil during post-monsoon 2016

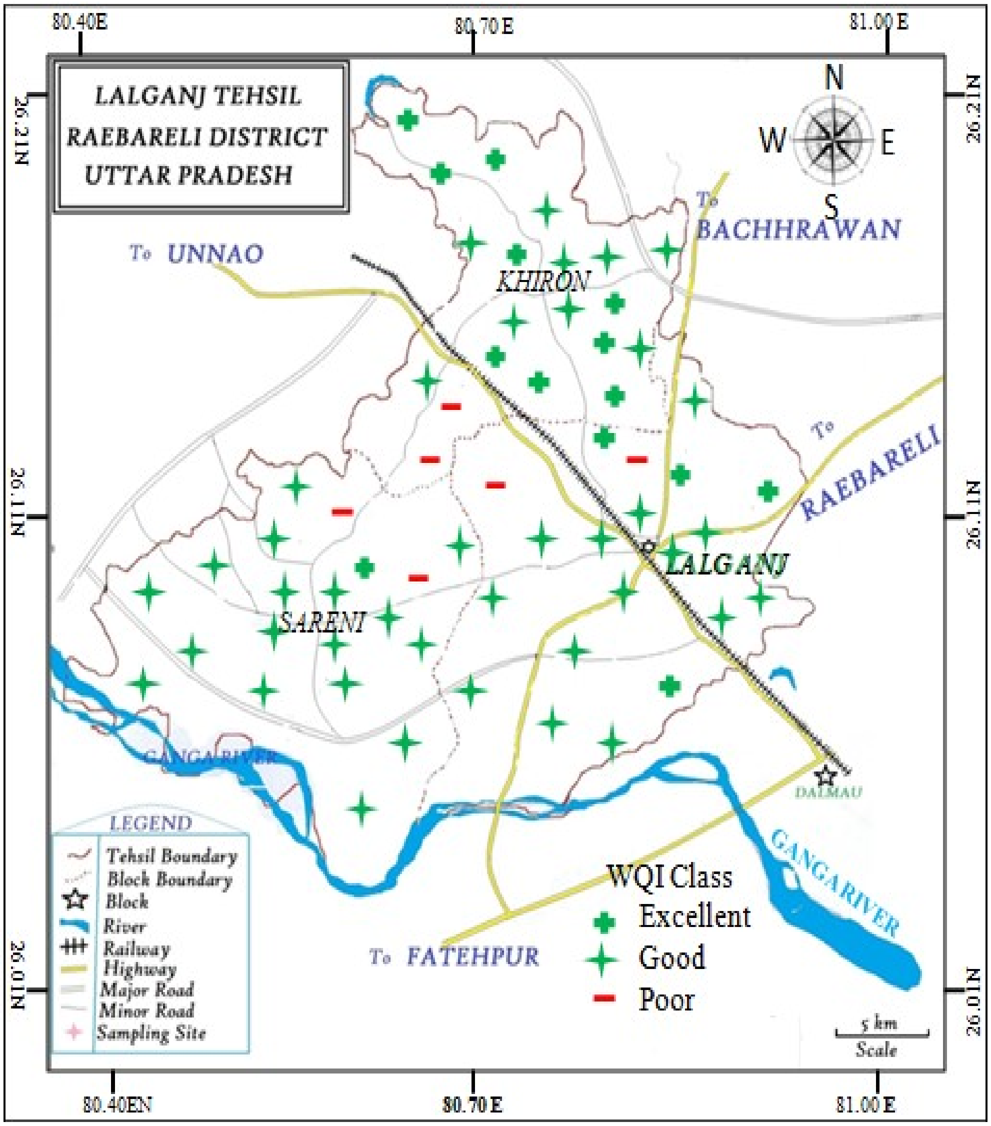


Figure 4.40: spatial variation in WQI value in Lalganj tehsil during pre-monsoon 2016

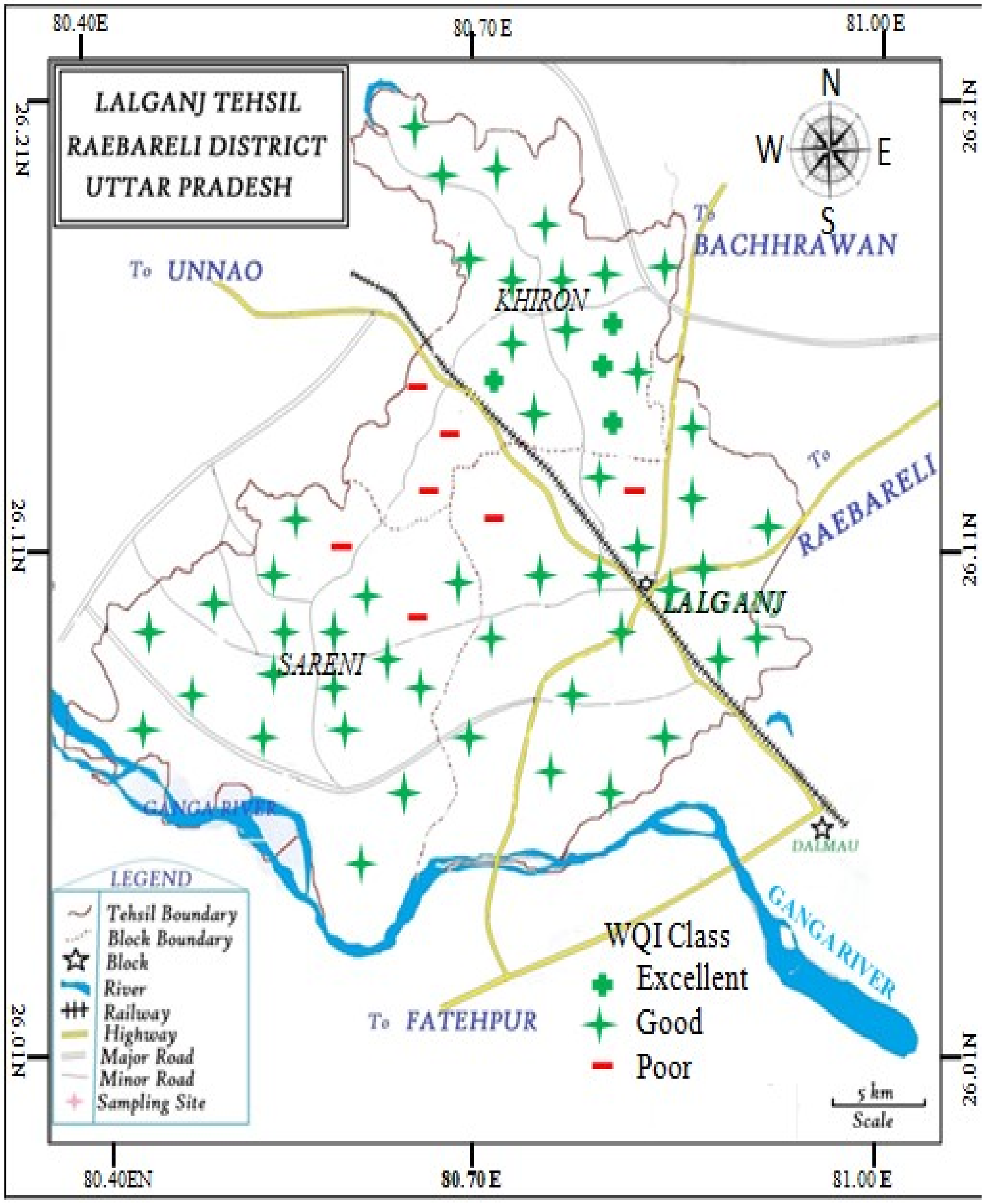


Figure 4.41: Spatial variation in WQI value in Lalganj tehsil during post-monsoon 2017

4.4.2 Heavy metal pollution assessment index

The mean concentration of metals (Zn, Fe, Ni, Mn, Pb, Cu, Cr, and Cd,) has been taken for HPI calculation and description of HPI are shown in **Table** 6 and Figure 4.4.1. The mean values of HPI for the groundwater samples during pre-monsoon 2016 for Lalganj, Sareni and Khiron block range from 0.24 to 16. 66, 0.24 to 25.22 and 0.10 to 21.66 respectively and during post-monsoon 2016, it ranged from 0.42 to 16. 37, 0.43 to 23.31 and 0.49 to 22.20 respectively. HPI value ranged from 0.76 to 18.33 with mean value 6.56, 0.45 to 23.79 with mean value 7.90 and 1.10 to 22.14 with mean value 8.02 during pre-monsoon 2017 and in post-monsoon 2017, value ranged from 1.09 to 18.89 with mean value 6.97, 0.56 to 23.83 with mean value 8.10, and 1.59 to 21.02 with mean value 8.34 for Lalganj, Sareni and Khiron block respectively.

Table 4.27: HPI calculation for groundwater of Lalganj, pre and post monsoon 2016.

Metals	Si	Ii	Wi	Pre-monsoon 2016			Post-monsoon 2016		
				Mi	Qi	Wi*Qi	Mi	Qi	Wi*Qi
Zn	15000	5000	0.00006	62.02	-49.38	-0.003	58.41	-49.42	-0.003
Fe	1000	300	0.001	255.91	-6.30	-0.006	249.38	-7.23	-0.007
Ni	20	0	0.02	5.35	26.74	0.535	6.17	30.87	0.617
Mn	300	100	0.0033	13.06	-43.47	-0.143	15.17	-42.42	-0.140
Pb	50	0	0.02	2.91	5.82	0.116	2.60	5.19	0.104
Cu	1500	50	0.0006	4.57	-3.13	-0.002	4.02	-3.17	-0.002
Cr	50	0	0.02	0.47	0.94	0.019	0.39	0.79	0.016
Cd	10	0	0.1	0.41	4.10	0.410	0.36	3.58	0.358

Table 4.28: HPI calculation for groundwater of Sareni block during pre and post monsoon 2016.

Metals	Si	Ii	Wi	Pre-monsoon 2016			Post-monsoon 2016		
				Mi	Qi	Wi*Qi	Mi	Qi	Wi*Qi
Zn	15000	5000	0.00006	142.82	-48.57	-0.003	139.07	-48.61	-0.003
Fe	1000	300	0.001	399.92	14.27	0.014	394.11	13.44	0.013
Ni	20	0	0.02	6.74	33.69	0.674	7.93	39.67	0.793
Mn	300	100	0.0033	20.14	-39.93	-0.132	22.60	-38.70	-0.128
Pb	50	0	0.02	3.94	7.88	0.158	3.39	6.77	0.135
Cu	1500	50	0.0006	3.15	-3.23	-0.002	2.95	-3.24	-0.002
Cr	50	0	0.02	0.66	1.32	0.026	0.58	1.15	0.023
Cd	10	0	0.1	0.51	5.09	0.509	0.44	4.45	0.445

Table 4.29: HPI calculation for groundwater of Khiron block during pre and post monsoon 2016.

Metals	Si	Ii	Wi	Pre-monsoon 2016			Post-monsoon 2016		
				Mi	Qi	Wi*Qi	Mi	Qi	Wi*Qi
Zn	15000	5000	0.00006	78.39	-49.22	-0.003	75.13	-49.25	-0.003
Fe	1000	300	0.001	189.98	-15.72	-0.016	183.46	-16.65	-0.017
Ni	20	0	0.02	5.40	26.98	0.540	6.51	32.55	0.651
Mn	300	100	0.0033	33.40	-33.30	-0.110	37.94	-31.03	-0.102
Pb	50	0	0.02	5.69	11.38	0.228	5.29	10.59	0.212
Cu	1500	50	0.0006	4.08	-3.17	-0.002	3.51	-3.21	-0.002
Cr	50	0	0.02	0.54	1.07	0.021	0.50	1.00	0.020
Cd	10	0	0.1	0.46	4.61	0.461	0.46	4.61	0.461

Table 4.30: HPI calculation for groundwater of Lalganj, pre and post monsoon 2017.

Metals	Si	Ii	Wi	Pre-monsoon 2017			Post-monsoon 2017		
				Mi	Qi	Wi*Qi	Mi	Qi	Wi*Qi
Zn	15000	5000	0.00006	61.162	-49.39	-0.003	52.425	-49.48	-0.003
Fe	1000	300	0.001	243.75	-8.04	-0.008	194.06	-15.13	-0.015
Ni	20	0	0.02	7.3817	36.91	0.738	8.536	42.68	0.854
Mn	300	100	0.0033	14.8	-42.60	-0.141	16.068	-41.97	-0.138
Pb	50	0	0.02	2.672	5.34	0.107	2.385	4.77	0.095
Cu	1500	50	0.0006	4.315	-3.15	-0.002	3.81	-3.19	-0.002
Cr	50	0	0.02	0.445	0.89	0.018	0.389	0.78	0.016
Cd	10	0	0.1	0.3735	3.74	0.374	52.425	-49.48	-0.003

Table 4.31: HPI calculation for groundwater of Sareni block during pre and post monsoon 2017.

Metals	Si	Ii	Wi	Pre-monsoon 2016			Post-monsoon 2016		
				Mi	Qi	Wi*Qi	Mi	Qi	Wi*Qi
Zn	15000	5000	0.00006	140.185	-48.60	-0.003	110.685	-48.89	-0.003
Fe	1000	300	0.001	397.675	13.95	0.014	350.545	7.22	0.007
Ni	20	0	0.02	8.5205	42.60	0.852	9.812	49.06	0.981
Mn	300	100	0.0033	22.6065	-38.70	-0.128	24.115	-37.94	-0.125
Pb	50	0	0.02	3.4645	6.93	0.139	2.7755	5.55	0.111
Cu	1500	50	0.0006	4.3565	-3.15	-0.002	3.8485	-3.18	-0.002
Cr	50	0	0.02	0.6065	1.21	0.024	0.536	1.07	0.021
Cd	10	0	0.1	0.452	4.52	0.452	110.685	-48.89	-0.003

Table 4.32: HPI calculation for groundwater of Khiron block during pre and post monsoon 2017.

Metals	Si	Ii	Wi	Pre-monsoon 2016			Post-monsoon 2016		
				Mi	Qi	Wi*Qi	Mi	Qi	Wi*Qi
Zn	15000	5000	0.00006	75.73	-49.24	-0.003	59.915	-49.40	-0.003
Fe	1000	300	0.001	181.66	-16.91	-0.017	153.285	-20.96	-0.021
Ni	20	0	0.02	7.495	37.48	0.750	8.875	44.38	0.888
Mn	300	100	0.0033	37.872	-31.06	-0.103	38.975	-30.51	-0.101
Pb	50	0	0.02	5.626	11.25	0.225	4.8665	9.73	0.195
Cu	1500	50	0.0006	3.64	-3.20	-0.002	3.0115	-3.24	-0.002
Cr	50	0	0.02	0.53	1.06	0.021	0.4855	0.97	0.019
Cd	10	0	0.1	0.451	4.51	0.451	59.915	-49.40	-0.003

Table 4.33: HPI Value for groundwater of Lalganj, block during pre and post monsoon 2016 and 2017.

Sample ID	Village	2016		2017	
		Pre-monsoon	Post-monsoon	Pre-monsoon	Post-monsoon
L1	Alampur	7.63	7.16	8.99	8.56
L2	Suddan khera	0.61	0.79	0.85	1.09
L3	Police station Lalganj	5.51	5.73	6.48	7.15
L 4	Datuli Lalganj	4.00	4.45	5.28	6.20
L 5	Lalganj tehsil	7.35	6.25	6.72	6.99
L 6	Banna mau	2.51	2.97	3.57	3.97
L 7	Huseni	1.23	1.58	2.48	2.75
L 8	Ekauni	9.56	9.18	10.27	9.98
L 9	Bahai	1.39	1.72	2.46	2.65
L 10	Semher paha	0.24	0.42	0.76	1.18
L 11	Lalamau	3.14	2.99	3.56	4.07
L 12	Chilaula	16.66	16.17	16.38	16.17
L 13	Aihar	8.17	7.99	8.88	9.09
L 14	Baras	1.14	1.87	3.71	4.69
L 15	Bhawani pur	1.75	2.31	2.76	3.38
L 16	Lodipur utrauwa	3.33	4.15	3.60	4.15
L 17	Dhannipur	9.21	9.26	9.44	9.42
L 18	Pure bhawani	16.03	16.37	15.42	16.31
L 19	Bahara	10.22	11.65	18.33	18.89
L 20	Udwa mau	5.72	4.73	6.31	7.48
Mean		5.61	5.72	6.56	6.97
Min		0.24	0.42	0.76	1.09
Max		16.66	16.37	18.33	18.89

Table 4.34: HPI Value for groundwater of Sareni block during pre and post monsoon 2016 and 2017.

Sample ID	Village	2016		2017	
		Pre-monsoon	Post-monsoon	Pre-monsoon	Post-monsoon
L 21	Sareni police station	5.11	5.86	6.47	6.43
L 22	Lakhanapur	0.41	0.43	0.45	0.56
L 23	Sareni ganw	4.29	4.71	5.35	5.60
L 24	Ghure mau	4.10	4.07	4.59	5.34
L 25	Ram khera	8.68	8.27	9.25	9.56
L 26	Madai khera	1.68	2.47	3.03	4.12
L 27	Sabji barua	20.05	23.31	23.79	23.83
L 28	Jalalpur	25.22	21.85	21.80	20.28
L 29	Jhampur	7.38	7.01	7.43	6.41
L 30	Madan ganw	3.97	4.80	5.15	5.69
L 31	Poore chheetu	0.24	0.94	1.55	2.75
L 32	Bhupganj	1.95	2.15	2.83	3.25
L 33	Dhagaicha	6.81	6.54	6.89	6.97
L 34	Hasanapur	14.48	13.13	14.15	13.00
L 35	Sareni khurmi	2.33	2.49	3.09	2.80
L 36	Champtpur manakhera	12.39	11.74	10.40	11.41
L 37	Rampur khurd	11.40	14.45	13.81	14.69
L 38	Rasoolpur	1.25	1.80	2.36	3.26
L 39	Bhojpur	4.55	4.97	5.06	6.20
L 40	Samodha	7.35	7.38	7.93	7.64
Mean		7.31	7.48	7.90	8.10
Min		0.24	0.43	0.45	0.56
Max		25.22	23.31	23.79	23.83

Table 4.35: HPI Value for groundwater of Khiron block during pre and post monsoon 2016 and 2017.

Sample ID	Village	2016		2017	
		Pre-monsoon	Post-monsoon	Pre-monsoon	Post-monsoon
L 41	Hariram khera	3.71	4.00	3.70	6.43
L 22	Husenabad	2.64	3.33	3.83	4.79
L 43	Khiron (Health centre)	16.04	16.35	17.09	16.76
L 44	Sarai mahmood	7.51	8.24	8.75	8.64
L 45	Haripur mirdaha	0.10	0.49	1.24	2.05
L 46	Paho	1.29	1.78	2.98	3.42
L 47	Atarhar	0.45	1.04	1.10	1.59
L 48	Jeti	7.66	7.96	9.44	10.02
L 49	Dokanha	0.57	1.74	2.57	3.05
L 50	Banai mau	3.00	3.73	4.42	4.92
L 51	Mishra khera	3.56	4.34	5.53	6.50
L 52	Haripur nihasta	16.80	17.39	17.77	17.79
L 53	Rampur majra	3.58	4.36	5.49	5.97
L 54	Jamidar ka purwa	5.94	6.82	7.24	7.74
L 55	Gurbux ganj	1.41	2.28	3.30	3.76
L 56	Chande mau	14.75	15.61	16.61	15.80
L 57	Akampur	7.45	7.99	7.42	7.97
L 58	Sidhaur	7.27	7.21	7.10	7.87
L 59	Khapura	8.83	9.11	9.85	10.62
L 60	Kanha mau	21.66	22.20	22.14	21.02
Mean	Hariram khera	6.78	7.39	8.02	8.34
Min	Husenabad	0.10	0.49	1.10	1.59
Max	Khiron (Health centre)	21.66	22.20	22.14	21.02

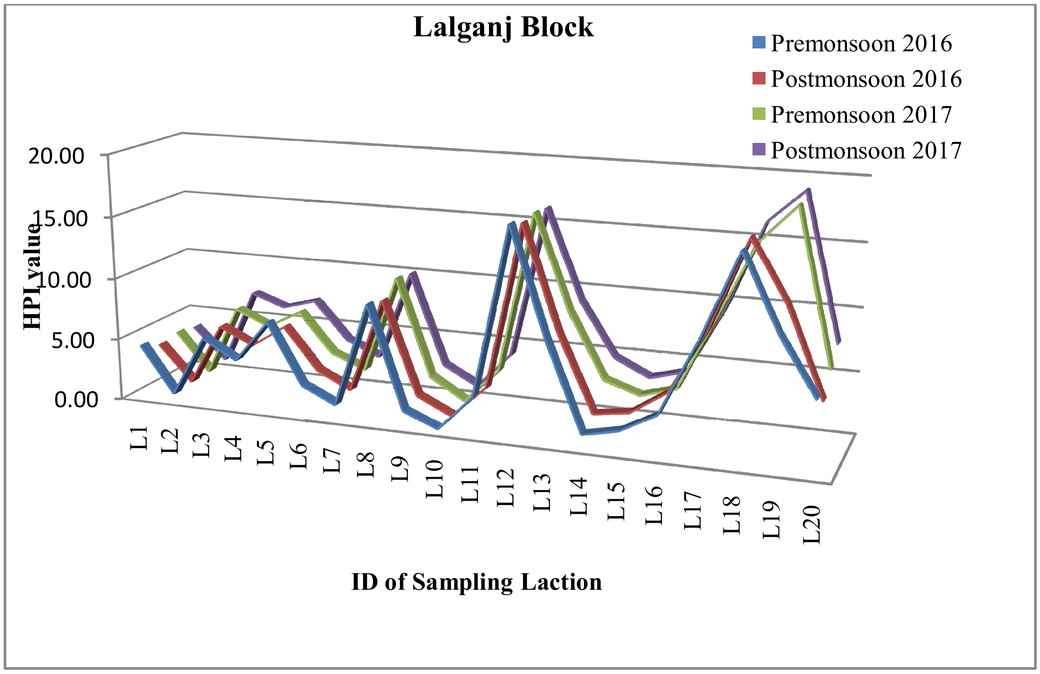


Figure 4.42: HPI value in groundwater sample of Lalganj block.

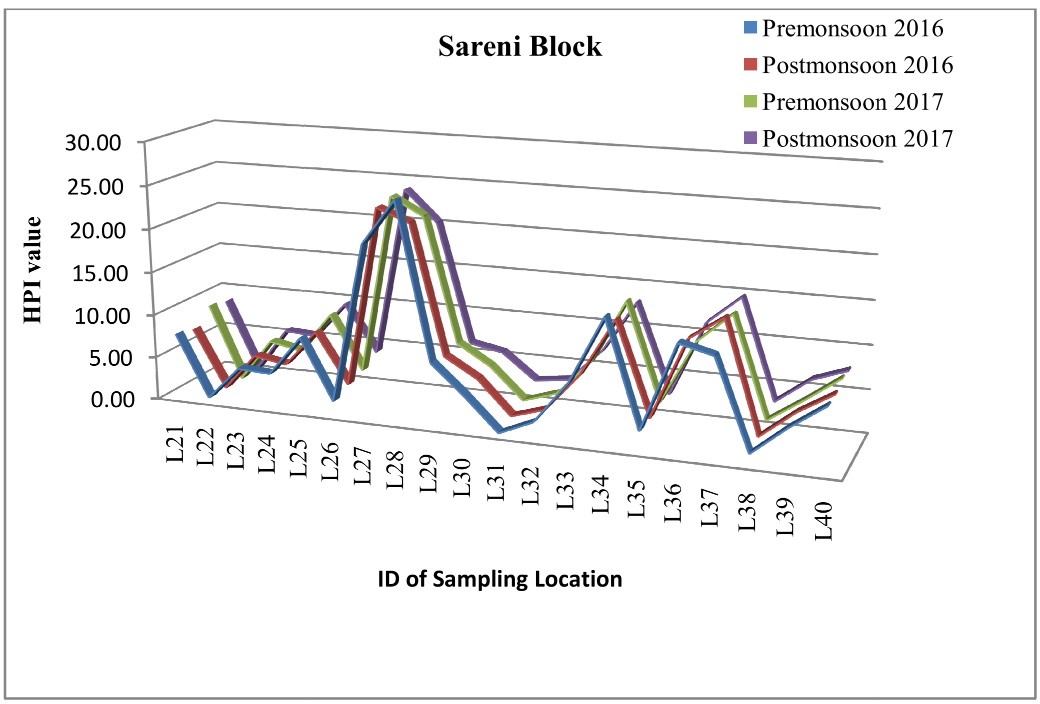


Figure 4.43: HPI value in groundwater sample of Sareni block.

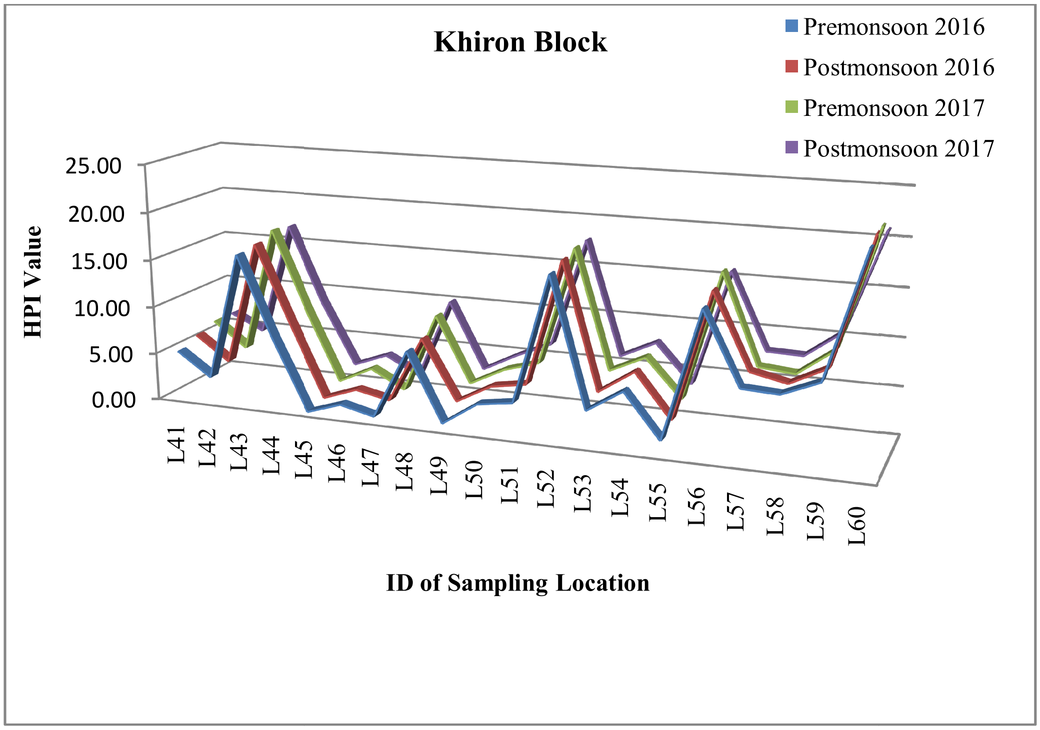


Figure 4.44: HPI value in groundwater sample of Khiron block.

Table 4.36: Classification of groundwater based on HPI value.

HPI Range	HPI class	No. of samples					
		Pre-monsoon 2016 and 2017			Post-monsoon 2016 and 2017		
		Lalganj	Sareni	Khiron	Lalganj	Sareni	Khiron
< 19	Low	20	18	19	20	18	19
19–38	Medium	-	2	1	-	2	1
>38	High	-	-	-	-	-	-

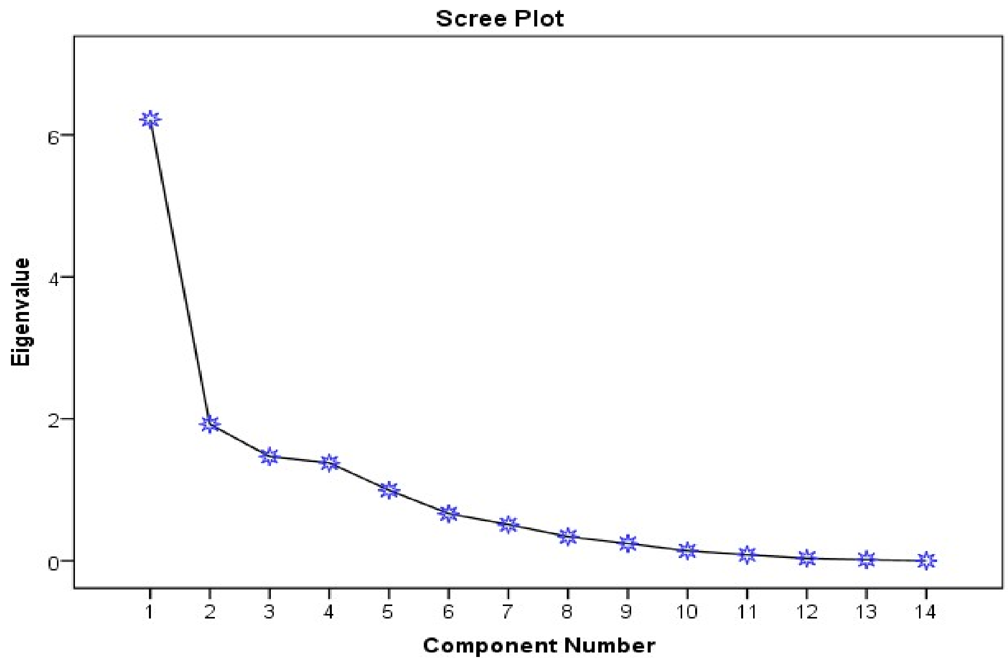
4.4.3 Factor analysis/Principal components analysis

4.4.3.1 Lalganj block

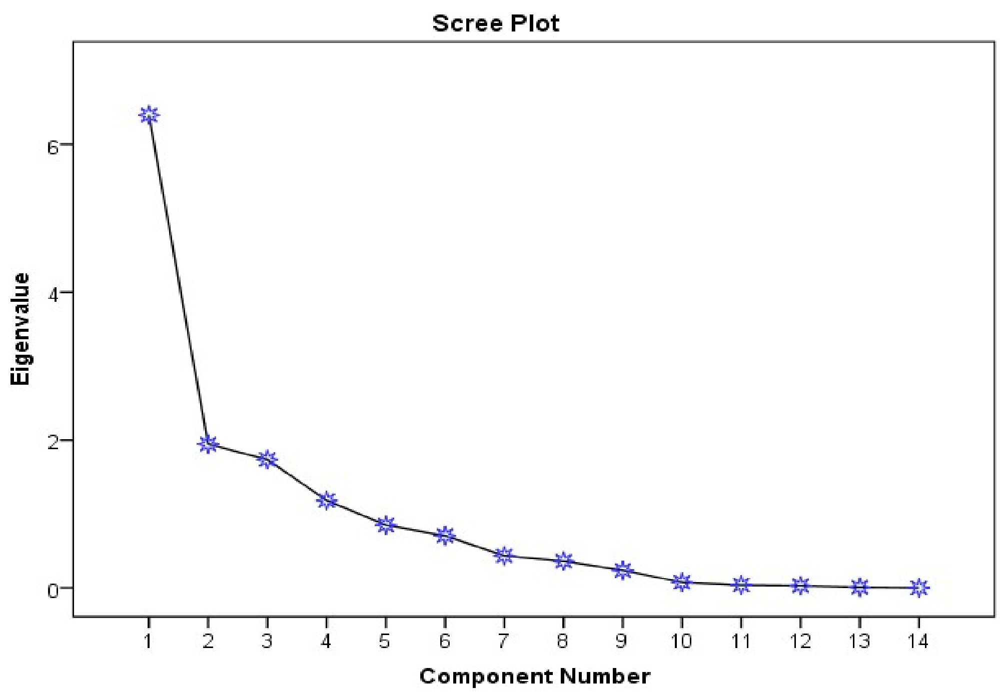
Table 4.37: Total Variance Explained for physic-chemical parameter during pre and post-monsoon 2016-17.

Total Variance Explained									
Pre-monsoon									
FA/ PCA	**Initial Eigen values**			**Extraction Sums of Squared Loadings**			**Rotation Sums of Squared Loadings**		
	Total	**% of Variance**	**Cumulative %**	**Total**	**% of Variance**	**Cumulative %**	**Total**	**% of Variance**	**Cumulative %**
1	6.215	44.396	44.396	6.215	44.396	44.396	5.708	40.775	40.775
2	1.923	13.735	58.131	1.923	13.735	58.131	1.893	13.525	54.300
3	1.467	10.479	68.611	1.467	10.479	68.611	1.832	13.082	67.382
4	1.379	9.849	78.460	1.379	9.849	78.460	1.551	11.078	78.460
Post-monsoon									
1	6.396	45.689	45.689	6.396	45.689	45.689	5.728	40.916	40.916
2	1.945	13.890	59.579	1.945	13.890	59.579	2.096	14.975	55.891
3	1.736	12.400	71.979	1.736	12.400	71.979	1.777	12.692	68.584
4	1.183	8.451	80.430	1.183	8.451	80.430	1.659	11.846	80.430

Extraction Method: Principal Component Analysis.



(I) Pre-monsoon



(II) Post-monsoon

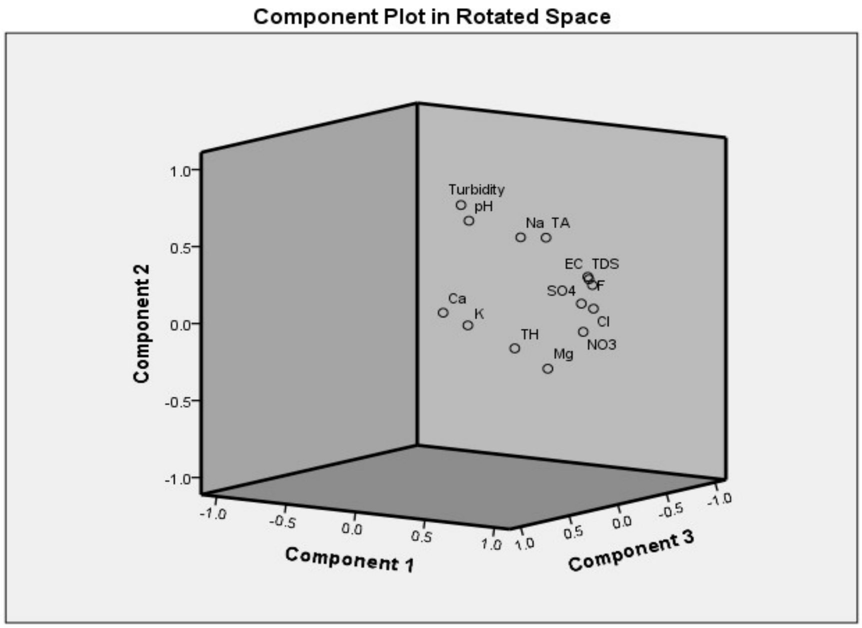
Figure 4.45: Eigen value for physico-chemical variable during pre (I) and post-monsoon (II) 2016-17

Table 4.38: Rotated Component loading for physic-chemical data during pre and post-monsoon 2016-17

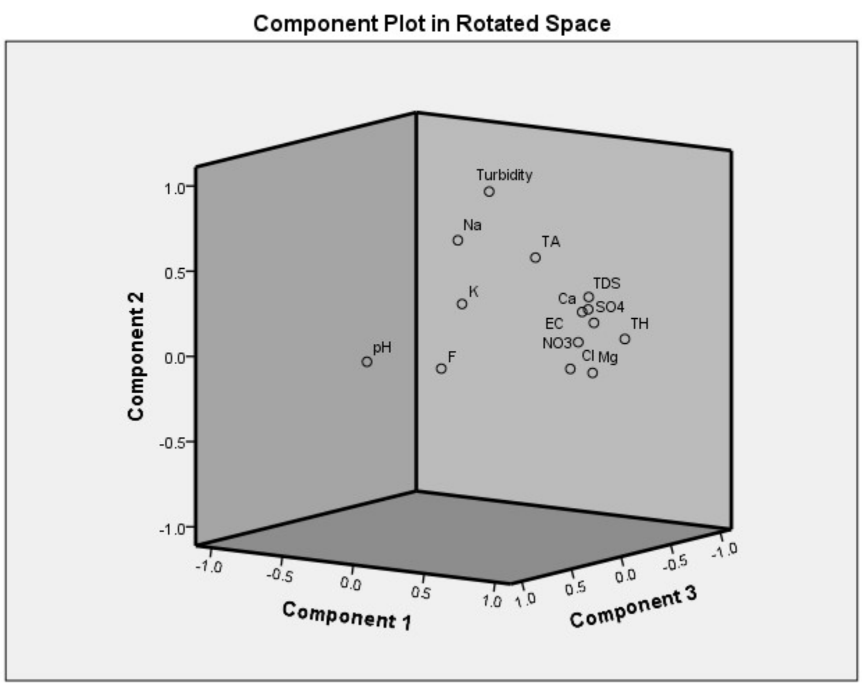
Rotated Component Matrix[a] Component								
Parameter	**Pre-monsoon**				**Post-monsoon**			
	FA 1	**FA 2**	**FA 3**	**FA 4**	**FA 1**	**FA 2**	**FA 3**	**FA 4**
pH	-0.181	0.556	-0.314	-0.165	-0.202	-0.001	0.685	-0.011
EC	**0.916**	0.352	0.029	0.115	**0.918**	0.328	0.055	0.133
TDS	**0.915**	0.334	0.018	0.175	**0.897**	0.394	0.021	0.161
Turbidity	0.212	**0.790**	0.329	0.060	0.098	**0.912**	-0.119	-0.027
TA	0.547	0.555	-0.066	0.047	0.473	0.572	-0.049	0.122
TH	**0.762**	-0.051	0.561	0.067	**0.754**	0.051	-0.548	0.146
Cl^-	**0.843**	0.115	-0.133	-0.272	**0.909**	0.002	0.222	-0.263
NO_3^-	**0.825**	-0.026	-0.052	-0.059	**0.791**	0.112	-0.026	-0.201
SO_4^{2-}	**0.899**	0.183	0.072	0.182	**0.879**	0.229	-0.058	0.253
F^-	0.325	0.110	-0.862	-0.089	0.392	0.033	**0.785**	-0.031
Ca^{2+}	0.333	0.155	0.686	-0.318	0.570	0.215	-0.381	-0.391
Mg^{2+}	**0.752**	-0.236	0.206	0.287	0.710	-0.114	-0.286	0.578
Na^+	0.305	0.520	-0.152	0.562	0.171	0.694	0.301	0.379
K^+	0.026	-0.059	-0.008	**0.923**	-0.031	0.252	-0.029	**0.878**

Extraction Method: Principal Component Analysis.
Rotation Method: Varimax with Kaiser Normalization.

a. Rotation converged in 7 iterations.



(I) Pre-monsoon



(II) Post-monsoon

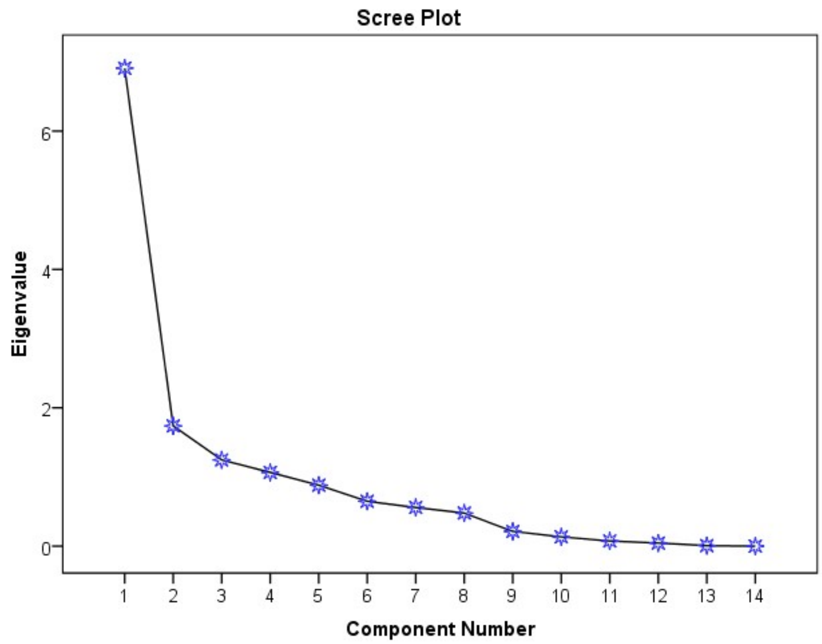
Figure 4.46: Component plot in rotate space for physico-chemical variable during pre (I) and post-monsoon (II) 2016-17

4.4.3.2 Sareni block

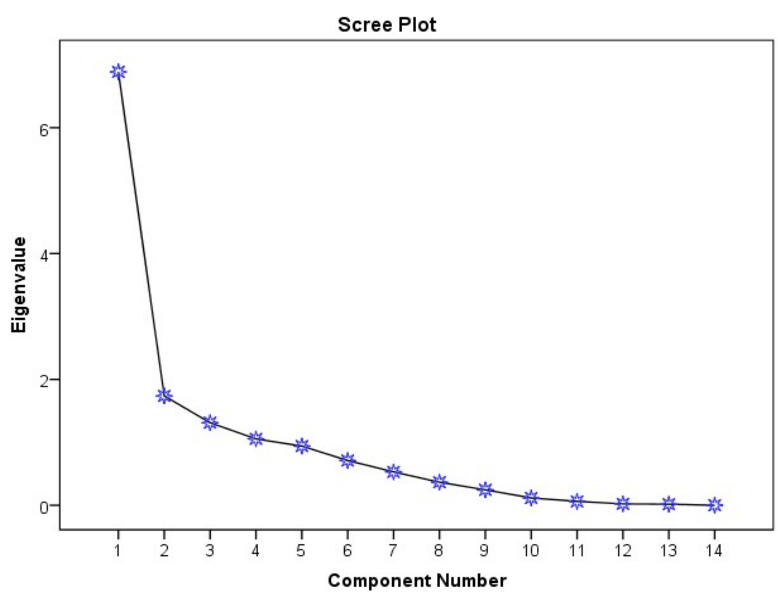
Table 4.39: Total Variance Explained for hydrochemical facies during pre and post-monsoon 2016-17.

Total Variance Explained									
Pre-monsoon									
FA/ PCA	**Initial Eigenvalues**			**Extraction Sums of Squared Loadings**			**Rotation Sums of Squared Loadings**		
	Total	**% of Variance**	**Cumulative %**	**Total**	**% of Variance**	**Cumulative %**	**Total**	**% of Variance**	**Cumulative %**
1	6.909	49.353	49.353	6.909	49.353	49.353	4.456	31.828	31.828
2	1.738	12.415	61.768	1.738	12.415	61.768	3.613	25.808	57.636
3	1.247	8.906	70.674	1.247	8.906	70.674	1.636	11.684	69.320
4	1.066	7.616	78.290	1.066	7.616	78.290	1.256	8.970	78.290
Post-monsoon									
1	6.887	49.192	49.192	6.887	49.192	49.192	5.534	39.526	39.526
2	1.739	12.419	61.610	1.739	12.419	61.610	2.925	20.890	60.416
3	1.311	9.368	70.978	1.311	9.368	70.978	1.332	9.513	69.929
4	1.055	7.534	78.512	1.055	7.534	78.512	1.202	8.583	78.512

Extraction Method: Principal Component Analysis.



(I) Pre-monsoon



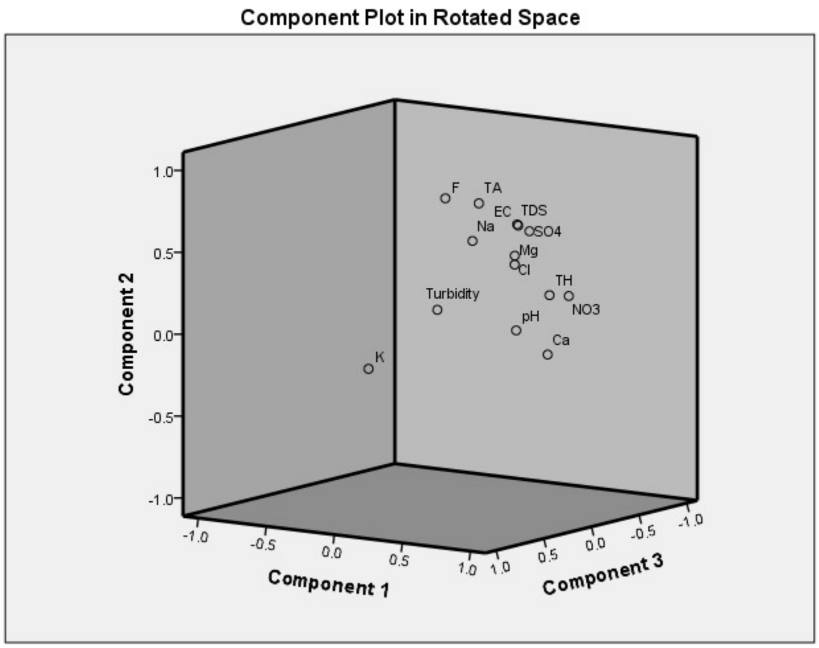
(II)Post-monsoon

Figure 4.47: Eigen value for physico-chemical variable during pre (I) and post-monsoon (II) 2016-17

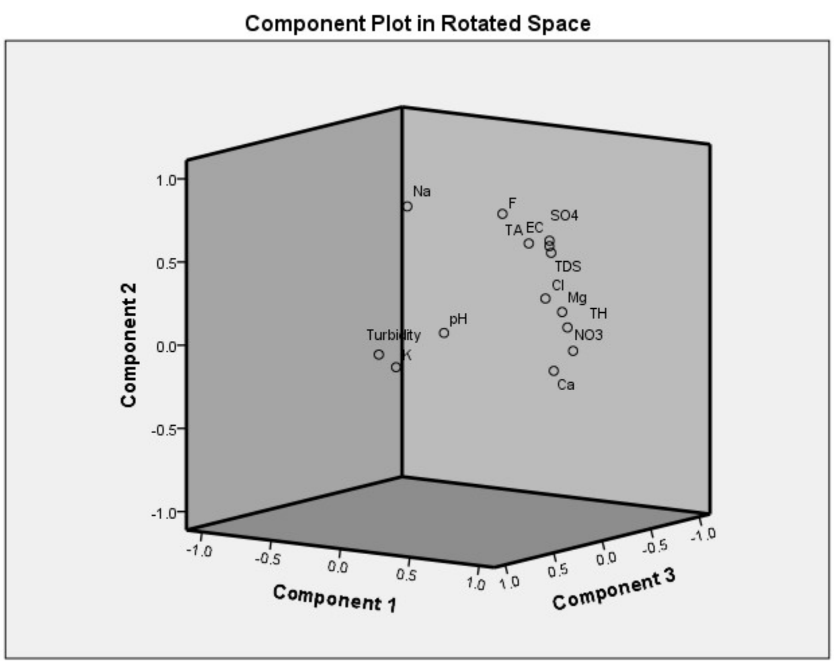
Table 4.40: Rotated Component loading for hydrochemical facies during pre and post-monsoon 2016-17

Rotated Component Matrix[a]								
Component								
Parameter	**Pre-monsoon**				**Post-monsoon**			
	F 1	**F 2**	**F 3**	**F 4**	**F 1**	**F 2**	**F 3**	**F 4**
pH	0.028	-0.131	**-0.757**	0.299	-0.031	0.022	-0.001	**0.876**
EC	0.645	0.704	0.114	-0.107	0.717	0.649	-0.019	-0.112
TDS	0.677	0.705	0.148	-0.092	**0.787**	0.596	0.063	-0.073
Turbidity	-0.046	0.091	-0.035	**0.876**	-0.017	-0.006	0.691	0.201
TA	0.315	**0.789**	0.044	-0.107	0.431	0.576	-0.214	-0.112
TH	**0.921**	0.308	0.168	-0.038	**0.951**	0.173	0.130	-0.059
Cl^-	0.695	0.532	0.209	-0.236	**0.829**	0.343	0.183	-0.079
NO_3^-	0.730	0.215	-0.306	0.009	**0.812**	-0.019	-0.127	0.297
SO_4^{2-}	0.668	0.651	0.017	0.006	0.703	0.613	-0.038	0.003
F^-	-0.050	**0.759**	-0.125	0.216	0.281	**0.750**	-0.157	0.030
Ca^{2+}	**0.766**	-0.100	-0.034	0.205	0.704	-0.143	-0.083	-0.349
Mg^{2+}	0.727	0.488	0.257	-0.231	**0.915**	0.263	0.132	-0.069
Na^+	0.208	0.536	-0.042	0.364	-0.148	**0.802**	0.210	0.134
K^+	0.089	-0.123	**0.879**	0.186	0.185	-0.045	**0.802**	-0.348

Extraction Method: Principal Component Analysis.
Rotation Method: Varimax with Kaiser Normalization.



(I) Pre-monsoon



(II) Post-monsoon

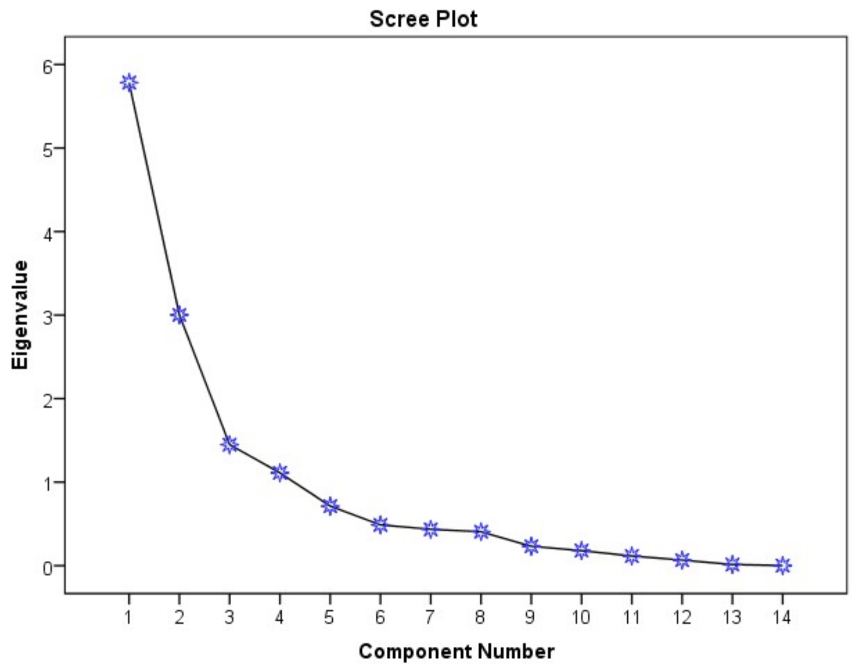
Figure 4. 48: Component plot in rotate space for physico-chemical variable during pre (a) and post-monsoon (b) 2016-17

4.4.3.3 Khiron block

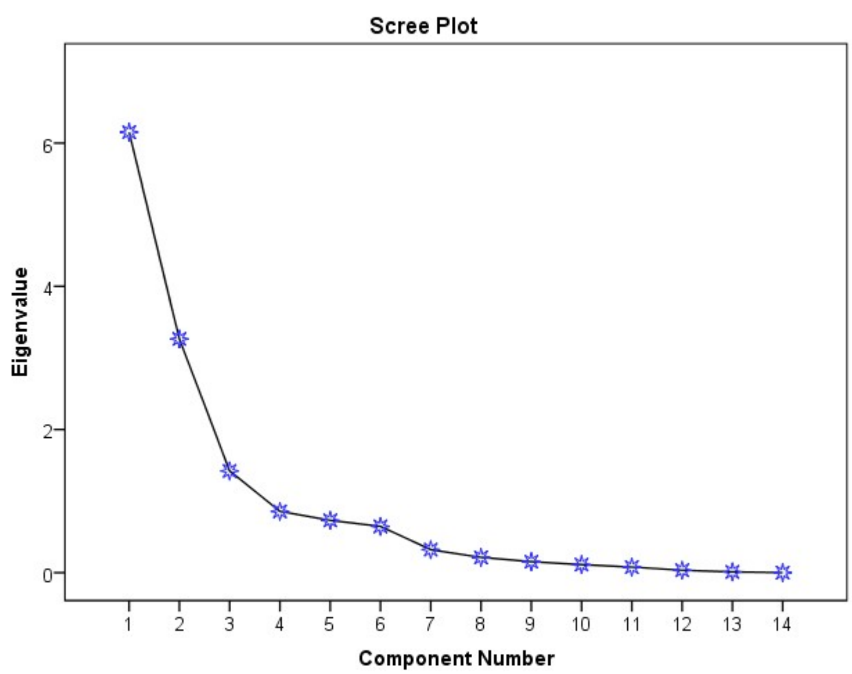
Table 4.41: Total Variance Explained for hydrochemical data during pre and post-monsoon 2016-17.

Total Variance Explained									
Pre-monsoon									
FA/PCA	**Initial Eigenvalues**			**Extraction Sums of Squared Loadings**			**Rotation Sums of Squared Loadings**		
	Total	**% of Variance**	**Cumulative %**	**Total**	**% of Variance**	**Cumulative %**	**Total**	**% of Variance**	**Cumulative %**
1	5.783	41.308	41.308	5.783	41.308	41.308	5.369	38.347	38.347
2	3.003	21.447	62.755	3.003	21.447	62.755	3.154	22.526	60.873
3	1.449	10.350	73.105	1.449	10.350	73.105	1.607	11.476	72.349
4	1.111	7.939	81.044	1.111	7.939	81.044	1.217	8.695	81.044
Post-monsoon									
1	6.152	43.945	43.945	6.152	43.945	43.945	5.998	42.846	42.846
2	3.266	23.326	67.271	3.266	23.326	67.271	2.782	19.871	62.717
3	1.421	10.152	77.423	1.421	10.152	77.423	2.059	14.706	77.423

Extraction Method: Principal Component Analysis.



(I) Pre-monsoom



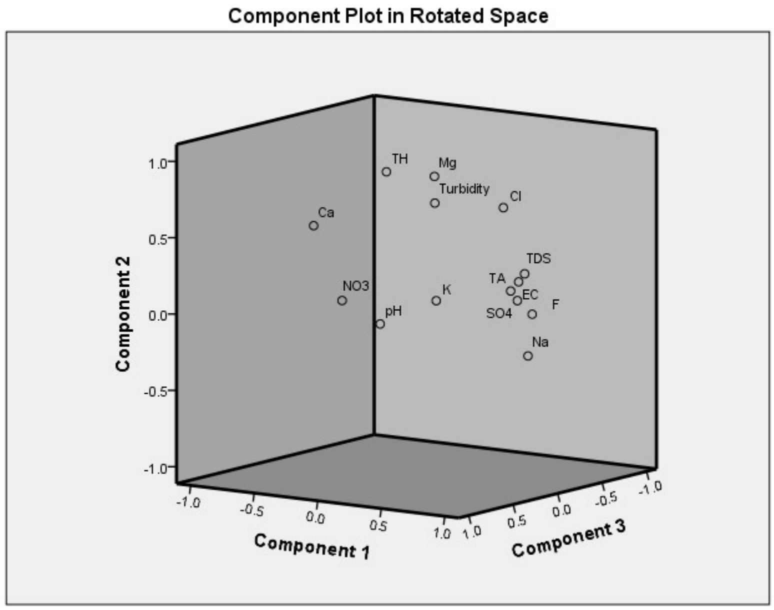
(II) Post-monsoon

Figure 4.49: Eigen value for physico-chemical variable during pre (I) and post-monsoon (II) 2016-17

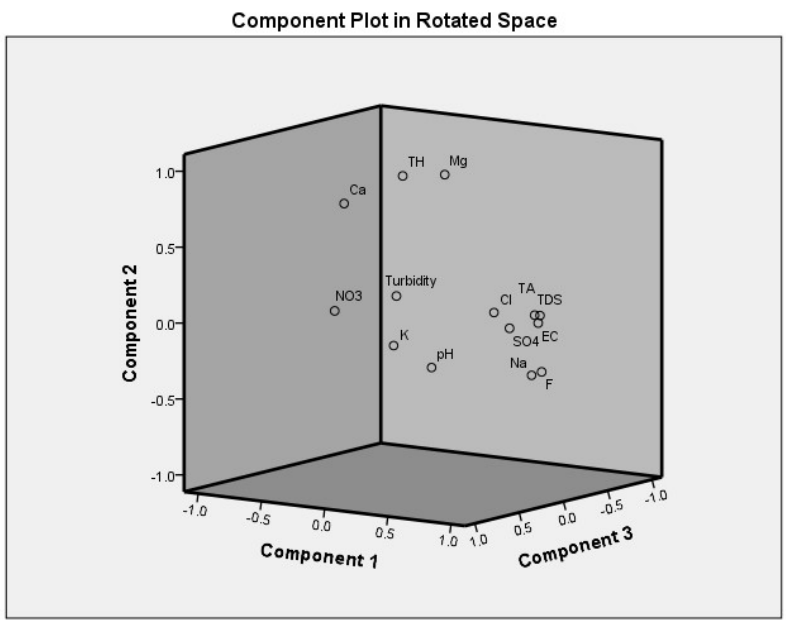
Table 4.42: Rotated Component loading for hydrochemical data during pre and post-monsoon 2016-17

Rotated Component Matrix Component							
Parameter	**Pre-monsoon**				**Post-monsoon**		
	F 1	**F 2**	**F 3**	**F 4**	**F 1**	**F 2**	**F 3**
pH	0.214	0.012	0.714	-0.506	-0.168	-0.407	-0.338
EC	**0.915**	0.278	0.158	0.092	**0.971**	0.063	0.085
TDS	**0.919**	0.322	0.097	0.113	**0.973**	0.121	0.128
Turbidity	0.267	0.731	0.176	-0.129	0.246	0.249	0.651
TA	**0.868**	0.217	0.182	0.150	**0.942**	0.100	0.024
TH	-0.109	**0.899**	0.183	0.223	-0.034	**0.944**	0.181
Cl^-	0.531	0.671	-0.219	-0.113	**0.770**	0.142	0.298
NO_3^-	0.027	0.169	**0.875**	0.167	-0.189	0.118	0.728
SO_4^{2-}	**0.794**	0.120	0.000	0.054	**0.851**	0.038	0.237
F^-	**0.844**	0.022	-0.095	-0.102	**0.850**	-0.302	-0.127
Ca^{2+}	-0.549	0.529	0.373	0.185	-0.391	**0.750**	0.333
Mg^{2+}	0.147	**0.869**	0.008	0.056	0.106	**0.927**	-0.095
Na^+	**0.909**	-0.224	0.045	0.000	**0.886**	-0.297	0.038
K^+	0.178	0.061	0.032	**0.872**	0.333	-0.046	**0.807**

Extraction Method: Principal Component Analysis.
Rotation Method: Varimax with Kaiser Normalization.



(I) Pre-monsoon



(II) Post-monsoon

Figure 4.50: Component plot in rotate space for physico-chemical variable during pre (a) and post-monsoon (b) 2016-17

4.4.4 Spearman correlation analysis

4.4.4.1 Correlation within physico-chemical variable

Table 4.43; Spearman correlation Coefficient within physic-chemical parameter of Lalganj tehsil during pre monsoon 2016-17 (n = 120)

	pH	EC	TDS	Turbidity	TA	TH	Cl^-	NO_3^-	SO_4^{2-}	F^-	Ca^{2+}	Mg^{2+}	Na^+	K^+
pH	1.000													
EC	0.070	1.000												
TDS	0.027	**0.974****	1.000											
Turbidity	0.135	0.421**	0.375**	1.000										
TA	0.107	**0.819****	**0.851****	0.212*	1.000									
TH	-0.160	0.556**	0.556**	0.338**	0.338**	1.000								
Cl^-	-0.071	0.641**	0.659**	0.409**	0.365**	0.452**	1.000							
NO_3^-	0.097	0.485**	0.444**	0.338**	0.322**	0.450**	0.248**	1.000						
SO_4^{2+}	0.045	**0.821****	**0.815****	0.303**	0.587**	0.532**	0.495**	0.399**	1.000					
F^-	0.231*	0.424**	0.427**	-0.026	0.477**	-0.070	0.220*	0.089	0.276**	1.000				
Ca^{2+}	-0.116	0.210*	0.200*	0.188*	0.139	0.671**	0.198*	0.314**	0.168	-0.202*	1.000			
Mg^{2+}	-0.123	0.595**	0.595**	0.369**	0.334**	**0.845****	0.491**	0.374**	0.564**	-0.038	0.336**	1.000		
Na^+	0.111	0.628**	0.640**	0.215*	0.502**	0.043	0.264**	0.277**	0.544**	0.449**	-0.182*	0.183*	1.000	
K^+	-0.331**	0.223*	0.264**	0.142	0.127	0.213*	0.154	0.097	0.083	-0.077	0.085	0.251**	0.148	1.000

(*) Correlation is significant at the 0.05 level and (**) at the 0.01 level,

Table 4.44: Spearman correlation Coefficient within physic-chemical parameter of Lalganj tehsil during post -monsoon 2016-17 (n = 120)

	pH	EC	TDS	Turbidity	TA	TH	Cl^-	NO_3^-	SO_4^{2-}	F^-	Ca^{2+}	Mg^{2+}	Na^+	K^+
pH	1.000													
EC	-0.130	1.000												
TDS	-0.139	**0.962****	1.000											
Turbidity	-0.100	0.324**	0.350**	1.000										
TA	-0.151	**0.812****	**0.831****	0.211*	1.000									
TH	-0.258**	0.481**	0.511**	0.226*	0.293**	1.000								
Cl^-	-0.066	0.594**	0.650**	0.350**	0.308**	0.453**	1.000							
NO_3^-	-0.163	0.330**	0.332**	0.220*	0.189*	0.479**	0.281**	1.000						
SO_4^{2+}	-0.038	**0.838****	**0.853****	0.262**	0.623**	0.511**	0.499**	0.321**	1.000					
F^-	0.068	0.406**	0.402**	-0.085	0.378**	-0.061	0.257**	-0.014	0.323**	1.000				
Ca^{2+}	-0.232*	0.248**	0.252**	0.159	0.203*	**0.724****	0.265**	0.379**	0.187*	-0.179	1.000			
Mg^{2+}	-0.213*	0.510**	0.521**	0.160	0.294**	**0.760****	0.392**	0.309**	0.508**	-0.017	0.410**	1.000		
Na^+	-0.049	0.587**	0.613**	0.233*	0.452**	-0.014	0.284**	0.117	0.534**	0.467**	-0.238**	0.118	1.000	
K^+	-0.215*	0.369**	0.402**	0.364**	0.230*	0.218*	0.271**	0.159	0.247**	0.010	0.106	0.243**	0.323**	1.000

(*)Correlation is significant at the 0.05 level and (**) at the 0.01 level,

4.4.4.2 Correlation within metallic variable

Table 4.45: Spearman correlation Coefficient within metallic contents of Lalganj tehsil during pre-monsoon 2016-17 (n = 120)

	Zn	Fe	Ni	Mn	Pb	Cu	Co	Cr	Cd
Zn	1.000								
Fe	0.378**	1.000							
Ni	0.077	0.108	1.000						
Mn	0.113	0.106	0.401**	1.000					
Pb	0.075	-0.101	0.136	0.194*	1.000				
Cu	0.155	0.331**	0.225*	0.100	0.082	1.000			
Co	0.203*	0.064	0.393**	0.020	0.325**	0.271**	1.000		
Cr	-0.055	-0.055	-0.239**	0.020	-0.067	-0.137	-0.065	1.000	
Cd	0.331**	0.183*	-0.138	-0.184*	-0.097	0.158	0.087	-0.080	1.000

(*) Correlation is significant at the 0.05 level and (**) at the 0.01 level,

Table 4.46: Spearman correlation Coefficient within metallic contents of Lalganj tehsil during post -monsoon 2016-17 (n = 120)

	Zn	Fe	Ni	Mn	Pb	Cu	Co	Cr	Cd
Zn	1.000								
Fe	0.378**	1.000							
Ni	0.077	0.108	1.000						
Mn	0.113	0.106	0.401**	1.000					
Pb	0.075	-0.101	0.136	0.194*	1.000				
Cu	0.155	0.331**	0.225*	0.100	0.082	1.000			
Co	0.203*	0.064	0.393**	0.020	0.325**	0.271**	1.000		
Cr	-0.055	-0.055	-0.239**	0.020	-0.067	-0.137	-0.065	1.000	
Cd	0.331**	0.183*	-0.138	-0.184*	-0.097	0.158	0.087	-0.080	1.000

(*)Correlation is significant at the 0.05 level and (**) at the 0.01 level,

4.4.5 Hierarchical cluster analysis

4.4.5.1 Clustering of sampling location through physico-chemical variable

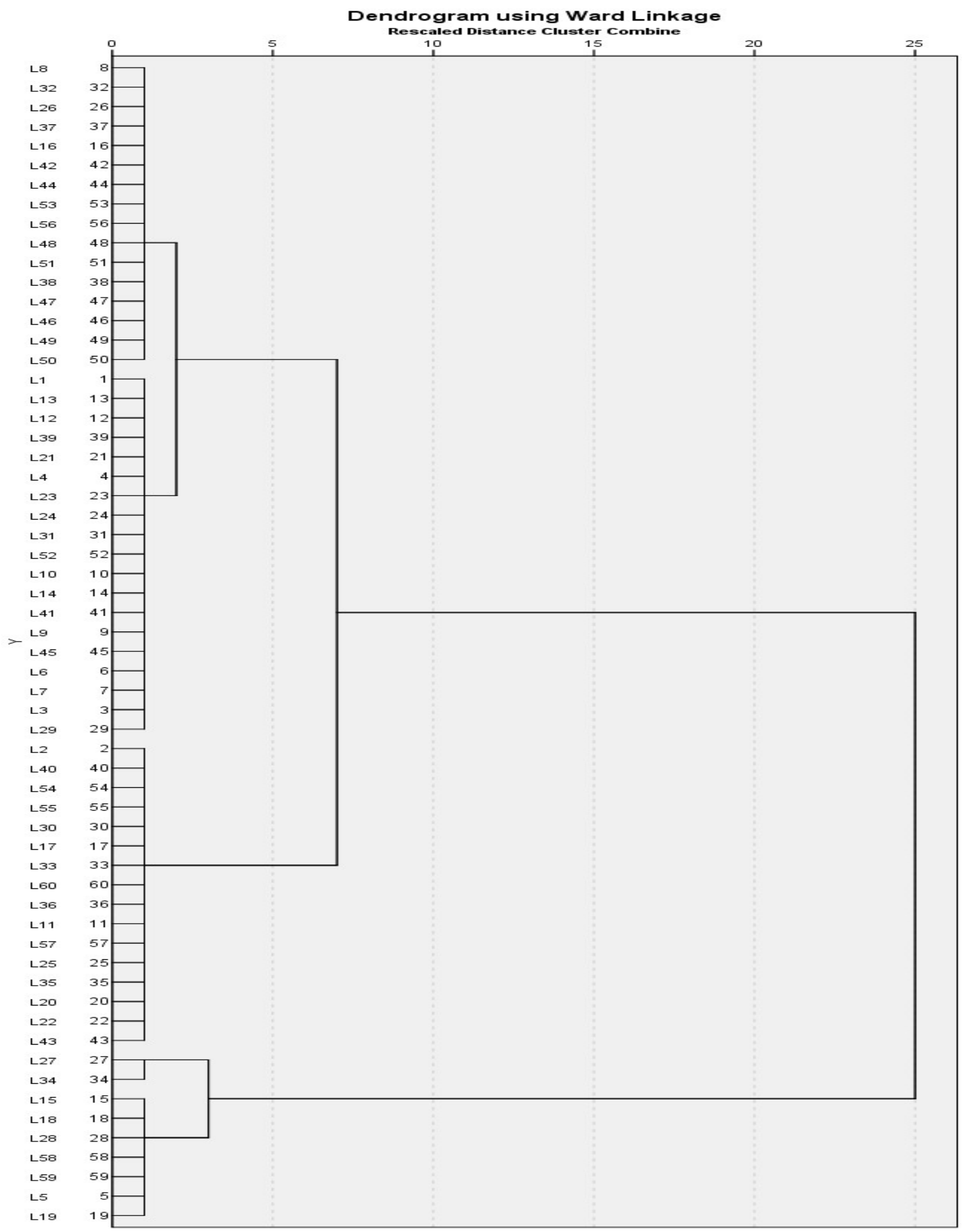


Figure 4.51: Dendrograms grouped samples through physico-chemical variable during pre-monsoon 2016-17

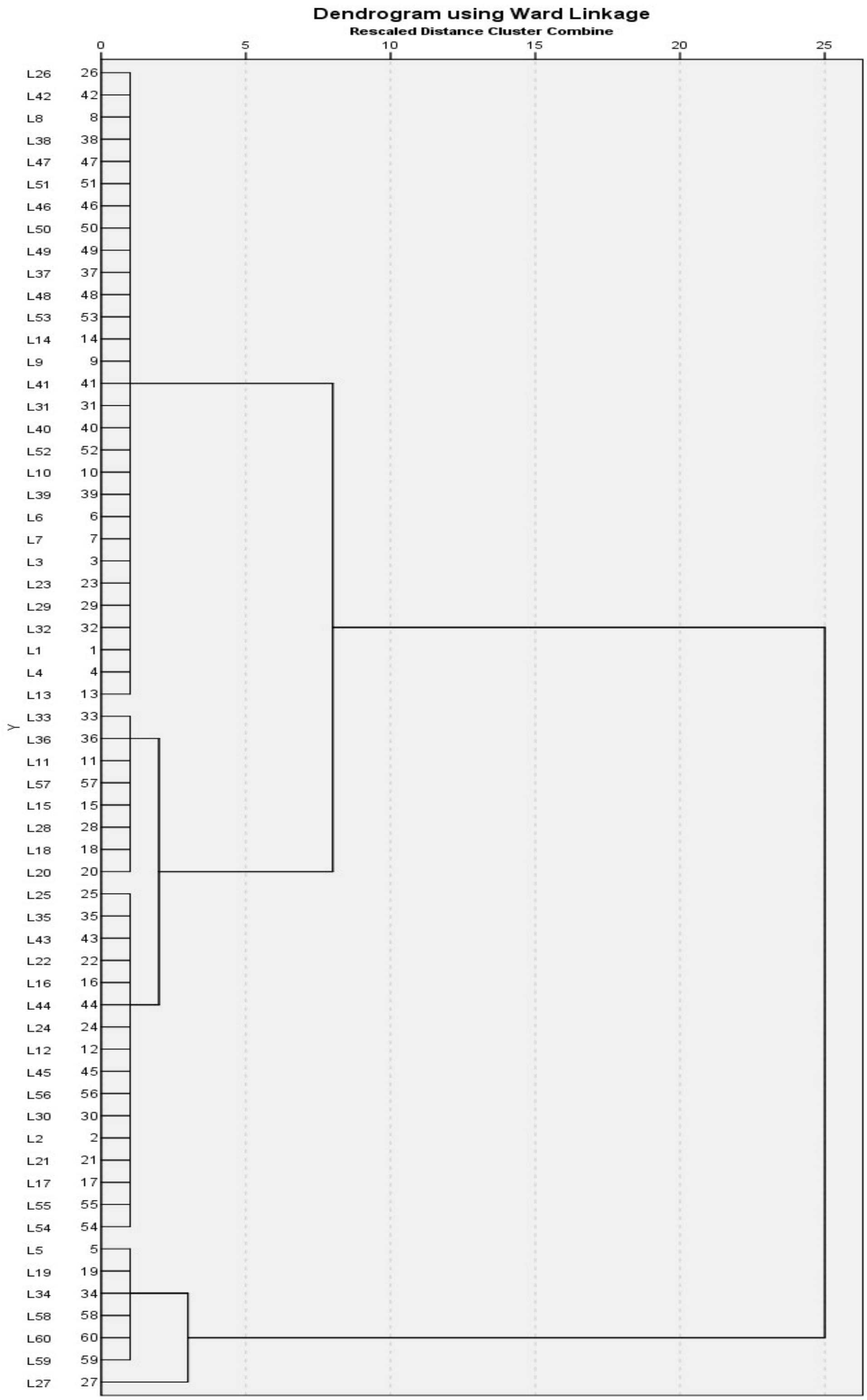


Figure 4.52: Dendrograms grouped samples through physico-chemical variable during post-monsoon 2016-17

4.4.5.2 Clustering of sampling location through metallic variable

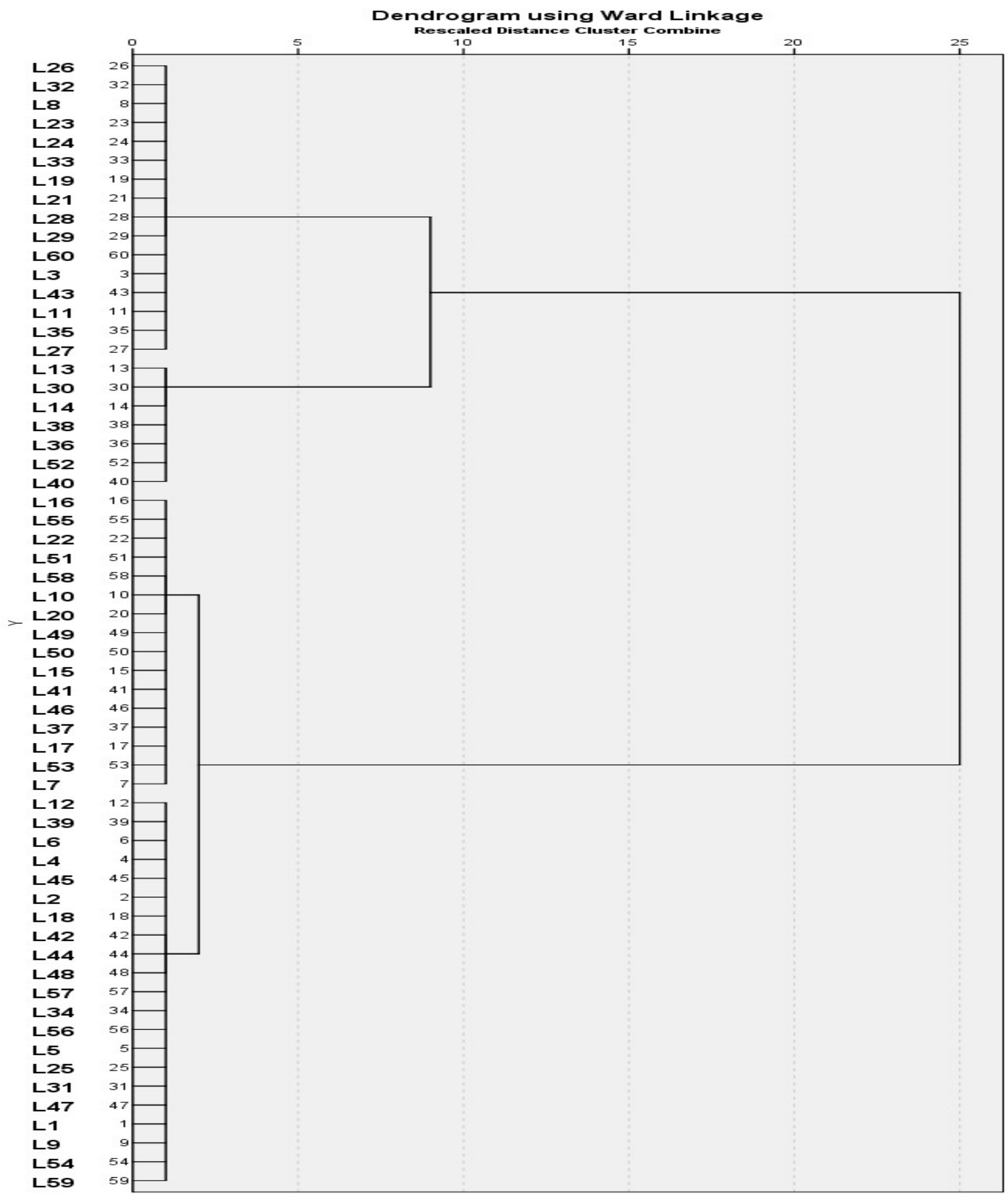


Figure 4.53: Dendrograms grouped samples through metallic variables during pre-monsoon 2016-17

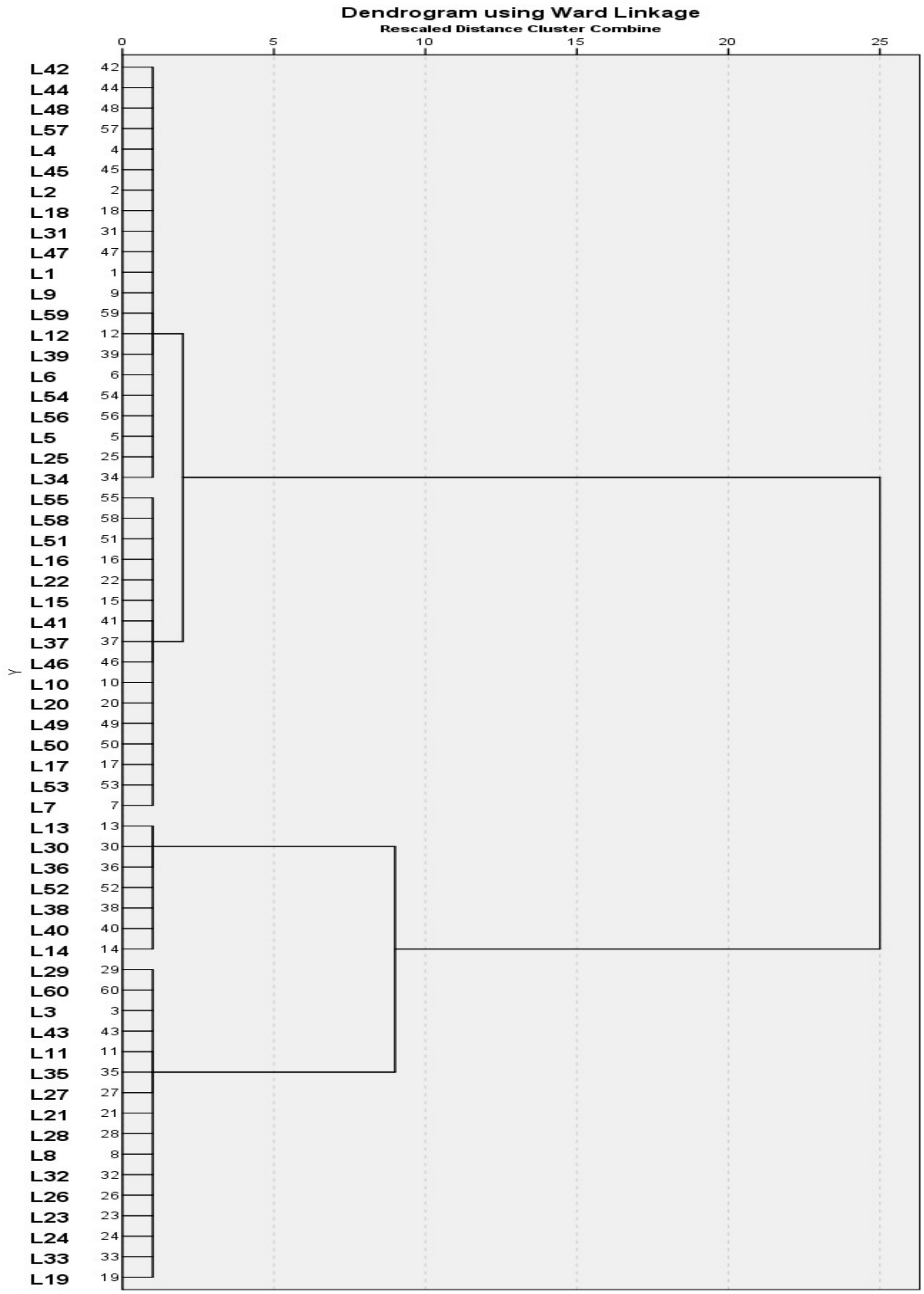


Figure 4.54: Dendrograms grouped samples through metallic variables during post-monsoon 2016-17

4.4.6 T-test

Table 4.47:T-test applied in physicochemical data in groundwater of Lalganj tehsil during pre and post monsoon (2016 and 2017) (n=120)

Physico-chemical parameter	Premonsoon 2016-17						Post monsoon 2016-17					Remark
	Unit	Mean	SEM	C.I.	Max	Min	Mean	SEM	C.I.	Max	Min	
pH	-	7.73	0.03	0.06	8.24	7.00	7.95	0.02	0.03	8.61	7.55	Significant
EC	µS/cm	1345.58	51.54	102.05	4083.00	601.46	1513.85	57.28	113.41	4275.18	831.00	Significant
TDS	mg/L	951.90	32.74	64.83	2201.48	459.02	1079.99	34.70	68.71	2309.10	534.53	Significant
Turbidity	NTU	2.65	0.14	0.28	7.00	0.00	3.66	0.14	0.27	8.00	0.00	Significant
Alkalinity	mg/L	416.68	13.77	27.26	1153.00	156.00	461.82	15.43	30.55	1234.00	231.00	Significant
Hardness	mg/L	274.46	11.48	22.73	742.00	28.00	295.80	11.60	22.97	782.00	26.00	Not Significant
Cl	mg/L	95.90	10.70	21.18	594.00	7.00	127.22	11.64	23.04	658.00	12.01	Significant
NO_3	mg/L	11.98	1.20	2.38	81.52	0.22	18.42	1.52	3.01	84.32	0.52	Significant
SO_4	mg/L	93.86	8.42	16.67	420.00	0.36	124.36	9.07	17.95	451.17	10.54	Significant
F	mg/L	2.09	0.21	0.41	16.20	0.52	2.32	0.23	0.46	17.20	0.44	Not Significant
Ca	mg/L	42.82	1.71	3.39	133.37	4.53	47.91	1.60	3.16	120.00	11.02	Significant
Mg	mg/L	65.66	3.24	6.42	214.00	4.53	73.49	3.17	6.27	235.00	15.62	Not Significant
Na	mg/L	187.30	5.34	10.57	396.41	111.00	196.97	5.16	10.21	386.00	119.65	Not Significant
K	mg/L	17.63	0.96	1.89	56.00	5.00	15.81	0.90	1.78	52.42	3.71	Not Significant

Critical value p =1.98 at 5% or 0.05 level for 238 degree of freedom

4.5 Health Risk Assessment due to possible intake of fluoride via dietary

4.5.1 Accumulation of Fluoride in plants and rhizospheric soil.

The concentration of fluoride in Rice (***Oryza Sativa L***) were ranged from 0.50 to 0.62 mg/kg (0.54 ±0.03) for Lalganj block, 0.42 to 0.54 mg/kg (2.43±0.13) for Sareni block and 0.51 to 0.71 mg/kg (0.59±0.05) for Khiron block while 0.02 to 0.05 mg/kg (0.04 ±0.01) found in Control block (Bachharawan). The mean moisture contents of rice was found 15 % and fluoride in rhizospheric soil were found 32, 38, 66 and 2.07 mg/kg in Lalganj, Sareni, Khiron, and Control block respectively. The fluoride contents in Wheat (***Triticum vulgaris***) were ranged from 0.28 to 3.31 mg/kg with mean value 2.66 ±0.24 for Lalganj block, 2.10 to 2.71 mg/kg with mean value 2.43±0.13 for Sareni block and 2.20 to 3.49 mg/kg with mean value 2.82±0.36 for Khiron block while BDL in Control block (Bachharawan). The mean moisture contents of Wheat was found 22 % and the mean fluoride in rhizospheric soil were found 52, 51, 72 and 0.23 mg/kg in Lalganj, Sareni, Khiron, and Control block respectively. The average concentration of fluoride in Pigeon pea (***Cajanus cajan***) was reported 9.22±0.41, 8.58±0.55, 8.72±0.88 and 0.11±0.01 mg/L in Lalganj, Sareni and Khiron block and control block with ranged from 8.18 to 10.11 mg/kg, 7.10 to 9.51 mg/kg, 7.20 to 10.29 mg/kg and 0.098 to 0.128 mg/kg, respectively. The mean moisture contents of Pigeon pea was found 15 % and the mean fluoride in rhizospheric soil were found 141, 80, 93 and 9.40 mg/kg in Lalganj, Sareni, Khiron, and Control block respectively.

The concentration of fluoride in Urad (***Vigna mungo***) were ranged from 5.53 to 6.41 mg/kg (5.98 ±0.20) for Lalganj block, 5.00 to 6.21 mg/kg (5.71±0.27) for

Sareni block and 5.10 to 6.59 mg/kg (5.82±0.42) for Khiron block while 0.062 to 0.112 mg/kg (0.08 ±0.01) found in Control block (Bachharawan). The mean moisture contents of Urad was found 12 % and fluoride in rhizospheric soil were found 112, 71, 69 and 0.60 mg/kg in Lalganj, Sareni, Khiron, and Control block respectively.The average concentration of fluoride in Tomato (***Lycopersicon esculentum***) was reported 7.96±0.16, 7.91±0.27, 7.57±0.16 and 0.06±0.01 mg/L in Lalganj, Sareni and Khiron block and control block with ranged from 7.71 to 8.41 mg/kg, 7.20 to 8.41 mg/kg, 7.30 to 7.89 mg/kg and 0.042 to 0.072 mg/kg, respectively. The mean moisture contents of Tomato was found 93 % and the mean fluoride in rhizospheric soil were found 199, 80, 94 and 0.81 mg/kg in Lalganj, Sareni, Khiron, and Control block respectively.The fluoride contents in Chilli (***Capsicum annuam***) were ranged from 6.90 to 7.91 mg/kg with mean value 7.40 ±0.21 for Lalganj block, 6.10 to 7.91 mg/kg with mean value 7.20±0.41 for Sareni block and 6.20 to 7.49 mg/kg with mean value 6.82±0.36 for Khiron block while 0.034 to 0.094 mg/kg with mean value 0.06±0.01 in Control block (Bachharawan). The mean moisture contents of Chilli was found 62 % and the mean fluoride in rhizospheric soil were found 115, 90, 69 and 0.90 mg/kg in Lalganj, Sareni, Khiron, and Control block respectively.

The concentration of fluoride in Potato (***Solanum tuberosum***) were ranged from 8.18 to 8.61 mg/kg (8.36 ±0.09) for Lalganj block, 8.20 to 8.61 mg/kg (8.40±0.08) for Sareni block and 8.30 to 8.49 mg/kg (8.37±0.05) for Khiron block while 0.046 to 0.076 mg/kg (0.06 ±0.01) found in Control block (Bachharawan). The mean moisture contents of Potato was found 80 % and fluoride in rhizospheric soil were found 130, 101, 87 and 5.57 mg/kg in Lalganj, Sareni, Khiron, and

Control block respectively. The average concentration of fluoride in Okra (***Abelmoschus esculentus***) was reported 14.11±0.54, 13.40±0.41, 14.00±0.92 and 0.14±0.03 mg/L in Lalganj, Sareni and Khiron block and control block with ranged from 13.07 to 15.60 mg/kg, 12.30 to 14.11 mg/kg, 12.40 to 15.69 mg/kg and 0.084 to 0.22 mg/kg, respectively. The mean moisture contents of Okra was found 42 % and the mean fluoride in rhizospheric soil were found 175, 120, 89 and 0.76 mg/kg in Lalganj, Sareni, Khiron, and Control block respectively. The fluoride contents in Cauliflower **(*Brassica oleracea botrytis*)** were ranged from 7.80 to 9.91 mg/kg with mean value 8.36 ±0.23 for Lalganj block, 7.80 to 9.91 mg/kg with mean value 8.45±0.24 for Sareni block and 7.71 to 7. 9 mg/kg with mean value 7.80±0.05 for Khiron block while 0.051 to 0.081 mg/kg with mean value 0.07±0.01 in Control block (Bachharawan). The mean moisture contents of Cauliflower was found 86% and the mean fluoride in rhizospheric soil were found 143, 92, 86 and 4.17 mg/kg in Lalganj, Sareni, Khiron, and Control block respectively.

The concentration of fluoride in Sponge gourd **(*Luffa aegyptiaca*)** were ranged from 1.31 to 2.91 mg/kg (2.06 ±0.38) for Lalganj block, 0.50 to 2.91 mg/kg (1.98±0.55) for Sareni block and 0.60 to 1.49 mg/kg (1.02±0.25) for Khiron block while BDL in Control block (Bachharawan). The mean moisture contents of Sponge gourd was found 76 % and fluoride in rhizospheric soil were found 76, 48, 46 and 0.41 mg/kg in Lalganj, Sareni, Khiron, and Control block respectively. The average concentration of fluoride in Coriander (***Coriandrum sativum***) was reported 2.78±0.15, 2.65±0.15, 2.80±0.26 and BDL in Lalganj, Sareni Khiron block and control block with ranged from 2.52 to 3.11 mg/kg, 2.26 to 2.96 mg/kg, 2.36 to 3.29 mg/kg and BDL, respectively. The mean moisture contents of Coriander was found

80 % and the mean fluoride in rhizospheric soil were found 72±1.45, 51±2.91, 68±1.86 and 0.11±0.10 mg/kg in Lalganj, Sareni, Khiron, and Control block respectively. The fluoride contents in Pointed gourd (***Trichosanthes dioica***) were ranged from 5.51 to 7.81 mg/kg with mean value 6.77 ±0.52 for Lalganj block, 5.20 to 7.81 mg/kg with mean value 6.81±0.60 for Sareni block and 5.30 to 5.69 mg/kg with mean value 5.47±0.1 for Khiron block while 0.074 to 0.114 mg/kg with mean value 0.09±0.01 in Control block (Bachharawan). The mean moisture contents of Pointed gourd was found 90 % and the mean fluoride in rhizospheric soil were found 137±2.96, 94±3.22, 94±2.91 and 2.07± 0.23 mg/kg in Lalganj, Sareni, Khiron, and Control block respectively.

The concentration of fluoride in Onion (***Allium cepa***) were ranged from 17.51 to 19.11 mg/kg (18.60 ±0.38) for Lalganj block, 16.20 to 19.11 mg/kg (18.0±0.67) for Sareni block and 16.30 to 19.29 mg/kg (17.77±0.85) for Khiron block while 0.056 to 0.116 mg/kg (0.08 ±0.01) found in Control block (Bachharawan). The mean moisture contents of Onion was found 90 % and fluoride in rhizospheric soil were found 193±4.18, 202±7.81, 222±5.13 and 1.53±0.35 mg/kg in Lalganj, Sareni, Khiron, and Control block respectively. The average concentration of fluoride in Pigweed (***Chenopodium album***) was reported 12.91±1.10, 11.52±0.52, 13.22±1.75 and 0.08±0.01 in Lalganj, Sareni Khiron block and control block with ranged from 11.13 to 16.11 mg/kg, 10.10 to 12.41 mg/kg, 10.20 to 16.29 mg/kg and 0.066 to 0.086 mg/kg, respectively. The mean moisture contents of Pigweed was found 89 % and the mean fluoride in rhizospheric soil were found 87±5.93, 119±3.22, 255±4.93 and 0.86±0.06 mg/kg in Lalganj, Sareni, Khiron, and Control block respectively. The fluoride contents in Cabbage (***Brassica***

***oleracea capitata*)** were ranged from 7.51 to 15.60 mg/kg with mean value 10.22 ±1.82 for Lalganj block, 6.20 to 9.11 mg/kg with mean value 8.00±0.67 for Sareni block and 6.30 to 15.69 mg/kg with mean value 10.95±2.69 for Khiron block while 0.068 to 0.108 mg/kg with mean value 0.09±0.01 in Control block (Bachharawan). The mean moisture contents of Cabbage was found 88 % and the mean fluoride in rhizospheric soil were found 81±1.86, 102±2.31, 254±5.20 and 0.53±0.05 mg/kg in Lalganj, Sareni, Khiron, and Control block respectively.

The concentration of fluoride in Bitter melon **(*Momordica Charntia*)** were ranged from 15.85 to 23.40 mg/kg (19.81 ±1.55) for Lalganj block, 12.20 to 20.21 mg/kg (17.26±1.88) for Sareni block and 12.30 to 23.49 mg/kg (17.85±3.21) for Khiron block while 0.12 to 0.14 mg/kg (0.13 ±0.01) found in Control block (Bachharawan). The mean moisture contents of Bitter melon was found 72 % and fluoride in rhizospheric soil were found 172±8.76, 222±4.49, 245±520 and 0.22±0.10 mg/kg in Lalganj, Sareni, Khiron, and Control block respectively. The average concentration of fluoride in Spinach (***Spinacea oleracea*)** was reported 25.24±0.76, 24.47±0.64, 26.02±0.35 and 0.07±0.01 in Lalganj, Sareni Khiron block and control block with ranged from 23.18 to 26.40 mg/kg, 23.40 to 26.20 mg/kg, 24.96 to 26.49 mg/kg and 0.05 to 0.08 mg/kg, respectively. The mean moisture contents of Spinach was found 80 % and the mean fluoride in rhizospheric soil were found 226±5.0, 243±10.48, 277±4.67 and 0.51±0.06 mg/kg in Lalganj, Sareni, Khiron, and Control block respectively. The fluoride contents in Radish **(*Raphanus sativus*)** were ranged from 42.55 to 51.20 mg/kg with mean value 46.09 ±1.83 for Lalganj block, 40.20 to 51.29 mg/kg with mean value 43.50±1.26 for Sareni block and 40.20 to 51.29 mg/kg with mean value 45.70±3.18 for Khiron block while 0.32 to 0.35 mg/kg with mean value 0.34±0.01 in Control block (Bachharawan). The mean moisture contents of Radish was found 93 % and the mean fluoride in rhizospheric soil were found 352±5.77, 306±4.93, 318±3.18 and 3.03±0.78 mg/kg in Lalganj, Sareni, Khiron, and Control block respectively.

The concentration of fluoride in Fenugreek (***Trigonella foenum-graecum***) were ranged from 2.37 to 3.50 mg/kg (3.06 ±0.26) for Lalganj block, 1.60 to 3.41 mg/kg (2.70±0.41) for Sareni block and 1.70 to 3.59 mg/kg (2.60±0.52) for Khiron block while Control block (Bachharawan) was BDL. The mean moisture contents of Fenugreek was found 90 % and fluoride in rhizospheric soil were found 45±4.37, 322±6.12, 74±5.04 and 0.08±0.08 mg/kg in Lalganj, Sareni, Khiron, and Control block respectively. The average concentration of fluoride in Bottle gourd (***Lagenaria siceraria***) was reported 7.57±0.51, 7.10±0.93, 5.97±0.74 and BDL in Lalganj, Sareni Khiron block and control block with ranged from 6.38 to 8.61 mg/kg, 4.60 to 8.61 mg/kg, 4.70 to 7.29 mg/kg and BDL, respectively. The mean moisture contents of Bottle gourd was found 93 % and the mean fluoride in rhizospheric soil were found 72±2.19, 103±2.40, 50±2.96 and 0.11±0.11 mg/kg in Lalganj, Sareni, Khiron, and Control block respectively. The fluoride contents in Brinjal (***Solanum melongena***) were ranged from 17.85 to 19.11 mg/kg with mean value 18.34±0.28 for Lalganj block, 17.50 to 18.41 mg/kg with mean value 18.02±0.20 for Sareni block and 17.60 to 19.29 mg/kg with mean value 18.42±0.48 for Khiron block while 0.62 to 0.68 mg/kg with mean value 0.65±0.01 in Control block (Bachharawan). The mean moisture contents of Brinjal was found 93 % and the mean fluoride in rhizospheric soil were found 160±4.67, 209±5.93, 316±6.98 and 5.00±0.42 mg/kg in Lalganj, Sareni, Khiron, and Control block respectively.

The concentration of fluoride in Broad bean (***Vicia faba***) were ranged from 1.08 to 2.41 mg/kg (1.53 ±0.31) for Lalganj block, 0.90 to 1.51 mg/kg (1.23±0.13) for Sareni block and 1.0 to 2.59 mg/kg (1.77±0.45) for Khiron block while BDL in Control block (Bachharawan). The mean moisture contents of Sem was found 90% and fluoride in rhizospheric soil were found 26±2.08, 49±4.06, 59±1.73 and 0.19±0.10 mg/kg in Lalganj, Sareni, Khiron, and Control block respectively. The average concentration of fluoride in Wild carrot (***Daucus carota***) was reported 27.09±1.02, 25.78±0.55, 27.27±1.66 and 0.56±0.01 in Lalganj, Sareni Khiron block and control block with ranged from 25.34 to 30.01 mg/kg, 24.30 to 26.71 mg/kg, 24.40 to 30.19 mg/kg and 0.53 to 0.01 mg/kg, respectively. The mean moisture contents of Wild carrot was found 86 % and the mean fluoride in rhizospheric soil were found 228±3.33, 205±8.29, 355±17.95and 4.57±0.32 mg/kg in Lalganj, Sareni, Khiron, and Control block respectively. The fluoride contents in Chaulai (***Amaranthus spinosus***) were ranged from 1.98 to 6.51 mg/kg with mean value 3.29 ±1.08 for Lalganj block, 2.20 to 2.41 mg/kg with mean value 2.30±0.04 for Sareni block and 2.28 to 6.69 mg/kg with mean value 4.49±1.24 for Khiron block while 0.52 to 0.58 mg/kg with mean value 0.55±0.01 in Control block (Bachharawan). The mean moisture contents of Chaulai was found 87% and the mean fluoride in rhizospheric soil were found 38±1.15, 40±2.60, 251±9.07 and 1.40±0.31 mg/kg in Lalganj, Sareni, Khiron, and Control block respectively.

Table 4.48: Descriptive statistics of Total fluoride contents rhizoshpheric soil of Lalganj and Sareni block.

Sl. No.	Rhizoshpheric soil of Plant	Lalganj block				Sareni block			
		Avg	Min	Max	SEM	Avg	Min	Max	SEM
1	***Oryza Sativa L***	32	26	36	2.96	38	36	42	2.00
2	***Triticum vulgaris***	52	42	62	5.77	51	45	54	2.85
3	***Cajanus cajan***	141	136	145	2.65	80	76	86	2.96
4	***Vigna mungo***	112	106	116	3.06	71	68	76	2.40
5	***Lycopersicon esculentum***	119	115	121	1.86	80	76	88	3.84
6	***Capsicum annuam***	115	106	123	4.91	90	89	92	0.88
7	***Solanum tuberosum***	130	126	134	2.31	101	93	105	3.84
8	***Abelmoschus esculentus***	175	165	182	5.13	120	116	123	2.03
9	***Brassica oleracea botrytis***	143	134	152	5.21	92	88	98	3.18
10	***Luffa aegyptiaca***	76	69	86	5.24	48	43	52	2.73
11	***Coriandrum sativum***	72	70	75	1.45	51	46	56	2.91
12	***Trichosanthes dioica***	137	133	143	2.96	94	88	99	3.22
13	***Allium cepa***	193	188	201	4.18	202	189	216	7.81
14	***Chenopodium album***	87	78	98	5.93	119	114	125	3.22
15	***Brassica oleracea capitata***	81	79	85	1.86	102	98	106	2.31
16	***Momordica Charntia***	172	156	186	8.76	222	216	231	4.49
17	***Spinacea oleracea***	226	216	231	5.00	243	230	264	10.48
18	***Raphanus sativus***	352	342	362	5.77	306	298	315	4.93
19	***Trigonella foenum-graecum***	45	40	54	4.37	322	312	333	6.12
20	***Lagenaria siceraria***	72	68	75	2.19	103	98	106	2.40
21	***Solanum melongena***	160	153	169	4.67	209	198	218	5.93
22	***Vicia faba***	26	23	30	2.08	49	42	56	4.06
23	***Daucus carota***	228	221	231	3.33	205	189	216	8.29
24	***Amaranthus spinosus***	38	36	40	1.155	40	36	45	2.60

Data in mg/kg except ***SEM(Standard Error Mean)***

Table 4.49: Descriptive statistics of Total fluoride contents rhizoshpheric soil of Khiron and Control block.

Sl.No.	Scientific Name	Khiron block				Bachhrawan block (Control)			
		Avg	Min	Max	SEM	Avg	Min	Max	SEM
1	***Oryza Sativa L***	66	56	76	5.77	2.07	1.50	2.60	0.32
2	***Triticum vulgaris***	72	56	86	8.76	0.23	BDL	0.36	0.11
3	***Cajanus cajan***	93	84	99	4.49	9.40	8.00	11.00	0.87
4	***Vigna mungo***	69	56	82	7.51	0.60	0.52	0.67	0.04
5	***Lycopersicon esculentum***	94	86	102	4.63	0.81	0.77	0.89	0.04
6	***Capsicum annuam***	69	52	85	9.56	0.90	0.86	0.95	0.03
7	***Solanum tuberosum***	87	77	99	6.49	5.57	4.90	6.20	0.38
8	***Abelmoschus esculentus***	89	81	97	4.62	0.76	0.51	0.88	0.12
9	***Brassica oleracea botrytis***	86	73	102	8.45	4.17	3.10	5.21	0.61
10	***Luffa aegyptiaca***	46	36	56	5.77	0.41	0.00	0.69	0.21
11	***Coriandrum sativum***	68	66	72	1.86	0.11	BDL	0.33	0.10
12	***Trichosanthes dioica***	94	89	99	2.91	2.07	1.60	2.30	0.23
13	***Allium cepa***	222	215	232	5.13	1.53	0.90	2.10	0.35
14	***Chenopodium album***	255	246	263	4.93	0.86	0.76	0.98	0.06
15	***Brassica oleracea capitata***	254	245	263	5.20	0.53	0.45	0.62	0.05
16	***Momordica Charntia***	245	236	254	5.20	0.22	0.02	0.32	0.10
17	***Spinacea oleracea***	277	268	284	4.67	0.51	0.41	0.62	0.06
18	***Raphanus sativus***	318	314	324	3.18	3.03	1.60	4.30	0.78
19	***Trigonella foenum-graecum***	74	67	84	5.04	0.08	BDL	0.23	0.08
20	***Lagenaria siceraria***	50	46	56	2.96	0.11	BDL	0.33	0.11
21	***Solanum melongena***	316	302	325	6.98	5.00	4.20	5.60	0.42
22	***Vicia faba***	59	56	62	1.73	0.19	BDL	0.32	0.10
23	***Daucus carota***	355	321	382	17.95	4.57	4.20	5.20	0.32
24	***Amaranthus spinosus***	251	234	265	9.07	1.40	0.80	1.80	0.31

Data in mg/kg except ***SEM(Standard Error Mean)***

Table 4.50: Descriptive statistics of Fluoride contents in different dietary sources in Lalganj and Sareni block

Sl. No.	Scientific Name	Lalganj block				Sareni block			
		Avg	Min	Max	SEM	Avg	Min	Max	SEM
1	***Oryza Sativa L***	0.54	0.50	0.62	0.03	0.49	0.42	0.54	0.03
2	***Triticum vulgaris***	2.66	2.28	3.31	0.24	2.43	2.10	2.71	0.13
3	***Cajanus cajan***	9.22	8.18	10.11	0.41	8.58	7.10	9.51	0.55
4	***Vigna mungo***	5.98	5.53	6.41	0.20	5.71	5.00	6.21	0.27
5	***Lycopersicon esculentum***	7.96	7.71	8.41	0.16	7.91	7.20	8.41	0.27
6	***Capsicum annuam***	7.40	6.90	7.91	0.21	7.20	6.10	7.91	0.41
7	***Solanum tuberosum***	8.36	8.18	8.61	0.09	8.40	8.20	8.61	0.08
8	***Abelmoschus esculentus***	14.11	13.07	15.60	0.54	13.40	12.30	14.11	0.41
9	***Brassica oleracea botrytis***	8.36	7.80	8.91	0.23	8.45	7.80	8.91	0.24
10	***Luffa aegyptiaca***	2.06	1.31	2.91	0.38	1.98	0.50	2.91	0.55
11	***Coriandrum sativum***	2.78	2.52	3.11	0.15	2.65	2.26	2.96	0.15
12	***Trichosanthes dioica***	6.77	5.51	7.81	0.52	6.81	5.20	7.81	0.60
13	***Allium cepa***	18.60	17.51	19.11	0.38	18.00	16.20	19.11	0.67
14	***Chenopodium album***	12.91	11.13	16.11	1.10	11.52	10.10	12.41	0.52
15	***Brassica oleracea capitata***	10.22	7.51	15.60	1.82	8.00	6.20	9.11	0.67
16	***Momordica Charntia***	19.81	15.85	23.40	1.55	17.26	12.20	20.21	1.88
17	***Spinacea oleracea***	25.24	23.18	26.40	0.76	24.47	23.40	26.20	0.64
18	***Raphanus sativus***	46.09	42.55	51.20	1.83	43.50	40.10	45.51	1.26
19	***Trigonella foenum-graecum***	3.06	2.37	3.50	0.26	2.70	1.60	3.41	0.41
20	***Lagenaria siceraria***	7.57	6.38	8.61	0.51	7.10	4.60	8.61	0.93
21	***Solanum melongena***	18.34	17.85	19.11	0.28	18.02	17.50	18.41	0.20
22	***Vicia faba***	1.53	1.08	2.41	0.31	1.23	0.90	1.51	0.13
23	***Daucus carota***	27.09	25.34	30.01	1.02	25.78	24.30	26.71	0.55
24	***Amaranthus spinosus***	3.29	1.98	6.51	1.08	2.30	2.20	2.41	0.04

Data in mg/kg except ***SEM(Standard Error Mean)***

Table 4.51: Descriptive statistics of Fluoride contents in different dietary sources in Khiron and Bachhrawan block

Sl. No..	Scientific Name	Khiron block				Bachhrawan block (Control)			
		Avg	Min	Max	SEM	Avg	Min	Max	SEM
1	***Oryza Sativa L***	0.59	0.51	0.71	0.05	0.04	0.02	0.05	0.01
2	***Triticum vulgaris***	2.82	2.20	3.49	0.36	BDL	BDL	BDL	-
3	***Cajanus cajan***	8.72	7.20	10.29	0.88	0.11	0.098	0.128	0.01
4	***Vigna mungo***	5.82	5.10	6.59	0.42	0.08	0.062	0.112	0.01
5	***Lycopersicon esculentum***	7.57	7.30	7.89	0.16	0.06	0.042	0.072	0.01
6	***Capsicum annuam***	6.82	6.20	7.49	0.36	0.06	0.034	0.094	0.01
7	***Solanum tuberosum***	8.37	8.30	8.49	0.05	0.06	0.046	0.076	0.01
8	***Abelmoschus esculentus***	14.00	12.40	15.69	0.92	0.14	0.084	0.22	0.03
9	***Brassica oleracea botrytis***	7.80	7.71	7.9	0.05	0.07	0.051	0.081	0.01
10	***Luffa aegyptiaca***	1.02	0.60	1.49	0.25	BDL	BDL	BDL	-
11	***Coriandrum sativum***	2.80	2.36	3.29	0.26	BDL	BDL	BDL	-
12	***Trichosanthes dioica***	5.47	5.30	5.69	0.10	0.09	0.074	0.114	0.01
13	***Allium cepa***	17.77	16.30	19.29	0.85	0.08	0.056	0.116	0.01
14	***Chenopodium album***	13.22	10.20	16.29	1.75	0.08	0.066	0.086	0.01
15	***Brassica oleracea capitata***	10.95	6.30	15.69	2.69	0.09	0.068	0.108	0.01
16	***Momordica Charntia***	17.85	12.30	23.49	3.21	0.13	0.12	0.14	0.01
17	***Spinacea oleracea***	26.02	24.96	26.49	0.35	0.07	0.05	0.08	0.01
18	***Raphanus sativus***	45.70	40.20	51.29	3.18	0.34	0.32	0.35	0.01
19	***Trigonella foenum-graecum***	2.60	1.70	3.59	0.52	BDL	BDL	BDL	-
20	***Lagenaria siceraria***	5.97	4.70	7.29	0.74	BDL	BDL	BDL	-
21	***Solanum melongena***	18.42	17.60	19.29	0.48	0.65	0.62	0.68	0.01
22	***Vicia faba***	1.77	1.00	2.59	0.45	BDL	BDL	BDL	-
23	***Daucus carota***	27.27	24.40	30.19	1.66	0.56	0.53	0.58	0.01
24	***Amaranthus spinosus***	4.49	2.28	6.69	1.24	0.55	0.52	0.58	0.01

Data in mg/kg except ***SEM(Standard Error Mean)***

4.4.2 Moisture contents in plant samples

Table 4.52: Moisture contents and the Intake Frequency (IF) in dry weight of food and vegetables in classified age groups

Sl.No.	Scientific Name	Moisture Contents (%)	3 to 6 years I F (g_{dwt}/day)	7 to 18 years I F (g_{dwt}/day)	19 to 70 years I F (g_{dwt}/day)
1	***Oryza Sativa L***	15	42	212.5	297.5
2	***Triticum vulgaris***	22	39	117	156
3	***Cajanus cajan***	15	21	42.5	64.75
4	***Vigna mungo***	12	22	44	66
5	***Lycopersicon esculentum***	93	1	1.05	1.4
6	***Capsicum annuam***	62	0.6	0.76	1.14
7	***Solanum tuberosum***	80	5	15	20
8	***Abelmoschus esculentus***	42	58	85.5	114
9	***Brassica oleraceabotrytis***	86	3.5	7	10.5
10	***Luffa aegyptiaca***	76	6	18	24
11	***Coriandrum sativum***	80	3	3	3
12	***Trichosanthes dioica***	78	5.5	16.5	22
13	***Allium cepa***	90	0.5	2	2.5
14	***Chenopodium album***	89	2.8	5.5	8.25
15	***Brassica oleracea capitata***	88	3.6	6	9
16	***Momordica Charntia***	72	7	21	28
17	***Spinacea oleracea***	88	3.6	9	12
18	***Raphanus sativus***	93	6.8	3.5	5.25
19	***Trigonella foenum-graecum***	90	3	5	7.5
20	***Lagenaria siceraria***	93	2.1	3.5	7
21	***Solanum melongena***	93	1.75	3.5	5.25
22	***Vicia faba***	90	2.5	5	7.5
23	***Daucus carota***	86	4.2	7	14
24	***Amaranthus spinosus***	87	3.25	6.5	9.75

4.5.3 EDI value of fluoride (CTE and RME scenario).

Table 4.53: In EDI Calculation, Average and 90 % concentration of fluoride were used for CTE and RME scenario

Sl.no.	Scientific Name	Lalganj		Sareni		Khiron		Control	
		CTE	RME	CTE	RME	CTE	RME	CTE	RME
1	***Oryza Sativa L***	0.54	0.62	0.49	0.54	0.59	0.71	0.04	0.05
2	***Triticum vulgaris***	2.66	3.31	2.43	2.71	2.82	3.49	BDL	BDL
3	***Cajanus cajan***	9.22	10.11	8.58	9.51	8.72	10.29	0.11	0.13
4	***Vigna mungo***	5.98	6.41	5.71	6.21	5.82	6.59	0.08	0.11
5	***Lycopersicon esculentum***	7.96	8.41	7.91	8.41	7.57	7.89	0.06	0.07
6	***Capsicum annuam***	7.40	7.91	7.20	7.91	6.82	7.49	0.06	0.09
7	***Solanum tuberosum***	8.36	8.61	8.40	8.61	8.37	8.49	0.06	0.08
8	***Abelmoschus esculentus***	14.11	15.6	13.40	14.11	14.00	15.69	0.14	0.22
9	***Brassica oleraceabotrytis***	8.36	8.91	8.45	8.91	7.80	7.9	0.07	0.08
10	***Luffa aegyptiaca***	2.06	2.91	1.98	2.91	1.02	1.49	BDL	BDL
11	***Coriandrum sativum***	2.78	3.11	2.65	2.96	2.80	3.29	BDL	BDL
12	***Trichosanthes dioica***	6.77	7.81	6.81	7.81	5.47	5.69	0.09	0.11
13	***Allium cepa***	18.60	19.11	18.00	19.11	17.77	19.29	0.08	0.12
14	***Chenopodium album***	12.91	16.11	11.52	12.41	13.22	16.29	0.08	0.09
15	***Brassica oleracea capitata***	10.22	15.6	8.00	9.11	10.95	15.69	0.09	0.11
16	***Momordica Charntia***	19.81	23.4	17.26	20.21	17.85	23.49	0.13	0.14
17	***Spinacea oleracea***	25.24	26.4	24.47	26.20	26.02	26.49	0.07	0.08
18	***Raphanus sativus***	46.09	51.2	43.50	45.51	45.70	51.29	0.34	0.35
19	***Trigonella foenum-graecum***	3.06	3.5	2.70	3.41	2.60	3.59	BDL	BDL
20	***Lagenaria siceraria***	7.57	8.61	7.10	8.61	5.97	7.29	BDL	BDL
21	***Solanum melongena***	18.34	19.11	18.02	18.41	18.42	19.29	0.65	0.68
22	***Vicia faba***	1.53	2.41	1.23	1.51	1.77	2.59	BDL	BDL
23	***Daucus carota***	27.09	30.01	25.78	26.71	27.27	30.19	0.56	0.58
24	***Amaranthus spinosus***	3.29	6.51	2.30	2.41	4.49	6.69	0.55	0.58
25	***Drinking water***	2.20	4.12	1.52	2.10	2.89	9.82	0.65	0.70

Data in ***mg/kg*** *except* ***SEM(****Standard Error Mean) ,F in Drinking water* ***(mg/L)***

Table 4.54: EDI value of fluoride in different dietary source for CTE scenario in Lalgaj and Sareni block.

Scientific Name	Lalganj block Age groups			Sareni block Age groups		
	3-6 y	7-18 y	19-70 y	3-6 y	7-18 y	19-70 y
Oryza Sativa L	0.0022	0.0041	0.0037	0.0020	0.0037	0.0034
Triticum vulgaris	0.0102	0.0112	0.0097	0.0093	0.0102	0.0089
Cajanus cajan	0.0081	0.0060	0.0060	0.0076	0.0056	0.0055
Vigna mungo	0.0018	0.0013	0.0013	0.0018	0.0013	0.0013
Lycopersicon esculentum	0.0008	0.0003	0.0003	0.0008	0.0003	0.0003
Capsicum annuam	0.0004	0.0002	0.0002	0.0004	0.0002	0.0002
Solanum tuberosum	0.0041	0.0045	0.0039	0.0041	0.0045	0.0039
Abelmoschus esculentus	0.0057	0.0031	0.0027	0.0054	0.0029	0.0025
Brassica oleraceabotrytis	0.0001	0.0001	0.0001	0.0001	0.0001	0.0001
Luffa aegyptiaca	0.0001	0.0001	0.0001	0.0001	0.0001	0.0001
Coriandrum sativum	0.0008	0.0003	0.0002	0.0008	0.0003	0.0002
Trichosanthes dioica	0.0002	0.0002	0.0002	0.0002	0.0002	0.0002
Allium cepa	0.0009	0.0013	0.0011	0.0009	0.0013	0.0011
Chenopodium album	0.0001	0.0001	0.0001	0.0001	0.0000	0.0000
Brassica oleracea capitata	0.0002	0.0001	0.0001	0.0001	0.0001	0.0001
Momordica Charntia	0.0004	0.0005	0.0004	0.0004	0.0004	0.0004
Spinacea oleracea	0.0008	0.0008	0.0007	0.0008	0.0007	0.0006
Raphanus sativus	0.0029	0.0005	0.0005	0.0027	0.0005	0.0005
Trigonella foenum-graecum	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000
Lagenaria siceraria	0.0001	0.0001	0.0001	0.0001	0.0001	0.0001
Solanum melongena	0.0010	0.0008	0.0007	0.0010	0.0008	0.0007
Vicia faba	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000
Daucus carota	0.0010	0.0006	0.0008	0.0010	0.0006	0.0008
Amaranthus spinosus	0.0001	0.0001	0.0001	0.0001	0.0001	0.0000

Table 4.55: EDI value of fluoride in different dietary source for CTE scenario in Khiron and control block.

	Khiron block Age groups			Bachhrawan (Control) Age groups		
Scientific Name	**3-6 y**	**7-18 y**	**19-70 y**	**3-6 y**	**7-18 y**	**19-70 y**
Oryza Sativa L	0.0024	0.0045	0.0041	0.0002	0.0003	0.0003
Triticum vulgaris	0.0108	0.0119	0.0103	BDL	BDL	BDL
Cajanus cajan	0.0077	0.0057	0.0056	0.0001	0.0001	0.0001
Vigna mungo	0.0018	0.0013	0.0013	BDL	BDL	BDL
Lycopersicon esculentum	0.0007	0.0003	0.0002	BDL	BDL	BDL
Capsicum annuam	0.0004	0.0002	0.0002	BDL	BDL	BDL
Solanum tuberosum	0.0041	0.0045	0.0039	BDL	BDL	BDL
Abelmoschus esculentus	0.0057	0.0031	0.0027	0.0001	BDL	BDL
Brassica oleraceabotrytis	0.0001	0.0001	0.0001	BDL	BDL	BDL
Luffa aegyptiaca	0.0000	0.0000	0.0000	BDL	BDL	BDL
Coriandrum sativum	0.0008	0.0003	0.0002	BDL	BDL	BDL
Trichosanthes dioica	0.0001	0.0002	0.0001	BDL	BDL	BDL
Allium cepa	0.0009	0.0013	0.0010	BDL	BDL	BDL
Chenopodium album	0.0001	0.0001	0.0001	BDL	BDL	BDL
Brassica oleracea capitata	0.0002	0.0001	0.0001	BDL	BDL	BDL
Momordica Charntia	0.0004	0.0004	0.0004	BDL	BDL	BDL
Spinacea oleracea	0.0009	0.0008	0.0007	BDL	BDL	BDL
Raphanus sativus	0.0028	0.0005	0.0005	BDL	BDL	BDL
Trigonella foenum-graecum	0.0000	0.0000	0.0000	BDL	BDL	BDL
Lagenaria siceraria	0.0001	0.0001	0.0001	BDL	BDL	BDL
Solanum melongena	0.0011	0.0008	0.0007	BDL	BDL	BDL
Vicia faba	0.0000	0.0000	0.0000	BDL	BDL	BDL
Daucus carota	0.0010	0.0006	0.0008	BDL	BDL	BDL
Amaranthus spinosus	0.0001	0.0001	0.0001	BDL	BDL	BDL

Table 4.56: EDI value of fluoride in different dietary source for RME scenario in Lalgaj and Sareni block.

Scientific Name	Lalganj			Sareni		
	3-6 y	7-18 y	19-70 y	3-6 y	7-18 y	19-70 y
Oryza Sativa L	0.0034	0.0063	0.0057	0.0030	0.0055	0.0050
Triticum vulgaris	0.0169	0.0185	0.0161	0.0138	0.0152	0.0132
Cajanus cajan	0.0119	0.0088	0.0087	0.0112	0.0083	0.0082
Vigna mungo	0.0026	0.0019	0.0019	0.0026	0.0019	0.0018
Lycopersicon esculentum	0.0011	0.0004	0.0004	0.0011	0.0004	0.0004
Capsicum annuam	0.0006	0.0003	0.0003	0.0006	0.0003	0.0003
Solanum tuberosum	0.0056	0.0062	0.0054	0.0056	0.0062	0.0054
Abelmoschus esculentus	0.0084	0.0045	0.0039	0.0076	0.0041	0.0036
Brassica oleraceabotrytis	0.0002	0.0001	0.0001	0.0002	0.0001	0.0001
Luffa aegyptiaca	0.0001	0.0001	0.0001	0.0001	0.0001	0.0001
Coriandrum sativum	0.0012	0.0004	0.0003	0.0012	0.0004	0.0003
Trichosanthes dioica	0.0003	0.0003	0.0002	0.0003	0.0003	0.0002
Allium cepa	0.0013	0.0018	0.0015	0.0013	0.0018	0.0015
Chenopodium album	0.0001	0.0001	0.0001	0.0001	0.0001	0.0001
Brassica oleracea capitata	0.0003	0.0002	0.0002	0.0002	0.0001	0.0001
Momordica Charntia	0.0007	0.0008	0.0007	0.0006	0.0007	0.0006
Spinacea oleracea	0.0012	0.0011	0.0009	0.0012	0.0011	0.0009
Raphanus sativus	0.0042	0.0008	0.0008	0.0038	0.0007	0.0007
Trigonella foenum-graecum	0.0001	0.0000	0.0000	0.0001	0.0000	0.0000
Lagenaria siceraria	0.0002	0.0001	0.0002	0.0002	0.0001	0.0002
Solanum melongena	0.0015	0.0011	0.0010	0.0014	0.0010	0.0010
Vicia faba	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000
Daucus carota	0.0015	0.0009	0.0012	0.0014	0.0008	0.0011
Amaranthus spinosus	0.0003	0.0002	0.0002	0.0001	0.0001	0.0001

Table 4.57: EDI value of fluoride in different dietary source for CTE scenario in Khiron and control block.

Scientific Name	Khiron			Control		
	3-6 y	**7-18 y**	**19-70 y**	**3-6 y**	**7-18 y**	**19-70 y**
Oryza Sativa L	0.0039	0.0072	0.0066	0.0003	0.0005	0.0005
Triticum vulgaris	0.0178	0.0196	0.0169	BDL	BDL	BDL
Cajanus cajan	0.0121	0.0089	0.0089	0.0002	0.0001	0.0001
Vigna mungo	0.0027	0.0020	0.0019	BDL	BDL	BDL
Lycopersicon esculentum	0.0010	0.0004	0.0003	BDL	BDL	BDL
Capsicum annuam	0.0006	0.0003	0.0003	BDL	BDL	BDL
Solanum tuberosum	0.0056	0.0061	0.0053	BDL	0.0001	BDL
Abelmoschus esculentus	0.0085	0.0046	0.0040	0.0001	0.0001	0.0001
Brassica oleraceabotrytis	0.0002	0.0001	0.0001	BDL	BDL	BDL
Luffa aegyptiaca	0.0001	0.0001	0.0001	BDL	BDL	BDL
Coriandrum sativum	0.0013	0.0005	0.0003	BDL	BDL	BDL
Trichosanthes dioica	0.0002	0.0002	0.0002	BDL	BDL	BDL
Allium cepa	0.0013	0.0018	0.0015	BDL	BDL	BDL
Chenopodium album	0.0001	0.0001	0.0001	BDL	BDL	BDL
Brassica oleracea capitata	0.0003	0.0002	0.0002	BDL	BDL	BDL
Momordica Charntia	0.0007	0.0008	0.0007	BDL	BDL	BDL
Spinacea oleracea	0.0012	0.0011	0.0009	BDL	BDL	BDL
Raphanus sativus	0.0043	0.0008	0.0008	BDL	BDL	BDL
Trigonella foenum-graecum	0.0001	0.0000	0.0000	BDL	BDL	BDL
Lagenaria siceraria	0.0002	0.0001	0.0001	BDL	BDL	BDL
Solanum melongena	0.0015	0.0011	0.0010	BDL	BDL	BDL
Vicia faba	0.0000	0.0000	0.0000	BDL	BDL	BDL
Daucus carota	0.0015	0.0009	0.0012	BDL	BDL	BDL
Amaranthus spinosus	0.0003	0.0002	0.0002	BDL	BDL	BDL

4.5.4 HI of fluoride (CTE and RME scenario) in classified age groups.

Table 4.58: Hazard Indexing of fluoride with reference to CTE scenario in classified age groups of Lalganj tehsil.

Dietary item	Lalganj			Sareni			Khiron			Control		
	3-6 y	7-18 y	19-70 y	3-6 y	7-18 y	19-70 y	3-6 y	7-18 y	19-70 y	3-6 y	7-18 y	19-70 y
Rice	0.0022	0.0041	0.0037	0.0020	0.0037	0.0034	0.0024	0.0045	0.0041	0.0002	0.0003	0.0003
Wheat	0.0102	0.0112	0.0097	0.0093	0.0102	0.0089	0.0108	0.0119	0.0103	0.0000	0.0000	0.0000
Pulses	0.0100	0.0074	0.0073	0.0093	0.0069	0.0068	0.0095	0.0070	0.0069	0.0001	0.0001	0.0001
Vegitables	0.0199	0.0136	0.0122	0.0192	0.0132	0.0118	0.0197	0.0134	0.0120	0.0002	0.0001	0.0001
Drinking water	0.1157	0.1269	0.1650	0.0800	0.0877	0.1140	0.1521	0.1667	0.2168	0.0342	0.0375	0.0488
$EDI_{cumulative}$	0.1580	0.1632	0.1979	0.1199	0.1217	0.1449	0.1945	0.2035	0.2501	0.0347	0.0380	0.0492
HI	2.6342	2.7201	3.2983	1.9977	2.0292	2.4144	3.2425	3.3920	4.1675	0.5783	0.6339	0.8208
$HI_{cumulative\ 3\text{-}70\ y}$	8.6525			6.4412			10.8020			2.0330		

Table 4.59: Hazard Indexing of fluoride with reference to RME scenario in classified age groups of Lalganj tehsil.

Dietary item	Lalganj			Sareni			Khiron			Control		
	3-6 y	7-18 y	19-70 y	3-6 y	7-18 y	19-70 y	3-6 y	7-18 y	19-70 y	3-6 y	7-18 y	19-70 y
Rice	0.0034	0.0063	0.0057	0.0030	0.0055	0.0050	0.0039	0.0072	0.0066	0.0003	0.0005	0.0005
Wheat	0.0169	0.0185	0.0161	0.0138	0.0152	0.0132	0.0178	0.0196	0.0169	0.0000	0.0000	0.0000
Pulses	0.0145	0.0107	0.0106	0.0137	0.0101	0.0100	0.0148	0.0109	0.0108	0.0002	0.0001	0.0001
Vegitables	0.0290	0.0196	0.0176	0.0270	0.0185	0.0166	0.0288	0.0194	0.0174	0.0003	0.0002	0.0002
Drinking water	0.2168	0.2377	0.3090	0.1105	0.1211	0.1575	0.5168	0.5665	0.7365	0.0368	0.0404	0.0525
$EDI_{cumulative}$	0.2807	0.2929	0.3589	0.1680	0.1705	0.2022	0.5822	0.6236	0.7882	0.0376	0.0413	0.0533
HI	4.6777	4.8810	5.9825	2.8008	2.8410	3.3706	9.7031	10.3933	13.1363	0.63	0.69	0.89
$HI_{cumulative\ 3\text{-}70\ y}$	15.54			9.01			33.23			2.20		

Table 4.60: Total fluoride contents in fodder part of crops in Lalganj tehsil.

Scientific Name	Fodder part	Lalganj block			Sareni block			Khiron block		
		Mean	Min	Max	Mean	Min	Max	Mean	Min	Max
Oryza Sativa L	Stem+Leaf	1.9	1.6	2.3	1.2	0.9	1.5	5.7	1.8	4.2
Vigna mungo	Stem+Leaf	27.4	24.8	30.6	17.1	15.7	18.0	37.3	32.0	41.6
Triticum vulgaris	Stem+Leaf	12.6	9.3	15.9	15.2	11.7	20.8	17.6	15.0	20.3
Sorghum bicolor	Stem+Leaf	12.3	8.0	17.0	13.3	12.0	15.0	18.0	15.0	21.0
Zea mays	Stem+Leaf	4.1	3.2	5.0	5.6	4.5	7.2	4.2	4.5	10.8

*Data in **mg/kg** except **SEM(**Standard Error Mean)*

CHAPTER 5

DISCUSSION

5.1 Drinking water suitability

5.1.1 Physicochemical perspective

The groundwater quality of Lalganj tehsil was diverse among all block with reference hydrochemical data. In this research, groundwater hydrochemical data (Physicochemical and metallic constituent) were compared with **IS (10500)** and **WHO (2011)** for suitability of groundwater to drinking purpose. The groundwater samples of Lalganj were free form order and turbid in few locations. Groundwater of Lalganj tehsil was alkaline in nature. The average pH in pre-monsoon and post-monsoon 2016-17 was observed 7.33 and 7.95, respectively (**Table 4.47**), both are within the safe limit (6.5-8.5), prescribed for drinking water by **IS (2012)** and **WHO (2011).** Most of the parameter affected by pH but it has not undeviating effect on human health. Murkiness of water because of dissolving of various suspended partials makes turbid to water and decrease the quality of water. The groundwater was found to be more turbid at groundwater sample of Bahara village in Lalganj block, Ram khera, Dhagaicha, Champtpur manakhera, Rampur khurd, Rasoolpur and Samodha villages in Sareni block and Kanha mau in Khiron block during 2016. In 2017, turbidity of groundwater sample had found more turbid in Dhagaicha, Sareni khurmi, Champtpur manakhera, Rampur khurd, and Samodha villages of Sareni block.

Total dissolve solid indicates total load of inorganic matter. The average TDS in groundwater samples of Lalganj, Sareni and Khiron block were found within the permissible limit (2000) of Indian standard and WHO but TDS value higher than acceptable limits (500). In the year of 2016 and 2017, the maximum value was observed in groundwater sample of Bahara village of Lalganj block, Sabji barua village of Sareni block and Khapura village of Khiron block. High concentration of TDS may be causing a gastrointestinal irritation in the consumers. Electrical conductivity in groundwater sample defer in location vice and EC of water totally depends TDS.

The daily consumption of drinking water have more than 45mg/L nitrate can causes to a number of health disorders, such as Blue baby syndrome or Methaemoglobinaemia in infants, gastric cancer, goitre, birth malformations and hypertension **(Majumdar and Gupta, 2000; Murali et al., 2011).** The concentration of NO_3 in the groundwater samples were 99% and 96% in pre-monsoon and post-monsoon season respectively which was within the limit for drinking water standard (**Table** 1). 10% of samples of Lalganj block, and 2.5% samples of Sareni block and 15% of samples of Lalganj block, and 2.5% samples of Sareni block were found beyond the given acceptable limit for nitrate in drinking water during 2016 and 2017. Average concentration of sulphate ions were found 93.86 and 124.36 mg/L in pre-monsoon and post-monsoon 2016-17. Sulphate concentration in 27.5, 15 and 15 % sample of Lalganj, Sareni and Khiron block during 2016 and 27.5, 10 and 10 % sample of Lalganj, Sareni and Khiron block during 2017, which was higher than highest desirable level (200 mg/L) stipulated by IS and WHO. In combination with Na^+ and Mg^{2+}, SO_4^{2-} also exerts a cathartic effect on digestive tracts **(Subba Rao, 2006)**.

Total Alkalinity represents the combination of bicarbonate and carbonate in water. Carbonate was absent in groundwater of the study area. Indian standard suggested that an acceptable limit of total alkalinity in drinking water is 200 mg/L **(Table 5.1)**. The Alkalinity in the groundwater samples of Lalganj tehsil ranged from 156 to 1234 mg/L (**Table** 4.47). 2.5% of samples of Lalganj block, 5% samples of Sareni block and 17.5% of samples of Khiron block was found beyond the given desirable limit (200 mg/L) for alkalinity in drinking water. However, in large quantities, it imparts a bitter taste to the water. Chloride in the groundwater samples of the study area varied from 7 to 658 mg/L. Chloride concentration in 5, 25 and 2.5 % sample of Lalganj, Sareni and Khiron block during 2016 and 10, 35 and 2.5 % sample of Lalganj, Sareni and Khiron block during 2017 were found higher than highest desirable level (250 mg/L) stipulated by IS, yet these values are well within the permissible limit (1000 mg/L). The surplus concentration of Cl^- in drinking water gives a salty taste and had a laxative effect on people not accustomed to it **(Subba Rao, 2006)**.

Total hardness is usually expressed as the total concentration of Ca^{2+} and Mg^{2+} in mg/L equivalent $CaCO_3$. The hardness is most important parameter for domestic and industrial purpose. Sulphates and chlorides of these cations caused permanent hardness which is not removed simply by the boiling. Permanent hardness is also called Total hardness which is generally caused by the presence of chloride and sulphate of calcium and magnesium. In general, surface water is softer than ground water. TH in pre-monsoon and post-monsoon (2016-17) were ranged from 28 to 742 and 26 to 782 mg/L, respectively. WHO and Indian standard suggested that total hardness in drinking water not more than permissible value (600 mg/L) and the desirable value 200 mg/L. The mean value exceeded drinking water standard during both season shown in **Table 4.47**. the groundwater samples of Lalganj, Sareni and

Khiron block classified according to different category was given in **Table 4.1**. More than 90% of the water sample belong to hard (150-300 mg/L) and very hard (>300 mg/L) category in Lalganj and Khiron block but 100% sample in Sareni block. The principal natural sources of hardness in groundwater are sedimentary rocks. In general, hard waters originate in areas with thick topsoil and limestone formations. Calcium (Ca^{2+}) and magnesium (Mg^{2+}), the important parameters for total hardness, Calcium in pre-monsoon and post-monsoon (2016-17) were 42.82 and 47.91 mg/L, while magnesium were 65.66 and 73.49 mg/L, respectively. IS and WHO's suggested the desire level 75 mg/L of calcium in drinking water. Four groundwater samples in Lalganj tehsil in 2016 exceeded the IS and WHO's acceptable limits for calcium in drinking water, while this number was five in Lalganj tehsil for the year of 2017. Magnesium plays important role to activation of enzyme in certain concentration but excessive can consider as laxative agents. The mean value of magnesium was recorded 65.66 and 73.49 mg/L in pre-monsoon and post-monsoon 2016-17, which was higher than the desirable limits of IS and WHO and well within permissible level given in **Table 5.1**.

Na^{+} and K^{+} are naturally occurring in groundwater, it play important role in cation anion balance in cell membrane of animals. In the study area, the concentration of sodium in the groundwater samples were 187.30 and 196.97 in pre-monsoon and post-monsoon 2016-17, which is well within the WHO guideline. And about 67.5% of samples of Lalganj block, 85% samples of Sareni block and Khiron block was found under the given limit of WHO. The mean concentrations of potassium in groundwater were found 17.63 and 15.81 for pre-monsoon and post-monsoon 2016-17 given in **Table 5.1**.

Deficiency of Fluoride in drinking water below 0.6 mg/L contributes to tooth caries while an excess of over 1.5 mg/L causes fluorosis **(WHO 2011 and IS 2012)** but within the limit, it becomes an important element for protective healthy teeth and bones. F^- Concentration was varied from 0.41 to 17.2 mg/L in the groundwater samples of the study area given in **Table 4.47** (Lalganj tehsil). The concentration of Fluoride in study area were observed more than the permissible limit of IS and WHO standard **(Table 5.1)**. The mean value of fluoride in water samples of Lalganj, Sareni and Khiron block were 2.16, 1.45 and 2.84 mg/L during 2016 and 2.25, 1.60 and 2.94 mg/L which exceeded maximum limit of drinking water of Indian Standard and WHO. 75, 42.5 and 45 % groundwater samples of Lalganj, Sareni and Khiron block exposed the concentration is above the guideline limit (1.50 mg/L) of WHO during 2016 while 80, 57.5 and 57.5 % groundwater sample in 2017.

5.1.2 Metallic perspective

The metals present in the water in colloidal and dissolved phases **(Adepoju-Bello, A. et. al., 2009)**. The individual ingestion of heavy metals via drinking water has been extensively reported **(Muchuveti et al. 2006)**. The concentration of heavy metals is above the acceptable limits that impart pessimistic consequences which decrease the quality of human life, injured the environment and may even be fatal **(Nagajyoti et al., 2010; Arkoch, 2014).** Zinc is an important element and natural appearance in groundwater in the colloidal form of organic complexes or salts **(WHO, 2006)**. **EPA(2013), IS (2012) and WHO (2011)** suggested 5 mg/L or 5000 ppb is the desirable limit of zinc in groundwater. The concentration of Zn in groundwater of Lalganj, Sareni and Khiron were given in **Table 4.19**. The concentration of Zn in the groundwater sample of study area was well within prescribed limits of **IS 10500: 2012** and **EPA 2013**. Iron plays an important function in the formation of the protein haemoglobin, for transporting of oxygen to all cells of the body. **EPA (2013), IS (2012) and WHO (2011)** suggested 0.3 mg/L or 300 ppb of Fe is desirable in drinking water. Deficiency of iron can caused anaemia, fatigue and also influence the immune system. The value of Fe in the groundwater were 252.64, 397and 186 μg/L in 2016 and 218.91, 374 and 167.47 in 2017 given in **Table 4.19** for the groundwater samples of Lalganj, Sareni and Khiron block. The concentration of Fe in groundwater of Sareni block has above the acceptable limit of drinking water. Long term intake of surplus concentration of iron containing drinking water may cause to liver diseases.

Nickel naturally presents in soil and widely distributed with depending on past geology. It is essential to human beings and plants but significant amount such as more than 30 mg may cause changes in muscle, brain, lungs, liver, kidney and can also cause cancer, tremor, paralysis and even death **(WHO, 1973)**. The mean concentrations of nickel was found 5.76±0.87, 7.34±1.17, 5.95±0.73 μg/L in groundwater samples for Lalganj, Sareni and Khiron block in 2016 and 7.96±1.06, 9.17±1.19, 8.19±0.73 μg/L in 2017. The mean concentrations of nickel in all block within the guideline value of Indian Standard (IS 2012).

Deficiency of Manganese can cause fatness, glucose intolerance while excess amount can cause respiratory tract and in the brains, it also cause Parkinson and lung embolism **(Barik et al., 2005** and WHO, 2011**)**. Manganese is most important required elements for proper functioning of many cellular enzymes in human and animals such as carboxylases, pyruvate and manganese superoxide dismutase. It can also activate many enzymes like hydrolases, decarboxylase, kinases and transfererases etc **(IPCS, 2002)**. WHO and IS suggested the desirable concentration of Mn in drinking water is 0.1 mg/L or 100 µg/L. In this investigation, the average value of Manganese found 14.11±2.01, 21.37±2.82 and 35.67±4.88 µg/L during year of 2016 for Lalganj, Sareni, Khiron and 15.43±1.96, 23.36±2.91, 38.42±4.97 in 2017. The concentration of manganese in groundwater was found under the limits.

The surplus concentration of lead produce harmful effects on human i.e. central nervous system, urinary genital system, peripheral nervous system **(EPA 2013)**, kidney tissue gets damaged due to decrease in blood haemoglobin **(Niazi, et. al., 2009)**. The average concentrations of lead in groundwater samples of study area found well within prescribed limit of WHO, IS and EPA during both year. 6%, 15% and 15% of the groundwater samples of the Lalganj, Sareni and Khiron block exceeded the acceptable limit of WHO and IS during 2016 while 6%, 7.5% and 12.5% groundwater samples in 2017. The effects of lead are shown primarily in nervous haemopoietic, urinary and genital systems. Kidney tissue gets damage due to decrease in blood haemoglobin **(Niazi, et al. 2009).** Copper is an essential element and good for health in very small quantities however excessive dose is potentially toxic risks to living being if there is too little or too much of copper in the environment. Large doses of copper irritate stomach **(Bruins et. al., 2000).** The average concentrations of Copper in the groundwater samples of Lalganj, Sareni, Khiron during both year **(Table 4.19)** under the acceptable limit 50 ppb **(IS 10500 : 2012)**. 100% groundwater samples of all block found under the acceptable limit of IS, WHO and EPA standard during both year.

Cd, Cr, and Pb are the mostly significant of every metal as they are toxic and Kidneys are the main target organs. Intake of higher concentration of cadmium containing drinking water may affect to blood, lungs, bones and teeth **(Subba Rao,**

2011). The average concentrations of cadmium in groundwater samples of study area found well within prescribed limit of WHO, IS and EPA during both year. The concentration of cadmium in 5% and 2.5% of the groundwater samples of the Sareni and Khiron block exceeded the acceptable limit of WHO and IS during 2016 while 2.5% groundwater samples of both block in 2017. Chromium responsible for ulcer, kidney damage, Allergic dermatitis, classified as a human carcinogen, comes from release by steel and pulp industries and weathering of deposited mineral **(WHO 2006; EPA 2013)**. Chromium is generally dispersed in the outer layer earth's. The average value of Chromium found 0.43±0.10, 0.62±0.15, and 0.52±0.16 μg/L for Lalganj, Sareni, and Khiron during year of 2016. In 2017, the mean concentration of Chromium in groundwater observed 0.42±0.10, 0.57±0.13, and 0.51±0.15 ppb for Lalganj, Sareni, and Khiron The concentration of Chromium in the groundwater sample of study area was well within prescribed acceptable limits of **IS 10500: 2012, EPA 2013 and WHO, 2011** given in **Table 4.19**. 100 % groundwater samples of all block were found under the acceptable limits of Cr in drinking water.

Table 5.1: Drinking water specification of Indian standard and WHO standard

Parameter	Units	(IS;10500) 2012		(WHO, 2011)	
		Desirable limits	Maximum permissible limits	Desirable limits	Maximum permissible limits
pH	-	6.5	8.5	6.5	8.5
EC	µS/cm	-	-	-	1500
TDS	mg/L	500	2000	500	1500
Turbidity	NTU	5	15	-	-
Total Alkalinity	mg/L	200	600	-	-
Total Hardness	mg/L	200	600	200	600
Cl	mg/L	250	1000	250	600
NO_3	mg/L	-	45	-	45
SO_4	mg/L	200	400	200	400
F	mg/L	1	1.5	0.60	1.5
Ca	mg/L	75	250	75	200
Mg	mg/L	30	100	50	150
Na	mg/L	-	-	-	200
K	mg/L	-	-	-	10

5.2 Fluoride in groundwater

5.2.1 Source of fluoride in groundwater of study area

Lalganj tehsil is part of Indo-Gangetic region. **Pandey (2001)** and **CGWB, 1999** also reported, the highest contents of fluoride in groundwater of Indo- Gangetic alluvium region because geology of the area is devoid of any hard rocks, alluvium is quaternary and recent deposits of mud, sand, and clays with fluoride bearing minerals i.e. muscovite and biotite. **Pandey (2001)** and CGWB, 1999 also reported, the highest contents of fluoride in groundwater of Indo- Gangetic alluvium region because of the alluvium devoid of any hard rocks, quaternary and recent deposits of mud, sand, and clays. **Kumar, and Saxena, 2011** and **Kanaujia, S. et al., 2013** found that groundwater of Upstream (Unnao) and downstream (Dalmau block) also contaminated with fluoride. **Kumar, S. and Saxena A., 2011**, studied the quality and type of sediment deposits in study area and the fundamental mineralogy of the sand fraction confirmed the dominant presence of fluoride containing minerals i.e. muscovite, feldspar and biotite as major minerals.

Geology of the region is dominantly consisted of mud with pockets of sand. Sand fraction made up fluoride containing minerals like muscovite or mica [$(KF)_2$ $(Al_2O_3)_3$ $(SiO_2)_6$ (H_2O)], biotite [$K(Mg,Fe)_3$ $(AlSi_3O_{10})$ $(F,OH)_2$] and tourmaline [$(Mg,Li,Al,Fe^{2+},Fe^{3+})_3$ $(Al, Mg)_6$ $(BO_3)_3$ Si_6O_{18} $(OH,O,F)_4$]. Along with several accessory minerals like and garnet, quartz, epidote, microcline, chlorite, plagioclase, hornblende, kyanight and a few opaque minerals are also present in pockets of sand **(Kumar and Saxena, 2011)**.

5.2.2 Temporal variation of fluoride in groundwater

Temporal variation of fluoride in groundwater in Lalganj, Sareni and Khiron block were given in **Figure 4.24** to **Figure 4.36**. The concentration of fluoride in groundwater was observed increasing trends pre to post monsoon. This trends is due dissolution of fluoride from fluoride bearing minerals. **Subba Rao 2003** also found increasing trends of fluoride during pre to post-monsoon. Elevated concentration of bicarbonate and sodium in groundwater can causes to high fluoride level because significant positive correlation of F^- with bicarbonate and sodium. Dissolution capacity of fluoride increase with increase the concentration of sodium due to ions exchange between calcium and sodium **(Gao et al., 2007, 2013; Singraja et al., 2013; Rao et al., 2015)**.Maximum variation noted in Alampur, Bhavanipur, Chilaula and Bahara village of Lalganj block, Sabji barua, Poore chheetu and Ghure mau village of Sareni block, Hariram Khera , Kanha mau and Khapura village of Khiron block.

5.2.3 Spatial variation of fluoride in groundwater

Spatial variation of fluoride in groundwater in Lalganj, Sareni and Khiron block were given in **Figure 4.27** to **Figure 4.30**. The concentrations of fluoride in different villages of all block were given in **Figure 4.24** to **Figure 4.36**. The higher Fluoride concentration found in Aihar and Lalganj tehsil area of Lalganj block have more than 4 mg/L, Lakhanapur, Jhampur and Sabji baruwa in Sareni block have more than 2 mg/L, more than 15 mg/L found in Sindhaure and Khapura village of Khiro block. The North part of Khiron block have beneficial category of fluoride level while south west part elevated level of fluoride in groundwater. The south east part of Khiron block have high concentration of fluoride may cause dental and skeletal effect on inhabitants. East part of Lalganj block has more than 4mg/L fluoride and another part have more than the drinking water standard. Samples collected from hand pumps (up to 150 feet) were found high fluoride as compare to bore well (more than 250 feet) proposed to distribution of fluoride bearing minerals found in high up to 250 feet depth.

Table 5.2: Level of Fluoride in drinking water and health outcome on human

F^- mg/L	Health Outcome	References
<0.5	Dental Caries	WHO 2011
0.6-1.0	Safe limit	IS 2012
1.1-3.0	Dental fluorosis (discoloration, mottling and pitting of teeth)	USPHS 1987
3.1-6.0	Skeletal fluorosis (stiffened and brittle bones and joints)	Meenakshi and Maheshwari 2006
Above 6.1	Crippling fluorosis (adverse changes in bone Structure). Deformities in knee and hip bones unable to walk or stand in straight	IPCS, 1984

5.2.4 Generate thematic map of fluoride content in groundwater

Both, excess and less amount of fluoride causes to negative health effect on humans given in **Table 5.2**. Based on **Table** 5.2, thematic maps were generated for groundwater sampling locations in study area were given in **Figure 4.27 to Figure 4.30** during pre and post-monsoon 2016-17. **Figure 5.1** demonstrate fluorosis effect of excessive fluoride on Inhabitant of Lalganj tehsil

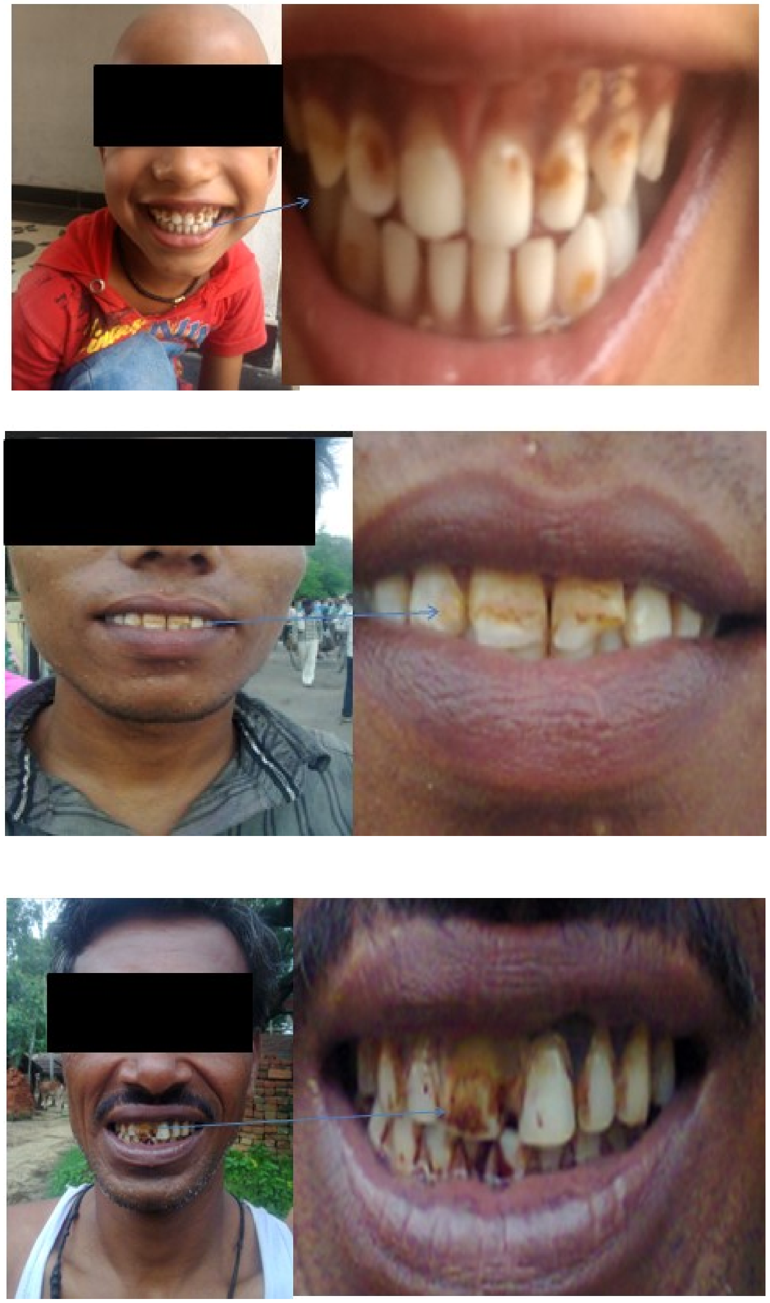


Figure 5.1: Fluorosis effect of excessive fluoride on Inhabitant of Lalganj tehsil

5.2.5 Correlation of fluoride with hydrochemical facies

Spearman correlation analysis were applied for determination of correlation between fluoride and other variable given in **Table 4.43** and **Table 4.44** for pre-monsoon and post-monsoon data of Lalganj tehsil. In pre-monsoon season, correlation significant at 0.01 levels with EC, TDS, total alkalinity, sulphate and sodium while in post-monsoon, significant with EC, TDS, TA, Cl^-, sulphate and sodium. Positive correlation significant at 0.05 level with pH, chloride but negative correlation with calcium in pre-monsoon season. Fluoride shows significant positive correlation with pH and bicarbonate and similar correlation found pH and bicarbonate infiltration of rain water react with soil CO_2, and form HCO_3^- and rises the pH of water **(Berner and Berner 1987;Subba Rao et al., 2017)**.

Higher value of total alkalinity and pH in groundwater during post-monsoon season as compare to pre-monsoon clearly signify a greater affinity of fluoride with pH and TA, due to activeness of the operation mechanism more during post-monsoon **(Subba Rao 2011)**. Similar study also carried by several researchers and proposed to ion exchange, dissolution and evaporation as the major factors to increase the concentration of fluoride in groundwater **(Handa 1975; Gupta et al.,1986; Apambire et al., Saxena and Ahmad 2001; Subba Rao 2003, 2009; Subba and John Devadas 2003; Chae et al., 2007; Jain 2005, Amini et. al., 2008)**

Therefore, negative correlation founds with TH, Calcium and magnesium because of high concentration of bicarbonate reacts with calcium, then form calcium carbonate and precipitates with decreasing the TH level. Similar results also found by **Subba Rao et al., (2011)**

5.3 Spatial and temporal variation in groundwater quality

For the assessment of groundwater quality based on hydrochemical data and it seasonal and spatial variability is one of the specific objectives of the present research. The groundwater samples collected during pre and post-monsoon of years 2016 and 2017 have been estimated for physicochemical and metallic content and result reported in **Table 4.20 to Table 4.23.** Seasonal variation in the concentration of physic-chemical fancies in groundwater is mainly due to dissolution of ions from soil or minerals during monsoon **(Subba rao, 2006)**.

5.3.1 Spatial and temporal variation physicochemical variable

The pH stands for "potential of hydrogen". The pH value is expressed as the negative logarithm of the hydrogen ion concentration. The concentration of hydrogen in a solution is important factor in maintaining the carbonate and bicarbonate levels in water. The value of pH stoops on various geochemical reactions because mostly chemical reactions are dependent on pH of the solution (Drever, 1997). It also controls the reaction involving trace metals and other organic compounds. It is known that pH of water have below 5.0 give sore tastes and above 8.5 produce alkaline taste. In the study area, pH was found alkaline in nature.

The mean pH values were 7.58, 7.43 and 7.52 recorded in pre-monsoon and 8.04, 7.92 and 7.52 in Lalganj Sareni and Khiron block during post-monsoon 2016. The pH of groundwater was 7.99, 7.84 and 7.99 in pre-monsoon and 7.80, 7.99 and 7.84 in post-monsoon 2017 for Lalganj, Sareni, and Khiron. pH of groundwater during post-monsoon was higher as compare to pre-monsoon during both year, because of dissolution of ion increase the pH of water. Temporal variations of pH in groundwater sample with sampling location are given in **Figure 4.1**. The mean value of pH in pre-monsoon and post-monsoon during both years given in **Table 4.47** shows that pH from pre to post monsoon was significant changes. Similar variation also studied in pH of groundwater by **Jayalakshmi et al., (2014) and Subba Rao 2011.** The pH of groundwater gives an important fragment of information in many types of geochemical balance or minerals solubility **(Hem 1985)**.

High values of Total Dissolve Solid in drinking water are not harmful for normal human beings but it may affect kidney and heart patient (Gupta et. al, 2004). High solids containing water may cause laxative or constipation effects (Kumaraswamy, 1999). WHO and IS suggested that acceptable limits of TDS for drinking water is 500 mg/L and maximum permitted limit is extended up to 2000 mg/L. The mean concentration of TDS (914, 964 and 784 mg/L in Lalganj, Sareni and Khiron block) and EC (1256, 1323 and 1052 μS/cm in Lalganj, Sareni and Khiron block) during pre-monsoon 2016 and both are increase in post-monsoon, TDS (1041, 1107 and 959 mg/L in Lalganj, Sareni and Khiron block) and EC (1445, 1533 and 1356 μS/cm in Lalganj, Sareni and Khiron block).

EC totally depends on TDS and TDS depend on all dissolved ions. EC in groundwater due to saline bed on salt containing minerals found in geology of area **(Yadana 2012).** Concentration of TDS in post-monsoon was found higher than pre-monsoon due to minerals dissolve during monsoon and affect the water quality. Temporal variations of EC and TDS in groundwater sample with sampling location are given in **Figure 4.2 and Figure 4.3.** The TDS in groundwater during post-monsoon significant loaded as compares to pre-monsoon because of leaching of minerals by recharging of water **(Subba Rao 2006)**. Long turn consumption of elevated concentration of TDS containing water may cause to chronic, acute and carcinogenic effects in humans and corrosive effects in metallic surface **(Sajil Kumar et al., 2013)**.

Turbidity is a measure of the cloudiness of water due to suspended particles dissolution from inorganic particles (silt, clay and natural chemical compounds like calcium carbonate and micro-organism). Water becomes poor quality, smell or taste due to Organic and inorganic particles in ground water. The mean value of turbidity in groundwater samples during pre-monsoon season (2016 and 2017), was observed in Lalganj block (1 and 3 NTU), Sareni block (3 and 4 NTU) and Khiron block (2 and 3 NTU) and post-monsoon season it was observed in Lalganj block (3 and 3 NTU), Sareni block (5 and 5 NTU) and Khiron block (3 and 4NTU). Temporal variations of turbidity in groundwater sample with sampling location are given in **Figure 4.4.** The turbidity in groundwater samples during post-monsoon found more than pre-monsoon due to dissolution of clay particles from soil during percolation of rain water via soil. Hardness is defined as the concentration of multivalent metallic cations in solutions.

The principle hardness causing cations are divalent calcium, magnesium, strontium, iron, manganese and anions are bicarbonate, sulphate, chloride, nitrate and silicate. Hardness when caused because of bicarbonates and carbonates of these cations is called temporary hardness which can be removed by boiling. Total Hardness in pre-monsoon 2016 ranged from 28 to 490 mg/L with mean value 273±28.0 mg/L for Lalganj block, 196 to 688 mg/L with mean value 316±32.14 mg/L for Sareni block and 42 to 368 mg/L with mean value 197±17.5 mg/L for Khiron block, while the concentration was increased in post-monsoon season were ranged from 26 to 497 mg/L with mean value 292±27.62 mg/L for Lalganj block, 214 to 736 mg/L with mean value 331±31.60 mg/L for Sareni block and 60 to 436 mg/L with mean value

220±18.84 mg/L for Khiron block. The mean value of TH during pre-monsoon 2017, it was observed 297±27.26 mg/L with ranged from 39 to 489 mg/L for Lalganj block, 337±31.60 mg/L with ranged from 219 to 742 mg/L for Sareni block and 227±18.73 mg/L with ranged from 64 to 442 mg/L for Khiron block, while the concentration was increased in post-monsoon season were ranged from 36 to 516 mg/L with mean value 323±26.90 mg/L for Lalganj block, 236 to 782 mg/L with mean value 367±32.27 mg/L for Sareni block and 68 to 456 mg/L with mean value 243±18.91 mg/L for Khiron block. In terms of the degree of hardness, groundwater of Lalganj tehsil was commonly classified in to four categories are given in **Table** 4.12. Temporal variations of total hardness in groundwater sample with sampling location are given in **Figure 4.6** The concentration of TH in postmonsoon > pre-monsoon such variation of TH suggests differential dissolution of calcium and magnesium in the groundwater samples during monsoon (**Jayalakshmi et al., 2014).** The hardness of water reflects the nature of geological formation with which it has been in contact. Determination of hardness serves as a basis for routine control of softening process.

5.3.2 Spatial and temporal variation in cations of groundwater

Among the cations (Na^{+}, K^{+}, Ca^{2+} and Mg^{2+}) ions ranged from 120 to 344, 9 to 46, 7 to 97 and 5 to 179 mg/L with mean value 1 84, 21, 43 and 66 mg/L during pre-monsoon 2016 for Lalganj block and the concentration observed in post-monsoon ranged from 131 to 316, 5 to 43, 16 to 105, and 34 to 147 mg/L with mean value 194, 16, 49 and 68 mg/L respectively. The mean concentration of Na^{+}, K^{+}, Ca^{2+} and Mg^{2+} in pre-monsoon 2017 was 201, 15, 48, and 65 while in post-monsoon, it was 210, 16, 54 and 74 mg/L in Lalganj block. The mean value of Na^{+}, K^{+}, Ca^{2+} and Mg^{2+} ions in Sareni block was observed 173, 26, 46 and 78 mg/L during pre-monsoon 2016 and in post-monsoon 2016, it was 186, 19, 51 and 83, mg/L respectively. The mean value 195, 19, 50 and 81 mg/L during pre-monsoon 2017 in groundwater of Sareni block and the concentration observed in post-monsoon 2017, it was found 205, 20, 54 and 89 mg/L. Temporal variations of Ca^{2+}, Na^{+}, Mg^{2+} and K^{+} in groundwater sample with sampling location are given in **Figure 4.11 to Figure 4.14**.

The average concentration of Na^{+}, K^{+}, Ca^{2+} and Mg^{2+} ions in Khiron block was analyzed 179, 13, 32 and 47 mg/L during pre-monsoon 2016 and in post-monsoon 2016, it was 186, 11, 37 and 60 mg/L respectively. The mean value 192, 12, 37 and 58 mg/L during pre-monsoon 2017 in groundwater of Sareni block and the concentration observed in post-monsoon 2017, it was found 202, 13, 42 and 68 mg/L respectively. The data of cations (Na^{+}, Ca^{2+} and Mg^{2+}) showing increasing trends in pre-monsoon to post-monsoon season. The concentration of all cations was found in following decreasing order ($Na^{+} > Mg^{2+} > Ca^{2+} > K^{+}$) in Lalganj, Sareni and Khiron block while the order change in control area ($Na^{+} > Ca^{2+} > Mg^{2+} > K^{+}$) due to elevated concentration of fluoride form insoluble CaF_2 and decease the concentration of Calcium.

Ca^{2+} and Mg^{2+} both are the important parameters for total hardness. Calcium ion play important role for development of teeth and bones. The effect of high calcium in water is development of scales in the water supply pipes which checks the water conducting volume of the same. The sources of calcium in the groundwater of the area are the disintegration of minerals like epidote, hornblende, fluorapatite, calcite, fluorite and feldspars. Calcium ion is directly influenced by fluoride because of its strong reactivity. Magnesium ion is important for bone density. High value of magnesium ions is responsible for scaling of water in pipes. Magnesium bearing minerals in the geology of the study region, they contribute magnesium to the groundwater. It is the vital constituent of chlorophyll and dominant cations in groundwater. The magnesium concentration increases in post-monsoon due to weathering process of minerals **(Srinivasamoorthy et al., 2008)**. Ferromagnesian minerals are responcible for elebveted concentration of calcium and magnesium in groundwater **(Hem 1991; Drever1997; Subba Rao 2014a; Subba Rao 2014b and 2014c)**. Calcium in groundwater was not found significant variation because of fluoride rich minerals in geology, calcium ions precipitated as a $CaCO_3$ **(Subba Rao 2017)**.

Sodium contents present in water combined with chloride and sulphate that make the water salty in taste and unfit for human consumption. Sodium naturally occurs in water up to 200 mg/L (Todd 1980) and WHO (2008) has also recommended this as tolerable limits of sodium present in water for drinking purposes. The concentration of sodium significantly change from pre to post-monsoon (**Table 4.47).** Dissolution of mineral with rain water can causes to excessive load of sodium in post-monsoon season **(Edmond 1983; Subba Rao 2014)**. Potassium plays significant role in various metabolic and physiological activities in flora and fauna (Lewis, 1997) its intoxication is rare as it is quickly excreted in nonappearance of pre existing kidney damage **(Gosselin et al., 1984 and Gennari, 2002). Subba Rao 2006** also found variation of Na^+ in groundwater pre to post monsoon is more prominent due to their higher solubility **(Hem 1991; Subba Rao et al., 2017; Drever 1997)**.

5.3.3 Spatial and temporal variation in anions of groundwater

Total Alkalinity is the sum of bicarbonate and carbonate, carbonate is absent in groundwater of study area. Carbonates, bicarbonates, thus formed are dissolved to yield hydroxyl ions. Bicarbonates and carbonates attribute the alkalinity of the water **(Jain et al. 2010)** and Indian standard suggested that an acceptable limit of Alkalinity for the drinking water is 200 mg/L. However, high concentration gives bitter taste to water. **Jayalakshmi et al., 2014** found in carbonate base material in the geology that can cause higher alkalinity in groundwater. Temporal variations of HCO_3 in groundwater sample with sampling location are given in **Figure 4.5** In this study, alkalinity significant change in post-monsoon as compare to pre monsoon shown in **Figure 4.55** and **Table 4.21 to Table 4.21**. Carbon dioxide, it's also called "neutralizing capacity of water" dissolve in rain water that percolate during monsoon and increase the alkalinity of groundwater during post-monsoon **(Laluraj and Gopinath 2006)**. Natural weathering or dissolution of mineral during rainy season increase the concentration of bicarbonate **(Drever, 1988; Stumm and Morgan 1996)**.

Chloride is a widely distributed element in rocks and its shows high affinity with sodium; as a result, its concentration is high in ground waters. Chloride is considered to be pollution indicating parameter beyond which it imparts a salty taste to the water. Seasonal variations of Cl^- in groundwater sample with sampling location are given in **Figure 4.7**. Surplus concentration of chloride appears from man-made source such as addition of bleaching agents, septic tank nearby sapling location and could be associated with chloride rich minerals (Karthikeyan et al., 2010). Chloride is the leading ion in all anions due to leaching from soil and domestic sewage and septic tanks (subba rao, 2014). Ranjana and Naverathna, 2011 have found elevated concentration of chloride in course of the river as a result of infiltration discharge of domestic effluents and sewage. The variation of Cl^- in groundwater pre to post monsoon is more prominent due to their higher solubility **(Todd 1980; Subba Rao 2006 Subba Rao 2014)**.

The sulphate concentration > 250 mg/L can cause gastrointestinal irritation mainly present of Mg^{2+} and Na^+ in groundwater. The water containing sulphate ions beyond 1000 mg/L have purgative effects (Singh and Garg, 2012). Seasonal variations of SO_4^{2-} in groundwater sample with sampling location are given in **Figure 4.9.** Sulphate occurs naturally in water as result of leaching from gypsum and other common minerals. plains. Excessive application of fertilizers, dissolution of gypsum and oxidation of sulphides plays significance roles to enrichments of sulphate in groundwater. Nitrate is the highest oxidisable form of nitrogen and occurs in trace quantity in surface water but may attain high levels in some ground water. In ground water, nitrates may find through leaching from soil and at times by contamination. The main contributor for nitrate in ground water is the nitrogenous fertilizers of both animal and chemical origin and also sewage and industrial waste.

This study found significant variation in concentration of sulphate and Nitrate in groundwater from pre to post-monsoon due to natural leaching process and excessive application of fertilizers also increase the level. During monsoon season NO_3^- and SO_4^{2-} dissolve in surface water which is easily go down or percolated and elevated the concentration of both ions. Seasonal variations of NO_3 in groundwater sample with sampling location are given in **Figure 4.8**. Similery also found surplus concentration of sulphate and nitrate in groundwater near the Indo-Gangetic by Chakrapani, 2005 and Valdiya, 1980. There is a significant variation of NO_3^- and

SO_4^{2-}, reflecting the involvement of anthropogenic sources like excessive use of fertilizers in agricultural activities, leakage of septic tank, and domestic wastes (Subba Rao, 2014; Todd, 1980; Subba Rao, 2006).

5.3.3 Spatial and temporal in metallic ingredient

Metals comes in to groundwater by naturals process like oxidation reduction reaction, ion-exchange process and weathering of minerals etc. it depends on various hydrological, topographical factors that control the process **(Roger, 1996; Magdalena 2005, and Drever, 1997).** Metals have density ≥ 5 g cm^{-3} are called heavy metals **(Lee, 2000 and Christensen et al., 2001)**. Deficiency and excess of heavy metals can cause health related issue in human being **(CPCB, 2001)**

A probable explanation is that the metal constituents in groundwater samples controlled by the geology or aquifer itself, as metal constituents in the aquifer usually will be diluted in the rainy season as compared with summer season because of the maximum groundwater recharge in the rainy season (Huang et al., 2008; Mehrabi et al., 2015).

Zinc is an important element for humans, animal and plants and natural appearance in groundwater in the colloidal form of organic complexes or salts (WHO, 2006). It is also microelement and an important cell component in several enzymes (Day 2000). Infants need 3–5 mg/day, adult males 15 mg/day, pregnant and lactating females 20– 25 mg Zn/day. However, heavy doses of Zn salt (165 mg) for 26 days causes vomiting, renal damage, cramps (Krishnaan et al., 1988). The chief sources of Zn in groundwater govern by ions exchanges and oxidation- reduction reaction from smithsonte ($ZnCO_3$), Zinc oxide (ZnO_2), and sphalerite (Z Fe)S minerals present in the geology. Seasonal variations of Zn in groundwater sample with sampling location are given in **Figure 4.15** special distribution given in **Table 4.10 to Table 4.18**.. The mean concentration of Zn in pre-monsoon 62.02, 142.82 and 78.39 µg/L in Lalganj, Sareni and Khiron block while the concentration were decrease in post-monsoon season were 58.41, 139.07 and 75.13 µg/L. Decreasing trends of Zn in pre to post-monsoon suggested that dilution of Zn after rain fall.

Iron is an important component and also essential element for human body. It mostly exists in nature in the form of oxides. Iron is the second most abundant metallic element in the Earth's crust; it is an essential element in the metabolism of animals and plants. Standard of iron in drinking water is 0.3 mg/l. Long term consumption of drinking water with high concentration of iron may cause to liver diseases. Iron is widely dispersed, naturally occurring metals in the upper layer of the earth. Weathering processes along with corrosion products release iron in water (Smith, 1981). Natural process such as oxidation-reduction reaction and ion exchange process release the Fe^{2+} level into groundwater **(Roger, 1996 and Drever 1997)**.

Seasonal variation of iron in groundwater was given in **fiure 4.16** special distribution given in **Table 4.10 to Table 4.18**.. The average concentrations of iron in groundwater samples of Lalganj block, Sareni block, and Khiron block, decrease order. Results suggested that the dilution factors can causes decreasing of iron. **Abdul Jamil et al., (2012)** higher concentration of iron found in clay soil and present of iron-reducing bacteria **(Tyrell and Housewam, 1997)**. Long term intake of surplus concentration of iron containing drinking water may cause to liver diseases. Iron plays an important function in the formation of the protein haemoglobin, for transporting of oxygen to all cells of the body.

Nickel naturally presents in soil and widely distributed with depending on past geology and manmade activities like industrialization, dumping of sewage, use of pesticides and fertilizers etc. distributes in the environment. Ni releases in groundwater from naturally weathering of soil and predominantly present in groundwater an the ion $Ni(H_2O)_6^{2+}$ at pH ranged from 5 to 9 (IPCS, 1991) . Nickel is present in very small concentrations in surface and groundwater in the form of soluble salts. Nickel found in various mineral such as annaberegite, millerite, pentalandite, ullamanite, nikline, gersdorffite **(Wadia 1978)**

Seasonal variation of iron in groundwater was given in **Figure 4.17** special distributions given in **Table 4.10 to Table 4.18**. The average concentrations of nickel in groundwater samples of Lalganj block, Sareni block, and Khiron block were increase order in pre to post-monsoon. Results suggested that the dissolution of nickel with rain water because it is naturally-occurring elements can be found universally in the soil. Rain water acidic in nature and disoolve it when contact with nickel containing clay particle or minerals.

Manganese is one of the most important trace elements; naturally-occurring elements can be found universally in the soil, air and water but abundant in the earth's crust. It is an essential for human and mammals and component of over 100 minerals but does not found in elemental form (ATSDR, 2000 and WHO, 1974). The deficiency of Mn is rare because it is presents in many common foodstuff. Mn can be present in eleven oxidative state but most important Mn compounds are those that contain $Mn^{2+,}$ Mn^{4+} or Mn^{7+}(USEPA, 1994).

Seasonal variation of Manganese in groundwater was given in **Table 4.18 and** special distribution given in **Table 4.10 to Table 4.18**. The average concentrations of Manganese in groundwater samples of Lalganj block, Sareni block, and Khiron block, increase order in pre to post-monsoon. Results suggested that the dissolution of Manganese with rain water because it is naturally-occurring elements can be found universally in the soil. Rain water acidic in nature and disoolve it when contact with Manganese containing clay particle or minerals.

The sources of lead introduce into the segments of environment from anthropogenic sources i.e. electrodes, batteries, newsprint and pigments in paints and natural dissolution of minerals. The sources of lead introduce into the segments of environment from anthropogenic sources i.e. electrodes, batteries, newsprint and pigments in paints and natural dissolution of minerals. The surplus concentration of lead produce harmful effects on human i.e. central nervous system, brain, urinary genital system, peripheral nervous system (EPA 2013), kidney tissue gets damaged due to decrease in blood haemoglobin (Niazi, et. al., 2009 and Subba Rao, 2011).

Seasonal variation of lead in groundwater was given in **Figure 4.18 and** special distribution given in **Table 4.10 to Table 4.18**. The average concentrations of Manganese in groundwater samples of Lalganj block, Sareni block, and Khiron block were 2.91, 3.94 and 5.69 for pre-monsoon 2016 while 2.60, 3.39 ad 5.29 in post-monsoon 2016. Similar decreasing trends also found in pre-to post-monsoon 2017. The main reason is that recharge of groundwater during the rainy season **(Huang et al., 2008; Mehrabi et al., 2015)**.

It is one of the most micronutrients for living being but elevated amount can causes several diseases in living being at alkaline pH **(Day 2000; European**

commission report 2002). Cuprites, malachite, chalcopyrite caledorites and chalcophyllite minerals are the chief sources of dissolution of copper in groundwater **(Day 2000)**. The source of copper is the industrial and domestic wastes or addition of salts during water treatment for algal control also contributes to copper level in water **(Sharma et al., 2007)**. Temporal variation of lead in groundwater was given in **Figure 4.21** and special distribution given in **Table 4.10 to Table 4.18**.

In the present study, the average copper content of the water sample found 4.57, 3.15, and 4.08 during pre-monsoon, while 4.02, 2.95, 3.51 in post-monsoon for 2016 Lalganj, Sareni, Khiron block. The concentration of Cu was decrease in post-monsoon of both years due to dilution with rain water.

Cobalt is a heard, silver-gray metal naturally found in earth's crust. It is released in the environment by extraction of ore and natural weathering of rocks. Several researchers found cobalt in groundwater ranged between BDL to 80.1 ppb. Inorganic form of cobalt is a micronutrient for algae, funji and bacteria. Cobalts largely used in manufacturing industries such as manufacture of high-strength alloys, magnetic, ceramic and paints. Cobalt compound such as cobalt (II) aluminates and cobalt silicate are uses for appears in deep blue color in inks, varnishes, glasses, paints and ceremics. WHO and Indian standards are not given specification for limitation of Cobalt in drinking water.

Chromium is widely distributed in the outer layer of the earth's crust and exits in Cr^{2+} and Cr^{6+} valence. Cr(VI) ismore toxic as compare to Cr(III). The maximum concentration of Cr(VI) permitted in domestic water supplies is 0.05 ppm. Food is major sources for intake of Chromium. Chronic exposures to high levels of Cd in food cause bone disorders, including bone fractures and osteoporosis. Intake of higher concentration of chromium in drinking water can causes ulcer, kidney damage, **(Lars Jarup, 2003)** classified as a human carcinogen, allergic dermatitis. Chromium mainly comes from release by steel and pulp industries and natural weathering of deposited mineral (WHO 2006; EPA 2013).

The concentration of Chromium in the groundwater sample of study area was well within prescribed acceptable limits (50 ppb) of IS 10500: 2012 and WHO, 2011 given in **Table 4.23**. 100 % groundwater samples of all block were found under the acceptable limits of Cr in drinking water.

Cadmium is naturally distributed in the earth's crust combination with zinc, minor amount also found in coal and petroleum. Cadmium is released in the river and groundwater water through weathering of rocks, in the air by volcanoes and forest fire and rest of the Cd released in environment by manmade activities such as byproduct of mining, extraction of zinc, lead and copper ore, manufacturing f phosphate fertilizer, batteries etc. geologic deposits of cadmium give out their appearance in groundwater and surface water when contact with soft or acid water like rain water.

5.4 Identification of groundwater type and hydrochemistry chemistry

5.4.1 Identification of groundwater type

Major cation and anion compositions plotted on a piper trilinear diagram **(Figure 4.31 to Figure 4.34)** point out that bicarbonate and chloride were the dominant anions, and sodium was the predominant cation in groundwater of Lalganj tehsil. In the piper diagram no difference observed between Lalganj and Sareni block, while minor difference found in Khiron block as compare to Lalganj and

Sareni block. Piper diagram presenting cation the groundwater of the Lalganj, Sareni and Khiron block was sodium type water indicating the cation exchange of Ca^{2+} with Na^+ while calcium type in control area. More than 75 % sampling locations of Lalganj and Sareni block have observed Na-Mg-HCO_3^- type of groundwater while sampling locations exceeded from 90% in Khiron block. The groundwater type of control area was found Ca-Mg-HCO_3^- type water in more than 80 % sampling locations. This is because of the dissolution of limestone in the sampling location.

5.4.2 Groundwater geochemistry

Carbonate reaction, oxidation reduction reaction and ion-exchanges processes are major geochemical process that may be possible between interaction of water and minerals during and after percolation or recharging of aquifer. The geochemical process depend on depth and types of soil, past geological formation, surface water bodies, organic matter present in soil and distribution of pollutants in atmosphere. Three processes (Carbonate reaction, oxidation reduction reaction and ion-exchanges processes) that control the quality of groundwater.

5.4.2.1 Carbonate reaction

Carbonate minerals mostly present in sedimentary, igneous and metamorphic rocks and easily react with water and carbonate chemistry plays significant role to evaluation of most of the groundwater. Carbonate reaction increase the dissolution of Ca^{2+} and bicarbonate level in groundwater

Carbon dioxide and water reacts and form bicarbonate with releasing Hydrogen ions that ion participate to dissolution of calcite minerals. Mechanisms are given in follows:

$$CO_{2(g)} + H_2O \rightarrow H^+ + HCO_3^- \ldots\ldots\ldots\ldots\ldots\ldots \textbf{eq. I}$$

$$CaCO_3 + H^+ \rightarrow Ca^{2+} + HCO_3^- \text{.......................................eq. II}$$

$$CaCO_3 + CO_{2(g)} + H_2O \rightarrow Ca^{2+} + 2HCO_3^- \text{..................eq. III}$$

5.4.2.2 Oxidation-reduction reaction

An oxidation-reduction is types of chemical reaction process involve a transfer of electron from one ion to another ions between and within to chemical species (set of atoms, ions and molecules) or any change in the oxidation number between participated reactants and the final product.

Reduction and oxidation half- reaction both are common types of redox reaction process. In oxidation half reaction process, reactants oxidised and release electrons (eq. IV), while in reduction half reaction process, reactants gains electrons and forms new product (eq. V and VI). Oxygen is the best example of oxidant and organic matter is reductant in the natural environments.

$$Al_{(S)} \longrightarrow Al^{3+}{}_{(aq)} + 3e^- \text{ ... ... eq. IV}$$

$$Cu^{2+}{}_{(aq)} + 2e^- \longrightarrow Cu_{(s)} \text{..................... eq. V}$$

$$Fe^{3+}{}_{(aq)} + e^- \longrightarrow Fe^{2+} \text{..................... eq. VI}$$

5.4.2.3 Ion-exchange process

Dissolved ions have a tendency to adsorb on surface of sub surface of solid materials or minerals, due to their electrical charge. Iron oxide and clay minerals have more than ions-adsorption capacity as compare to feldspar. The decreasing adsorption capacity of chief cations in water is follows:

$$Ca^{2+} > Mg^{2+} > K^+ > Na^+$$

cations drives in groundwater mainly from interaction with soil, when it seep into surface of minerals, cations (calcium and magnesium ions) superior adsorbed or exchange by another anions. The potassium generally governs from silicate minerals such as nepheline, orthoclase, leucite, boitite and microcline. Sulphate dissolved in groundwater from oxidation of igneous rock and sedimentary rock by bacteria. Chloride is a major component in sea water and also groundwater, halite minerals and atmospheric moisture both are major sources of chloride in groundwater. The fluoride- bearing minerals is primary factor for fluoride contents in groundwater and other factor such as pH, bicarbonate ion, calcium and sodium contents, solubility of minerals are also control the dissolution process. Fluoride in groundwater mainly governs from mineral such as fluorapatite $\{Ca_3(PO)_2 Ca(FCl)_2\}$, muscovite or mica $\{(KF)_2 (Al_2O_3)_3 (SiO_2)_6 (H_2O)\}$, fluorspar or fluorite $\{CaF_2\}$, Cryolite $\{Na_3 AlFPO_6\}$, biotite $\{K (Mg,Fe)_3 (AlSi_3O_{10}) (F,OH)_2\}$, and tourmaline $\{(Mg,Li,Al,Fe^{2+},Fe^{3+})_3 (Al,Mg)_6 (BO_3)_3 Si_6O_{18} (OH,O,F)_4\}$.

Termination of fluoride will be high in the alkaline water (eq.VII)and elevated concentration of sodium bicarbonate in the percolat ion water (eq.VIII).

$$\mathbf{CaF_2 + 2HCO_3{}^-} \rightarrow \mathbf{CaCO_3 +\ 2F^-} +\ CO_2 + H_2O \ldots\ldots\ldots\ldots\ldots\ldots\ldots \mathbf{eq.\,VII}$$

$$\mathbf{CaF_2 + 2NaHCO_3{}^-} \rightarrow \mathbf{CaCO_3 +\ 2Na^+ +\ 2F^-} + CO_2 + H_2O \ldots \mathbf{eq.\,VIII}$$

5.5 Statistical approach for water quality assessment

5.5. 1 Water quality index (WQI):

WQI is a extremely helpful technique for communicating positive or negative information about overall quality of water**.** In this study water quality index has been calculated to assess the suitability or utilizing of groundwater for for drinking purpose. WQI value of groundwater for Lalganj tehsil during pre-monsoon and post-monsoon 2016 was given in **Table 4.24** and during pre-monsoon and post-monsoon 2017 in **Table 4.25**. Acoording to **Sahu and Shekher, (2008),** WQI was classified into five class were presented in **Table 4.26**. Lower rates of WQI conform that the water is free from pollutant or impurities and suitable for drinking purpose. If WQI value higher than 100, it is established that water is contaminated and unsuitable for drinking purpose. The mean values of WQI calculated for Lalganj, Sareni and Khiron block were 64.45, 66.35 and 58.71 respectively. It was ranged from 44.37 to 111.76, 40.19 to 119.62, and 28.75 to 155.24 for Lalganj block, Sareni block and Khiron block during 2016. In 2017, the mean WQI values calculated for Lalganj, Sareni and Khiron block were 68.90, 71.23 and 65.62 respectively with ranged from 47.67 to 114.80 for Lalganj block, 46.58 to 124.66 for Sareni block and 35.71 to 157.44 for Khiron block. The average value was observed below 100 for all block, which shows that the status of water quality of the study area is good.

In the presents study, it is observed that the majority of the groundwater samples classified in "Good" category. The category of groundwater quality is excellent in 22.5, 17.4 and 60 % samples, good in 70, 75 and 30 % and poor in 7.5, 7.5 and 10% samples of Lalganj, Sareni and Khiron block during 2016 while in 2017, the groundwater quality excellent in 10, 5 and 32.5 % samples, good in 80, 85 and 55 %

samples and poor in 10, 10 and 12.5 % samples. In that location where found poor water quality contains higher than standard value, the reflected parameter are particularly TDS, sulphate, nitrate and bicarbonate and hardness. The poor water quality needs special treatment. Therefore, all the groundwater samples of Lalganj tehsil were consider suitable for human and animal consumption except presence of higher concentration of fluoride.

5.5. 1.1 Spatial and temporal variation in WQI.

Spatio-temporal variation in WQI during pre-monsoon and post-monsoon are calculated during both years and presented in **Table 4.24** and **Table 4.25** and **Figure 4.35** to **Figure 4.41**. WQI have been developed in the physic-chemical data of groundwater to indicate overall variation in the quality of groundwater in different season. It is observed from the results that WQI mean value in pre-monsoon and post-monsoon was found 61.21 and 67.70 for Lalganj block, 62.92 and 69.77 for Sareni block, 53.68 and 63.73 in Khiron block during 2016. The maximum temporal variation found in Khiron block and minimum in Lalganj block. The line graph had drawn using WQI values for any changes in all over water quality in groundwater samples of pre-monsoon and post-monsoon season. The graphs are presenting narrow change in groundwater samples of all blocks. The results revels that the majority of the groundwater sampling location classified in "Good" category. The category of groundwater quality is excellent in 9, 7 and 24 sampling location, good class in 28, 30 and 12 sampling location and poor class in 3, 3 and 4 sampling location of Lalganj, Sareni and Khiron block during 2016 while in 2017, the groundwater quality excellent in 4, 2 and 13 sampling location, good class in 32, 34 and 22 sampling location and poor category in 4, 4 and 5 sampling location. **Figure**

4.3.2 and **Figure** 4.3.3 showing the spatial variation of the WQI in the Lalganj tehsil for deferent season.

5.5.2 Heavy metal Pollution Index (HPI)

The mean concentration of metals (Zn, Fe, Ni, Mn, Pb, Cu, Cr, and Cd,) has been taken for HPI calculation and description are shown in **Table 4.27** to **Table 4.32**. HPI Value for groundwater of Lalganj, Sareni and Khiron block during pre and post monsoon 2016 and 2017 were given in **Table 4.33** to **Table 1.35 and Figure 4.42** to **Figure 4.45**. According to Kumar et al 2012, HPI can be categorized in to 3 class based on accounted numerical value are low (<19), medium (19–38) and high (>38) show in **Table 4.36** and another fourth category is critical pollution index having score more than 100 (Mohan et al., 1996). 100, 90 and 95 percent of the groundwater samples found within the low category for Lalganj, Sareni and Khiron while the rest of the groundwater samples calculated under medium categories. Sabji barua and Jalalpur villages of Sareni block were found medium category in HPI classification, while Kanha mau village of Khiron block during all both year. The greatest score (25.22) was calculated for Kanha mau village of Sareni block during pre-monsoon 2016.

5.5.3 Factor Analysis/Principal Component Analysis

Factor Analysis is a multivariate statistical technique, which attempts to extract a lower dimensional linear structure from the data set. These factors can be interpreted in terms of new variables. Factor analysis is a technique that can be used to simplify a dataset **(Cattel 1965)**. The 1st principal component is oriented so that it explains as 70% of the variance as possible in the data sets. Then the 2nd

principal component is oriented to explain remaining 20% variance as possible. Then the 3rd principal component is oriented 10%, etc. In factor analysis one chooses the number of components up front and then seeks to orient them together so that in sum they explain as much of the total variance as possible.

The Principal component analysis or factor analysis is performed to extract the most important factors affecting the water quality which was described by 14 physicochemical parameters from 20 locations during pre-monsoon and post-monsoon season for two year. Due to the complex associations between physicochemical parameters, it was tough to draw clear conclusions but principal component analysis extracts the information and explains the variables. Physicochemical data was generally normalized to drop misclassification due to the diverse order of magnitude and range of variation of the analytical parameter. The rotation of the factors was executed by the Varimax with Kaiser Normalization. Any principal components or factors with an eigen value greater than 1 are considered significant **(Liang, 2000).** In this study remaining factors have eigen value of less than unity. The factor loading includes both positive and negatives loadings. Loadings between 0 to ± 0.49 indicate weak correlation, ± 0.5 to ± 0.74 indicate moderate correlation, if more than ± 0.75 are considered strong correlation and loadings more than ±0.90 indicate the significant or very strong correlation **(Lui et al., 2003)**.

5.5.3.1 Lalganj block

All selected physicochemical parameters were pH, EC, TDS, Turbidity, BiC, TH, Cl^-, NO_3^-, SO_4^{2-}, F^-, Ca^{2+} Mg^{2+}, Na^+, K^+ for FA during pre-monsoon and post-monsoon season. The physicochemical parameters were reduced to 4 PCs having values greater than one and together they account for 78.46% and 80.43% total cumulative variance of the data set for pre and post-monsoon season. Rotation sums of squared loadings are measuring the degree of closeness between the variables and the factors are given in **Table 4.38** and **Figure 4.46**.Eigen value for pre-monsoon and post-monsoon season given in **Figure 4.45**.

In pre-monsoon, FA 1 having 40.775% variance of the total cumulative variance; it has significant loaded with electrical conductivity and total dissolve solids, strong loaded with total hardness, Cl^-, SO_4^{2-}, and Mg^{2+}, while having moderate loaded with total alkalinity. Two processes are proposed, anthropogenic activity like septic tank and excessive using of fertilizers increase the level of chloride and sulphate and second is weathering of dissolution of magnesium containing minerals increase the dissolve solids. FA 2 holds 13.525% variance of the total cumulative variance, has strong loaded with turbidity while moderate loading on pH, total alkalinity and Na^+. FA 3 illustrates 13.082 % variance of the total cumulative variance and it has moderate loaded with total hardness and Ca^+. FA 4 explains 11.078% variance of the total cumulative variance; it has significantly loaded with K^+ while having moderate loaded on Na^+.

During post-monsoon, F 1 is significantly loaded with electrical conductivity and Cl^-, strongly positively loaded with total dissolve solids, total hardness, SO_4^{2-}, and NO_3^- while moderately loaded with total alkalinity, $Mg^{2+}$and Ca^{2+}. These parameters strongly influence the quality of the groundwater with 40.916% variance. F2 contributes 14.975 % variance of the total cumulative variance in the data set and turbidity was significant loaded variables as compare to pre-monsoon while moderate loaded with total alkalinity and Na^+. F 2 explain that dissolution of salt and clay particle can responsible to increase turbidity during after monsoon. F3 strong loaded with F^- and moderate positive loaded with pH, while total hardness shown negative moderate correlation because of due to excessive fluoride in groundwater calcium precipitated as calcium carbonate then decrease the level of permanent hardness. this parameter illuminates 12.692 % variance of the total cumulative variance. F 4 was strong loaded with K^+ and moderately loaded with Mg^{2+} both parameter are accounts 11.846 % variance of the total cumulative variance.

5.5.3.2 Sareni block

Factor analysis was conducted for the determination of major components that affect the quality of groundwater of Sareni block and identification of possible source. All selected physicochemical parameters were pH, EC, TDS, Turbidity, BiC, TH, Cl^-, NO_3^-, SO_4^{2-}, F^-, Ca^{2+} Mg^{2+}, Na^+, K^+ for FA during pre-monsoon and post-monsoon season. The physicochemical parameters were reduced to 4 PCs having values greater than one and together they account for 78.29% and 78.51% total cumulative variance of the data set for pre and post-monsoon season. Rotation sums of squared loadings are given in **Table 4.40** and **Figure 4.48**. Eigenvalues are normally used to define the number of Factors or principal components that can be taken for further study. Eigenvalue for pre-monsoon and post-monsoon season given in **Figure 4.47**.

In pre-monsoon season, first four factors or principal components have eigenvalues greater than or close to unity and explain 31.828%, 25.808%, 11.684% and 8.970% of the total variances of evidence contained in the original dataset for physico-chemical variables (**Table** 34.9). **Factor 1** having Eigen value with 6.909 and 31.828% of the variance, has very strong loadings on total hardness, strong loadings with Ca^{2+} and moderate loadings with electrical conductivity, total dissolve solids, chloride, nitrate, sulphate and magnesium. Factor 2 explains 25.808% of the variance, eigenvalue with 1.738 and has strong loadings on total alkalinity and fluoride, while moderate loadings with electrical conductivity, total dissolved solid, chloride sulphate, and sodium. Factor 3 illustrates 11.684% of the variance and strong positive loaded with potassium and strong negatively correlated with pH. Results suggested that negative correlation of pH increase the dissolution of fluoride from fluoride bearing minerals. Factor 4 shows 8.970% of the variance with strong loaded on turbidity.

During post-monsoon season, first four factors or principal components have eigenvalues greater than or close to unity and explain 39.526%, 20.890%, 9.513% and 8.583% of the total variances of evidence contained in the original dataset for physico-chemical variables (**Table** 34.9). **Factor 1** having Eigen value with 6.887 and 39.525% of the variance, has very significant correlated on total hardness and magnesium, strong correlated with total dissolve solids, chloride and nitrate while moderate loadings with electrical conductivity, sulphate and Ca^{2+}. Results suggested that weathering of magnesium bearing minerals increase the total hardness. Factor 2 explains 20.890% of the variance, eigenvalue with 1.739 and has strong loadings on sodium and fluoride, while moderate loadings with electrical conductivity, total dissolved solid, sulphate and total alkalinity. Results suggested that positive strong correlation of total alkalinity and sodium increase the dissolution probability of fluoride from fluoride bearing minerals and negative correlation with calcium explain that ions exchange with sodium. Similar relation also found by **Subba Rao et al., (2017)**. Factor 3 illustrates 9.513% of the variance and strong positive loaded with potassium and moderate correlated with turbidity.

Factor 4 shows 8.970% of the variance with strong loaded on pH and weak positive correlative with turbidity, nitrate sulphate, chloride. fluoride and sodium.

5.5.3.3 Khiron block

Three principal components of factors are obtained for physicochemical parameter of groundwater (pH, EC, TDS, Turbidity, BiC, TH, Cl^-, NO_3^-, SO_4^{2-}, F^-, Ca^{2+} Mg^{2+}, Na^+, K^+) during pre-monsoon and post-monsoon season years of 2016-17. The physicochemical parameters were reduced to 4 and 3 factors or PCs having values greater than one and together they account for 81.0.44% and 77.706% total cumulative variance of the data set for pre and post-monsoon season. This indicates that and four three main controlling factors influenced the quality of groundwater in the study area. Rotation sums of squared loadings are measuring the degree of closeness between the variables and the factors are given in **Table 4.42** and **Figure 4.50**.Eigen value for pre-monsoon and post-monsoon season given in **Figure 4.49**.

During pre-monsoon, F 1 is significantly loaded with electrical conductivity, total dissolve solid and Na^+, strongly positively loaded with total alkalinity, SO_4^{2-}, and F^- while positive moderately loaded with Cl^- and negative moderately loaded with Ca^{2+}. These parameters strongly influence the quality of the groundwater with 38.308% variance. Results suggested that strongly positive correlated with sodium and total alkalinity and negative correlation with calcium proposed cation exchange with sodium ions, precipitation of calcium ions can causes increase the level of fluoride in groundwater. F2 contributes 22.526 % variance in the data set; total hardness and magnesium was significant loaded variables, while moderate positive loaded with turbidity, chloride and calcium. F3 strong loaded with nitrate and moderate positive loaded with pH. This parameter illuminates 11.476 % variance. F 4 accounts 8.695 % variance and strong loaded with K^+.

In post-monsoon, FA 1 explains 42.846% variance in the data sets; it has significant loaded with electrical conductivity, total dissolve solids total alkailinity and sodium, strong loaded with Cl^-, SO_4^{2-}, and F^-, while having moderate loaded with total alkalinity. Results explaining that elevated level of total alkalinity and sodium sulphate and second is weathering and dissolution minerals increase the dissolve solids as compare to pre-monsoon data. FA 2 holds 19.871% variance in the data sets, has very strong loaded with total hardness and magnesium while strong correlated with calcium. FA 3 illustrates 14.706 % variance of the total cumulative variance and it has strong correrated with K^+ while moderate loaded with turbidity and NO_3^-.

5.5.4 Spearman Correlation Matrix

Correlation analysis is stastical analysis which is a finding of association and interrelation between two variables **(Nair et al., 2005)**. Spearman correlation matrix was applied for in SPSS software, to evaluate the relation within the physicochemical parameter during pre-monsoon and post-monsoon 2016-17 for Lalganj tehsil were given in **Table 4.43 to Table 4.44** and within metallic contents were given in **Table 4.45 to Table 4.56**. In the **Table 4.43 to Table 4.46** significant correlated variable marks with single star (*****) at 0.05 level and double star (******) at 0.01 level. Correlation matrix confirmed that after monsoon, minerals dissolved with water during percolation and increases the concentration of physic-chemical parameter.

5.5.4.1 Correlation within physico-chemical variable

The two-tailed bivariate correlation was carried out to investigate the relationship within physicochemical parameters shown in **Table 4.43 to Table 4.44**. During pre-monsoon and post-monsoon, EC significant positive correlated with TDS, turbidity, TA, TH, Cl^-, NO_3^-, SO_4^{2+}, F^-, Mg^{2+}, Ca^{2+} and Na^+, and potassium; TDS significant correlated with t turbidity, TA, TH, Cl^-, NO_3^-, SO_4^{2+}, F^-, Mg^{2+}, Ca^{2+} and Na^+, and potassium. This types of correlation suggested that presence of all variable in groundwater influence the total dissolve solid and electrical conductivity of water. Similar correlation also found by **Kanmani and Gandhimathi (2013)** in TDS and EC with all variables in groundwater. Turbidity significant correlated with EC, TDS, TA, TH, NO_3^-, Cl^-, SO_4^{2+}, Mg^{2+} , Ca^{2+} and Na^+ during pre-monsoon while in post-monsoon significant correlated with EC, TDS, TA, TH, NO_3^-, Cl^-, SO_4^{2+}, Na^+ and K^+. Chief proposed process is all dissolve variable contribute to make turbid to water. Total alkalinity significant correlated with EC, TDS, turbidity, NO_3^-, Cl^-, SO_4^{2+}, Mg^{2+}, and Na^+ during pre-monsoon while post-monsoon significant correlated with EC, TDS, turbidity, TH, Cl^-, NO_3^-, SO_4^{2+}, F^-, Mg^{2+}, Ca^{2+} and Na^+, and K^+ but negative correlated with pH. Total hardness significant correlated with EC, TDS, turbidity, TA, NO_3^-, Cl^-, SO_4^{2+}, Ca^{2+}, Mg^{2+} and K^+ during pre-monsoon while post-monsoon significant correlated with EC, TDS, turbidity, TA, Cl^-, NO_3^-, SO_4^{2+}, Ca^{2+}, Mg^{2+} and K^+ but significant negative correlated with pH. Good correlation with Ca^{2+}, Mg^{2+} , TA and Cl^- is because of that variables are major component of total hardness **(Marbooti et al., 2015).**

Chloride significant correlated with TDS, turbidity, TA, TH, NO_3^-, SO_4^{2+}, F^-, Mg^{2+}, Ca^{2+} , Na^+ and K^+ in pre-monsoon, while similar significant positive correlated also found in post-monsoon total dissolve solid, turbidity, total alkalinity, total hardness, NO_3^-, SO_4^{2+}, F^-, Mg^{2+}, Ca^{2+} , Na^+ and and K^+. pH significant positive correlated with fluoride and negative correlated with potassium at 0.05 level in pre-monsoon while post-monsoon it shows negative significant correlation with TH, Mg^{2+} , Ca^{2+} and K^+. Similar negative correlation also observed in groundwater sample by **Kanmani and Gandhimathi (2013).** Results suggested that positive correlated with fluoride because of dissolution of fluoride in groundwater increase the pH level. Nitrate significant positive correlated with all parameter except pH, F^-, and K^+ in pre-monsoon, while positive correlated found in post-monsoon with all parameter except pH, F^-, Na^+ and K^+. Sulphate significant positive correlated with EC, TDS, turbidity, TA, TH, Cl^-, NO_3^-, F^-, Mg^{2+}, and Na^+ in pre-monsoon, while in post-monsoon significant positive correlated with EC, TDS, turbidity, TA, TH, Cl^-, NO_3^-, F^-, Mg^{2+}, Ca^{2+} , Na^+ and and K^+. **Kapil et al., (2009)** also found in his studied that chief linier or significant positive correlation between all parameter.

.5.5.4.2 Correlation within metallic variable

The one-tailed bivariate correlation was carried out to investigate the relationship within metallic constituents shown in **Table 4.45** and **Table 4.46** for pre and post-monsoon for the years of 2016-17. The significance positive correlation found at 0.05 levels between Zn-Co, Fe-Cd, Ni-Cu, Mn-Pb, in pre-monsoon while significance positive correlation between Zn-Co, Fe-Cd, Ni-Cu, Mn-Pb, in post-monsoon but negative corilation with Mn-Cd during both season. The significance positive correlation found at 0.01 levels between Zn-Fe, Zn-Cd, Fe-Cu, Ni-Mn, Ni-Co, Ni-Cr, Pb-Co, and Cu-Co in pre-monsoon while Zn-Fe, Zn-Cd, Fe-Cu, Ni-Mn, Ni-Cu, Ni-Co, Ni-Cr, Pb-Co, Cu-Co in post-monsoon. Oxidation-reduction reaction and ion exchange process release the metals level into groundwater **(Prasad et al., 2014)**.

5.5.5 Hierarchical Cluster Analysis

HCA is a powerful data mining technique, which classifies variables into clusters on the basis of similarities within a group and dissimilarities between different groups. Hierarchical Cluster Analysis was performed, after careful consideration of available combinations of similarity/dissimilarity measurements. HCA was run by Ward's method for similarity measurement which provided visually meaningful dendrogram and distinct the groups. HCA was conducted bases on cases means clustering to samples not variable. Therefore, sixty groundwater sampling location of Lalganj tehsil were classified though cluster in mean value during pre-monsoon and post-monsoon season for year of 2016 and 2017. In the dendrograms, sample ID were classified and location were given in **Table 3.1 to Table 3.4**.

5.5.5.1 Clustering of sampling location through physico-chemical variable

The sampling location was clustering based similarity found in physicochemical variables given in **Figure 4.51 to Figure 4.52** for pre-monsoon and post-monsoon during both years.

In pre-monsoon and post-monsoon season, the dendrogram has classified the sixty locations into 9 groups given in **Figure 4.51 and Figure 4.52.** Cluster or groups one sample (L8, L32, L26, L37, L16, L42, L44, L53, L56, L48) represents maximum similarity based on physic-chemical variable, while in post-monsoon, were L26, L42, L8, L38, L47, L51, L46, L50, L49,L37, L48, L53, L14, L9. Sapling locations or samples and sequence of similarity were differing from pre to post-monsoon due to effect on monsoon. In pre-monsoon season, the samples L51, L38, L47, L46, L49, and L50 were grouped into Cluster 2, while during post-monsoon season, cluster 2 were grouped by L41,L31, L40, L52, L10, L39, L6, L7, L3, L23, L29, L2, L4 and L13. Similarity measurements of sampling location during post-monsoon season were more as compare to pre-monsoon season. Cluster 3 was grouped with samples L1, L13, L12, L39, L21, L4 in pre-monsoon, but sample L33 was only one samples that grouped in cluster 3 during post-monsoon Cluster 4 grouped with samples L23, L24, L31, L52, L10, L14, L41, L9, L45, L6, L7, L3 L2 during pre-monsoon, while samples L36, L11, L57, L15, L28, L18, L20 in post-monsoon. In pre-monsoon, cluster 5 was grouped with samples L2, L40, L54, L55, L30, L17, but L25, L35, L43, L22, L16 in post-monsoon. All samples were change during post-monsoon in cluster 5. Similarity observed in samples L33, L60, L36, L11, L57, L25 L35, L20, L22 and L43 with grouped the Cluster 6 in pre-monsoon, while similarity found in this samples (L44, L24, L12, L45, L56, L30 L2, L21, L17, L55 and L54) during post-monsoon. Similarity found in samples between L27 and L34 with formed cluster 7 in pre-monsoon season but in post-monsoon season only samples L5 and L19 grouped into cluster 7. Cluster 8 grouped with samples L15, L18 and L34, L58, L60 and L59 for pre and post-monsoon season. Cluster 9 grouped by samples L28, L58, L59, L5, in pre-monsoon season but only one sample (L27) contributes during post-monsoon.

The results illustrate that cluster 1 to 9 divided on the basis of dissimilarity but the maximum similarity in samples found within cluster while if found dissimilarly it's divided in to another cluster. In the **Figure 4.51** and **Figure 4.52** exposed to samples of cluster 8 and cluster 9 excessive loaded with TDS, sulphate, total alkalinity and fluoride.

5.5.5.2 Clustering of sampling location through metallic variable

In pre-monsoon and post-monsoon season, the dendrogram has classified the sixty locations into 8 cluster given in **Figure 4.53 and Figure 4.54**. Total sixty samples divided in two broad groups based on metallic contents during both season. further broad group 1 divided into two sub-groups (sub-groups 1) and (sub-groups 2). Sub-group 1 further divided in to divided into two cluster, sample (L26, L32, L8, L23, L24, L33, L19, L21) contributed to cluster 1 and cluster 2 prepared with samples (L28, L29, L60, L3, L43, L11, L35, L27) in pre-monsoon, while cluster 1 contributed sample (L42, L44, L48, L57, L04, L45, L2, L18, L31, L47, L1, L9, L59) and cluster 2 (L39, L06, L54, L56, L5, L25, L34) in post-monsoon. Sub-group 2 further divided in to divided into two cluster, sample (L13) contributed to cluster 3 and cluster 4 prepared with samples (, L30, L14, L38, L36, L52, L40) in pre-monsoon, while cluster 3 contributed sample (L55, L58, L51, L16, L22, L15, L41) and cluster 4 (L37, L46, L10, L20, L49, L50, L17, L53, L7) in post-monsoon.

Further broad group 2 divided into two sub-groups (sub-groups 3) and (sub-groups 4). Sub-group 3 further divided in to divided into two cluster, sample (L16, L55, L22, L51, L58) contributed to cluster 5 and cluster 6 prepared with samples (L10, L20, L49, L50, L15, L41, L46, L37 L17, L53, L7) in pre-monsoon, while cluster 5 contributed sample (L13) and cluster 6 (L30, L36, L52, L38, L40, L14) in post-monsoon. Sub-group 4 further divided in to divided into two cluster, sample (L12, L39, L6, L4, L45, L2, L18, L42) contributed to cluster 7 and cluster 8 prepared with samples (L44, L48, L57, L34, L56, L5, L25, L31, L47, L1, L9, L54, L59) in pre-monsoon, while cluster 7 contributed sample (L29, L60, L3, L43, L11) and cluster 8 (L35, L27, L21, L28, L8, L32, L26, L23, L24, L33, L19) in post-monsoon.

The results illustrate that cluster 1to 8 divided on the basis of dissimilarity but the maximum similarity in samples found within cluster while if found dissimilarly it's divided in to another cluster. Maximum dissimilarity found in with cluster 7 and cluster 8 because of greatest concentration of Zn and Fe found in samples of this cluster.

5.6 Accumulation of of Fluoride in rhizopheric soil

The fluoride concentration was analyzed in 24 rhizospheric soil from each block of Lalganj tehsil with control area. Descriptive statistics of total fluoride contents in rhizoshpheric soil of Lalganj and Sareni block were given in **Table 4.48** and Khiron and Control area were given in **Table 4.49**. The maximum concentration of fluoride found in 352 mg/kg in Lalganj block, 322 mg/kg in Sareni block, and 355 mg/kg in Khiron block while 9.40 mg/kg in control area. Different anthropogenic activity such as fluoride containing fertilizers, agro-chemical, and irrigation of fluoride containing water can causes to high fluoride in soil **(Brindadha et al. 2001)**. The observed concentration of fluoride was detected to be higher than the **Hall and Cain (1972)** and lower than the **Bhattacharya et al. (2017)**. The fluoride concentration in all block found more than the control area. Accorging to **Pickering (1985)** the mobility of fluoride in the soil are totally depend on soil pH, rate of deposition, formation of s**Table** complex with calcium and aluminum, and climatic condition of the area. **Barrow and Ellis (1986)** found alkaline soil enhance the maximum fluoride in groundwater.

5.7 Bioaccumulation of Fluoride in cultivated crops and fodder plants

The fluoride concentration was analyzed in 24 rhizosphericr rice, wheat, and cultivated vegetables from each block of Lalganj tehsil with control area. Descriptive statistics of total fluoride contents in different dietary sources for Lalganj and Sareni block were given in **Table 4.50** and Khiron and Control area were given in **Table**

4.51. Results shows that maximum F- accumulate in *Raphanus sativus* (Raddish) 46.09, 43 and 45.70 mg/kg in Lalganj block, Sareni block and Khiron block while 0.34 mg/kg found in control area. The observed concentration of fluoride was detected to be less than the **Bhattacharya et al. (2017)**. The concentration of fluoride in rice **(*Oryza Sativa L*)** were 0.54 mg/kg for Lalganj block, 02.43 mg/kg for Sareni block and 0.59 mg/kg for Khiron block 0.04 found in Control block (Bachharawan). The concentration of fluoride in rice was accumulated greater than to control area. The average concentration of fluoride in spinach (***Spinacea oleracea***) was reported 25.24, 24.47, and 26.02 mg/kg in Lalganj, Sareni Khiron block but accumulation of fluoride in spinach grown in control block was observed 0.07 mg/kg. Spinach demonstrate a good accumulator of fluoride specially in fluoride contaminated area **(Haidouti et al. 1993)**. The observed concentration of fluoride in spinach was detected to be less than the **Saini et al. (2013)** and **Bhattacharya et al. (2017)**. **Gautam et al. (2010)** also found the fluoride accumulation in leafy vegetable like spinach, and methi. The fluoride mean contents in Brinjal **(*Solanum melongena*)** of Lalganj, Sareni and Khiron block found more than the control area. The mean value were analyzed 18.34, 17.50, 18.41 mg/kg for Lalganj block, Sareni block and Khiron block while 0.65 mg/kg in Control block. The concentration of fluoride in Onion **(*Allium cepa*)** was found in following decreasing order Lalganj block > Sareni block > Khiron block > Control block. Significantly amount of fluoride accumulated in agricultural crops, cultivated and pulses.

Simultaneous level of fluoride also reported by **Paul et al. (2011).** The maximum fluoride contents in Cauliflower **(*Brassica oleracea botrytis*)** was found in Khiron block (8.45 mg/kg) and minimum accumulation in Sareni block (7.80 mg/kg). Susheela (1999) found the elevated concentration of fluoride in carrot, potato, brinjal, tomato, cabbage, radish and cauliflower. This vegetable significant accumulates fluoride and became a chief source of dietary intake of fluoride up to 56% **(Gupta and banerjee 2011)**. The results reveals that the consumption of *Abelmoschus esculentus* (Okra), *Allium cepa* (Onion), *Chenopodium album* (Pigweed), *Brassica oleracea capitata* (bgba), *Momordica Charntia* (Bitter melon), *Spinacea oleracea* (Spinach), *Raphanus sativus* (Radish), *Solanum melongena* (Brinjal), *Daucus carota* (Wild carrot), *Cajanus cajan* (Pigeon pea) are indirectly contribute simultaneous amount of fluoride intake.

Table 4.60 illustrated that the increasing order of fluoride in fodder part of plants in Lalganj block were *Oryza Sativa L*< Zea mays < *Triticum vulgaris* < *Sorghum bicolor* < *Vigna mungo*, for Sareni block were *Oryza Sativa L* < Zea mays < *Sorghum bicolor* < *Triticum vulgaris* < *Vigna mungo, for Khiron block were Oryza Sativa L* < Zea mays *Sorghum bicolor* < *Vigna mungo*. Cattle usually ingested few amount of fluoride through diet without any adverse effect but increased amount can causes to incurable bone problems like fluorosis. Leaf and stem part of the above plants were used as a livestock feed in study area, animals of the study may cause potential risk due to excess fluoride.

5.8 Risk Assessment due to possible intake of fluoride via dietary

Hazard Index (HI) represents total exposure pathway of intake of fluoride is used to human health risk assessment. According to **Canada Health Act Annual Report (2004)** no risk found if HI value < 1 but if found HI >1 than required to risk management and mitigative measures should be adapted in affected area. Hazard index was calculated for categorized three groups (3-6 years, 7 to 18 years and 19 to 70 years) of Lalganj, Sareni and Khiron block with control area were given in **Table** 4.58 for CTE scenario and **Table 4.59** for RME scenario.

The RfD value (0.06 mg/kg) was taken from **USEPA (1987)** because absence of Indian guidline and RfD value sum of dietary intake of fluoride (0.01 mg/kg) and drinking water(0.05 mg/kg).

The HI value in CTE scenario for children (3-6 years), teenagers (7-8 years) and adults (19 to 70 years) were estimated 2.6342, 2.7201 and 3.2983 for Lalganj block, 1.9977, 2.0292 and 2.4144 for Sareni and 3.2425, 3.3920 and 4.1675 for Khiron block while 0.5783, 0.6339 and 0.8208 for control block. In RME scenario, The HI value for children (3-6 years), teenagers (7-8 years) and adults (19 to 70 years) were estimated 4.6777, 4.8810 and 5.9825 for Lalganj block, 2.8008, 2.8410 and 3.3706 for Sareni and 9.7031, 10.3933 and 13.1363 for Khiron block while 0.7882, 0.0376 and 0.0413 for control block.

The maximum HI value found for adults groups because of high fluoride in drinking water and the average daily consumption of drinking water is high for adult as compare to children and teenagers. But the absorption of fluoride in children and teenager have more than to adults. This is fearsome value of for toxic effects creating in inhabitant of children and teenagers. Inhabitants of the study area have to high potential for developing of incurable fluorosis.

The noncancerous lifetime hazards ($HI_{cumulative}$) also calculated in population for 3 to 70 years. $HI_{cumulative}$ was found 8.6525, 6.4412 and 10.8020 for Lalganj, Sareni and Khiron block. The population of Lalganj, Sareni and Khiron block exposed to cumulative life time risk, which were 4.26, 3.17 and 5.31 times higher than to inhabitant of Control area in CTE scenario **(Table 4.58)**. The population of Lalganj, Sareni and Khiron block exposed to cumulative life time risk, which were 7.06, 4.09 and 15.10 times higher than to inhabitant of Control area in RME scenario **(Table 4.59)**.

CHAPTER 6

SUMMARY AND CONCLUSION

5.1 Summary

Present work entitled "Study of Fluoride Contaminated Ground Water Quality and Health Risk Assessment Owing to Bioaccumulation of Fluoride in Cultivated Crops and Fodder plants" carried out under the supervision of Dr. Pramod Kumar Singh (Associate Professor) Babu Banarasi Das University, Lucknow, and Dr. Ganesh Chandra Kisku (Chief Scientist and AcSIR Professor) CSIR-Indian Institute of Toxicology Research, Lucknow (CSIR-IITR). With concern to make available valuable in order to suitability of groundwater with special reference of fluoride and associated risk in Lalganj tehsil (Lalganj, Sareni and Khiron block), Raebareli district, Uttar Pradesh that have been chosen. The study was completed with identified specific objectives are, the causes of groundwater pollution and study of special and temporal variation in groundwater quality with an approach of water quality indexing, to scrutinize the extent of fluoride content in groundwater with generate thematic map and differentiate area for suitability of drinking purpose, to determination of bioaccumulation and biotransformation of fluoride in cultivated crops and fodder plants and to assess the potential health risk from additional exposure of fluoride through dietary source.

This thesis covers six chapters. Chapter 1 provides generals introduction about need and scientific importance groundwater, groundwater contamination and its geochemistry that influence groundwater quality with reference to fluoride, also discussed about global and Indian scenario of fluoride contamination, their sources and distribution. This chapter also covered with health effect on human and plant owning to excessive fluoride in drinking water and aims and objective of present work.

Chapter 2 covered the details of review of the previously published research paper, and articles with reference to assessment of groundwater quality, groundwater quality defined via WQI as effective tools, review of fluoride containing groundwater quality and associated health risk conducted in the global, India and Uttar Pradesh, review on bioaccumulation of fluoride in fodder and cultivated crops, review done in the statistically studies on groundwater quality.

Chapter 3 provided information about study area and salient features of the study area, brief information about collection of groundwater and foodstuff samples from the study area, specific method adopted for analysis of different physico-chemical parameter and metals in this research work. Quality control and quality assurance, instrumental condition and for assessment of groundwater quality, statistical approach (Water quality index (WQI), Heavy metal Pollution Index (HPI), Factor Analysis/Principal Component Analysis (PCA/FA), Spearman Correlation Matrix, Hierarchical Cluster Analysis (HCA) also explained in this chapter. This chapter also content with human health Risk assessment from exposure of fluoride via dietary intake.

Chapter 4 deals with the outcome of present research work. This chapter contents with hydrochemical facies and trace constituents in groundwater, seasonal variance in ground water quality, statically approach such as WQI, HPI, CA/FA, correlation and HCA for assessment of groundwater quality bioaccumulation of Fluoride in cultivate crops and fodder plant also discussed in this chapter, Possible dietary intake of fluoride also calculated.

Chapter 5 deals with discussion of result obtained from chapter 4. result comparison with previous study conduction in this field and standard guideline given by different government regulatory bodies. Discussed on Suitability of groundwater quality for drinking propose, seasonal variance in ground water quality, water quality indexing, statically approach (WQI, HPI, CA/FA, correlation and HCA) for water quality assessment. This chapter also discussed on bioaccumulation of Fluoride in cultivate crops and fodder plants and health risk assessment owing total dietary intake of fluoride also calculated and characterized health risk may be impose to rural inhabitants.

Chapter 6 comprises summary and conclusion of the presents study with recommendation for removal strategies and preventive option should be taken in highly affected location of study area and future work. References of cited literatures in this thesis and in the last page list of publication were attached end of conclusion.

5.2 Conclusion

The finding as per follows:

- The results of hydrochemical investigation are compared with (WHO 2011) and Indian Standard (2012) for the evolution of suitability of drinking water quality with respect to physic-chemical parameter following parameter pH, turbidity, chloride (Cl^-), nitrate (NO_3^-), sulphate (SO_4^{2-}), calcium (Ca^{2+}) magnesium (Mg^{2+}), sodium (Na^+) were found the well within the desirable limits of drinking water standard. But following parameter such as electrical conductivity (EC), total dissolved solids (TDS), total hardness (TH), total alkalinity (TA), fluoride (F^-), potassium (K^+) were exceeded the desirable limits of drinking water standard, in this parameter fluoride can causes significant effect on human health.

- For the evolution of drinking water quality with respect to trace metals such as zinc, nickel, manganese, lead, copper, cobalt, chromium and cadmium, the groundwater of the study area (all block) were well within the prescribe standard of drinking water quality (WHO 2011; EPA 2013; IS 2012). But with respect to iron in the groundwater samples, of Sareni block were found more than the desirable limits of drinking water standard. Iron may causes to negative health effect on rural inhabitants. Long term consumption of drinking water with high concentration of iron may cause to liver diseases.
- The elevated concentration of fluoride found in groundwater of Lalganj, Sareni and Khiron block due to occurrence of fluoride bearing minerals in geology of the study area. 75, 42.5 and 45 % groundwater samples of Lalganj, Sareni and Khiron block exposed the concentration is above the guideline limit (1.50 mg/L) of WHO during 2016 while 80, 57.5 and 57.5 % groundwater sample in 2017.
- Investigation of temporal variation in groundwater quality was done with respect to physico-chemical parameter in groundwater of Lalganj tehsil. The results revels that the concentration observe increasing trends from pre to post-monsoon for pH, electrical conductivity (EC), , total dissolved solids (TDS), turbidity, total hardness (TH), total alkalinity (TA), nitrate (NO_3^-), sulphate (SO_4^{2-}), chloride (Cl^-), fluoride (F^-), calcium (Ca^{2+}) magnesium (Mg^{2+}), sodium (Na^+), potassium (K^+).
- While the t-test was applied in this physicochemical parameter with respect to pre-monsoon and post-monsoon. Significant variation were found in pH, electrical conductivity (EC), , total dissolved solids (TDS), turbidity, total alkalinity (TA), nitrate (NO_3^-), sulphate (SO_4^{2-}), chloride (Cl^-), calcium

(Ca^{2+}). Three proposed process (ion exchange, carbonate reaction and oxidation reduction reaction) are the dominant process that processed in aquifer of the study area and affect the quality of water.

- Temporal variation of trace elements in groundwater quality was done with respect to physic-chemical parameter in groundwater of Lalganj tehsil. The results revel that the concentration observes decreasing trends from pre to post-monsoon. The results proposed to dilution of trace mental due to recharging of huge amount of rain water during rainy season.
- Piper diagram presenting cation the groundwater of the Lalganj, Sareni and Khiron block was sodium type water indicating the cation exchange of Ca^{2+} with Na^{+} while calcium type in control area. More than 75 % sampling locations of Lalganj and Sareni block have observed Na-Mg-HCO_3^- type of groundwater while sampling locations exceeded from 90% in Khiron block. The groundwater type of control area was found Ca-Mg-HCO_3^- type water in more than 80 % sampling locations. This is because of the dissolution of limestone in the sampling location.
- The result of WQI reveals that the majority of the groundwater samples classified in "Good" category. The category of groundwater quality is excellent in 22.5, 17.4 and 60 % samples, good in 70, 75 and 30 % and poor in 7.5, 7.5 and 10% samples of Lalganj, Sareni and Khiron block during 2016 while in 2017, the groundwater quality excellent in 10, 5 and 32.5 % samples, good in 80, 85 and 55 % samples and poor in 10, 10 and 12.5 % samples. In that location where found poor water quality contains higher than standard value, the reflected parameter are particularly TDS, sulphate, nitrate and bicarbonate and hardness. The poor water quality needs special treatment.

Therefore, all the groundwater samples of Lalganj tehsil were consider suitable for human and animal consumption except presence of higher concentration of fluoride.

- The results of HPI classification illustrated that 100, 90 and 95 percent of the groundwater samples found within the low category (Good quality) for Lalganj, Sareni and Khiron while the rest of the groundwater samples calculated under medium categories. Sabji barua and Jalalpur villages of Sareni block were found medium category in HPI classification, while Kanha mau village of Khiron block during all both year. The greatest score (25.22) was calculated for Kanha mau village of Sareni block during pre-monsoon 2016.
- Principal component analyses (PCA) was conducted to expose the main variable or source identification of highly loaded variables in conducted parameter of groundwater. PCA find out four factors that affected the quality of groundwater during pre-monsoon in all block and in post-monsoon found four factors for groundwater of Lalganj and Sareni block and three factors in Khiron block with respect to physic-chemical variable.
- Hierarchical cluster analysis illustrates major 9 clusters to 60 samples of Lalganj block based on similarity and dissimilarity for physic-chemical parameter and 8 cluster for metallic ingredients.
- Correlation metrics reveals that in pre-monsoon, correlation of fluoride significant at 0.01 levels with EC, TDS, total alkalinity, sulphate and sodium while in post-monsoon, significant with EC, TDS, TA, Cl^-, sulphate and sodium. This parameter shows highly affinity with fluoride in the groundwater of Lalganj tehsil.

- The study also done to identify the bioaccumulation capacity of fluoride in fodder and cultivated crops. Results illustrated that maximum F^- found ***46.09***, 43 and 45.70 mg/kg in ***Raphanus sativus*** (Radish) in Lalganj block, Sareni block and Khiron block while 0.34 mg/kg found in control area. The results identified that the chief accumulation of fluoride in cultivable or vegetables plants species *i.e. Abelmoschus esculentus* (Okra), *Allium cepa* (Onion), *Chenopodium album* (Pigweed), *Brassica oleracea capitata* (bgba), *Momordica Charntia* (Bitter melon), *Spinacea oleracea* (Spinach), *Raphanus sativus* (Radish), *Solanum melongena* (Brinjal), *Daucus carota* (Wild carrot), *Cajanus cajan* (Pigeon pea). This are indirectly contribute simultaneous amount of fluoride intake.
- The HI value found more than guideline value for adults groups because of high fluoride in drinking water and the average daily consumption of drinking water is high for adult as compare to children and teenagers. But the absorption of fluoride in children and teenager have more than to adults. This is fearsome value of for toxic effects creating in inhabitant of children and teenagers. Inhabitants of the study area have to high potential for developing of incurable fluorosis.
- The noncancerous lifetime hazards ($HI_{cumulative}$) also calculated in population for 3 to 70 years. The population of Lalganj, Sareni and Khiron block exposed to cumulative life time risk, which were 4.26, 3.17 and 5.31 times higher than to inhabitant of Control area in CTE scenario. The population of Lalganj, Sareni and Khiron block exposed to cumulative life time risk, which were 7.06, 4.09 and 15.10 times higher than to inhabitant of Control area in RME scenario.

Multivariate Statistical interpretation also discloses that the geogenic factor is the chief factor controlling the hydro-geochemistry of the study area which is sometimes dictated by minerals weathering and anthropogenic input. This work has demonstrated that hydro-geochemical studies, the above results can be used for future sustainable development of the basin by government authorities and decision makers.

5.3 Recommendation

- Our investigation drastically assesses the effectiveness of the preventive strategies adopted by the central governments like Nation Program for preventive and control of fluorosis (NPPCF).
- Water conservation structures and harvesting structures can be promoted especially for of the basin. Less water consuming crops can be irrigated in the summer period and in the low rainfall period. Judicious utilization of water resources is the prime need of the hour in the entire basin area.
- By using fluoride amelioration technique: Majority of the groundwater samples need to be treated for fluoride, using modern technology like, ion-exchange, membrane filter, adsorption and coagulation–precipitation process. The Nalgonda technique has been design by CSIR-NEERI, Nagpur. The technology is based on coagulation–precipitation process, mutually using of lime and potash alum in a two-step process. This technique has installed in many village of India and it has been observed as the most cost-effective technique for removal of fluoride. The pH under 5.5 to 7.5 is the best condition for optimum removal of fluoride.

- Improving the recital of available irrigation system by appropriate structures measures like deep well, surface water and rain water harvesting.
- Popularize the awareness programmes among the public, especially farmers at various levels, which should be made effective so as to attain self sufficiency in the sustainable water resources development.
- Groundwater extraction can be restricted so as to fix the horse power of motor within a desired limit wherever the areas to be over-extraction areas.
- Using alternate water sources: In the high fluoride zone, people should be used surface water after treatment because fluoride in surface water much lower than ground water. Other seasonal alternative sources like rainwater harvesting needed.
- Prioritization should be given in the over-extracted areas in the basin so as to conserve the water and for planning appropriate harvesting structures to be put into action.
- Improving Nutritional diet: Nutritional diet such as calcium, phosphorus-rich food and vitamin C is advised to consume those people who lived at fluoride contaminated area, because its decreases fluoride retention capability of human body.

5.4 Limitation and Future Research

- Bacteriology investigations can be also conducts in that area.
- The prediction modeling can be applies for the better understanding to status of water quality in future.
- An investigation can also be investigates for screening of fluorosis affected inhabitants and animals.
- A study on groundwater quality movement can be carried out.
- The investigation can also be accomplish for land use application through GIS software.
- A study of groundwater movements can be also studies for better understanding to hydro-geochemical reaction.
- For the better understanding of any changes in groundwater quality, continuous monitoring of groundwater quality can suggested for the district.
- Some application can also be applies for water quality assessments for irrigation suitability, vulnerability index, and saturation index.

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