GROUNDWATER CONTAMINATION BY HEAVY METALS FOR GURUKUL NARSAN, HARIDWAR

A DISSERTATION

Submitted in partial fulfillment of the

Requirements for the award of the degree

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In

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By

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CANDIDATE'S DECLARATION

I hereby declare that the work which is has been presented in this dissertation entitled, "GROUNDWATER CONTAMINATION BY HEAVY METALS FOR GURUKUL NARSAN, HARIDWAR" in partial fulfillment of the requirements for the award of the degree of INTEGRATED MASTER OF TECHNOLOGY in GEOLOGICAL TECHNOLOGY, submitted in the Department of Earth Sciences, Indian Institute of technology, Roorkee, is an authentic record of my own work carried out under the guidance of Dr. Nachiketa Rai, Department of Earth Sciences, IIT Roorkee, during the period of May 2018 to May 2019.

The matter embodied in this dissertation has not been submitted by me for the award of any other degree or diploma of this institute or any other university/institute.

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CERTIFICATE

This is to certify the work presented in this thesis titled “GROUNDWATER CONTAMINATION BY HEAVY METALS FOR GURUKUL NARSAN, HARIDWAR” submitted by Mr. Gautam Yadwani to Department of Earth Sciences, Indian Institute of Technology, Roorkee, India, in partial fulfillment of the requirements for the award of the degree of INTEGRATED MASTER OF TECHNOLOGY in GEOLOGICAL TECHNOLOGY is a document of original work carried out by him under my supervision during the academic year 2018- 2019.

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Gautam Yadwani

CONTENTS

ABSTRACT

This dissertation was aimed at one of the most crucial problems of modern world and that is degradation of the natural resources at the cost of human suffering. The heavy metal poisoning has become a major issue in countries like Bangladesh and Nigeria. These have become national issues in these countries. Some of the major reasons involve natural leaching of heavy metals and anthropogenic sources like industrial wastes. The rapid growth of industries have resulted in huge waste generation. This waste can be toxic and hazardous if not disposed properly. There have been evidences that industries around the world through their sewage and effluents have been responsible to contaminate the natural water resources which in turn have affected the general population via development of serious conditions by the heavy metal poisoning. This study involved sample collection from 24 locations in the Gurukul Narsan Block of Haridwar district in the state of Uttarakhand in India. The samples were analysed for following in-situ measurements, pH, temperature and Electrical Conductivity. These were analyzed for these elements using the ICP-MS technique: Gold(Au), Arsenic(As), Calcium(Ca), Chromium(Cr), Uranium(U), Barium(Ba), Cadmium(Cd), Nickel(Ni), Copper(Cu), Iron(Fe), Manganese(Mn), Lead(Pb), Selenium(Se), Potassium(K), Magnesium(Mn) and Sodium(Na). The values obtained were judged for their maximum permissible limits as prescribed by the Bureau of Indian Standards(BIS). The conclusion was drawn that the groundwater samples in this area suggest that the water doesn’t contain hazardous levels of heavy metals. This might not pose a problem in recent times but as industrialization booms in the area, these can serve as potential hotspots for the heavy metal poisoning. And thus strict regulations for the treatment and monitoring of waste disposal should be a benchmark for the industries in the area.

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Chapter 1: INTRODUCTION

844 million, that is the number of people around the world that still lack a basic drinking water service(WHO, 2015). Asia with 20% and South Africa with 42% are leading in this number. (WHO, 2000). Thus, people in developing country suffer numerous diseases which may lead to death due to lack of safe drinking water (WHO 2000).

The main source of water for irrigation, domestic and industrial demands is Groundwater. The main problem with Groundwater in the study area is the deterioration of its quality in terms of the heavy metal concentration in some parts. Human population is on a rapid rise and ever increasing water supply demand for drinking, agricultural and industrial purpose is heavily dependant on groundwater. Groundwater is a crucial source of freshwater. However, in many parts of the country, groundwater sources are being contaminated as a result of the dumping of untreated industrial wastes which gradually pollute water supplies (World Water Day, 2010).

Impure water sources results in diseases such as cholera, dysentery. Due to heavy metal poisoning and accumulation it may cause long term health effects that may be permanent in nature. Heavy metal poisoning is a reality in Bangladesh. Bangladesh has 20% well water with high levels of Arsenic naturally (WHO/UNICEF, 2000). High levels of Fluoride and Arsenic has been reported in the Karbi Angling and Nagaon districts of Assam in India (Sabhapandit et al., 2010).

Industrial waste has been defined as waste generated by manufacturing and industrial processes. It has been a matter of serious concern since the start of the industrial revolution. This waste can be poisonous, flammable, corrosive and highly sensitive to surroundings. If not treated properly, the industrial waste can lead to several serious health and environmental concerns.

Areas close to industries have had a history of higher levels of heavy metals in groundwater and such instances are even recorded in India. (Yadav et al., 2011)

The government and management norms should make it necessary to make the industrial processes more efficient to manage the resources for better treatment of this waste and also taking all the measures to minimise the harm to human life and environment. The waste water from these industries may become a source of grave harm to the environment, surface and ground waters (Jo et al., 2012; Adefemi, and Awokunmi, 2010; Agarwal and Saxena, 2011; Kataria et al., 1996; Ellis, 1989).Groundwater is not only used for irrigation purposes but is the main source of fresh water for drinking purposes all around the world. Industrial waste and ground water in the affinity of industrial plants contains a significantly higher amount of heavy metals.Natural water contains small amounts of Heavy metals, and some are even hazardous at extremely low concentrations although a lot of these metals are consequential components of the biological system (Bharti et al., 2013; Adeyeye, 1994; Chavan et al., 2005; Hemkes et al., 1980; Jakkala and Ali, 2015). For ex As, Pb, Ni, Hg, Cd, Zn, Cr, Co and Se are harmful even in smaller quantity.

Industrial effluents discharged on the surface as well as releasing into the surface water percolates into the groundwater and results to contamination by the increasein concentration of toxic metals, thus making it unfit for human drinking because these contaminants may not degrade completely (Malarkoodi et al., 2007; Ahmad and Krishnamurthi, 1990; DeGrandpere, 1993; Dickson and Goye, 1994; Hoppkinson, 1985). This problem of groundwater pollution is a major problem in developing nations but the developed world is not completely free of it(Dipali and Joshi., 2012; Kumar and De, 2001; Kumar and Sinha, 2010; Manjre et al., 2010).

1.1 Problem Statement:

Haridwar came into existence as the newly formed district of the state of Uttar Pradesh in the year 1998 and was later one of the thirteen districts of the newly formed Uttarakhand state in 2000. Haridwar is the most crucial religious, cultural and spiritual hub of the country and also acts as the starting point to Char Dham pilgrimage in Uttarakhand. The district has a total spanning area of 2360 sq. km and is divided into three tehsils and six development blocks. Haridwar is situated on a 29.580 N latitude and 78.130 E longitude. This study focuses on the development block of Haridwar known as Gurukul Narsan to study if there is any effect of adjoining area industries on the groundwater in this area. In this study samples from twenty two various locations of the block comprising of domestic areas were taken. Samples were analyzed for various parameters like pH, electrical conductivity and heavy metal concentrations. The other industrial areas of Haridwar have been found to disturb the ecological balance in the region in the past, mentioned in other studies. For ex, industries in the SIDCUL region have been a source of untreated effluents. The local community which comprises of thousands of villagers who are totally dependent on this groundwater for their survival could be affected by this.

1.2 Main Objective:

- The objectives of this study was to investigate water quality of groundwater of Gurukul Narsan by collecting samples from twenty three handpumps in the area.

1.2.1 Specific Objectives:

- Study and understand the groundwater distribution in Gurukul Narsan Block of Haridwar District.
- Sampling of groundwater from hand pumps and various other sources(Domestic water, Surface Water, Industrial Wastewater)

- Carry out multiple analysis like:
  - Spatial analysis- samples covering the geographic extent of Bhagwanpur
  - Temporal analysis- Post Monsoon(December) and Pre Monsoon(March)
  - Depth profile- Establish a depth profile(subject to depth data of handpumps)
- Lab measurements of concentration of Heavy Metals(As, Cd, Cr, Cu, Ni, Zn, Pb, Hg) using the ICP-MS technique.

1.3 Why Gurukul Narsan?

There are instances of water shortages not only in the country but all across the world. People, specially in the developing world are having a daily struggle to find pure drinking water. This reflects in the numbers as well. On an average a total of twenty five thousand people die globally every day with water related diseases(World Health Org 2002). Groundwater being one of the major source of drinking water, specially in Indian villages, has increased the responsibility to maintain this resource and maintain its quality.

Heavy metals are toxic in nature and in significant concentrations these can prove to be fatal. This attribute makes water polluted to these, unfit for drinking and utilisation in domestic civilisations (Nagendrapa et al., 2010). The adjacent areas of Bhagwanpur and Saharanpur have a spurr of industrial units comprising of Pharmaceutical, Paint, electrical, spare parts etc. While there have been studies in the area of SIDCUL, Haridwar relating to these heavy metals, there have been no study in the said area.

The dissertation would;

• Quantify whether heavy metals concentration in groundwater sources in the “Gurukul Narsan” is significant enough to pose a danger to the people of the area.
• Provide basic data of heavy metal concentrations of groundwater in the “Gurukul Narsan” area.

Chapter 2: LITERATURE REVIEW

2.1 Sources of Water:

Water is the most important natural component that is sustaining natural life in all its forms, animal and plant (Vanloon and Duffy, 2005). There are two primary natural water sources. First is surface water that is all the fresh water obtained from rivers, lakes, ponds and streams. Second is the groundwater, that is obtained by human planted devices such as hand pumps and wells (McMurray and Fay, 2004). Water has unique chemical properties due to its polarity and hydrogen bonds which means it is able to dissolve, absorb, adsorb or suspend many different compounds (WHO, 2007). Therefore natural water is full of contaminants that may be suspended in it or either are dissolved in it. These may be a result of natural, biological or anthropogenic reasons (Mendie, 2005).

2.1.1 Groundwater:

Groundwater is underground or subsurface water. It generates from surface water seeping through soils and it rests in the pore spaces between particles of soil. Geological formations which have all of these pore spaces completely saturated with water are called saturated zones or aquifers. Water table is defined as the top of this aquifer zone. Gravel, sand, sandstone, or fractured rock, like limestone form the aquifers, mostly. These materials are permeable since these have connected spaces that allow water to flow. The amount of groundwater and the speed at which groundwater flows depends on the size of the spaces in the soil or rock and how well the spaces are connected (USGS, 2009).

Water wells are built to facilitate the pumping of groundwater to the surface. These wells extend well to the aquifers. Groundwater is present in the pore spaces of the geological particles that are restricted by an impermeable layer that restricts water flow. It isn't in the form of a pool or a river. The quality of groundwater is the sum of all the processes and reactions that act on the water from the moment it condensed in the atmosphere to the time it is discharged by a well or spring and varies from place to place and with the depth of the water table (Jain et al., 1995). With enough water infiltration, soil contaminants such as heavy metals can percolate to the underlying groundwater.

2.2 Water Pollution:

Water has a unique property to it. The property of cleaning itself. The major contaminants of water are self removed, by multiple processes. These can be either sedimentation that is settling of suspended particles or can be diluting the other dissolved contaminants to the point where these become harmless. But this natural process is elaborate and time consuming. Thus when these concentrations exceed a certain amount these are difficult to remove naturally. Water pollution is thus defined when water cannot be naturally freed of these extra particles which may cause harm to all the beings when consumed untreated.

In simple terms, water pollution is the contamination of various water sources by pollutants that can be of anthropogenic origin and are discharged without treating them first. This may be hazardous to all the living species surrounding that environment. It has harmful effects on plants, animals and other biological units as well.

With 14000 people dying in a day, water pollution has been termed the leading cause of worldwide deaths (Larry, 2006). An estimated 700 million Indians have no access to a proper toilet, and 1,000 Indian children die of diarrhoeal sickness every day (A special report on India, 2008).

Water is termed as polluted when it is damaged by anthropogenic activities and either is not fit for human consumption and/or is no longer able to support its comprising biological communities. Various natural phenomena such as volcanoes, algae blooms, storms, and earthquakes result in huge changes in water quality.

2.3 Sources of Water Pollution:

Sources of surface water pollution are categorised as following:

2.3.1 Point Sources:

The sources of water pollution that can be pinpointed to a single source of entry into the water system. An example could be a factory discarding its waste in the river or a sewer that opens up in the stream. It may also include industrial sources and other effluent discharged by these industries.

2.3.2 Non-Point Sources:

Non point sources are defined as the sources of water pollution that cannot be decisively pinpointed as originated from a single source. Rather it has wide variety of cumulative contamination roots. These could be in the form of urban runoff that is a sum of all the discharges from a municipal region that cannot be said from one source.

2.4 Heavy Metals:

Heavy metals is a term which comprises a group of metals and metalloids with density greater than 4 g/cm^3. Heavy metal pollution even if low in concentration may cause grave dangers when clubbed with exposure for larger intervals of time. This is one of the leading health degrading concerns around the world (Yahaya et al., 2010). These metals in their natural amounts are not harmful to the beings or our environment but when these exceed the defined levels may cause fatal effects. For example, Bangladesh has higher levels of arsenic in groundwater which has resulted in catastrophic results (Tuzen and. Soylak, 2006).

The advent of industrialisation and the superlative technologies have resulted in introducing these heavy metals in our environment(Abidemi, 2011). Heavy metals are part of the Earth's crust. They cannot be destroyed (Lenntech, 2005). Some of the most potentially hazardous heavy metals include Cd, Cr, Pb, As, Fe and Cu (Alloway, 1995). Anthropogenic pollution by various industrial and other activities, weathering of natural rocks and metal deposits are some of the major sources of heavy metals in groundwater(Akoto et al., 2008).

2.4.1 Necessary Heavy Metals:

A few of the heavy metals are consumed, in small quantities, and are even nutritionally beneficial for human consumption. Fe, Mn, Zn and Cu; many of these are consumed by humans in the form of naturally occurring fruits and vegetables and via man made vitamin tablets. Gallium is injected in humans for radiological purposes. While Pb is used for x-ray examinations. Other uses of these heavy metals are in various daily use items like the pesticides, batteries and alloy spare parts. These heavy metals are used in our homes in some form or another.

2.4.2 Heavy Metal toxicity:

These metals become toxic when they become hard to degrade and start accumulating in the body. They can enter our bodies via the food we eat or the air we breath or the water we drink.

Metals like Argon, Cadmium and Lead have been analyzed to have no biological significance for humans and even their low consumption can be toxic (Yahaya et al., 2010).

Human adults and children who are exposed to industries are at a direct risk of heavy metal ingestion. For children the consumption of non edible items such as contaminated soils can be a direct source (LEIC,2011). Heavy metals enter water by industrial and commercial waste, or even from acid rain breaking down soil and releasing heavy metals into groundwater (Lenntech, 2005).

2.5 Heavy Metal retention and mobility:

Heavy metal are in the groundwater both in the dissolved as well as suspended state. The basis of this existence depends on two major factors. Sorption and precipitation defines the state of existence of heavy metals in the groundwater (Asklund and Eldvall, 2005). The other parameters that have an effect on this are, pH, Eh and redox state.

2.6 Heavy Metal poisoning of Groundwater:

Contamination of soil by heavy metals is fairly easy as it acts as a repository to all the pollutants and toxic substances. With enough of the surface water percolating through this layer of soil and entering the groundwater, this may result in heavy metals being leached into the groundwater. The quality of ground water varies from place to place and with the depth of the water table. (Shyamala et al., 2008).

2.7 Naturally occurring heavy metals in groundwater:

Groundwater quality is mainly depended on its depth from surface, new water entering the area and the chances of its pollution by human intervention (USEPA, 2002). Groundwater may contain some naturally occurring amounts of these contaminants without any human contribution and this may be as a result of the physical and chemical weathering of the geological material the water has moved through.

Bangladesh has recently seen an unprecedented rise in the natural As levels in groundwater causing this to become a hazard to population.

Rocks and minerals present underground may contribute in leaching elements like Ca, Mg and ions like Cl^-. Uranium is a key component in soils. This U when breaks down may cause levels of As, fluorides to increase in the soils and thus groundwater. The incidence of high F^- and As in groundwater of areas of Assam, India and its festeration in the form of fluorosis has been studied. (Sabhapandit et 15 al., 2010).The amount of these contaminants decide whether these may or may not pose a threat to human consumption. The results of these natural sources of pollutants of groundwater rely on the type of pollutant and its quantity (USEPA, 2002).

2.8 Anthropogenic sources of Heavy Metals in groundwater:

Industrial wastes are one of the most direct sources of water pollution. So is sewage systems and agricultural waste. Manufacturing units may discard the waste that may be hazardous in nature. This may include the lead battery units, or the paint units, and also the metal spare parts units. These may result in heavy metal being directly entering the surface water and gradually becoming a part of the groundwater systems. Industrial waste may be toxic, ignitable, corrosive or reactive. If improperly managed, this waste can pose dangerous health and environmental consequences.

Metal	Manufacturing Industries
Arsenic	Phosphate and Fertilizer, Metal Hardening , Paints And Textile
cadmium	Phosphate Fertilizer, Electronics, Pigments And Paints
chromium	Metal Plating , Tanning, Rubber And Photography
copper	Plating, Rayon And Electrical
Lead	Paints, Battery
Nickel	Electroplating , Iron Steel
Zinc	Galvanizing, Plating Iron And Steel
Mercury	Chlor-Alkali, Scientific Instruments , Chemicals

Table 2.1: Various pain industries contributing in the Heavy metal conc.Source: INSA 2011

2.9 Heavy metals and their impacts on human health:

2.9.1 Arsenic: Soluble inorganic As can have toxic effects at once. Gastrointestinal problems such as severe vomiting, defects of the blood and circulation, harm to the nervous system, and may have fatal result by large quantities of As. When not fatal, such huge quantities may lower blood cell production, destroy red blood cells in the circulation, make the liver larger, alteration in the color the skin, produce slight to major tingling and loss of sensation in the some limbs, and may cause damaging effects to the brain. Exposure to inorganic As for longer times in drinking water in Bangladesh has caused many people to have black foot disease, lower limbs have a severe damage of the blood vessels in them, which might result in formation of gangrene. Arsenic poisoning have strongest impact on the blood pressure and may result in heart attacks and other cardio disease. The studies for diabetes and reproductive effects is not available. Evidences for As having effects like strokes, neurological effects, and cancer(except lung, kidney) are not strong. Human skin might suffer certain changes such as hyperkeratosis and pigmentation changes.

Fig 2.1 Blackfoot disease caused by As poisoning. Source: https://ihrr.files.wordpress.com/2010/06/arsenic-poisoning-manzur.jpg

Fig 2.2 Patient suffering from As poisoning due to long term exposure to the groundwater. Photo Courtesy: Dr. Joseph Graziano

2.9.2 Cadmium: The main sources of Cadmium poisoning in humans is through the inhalation or through the ingestion. The ingestion through dietary means may result in kidney and bone problems in adults. The inhalation through tobacco smoking may cause damage to the lungs. Ninety percent of the non-smoking population have a chance of exposure through diet and direct intake. Cd is extremely harmful to other animals and plants in the environment as well. The accumulation of Cadmium in the bodies of various organisms is a direct result of no degradation of the metal.

Wastewater is a major contributor of environmental cadmium contamination. Widespread usage of fertilizers and the industrial air emissions are also key sources of Cd in the environment. Kidneys are the main organs affected by Cd pollution in the working and non working environments both.

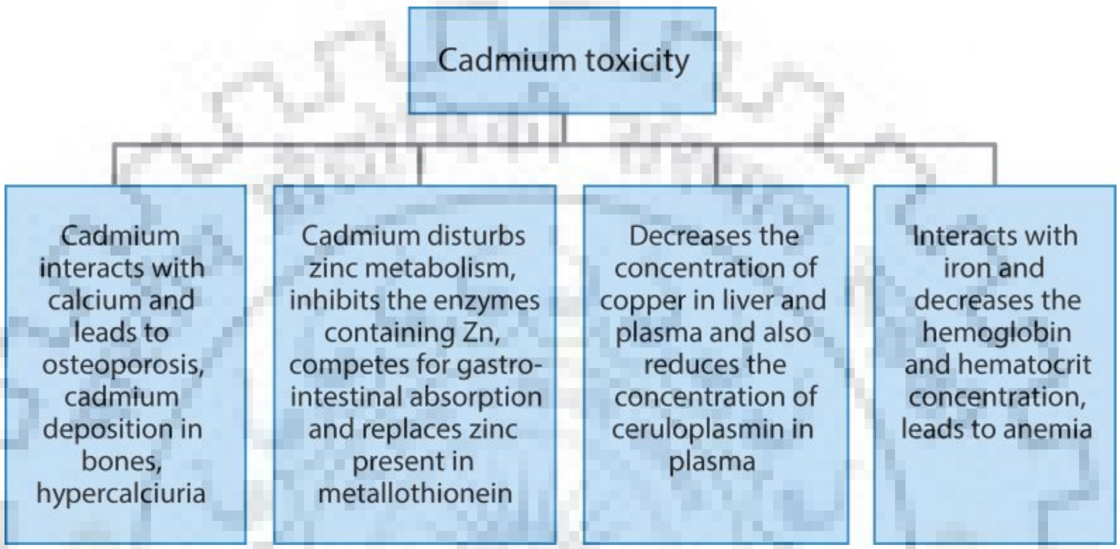


Fig 2.3 Effects of Cadmium on humans. Source: Adapted from Flora et al., 2008

2.9.3 Copper: Nausea, vomiting and abdomen pain are a few symptoms of the gastrointestinal problems caused by over intake of Cu. Liver toxicity may have fatal reactions if taken in high quantities. It may result in anaemia bu causing obstruction to the red blood cells.Mammals are naturally equipped with systems that can deal with smaller quantities of Cu, but if taken in sufficiently larger amounts it may cause liver or kidney damages. Wilson's disease is an hereditary problem in which Cu deposits in the liver. Jaundice, swelling, pain usually do not appear until teenage. No strong evidence is found for it to suggest that copper may have carcinogenic effects.

2.9.4 Nickel: Eating vegetables and fruits grown in the polluted soils is a major source of Ni intake . Ni gets accumulated in plants and thus the vegetables can cause higher intake. People who smoke are more prone to Ni entering via their lungs. Humans may be exposed to nickel by breathing air, drinking water, eating food or smoking cigarettes.

Skin contact with nickel-contaminated soil or water may also result in nickel exposure. Larger amounts of nickel can lead to: Development of lung cancer, nose cancer, larynx cancer and prostate cancer. Sickness and dizziness after exposure to nickel gas Respiratory failure, Lung embolism, Birth defects, Asthma and chronic bronchitis, Allergic reactions such as skin rashes, mainly from jewelry, Heart disorders. Nickel fumes are respiratory irritants and may cause pneumonitis. Exposure to nickel and its compounds may result in the development of a dermatitis known as “nickel itch” in sensitized individuals.

2.9.5 Lead: The examinations found an expanded danger of stomach cancer growth with higher lead introduction. In spite of the fact that it is far-fetched these outcomes would be influenced by smoking or arsenic introduction, the examinations didn't consider different components that could likewise have influenced stomach cancer growth hazard. Studies have likewise seen potential connections between working environment exposures to lead and different malignant growths, including tumors of the cerebrum, kidney, bladder, colon, and rectum. The consequences of these investigations have been blended. A few examinations have discovered connections, while others have not. The connection between lead presentation and malignant growth is plainly a worry, and more research is expected to all the more likely characterize the conceivable connection between lead introduction and various diseases.

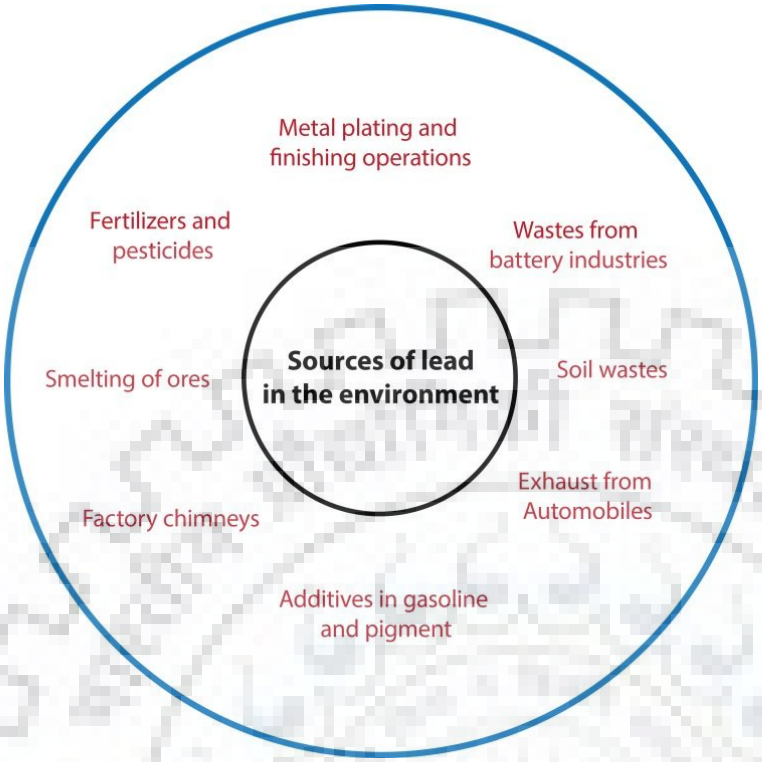


Fig 2.4: Sources of Lead in Environment. Source: Sharma and Dubey, 2005

Pollutants	Major sources	Effect on human health	Permissible level (mg/l)
Arsenic	Pesticides, fungicides, metal smelters	Bronchitis, dermatitis, poisoning	0.02
Cadmium	Welding, electroplating, pesticide fertilizer, Cd and Ni batteries, nuclear fission plant	Renal dysfunction, Lung disease, Lung cancer, Bone defects (Osteomalacia, Osteoporosis), increased blood pressure , kidney damage, bronchitis, gastrointestinal disorder, bone marrow, cancer	0.06
Lead	Paint, pesticide, smoking, automobile emission, mining, burning of coal	Mental retardation in children, developmental delay, fatal infant encephalopathy, congenital paralysis, sensor neural deafness and, acute or chronic damage to the nervous system, epilepticus, liver, kidney, gastrointestinal damage	0.1
Manganese	Welding, fuel addition, ferromanganese production	Inhalation or contact causes damage to central nervous system	0.26
Mercury	Pesticides, batteries, paper industry	Tremors, gingivitis, minor psychological changes, acrodynia characterized by pink hands and feet, spontaneous abortion, damage to nervous system, protoplasm Poisoning	0.01
Zinc	Refineries, brass manufacture, metal Plating, plumbing	Zinc fumes have corrosive effect on skin, cause damage to nervous membrane	15
Chromium	Mines, mineral sources	Damage to the nervous system, fatigue, irritability	0.05
Copper	Mining, pesticide production, chemical industry, metal piping	Anemia, liver and kidney damage, stomach and intestinal irritation	0.1

Fig 2.5: Heavy metals, their effects and the permissible values. Source: Singh, Reena & Gupta, Vineet & Mishra, Anurag & Gupta, Rajiv. (2011). Heavy metals and living systems: An overview. Indian journal of pharmacology. 43. 246-53. 10.4103/0253-7613.81505.

2.10 In Situ properties:

2.10.1 Temperature: Effluents discharged into water systems, raise the temperature of the water. The sun has much less effect in warming the waters of streams with greater and swifter flows than of streams with smaller, slower flows. Temp hasan effect on the concentration of dissolved oxygen. Oxygen is more easily dissolved in cold water. (Missouri Department of Natural Resource, accessed on May 9th, 2012). Temperature of a water system determines the kind of biological activity that it can sustain.

2.10.2 pH: The balance of positive hydrogen ions (H^+) and negative hydroxide ions (OH^-) in water determines how acidic or basic the water is. pH is expressed in a scale with ranges from 1 to 14. An acidic solution has more H^+ ions than the OH^- ion concentration. While a basic solution has a higher OH^- concentration. In pure water, the concentration of positive hydrogen ions is in equilibrium with the concentration of negative hydroxide ions, and the pH measures exactly 7.pH is one of the most important factor that if the water system can sustain life or not. If the water becomes too acidic or too basic the life system can be at harm. pH will produce a synergistic effect when acid waters (waters with low pH values) come into contact with certain chemicals and metals, they often make them more toxic than normal. (http://www.h2ou.com/h2wtrqual.htm/, assessed on April 10, 2012)

2.10.3 Electrical Conductivity: Conductivity is a proportion of the capacity of water to pass an electrical current. Conductivity in water is influenced by the presence of inorganic broke down solids, for example, chloride, nitrate, sulfate, and phosphate anions (particles that convey a negative charge) or sodium, magnesium, calcium, iron, and aluminum cations (particles that convey a positive charge). Releases to streams can change the conductivity relying upon their make-up. A fizzling sewage framework would raise the conductivity due to the nearness of chloride, phosphate, and nitrate; an oil slick would bring down the conductivity. The fundamental unit of estimation of conductivity is the mho or siemens. Conductivity is estimated in micromhos per centimeter (µmhos/cm) or microsiemens per centimeter (µS/cm). (Missouri Department of Natural Resource, got to on May ninth, 2012).

Chapter 3: MATERIALS AND METHODS

3.1 Study Area:

Haridwar is one of the biggest districts of the state of Uttarakhand in India. The districts largest city, Haridwar city is its headquarter. The district is edged by the district of Dehradun in the northern and eastern boundaries, Pauri Garhwal in the eastern and the Uttar Pradesh's districts of Muzaffarnagar and Bijnor in the southern and Saharanpur in the western boundary. Time and again Haridwar district has proven to be a paradise for nature lovers and one of the holiest places of significance in Hinduism. Haridwar presents a kaleidoscope of Indian culture and civilization.

Saharanpur Divisionary Committee, which enforced the 'Uttar Pradesh Reorganisation Bill', 1998', on 24th of Sep 1998,formed the new district of Haridwar. This came into existence on the 28th of Dec 1998. In 2000, the 'Uttar Pradesh Reorganisation Act 2000' was passed by the Indian Parliament, and thus on 9 November 2000, Haridwar became part of the newly formed Uttarakhand (then Uttaranchal), the 27th state in the Republic of India. Since 2011, Haridwar is the most populous district of the state. Haridwar, BHEL Ranipur, Roorkee, Jhabrera, Laksar, Landaura and Mohanpur Mohammadpur are the major towns in the district.The 2011 census estimate of the district's population is 1,927,029, roughly equal to the nation of Lesotho. With the population density of 817 people per square Km, the district is one of the densest. Population growth rate in Haridwar district in between 2001-2011 was 33.16 %. The district has a sex ratio of 879 females for every 1000 males, and a literacy rate of 74.62. Being a position of exceptional religious criticalness, Haridwar additionally has a few religious celebrations consistently; prevalent among them are the Kavad Mela, Somvati Amavasya Mela, Ganga Dashara, Gughal Mela,in which around 20-25 lacs (2-2.5 million) individuals partake. The study focuses on the Gurukul Narsan development block of the region.

3.1.1 Location and Land Area:

The Gurukul Narsan development block of the Haridwar district is one of the six major blocks of the region. The region has an area of about 390 sq Km, about one-sixth of the district. The region is situated in southern part of the district of Haridwar. The Haridwar district is situated in the western part of the state of Uttarakhand. It's latitude and longitude are 29.58 degree north and 78.13 degree east respectively. The height from the sea level is 249.7 mts. The district was earlier part of Uttar Pradesh state and was formed in 1998. The district is administratively subdivided into three tehsils i.e. Haridwar, Roorkee and Laksar and six development blocks i.e. Bhagwanpur, Roorkee, Narsan, Bahadrabad, Laksar and Khanpur.

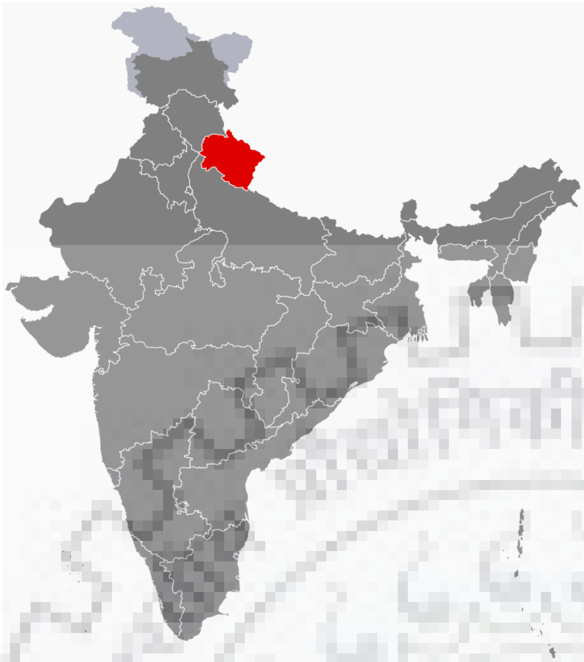


Fig 3.1: State of Uttarakhand shaded red. Source: Wikipedia

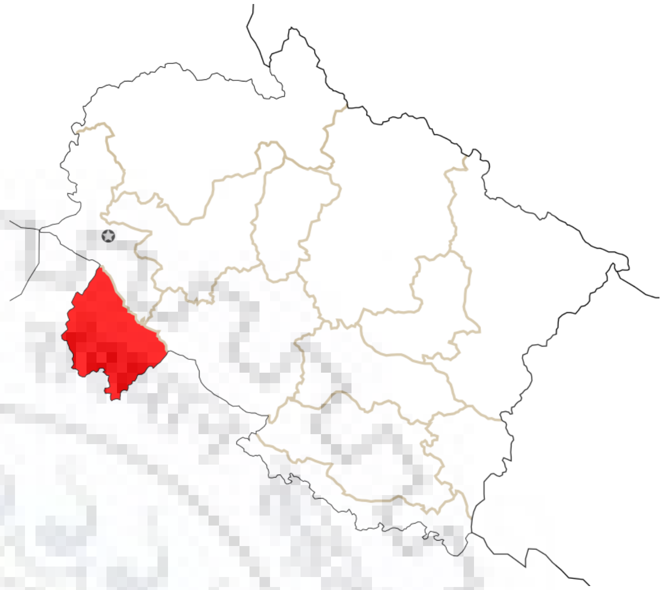


Fig 3.2: District Haridwar marked as red in Uttarakhand India Source: Wikipedia

Fig 3.3: Gurukul Narsan marked as red pin in the administrative map of Haridwar. Source: http://cgwb.gov.in/AQM/NAQUIM_REPORT/Uttarakhand/Haridwar.pdf

3.1.2 Climate:

The block is a sub-humid to dry region with mostly alluvium based soils. This has a hot, sub-humid and dry climate. Moderate subtropical to humid climate is experienced here in other seasons. The three main season are summer followed by rainy and then winters. There is an increase in temperature in the months of March from 27 degrees celsius to a maximum of 37 degrees in the month of May. In the md of June, the monsoon season begins and thus the temperature begins to lower by the end of June. As in the winters season the temperatures range from 24 degrees to 17 degree celsius in the months from Dec to Feb. Summers see the highest wind speeds, with a mean of 2.4 kmph. The min wind speed is measured in winter at 0.5 kmph in November. The evaporation is maximum in the month of May 156 mm and minimum 24.5 mm in the month of January.

3.1.3 Rainfall:

Haridwar district receives a cumulative average rainfall of 1174.3 mm in a year, of this approximately 84% is received during monsoon and only 16% occurs during other seasons. Northern parts receive the greatest rainfall. As move towards the south, the rainfall decreases. Table 2 has a record of the monthly average rainfall over the year for the Gurukul Narsan block of the district. The month to month dissemination of precipitation amid the storm season over the square demonstrates that June, July and August are the wettest month in the area. The most noteworthy precipitation is recorded amid the long stretch of August. The rainstorm retreat in the principal fortnight of October giving a pitiful precipitation of 24.6 mm. Greatest precipitation happens in the lower regions of Himalayas and continuously diminishes towards south.

Sn	Agroecological Zone	Avrage monthly rainfall (mm)	No. of Rainy Days (No.)	Maximum Rainfall intencity			Avrage weekly tem									Potencial Evapo transpiration		
							Period									Period		
				up to 15 minute (mm)	Beyond 15 but up to 30 min (mm)	Beyond 30 but up to 60min (mm)	Summer(April may)			Winter (Oct-March)			Rainy (June Sep)			Summer	Winter	Rainy
							Min	Max	mean	Min	Max	mean	Min	Max	mean			
Name of Block -Narsan																		
3	Hot Sub humid (Dry)	1080	37	91	35	10	10.1	23.7	16.9	1.1	19.3	10.2	12	23.4	17.7	4.04	1.92	3.7

Fig 3.4 Rainfall data and seasonal variation in Gurukul Narsan block. Source: http://cgwb.gov.in/AQM/NAQUIM_REPORT/Uttarakhand/Haridwar.pdf

3.1.3 Physiography:

The physiography can be divided into three main parts:

i) The structural hills: The north and northeast part of the district is called the Shiwaliks. These are the structural hills which is defines as high relief and steep slopes. Rugged topography and homogenous lithology in these parts result in higher runoff. Sand stones, conglomerates, sands, clay, silt etc form the major parts of these areas. These hills are intersected by many local minor and major faults.

ii) The Bhabhar: this unit lies right below the previous ones. These are largely composed of pebbles, cobbles, boulders, etc. These also are at higher relief than the plains and are having steep slopes. This is termed as a mixture of various types of rocks that may differ in sizes ranging from boulders to clay. These vary from place to place and is dependent on the siwaliks and the kind of drainage systems as well.

iii) The Plain: Below the Bhabhar there lies what we call as the tarai or the piedmont plains. These are areas with lower slopes and predominantly finer grain rocks like sand, silt and clay. The older plains, which characterize homogenous lithologic components brought by river Ganga have undulating topography. The younger plains with inhomogenous components have younger alluvium and lie parallel to the Ganga river.

3.1.4 Geomorphology:

The geomorphology of the area is typically divided in two parts:

1) Varanasi Uplands that is area free from flood (Banger). This is further subdivided in two parts:
    - Piedmont Zone (Bhabar): A limited southerly inclining northern piece of the upland abutting Siwalik slopes with moderate southerly inclination, regularly dynamic fluvial channel ceasing to exist and returning as spring line at distal end converging with the Varanasi plain and shaping nearby swampy (terai) conditions.
    - Varanasi Plain: Practically level with south-easterly inclination, described by low sandy hills and edges in northern part (Bhur surface) and wide broad clayey southern part with soil alkalization, plenteous relict fluvial highlights palaeochannels with wander shorts, bull bow lakes and tals.

2) Flood Plain (Khadar). This is further divided in:
    - Old Flood Plain: Characterized by palaeo-manages an account with feigns and appearing of patios, the most elevated privately created/protected is erosional and did not get mitigation while lower, topped off by Terrace alluvium, gets overwhelmed amid high floods. Portrayed by levees, wander scrolls, bull bow lakes and surrendered channels
    - Active Flood Plain: Swaying/transient dynamic channel characterized by banks with an account with point-bar, channel bar sands and over bank sediments.

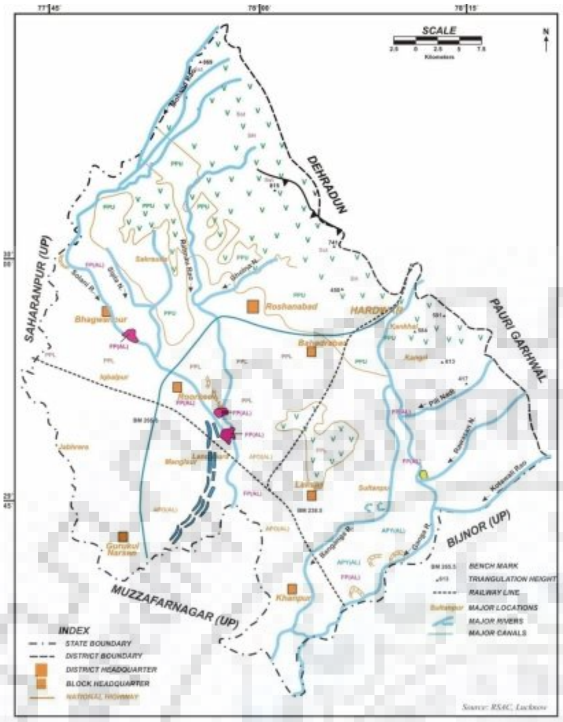


Fig 3.5 Geomorphological map of Haridwar. Source: http://cgwb.gov.in/AQM/NAQUIM_REPORT/Uttarakhand/Haridwar.pdf

These geomorphic features are summarised in the below table:

Age	Morphostratigraphic Units			Morphological Features
Late Holocene to Present	Ganga Plain	Flood Plain (Khadar)	Active Flood Plain	Oscillating/migratory active channel defined by banks with point-bar, channel bar sands and over bank silts
			Old Flood Plain	Defined by palaeobanks with bluffs and showing developments of terraces, the highest locally developed/preserved is erosional and did not receive alleviation while lower, filled up by Terrace alluvium, gets flooded during high floods. Characterized by levees, meander scrolls, ox-bow lakes and abandoned channels.
Late Pleistocene to Early Holocene		Varanasi Uplands or interfluves area free from flood (Banger)	Piedmont Zone (Bhabar)	A narrow southerly sloping northern part of the upland adjoining Siwalik hills With moderate southerly gradient, seasonally active fluvial channel dying out and reappearing as spring line at distal end merging with the Varanasi plain and forming local swampy (terai) conditions.
			Varanasi Plain	Almost flat with south-easterly gradient, characterized by low sandy mounds and ridges in northern part (Bhur surface) and wide extensive clayey sourthern part with soil alkalization, abundant relict fluvial features- palaeochannels with meander

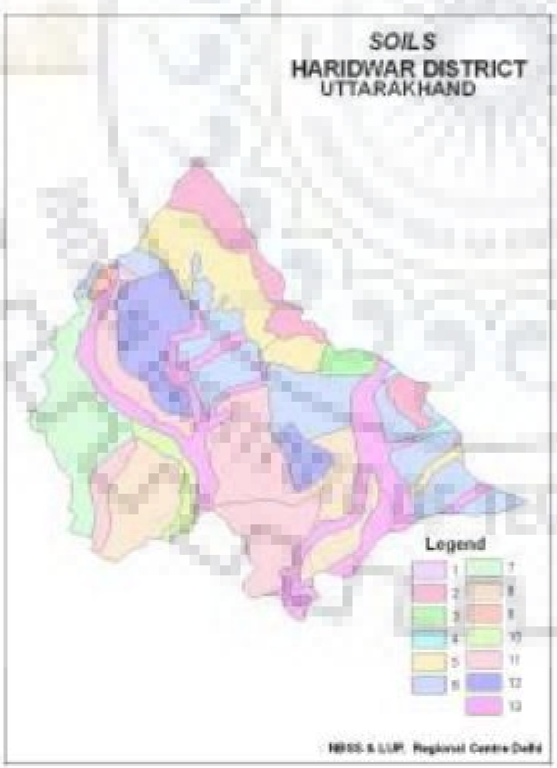
Table 3.1 Table depicting stratigraphic sequence of Haridwar. Source: http://cgwb.gov.in/AQM/NAQUIM_REPORT/Uttarakhand/Haridwar.pdf

3.1.5 Soil: Soil of a region plays an important role in the recharging process of the groundwater of a location and for the agricultural produce as well. The soils of this region are extremely fertile and fruitful. The soils in the region are divided in following categories:

Ultisols: Brown soils of the hilly areas, mostly in the northern regions.

Entisols: These exist from the foothills up until the Tarai plains. Despite the presence of boulders and other larger particles, these soils are quite fertile.

Molisols: Southern region soil also called as Tarai soils. Fine grain sand, silt content is its composition. Nearly black in appearance with maximum organic content.



SOILS OF HARIDWAR DISTRICT OF UTTAR

Shiwaliks
Summits and Ridge Tops (30-50% slopes)
1. Shallow, loamy soils severely eroded and moder
Side Slopes (30-50% slopes)
2. Medium deep, loamy soils,
3. Deep, loamy soils
Fluvial Valley (3-5% slopes)
4. Deep, loamy soils
Piedmont Plain (1-3% slope)
5. Deep, stratified loamy sandy soils .
6. Deep, loamy soils
Alluvial plain (0-1% slopes)
7. Deep, loamy soils
8. Deep, loamy silt soils
9. Deep, silt soils
10. Deep, loamy soils
Recent Flood Plain (0-3% slope)
11. Deep, loamy soils
12. Deep, silty soils
Active Flood Plain (0-3% slope)
13. Deep, sandy soils

Fig 3.6: Soils of Haridwar district. Source: http://agricoop.nic.in/sites/default/files/haridwar.pdf

3.1.6 Drainage: Ganga is the main flowing river in the district. The river enters the district and moves south and finally exits from the eastern portions. One stream rises up out of waterway Ganga at close Shahpur Sheetlakhera and passes through Bhogpur, Sultanpur Patti and Raisi called Ban Ganga River. Stream KotwaliRoa, Rasawan Nadi and Pili Nadi rising up out of Siwalik Hills in the eastern piece of the locale are the tributary of River Ganga River Ganges and Solani are the perpetual waterways. The other noticeable waterway in the region is Solani, which depletes the focal piece of the region. The Solani River starts from Saharanpur. Sipla Nadi joins Solani stream among Bhagwanpur and Roorkee. Mohand Roa, Chillawal Roa, the occasional tributaries meets Solani River at the northern piece of the region.

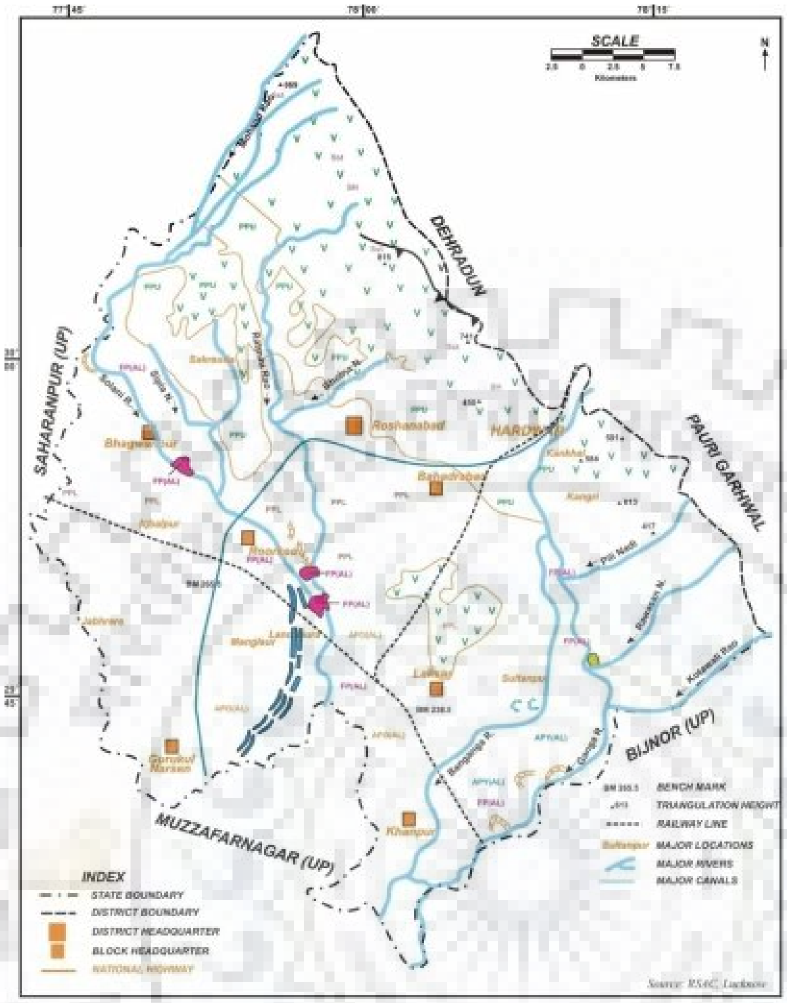


Fig 3.7: Drainage map of Haridwar. Source: http://cgwb.gov.in/AQM/NAQUIM_REPORT/Uttarakhand/Haridwar.pdf

3.1.7 Geology:

1) The northern parts of the district has hills called the Siwalik range. These have heights ranging from 600 to 900 metres.
2) This is trailed by uncovered center Siwaliks. These include Sandstone with boulders,cobbles, Pebbles, Conglomerate and related Clay and a thickness of approx 2000m.
3) Just beneath the Siwaliks are the Bhabar territory which is described by the alluvial fans, which are comprises of stone, cobbles, rocks, rock with dirt and sediments. The source residue have administered the lithological piece of the Bhabar arrangement. The

residue of the Bhabar region are heterogeneous in structure and surface, as the dregs are gotten from the lower region as well as from higher land zone in Himalayas.

4) The alluvium has been stretched out down to south in complete region. The surface has additionally changed as we go from north to south contingent on the term, separation of transportation and nature of affidavit of silt.

Era	Period	Age	Formation	Group	Lithology
Cenozoic	Neogene	Holocene	Younger alluvium Terraces, channels, flood plains, fans, paleochannels	Newer/Younger Alluvium	Sands of various grade, silt and clays
		Middle to Upper Pliestocene	Older Alluvium (Bhabber and Terai)	Ramnagar/ Varanasi/ Ambala	Boulders, Cobbles, Pebbles, Gravels, Sand, Silt & Clay
		Pliestocene to Early Pliestocene	Sedimentaries	Middle Siwaliks	Sandstone with boulders,cobbles, Pebbles, Conglomerate and associated Clay
				Upper Siwaliks	Conglomerates, Sandstones, Siltstones, Shales with boulders,Pebbles, Sands and Clay

Table 3.2 Table depicting lithologic sequence of Haridwar.

Source: http://cgwb.gov.in/AQM/NAQUIM_REPORT/Uttarakhand/Haridwar.pdf

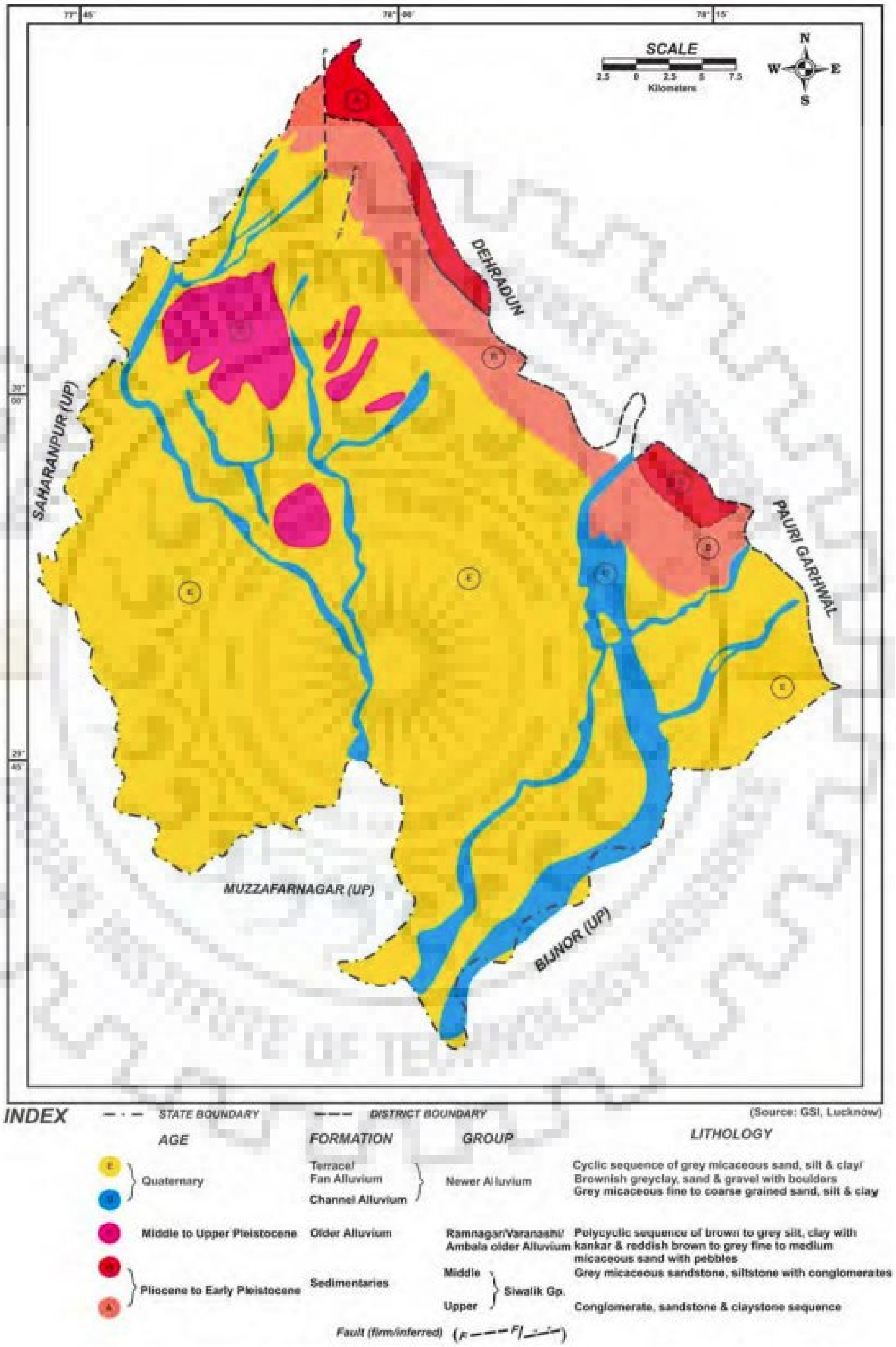


Fig 3.8: Geological map of Haridwar. Source: http://cgwb.gov.in/AQM/NAQUIM_REPORT/Uttarakhand/Haridwar.pdf

3.1.8 Hydrogeology:

Gurukul Narsan square covering a territory of 273 sq. km. lies in the focal point of the region between succession of dim micaceous sand, sediment and earth/tanish dim dirt, sand and rock with intermittent rocks and stones of patio, fans and channel alluvium of quaternary age.The depth to water level in the vast majority of this square lies between 3.20 to 19.39 m below ground level. At certain places the depth to water table of the wells rests between 11.00 to 18.00 m below ground level. The regular variation goes between 0.47m to 3.65 meters.

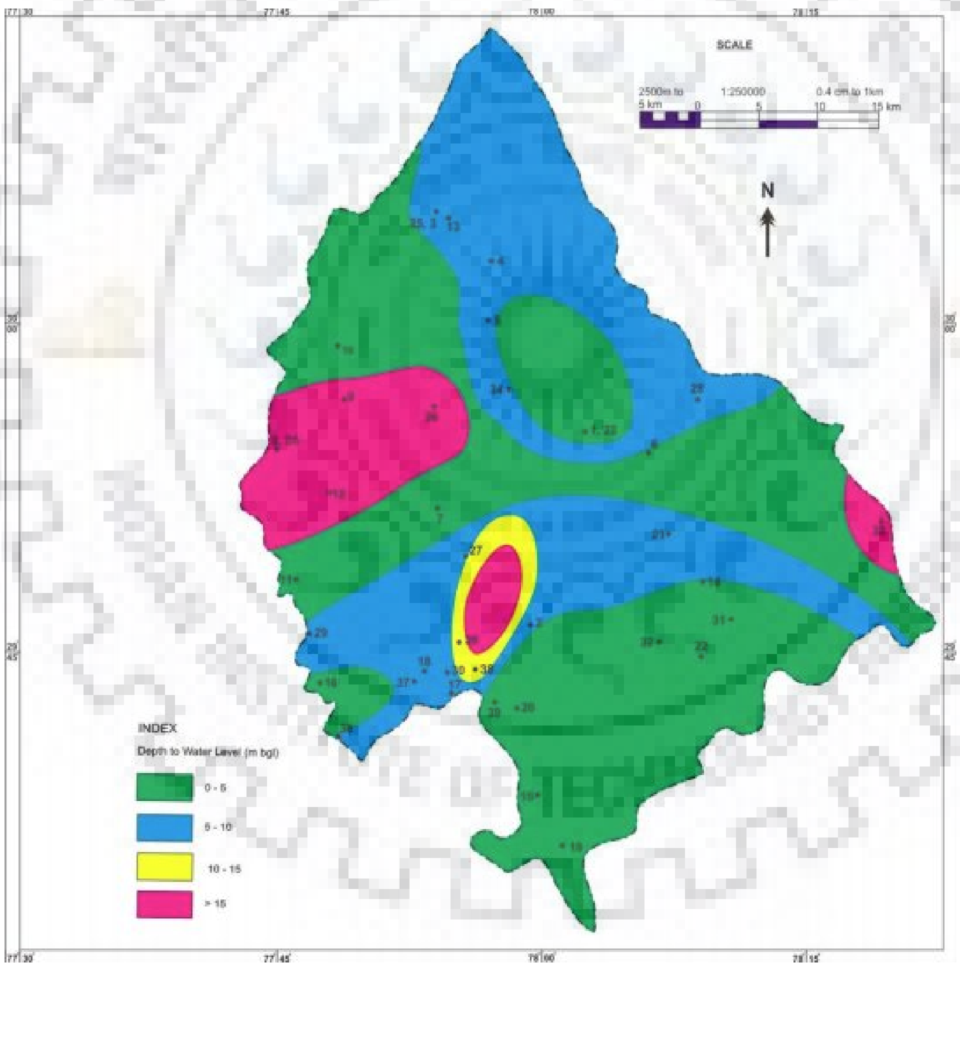


Fig 3.9: map of Haridwar showing depth of water level in the stretch. Source: http://cgwb.gov.in/AQM/NAQUIM_REPORT/Uttarakhand/Haridwar.pdf

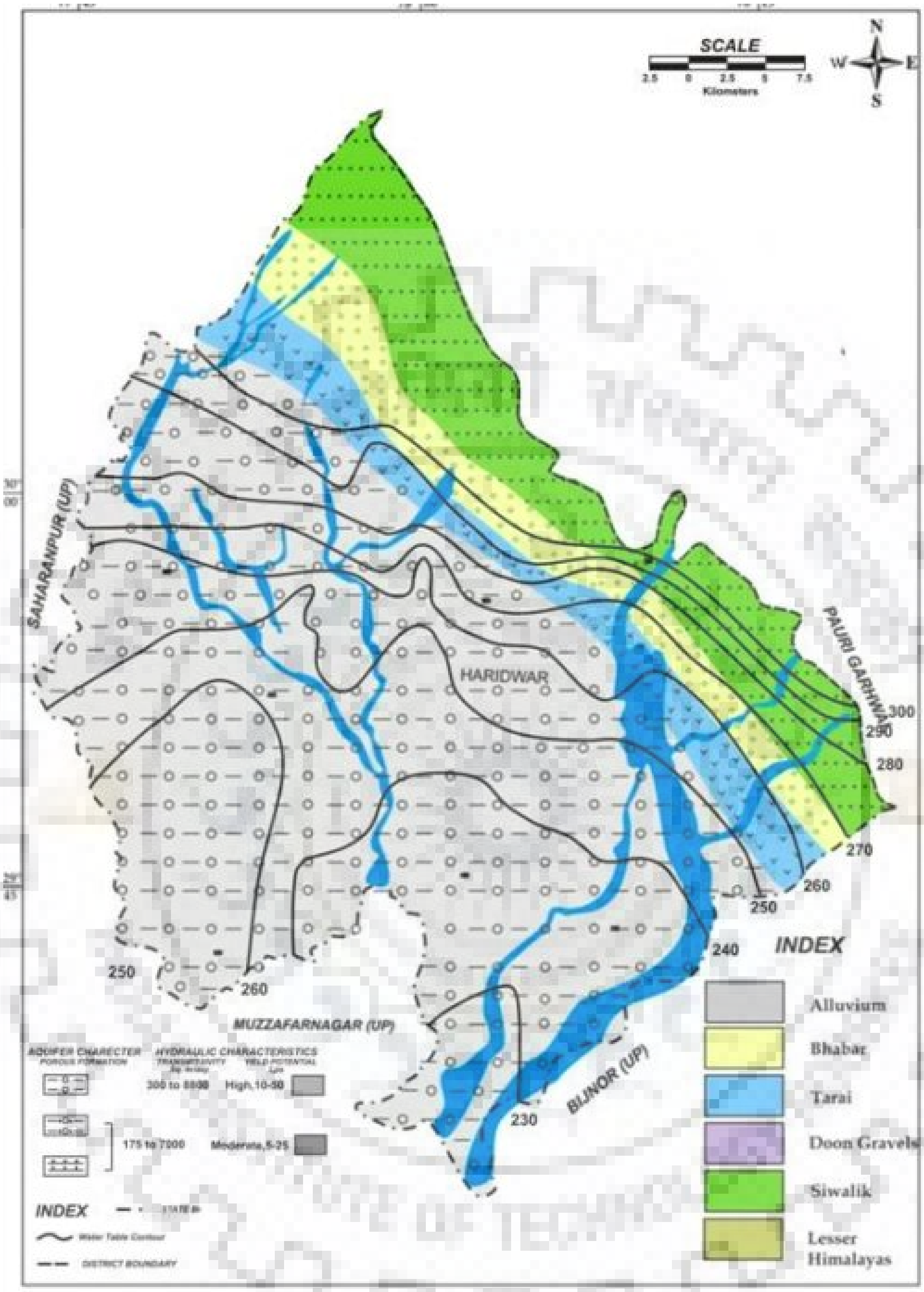


Fig 3.10: map of Haridwar showing Hydrogeology of the region.
Source: http://cgwb.gov.in/AQM/NAQUIM_REPORT/Uttarakhand/Haridwar.pdf

3.2 Sampling:

1. Using the Global Positioning system, the locations of the sampling sites were recorded. A total of 24 sampling locations were chosen covering the entire stretch of the Gurukul Narsan Block.
2. There were two phases of sampling. One in the December 2018(Post Monsoon) and second in the April 2019(Pre Monsoon)
3. The samples were collected in the 120mL plastic water bottles. Water from the source handpumps was drained at a very fast rate for obtaining results without influence of temperature of the outer metal tap. This pumping was done for five minutes continuously for every sample collected.
4. These samples were named according to a pre decided pattern.
5. The in-situ parameters mainly temperature, pH and EC were measured using the standard equipments mentioned below. The process was repeated for all the samples.
6. The two phases of sampling that is December 2018 and April 2019 are referred as Winter and Summer phases of sampling hereafter.

Fig 3.11 The sampling sites involved in this study. Source: Google Maps

Fig 3.12 The sampling sites on ground photographs. Source: Gautam Yadwani

Table 3.3 Names of the samples along with latitudes and longitudes

Sample number	Sample name	Latitude	Longitude
1	GKN-GN-1	29°41'50"	77°5058"
2	GKN-GN-2	29°4214"	77°5059"
3	GKN-GN-3	29°4212"	77°5122"
4	GKN-BP-1	29°4213"	77°5258"
5	GKN-BP-2	29°4510"	77°5316"
6	GKN-HP-1	29°4343"	77°536"
7	GKN-HP-2	29°4434"	77°518"
8	GKN-MN-1	29°523"	77°5719"
9	GKN-MU-1	29°4548"	77°5047"
10	GKN-MU-2	29°4547"	77°5113"
11	GKN-TH-1	29°4610"	77°5011"
12	GKN-TH-2	29°459"	77°4947"
13	GKN-BK-1	29°4658"	77°5030"
14	GKN-BK-2	29°4732"	77°4841"
15	GKN-KU-1	29°4613"	77°5120"
16	GKN-KU-2	29°4616"	77°5122"
17	GKN-KU-3	29°4732"	77°5058"
18	GKN-NZ-1	29°4724"	77°527"
19	GKN-LN-1	29°4737"	77°5240"
20	GKN-LN-2	29°4744"	77°5332"
21	GKN-LN-3	29°4751"	77°5418"
22	GKN-AN-1	29°4741"	77°5228"
23	GKN-AN-2	29°4852"	77°5247"
24	GKN-AN-3	29°4932"	77°5251"

3.3 Determination of in-situ parameters:

3.3.1 Temperature:

A standard pocket thermometer was used onsite to determine the temperature of the sample. The instrument was dipped in the water and the reading was recorded.

Fig 3.13 Instrument used in the study for temperature measurements. Source: snapdeal.com
Fig 3.14 Instrument used in the study for pH measurements. Source: snapdeal.com

3.3.2 pH:

pH was measured using a pH meter HANNA HI 83141, (degree of accuracy 0.01) which is also equipped to measure temperature. The calibration was done by using buffer solution of known pH (pH 4) and immersing the pH electrode into it and the asymmetric potential control toggled until the digital meter reads the known pH value. The standard electrode after rinsing with distilled water was further immersed in a second buffer solution (pH 9) and the instrument adjusted to read the pH value of this buffer solution. The above procedure is prerequisite before taking any of the sample readings. With the pH meter calibrated, the instrument was washed with the water sample to be analyzed before it was immersed in the water sample. The beaker and the electrode were washed in between samples with Mili-Q water in order to prevent contamination by other samples.

3.3.3 Electrical Conductivity:

The conductivity meter of this brand was used. It was calibrated using the known solution of this conductivity. The sample were measured in the laboratory within one day of sample collection. Within different samples the probe was washed properly with the mili-q water.

Fig 3.15 EC meter used in this study. Source: snapdeal.com

3.3.4 Heavy Metal analysis:

Standard procedure of open digestion set by the APHA (2009) was employed for the digestion of water samples. 50 mL well-mixed, acid preserved sample was measured and transferred into a beaker. 5 mL of concentrated HNO3 was added to 50 mL of the water sample. The digested samples were used to measure the individual metal concentrations in the water using an atomic absorption spectrometer (AAS).

Fig 3.16 ICPMS probe used in this study. Source: https://www.iitr.ac.in/centers/IIC/pages/Organisation+Home.html

Chapter 4: RESULTS AND DISCUSSION

4.1 In-situ Measurements:

The temperature and pH of the samples was measured on ground, the EC was measured in the lab within two hours of sampling.

4.1.1 Temperature values:

The values of temperature in degree celsius ranged from 21.8-24.4 in phase 1 of sampling and had a mean and standard deviation of 22.948 and 0.631 respectively. For phase 2 the range is 24.2-27.4 and values of mean and standard deviation are 25.605 and 0.886.

Table 4.1 Names of the samples along with latitudes and longitudes and temperatures for phases 1 and 2

Sample no.	Sample name	Temp(in deg C) Phase 1	Temp(in deg C) Phase 2
1	GKN-GN-1	23.2	26
2	GKN-GN-2	24.4	27.2
3	GKN-GN-3	24.2	25.4
4	GKN-BP-1	22.5	27
5	GKN-BP-2	23.5	25.8
6	GKN-HP-1	24.3	26.6
7	GKN-HP-2	22	24.5
8	GKN-MN-1	22.8	25.8
9	GKN-MU-1	22.3	26.1
10	GKN-MU-2	22.6	25.8
11	GKN-TH-1	23.3	27.4
12	GKN-TH-2	23.1	25.1
13	GKN-BK-1	22.4	25.5

14	GKN-BK-2	23	Handpump damaged
15	GKN-KU-1	22.8	25.8
16	GKN-KU-2	22.4	Handpump damaged
17	GKN-KU-3	22.7	24.6
18	GKN-NZ-1	22.8	24.2
19	GKN-LN-1	21.8	24.9
20	GKN-LN-2	22.6	24.8
21	GKN-LN-3	23.5	26.3
22	GKN-AN-1	22.8	25
23	GKN-AN-2	22.6	24.6
24	GKN-AN-3	22.9	24.9

Table 4.2 Mean and Ranges of Temperature for both phases

Phase	Mean±S.D.	Range
Winter(Post Monsoon)	22.948±0.631	21.8-24.4
Summer(Pre Monsoon)	25.605±0.886	24.2-27.4

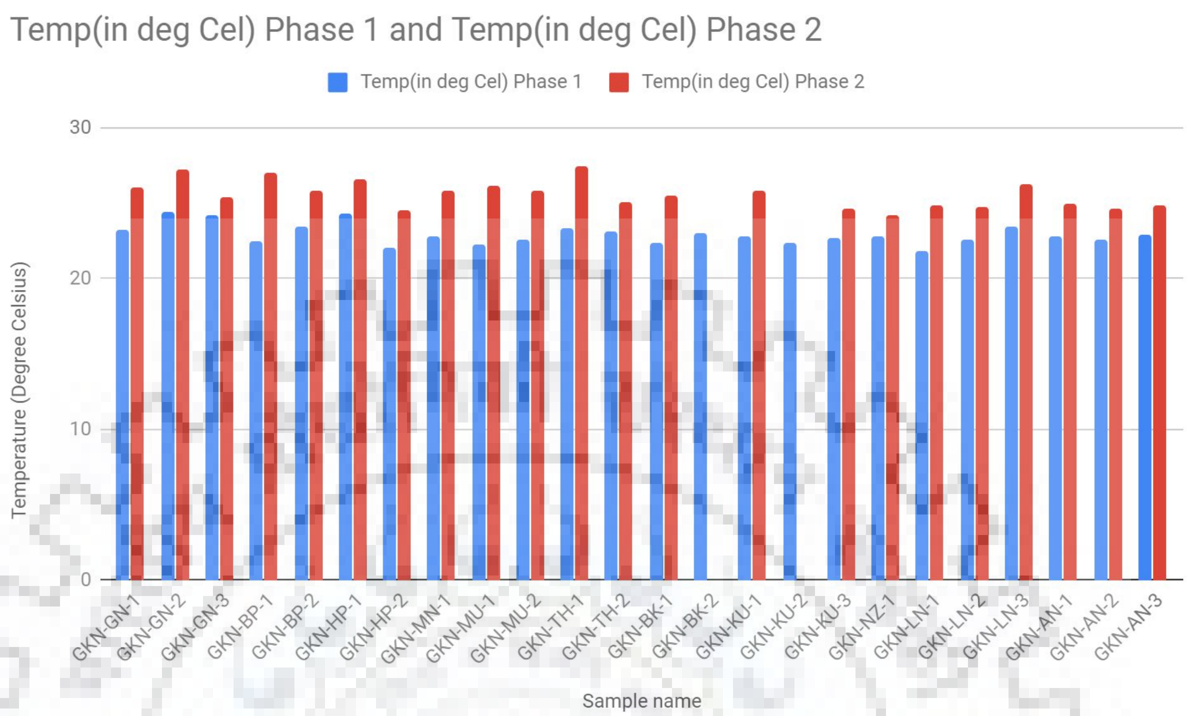


Fig 4.1 Temperature variation in the two phases of sampling for all locations. Source: Made by Gautam Yadwani

4.1.2 pH values:

The values of pH ranged from 7.12-7.9 in phase 1 of sampling and had a mean and standard deviation of 7.456 and 0.205 respectively. For phase 2 the range is 7-8.5 and values of mean and standard deviation are 7.823 and 0.351. The permissible limits for drinking water as advised by BIS 2012 is 6.5 to 8.5 on the pH scale.

Table 4.3 Names of the samples along with latitudes and longitudes and pH for phases 1 and 2

Sample no.	Sample name	Latitude	Longitude	pH phase 1	pH phase 2
1	GKN-GN-1	29°41'50"	77°5058"	7.6	7.6
2	GKN-GN-2	29°4214"	77°5059"	7.12	7
3	GKN-GN-3	29°4212"	77°5122"	7.58	7.6
4	GKN-BP-1	29°4213"	77°5258"	7.3	7.8
5	GKN-BP-2	29°4510"	77°5316"	7.44	7.8
6	GKN-HP-1	29°4343"	77°536"	7.36	7.9

7	GKN-HP-2	29°4434"	77°518"	7.6	8.5
8	GKN-MN-1	29°523"	77°5719"	7.21	7.8
9	GKN-MU-1	29°4548"	77°5047"	7.24	7.1
10	GKN-MU-2	29°4547"	77°5113"	7.25	7.6
11	GKN-TH-1	29°4610"	77°5011"	7.49	7.9
12	GKN-TH-2	29°459"	77°4947"	7.45	7.9
13	GKN-BK-1	29°4658"	77°5030"	7.51	7.8
14	GKN-BK-2	29°4732"	77°4841"	7.88	damaged
15	GKN-KU-1	29°4613"	77°5120"	7.62	7.8
16	GKN-KU-2	29°4616"	77°5122"	7.78	damaged
17	GKN-KU-3	29°4732"	77°5058"	7.9	8.2
18	GKN-NZ-1	29°4724"	77°527"	7.27	7.8
19	GKN-LN-1	29°4737"	77°5240"	7.65	7.7
20	GKN-LN-2	29°4744"	77°5332"	7.42	8.1
21	GKN-LN-3	29°4751"	77°5418"	7.25	7.5
22	GKN-AN-1	29°4741"	77°5228"	7.35	8.1
23	GKN-AN-2	29°4852"	77°5247"	7.34	8.2
24	GKN-AN-3	29°4932"	77°5251"	7.38	8.4

Table 4.4 Mean and Ranges of Temperature for both phases

Phase	Mean±S.D.	Range
Winter(Post Monsoon)	7.456±0.205	7.12-7.9
Summer(Pre Monsoon)	7.823±0.351	7-8.5

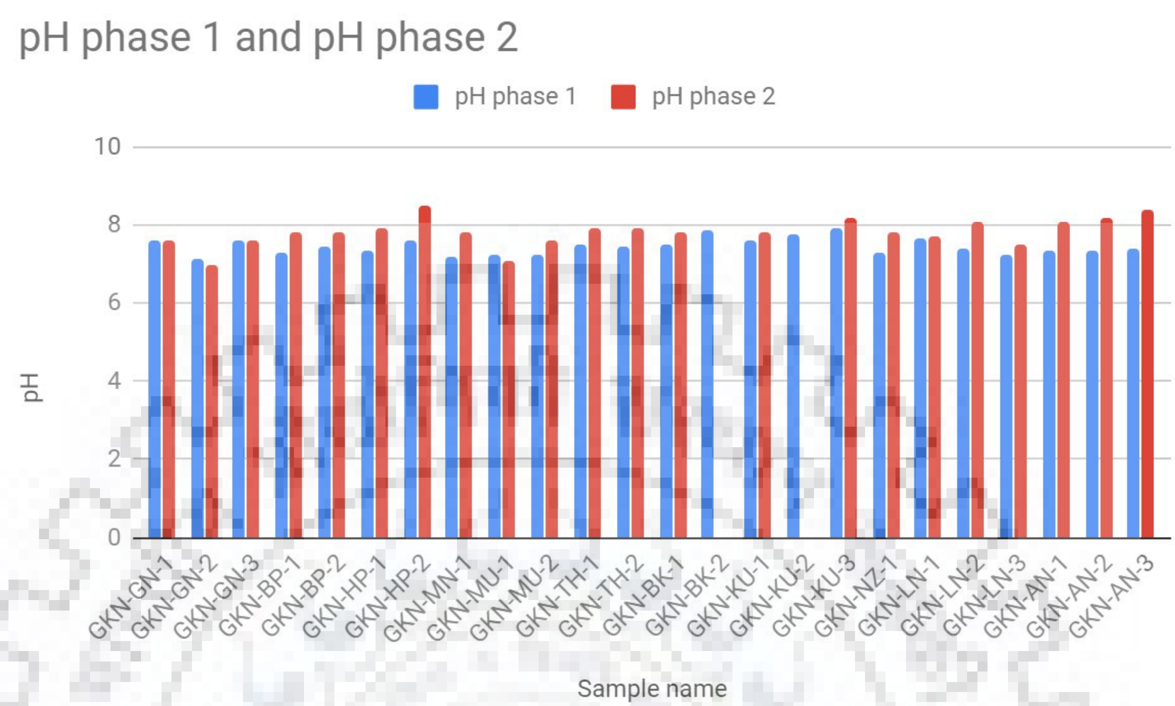


Fig 4.2 pH variation in the two phases of sampling for all locations. Source: Made by Gautam Yadwani

4.1.3 Electrical Conductivity:

The values of EC ranged from 168-878 uS/cm in phase 1 of sampling and had a mean and standard deviation of 458.75 uS/cm and 176.441 uS/cm respectively. For phase 2 the range is 191-716 uS/cm and values of mean and standard deviation are 441.773 uS/cm and 160.424 uS/cm. Typical fresh drinking water values for electrical conductivity lie between 0 and 1500 uS/cm.

Table 4.5 Names of the samples along with latitudes and longitudes and EC for phases 1 and 2

Sample number	Sample name	EC(uS/cm) phase 1	EC(uS/cm) phase 2
1	GKN-GN-1	462	368
2	GKN-GN-2	523	529
3	GKN-GN-3	623	716

4	GKN-BP-1	456	478
5	GKN-BP-2	485	517
6	GKN-HP-1	458	451
7	GKN-HP-2	192	191
8	GKN-MN-1	639	673
9	GKN-MU-1	611	491
10	GKN-MU-2	568	549
11	GKN-TH-1	407	543
12	GKN-TH-2	437	435
13	GKN-BK-1	450	461
14	GKN-BK-2	209	damaged
15	GKN-KU-1	438	515
16	GKN-KU-2	310	damaged
17	GKN-KU-3	357	244
18	GKN-NZ-1	758	398
19	GKN-LN-1	526	575
20	GKN-LN-2	300	306
21	GKN-LN-3	878	695
22	GKN-AN-1	584	191
23	GKN-AN-2	171	192
24	GKN-AN-3	168	201

Table 4.6 Mean and Ranges of EC for both phases

Phase	Mean±S.D.	Range
Winter(Post Monsoon)	458.75±176.441	168-878
Summer(Pre Monsoon)	441.773±160.424	191-716

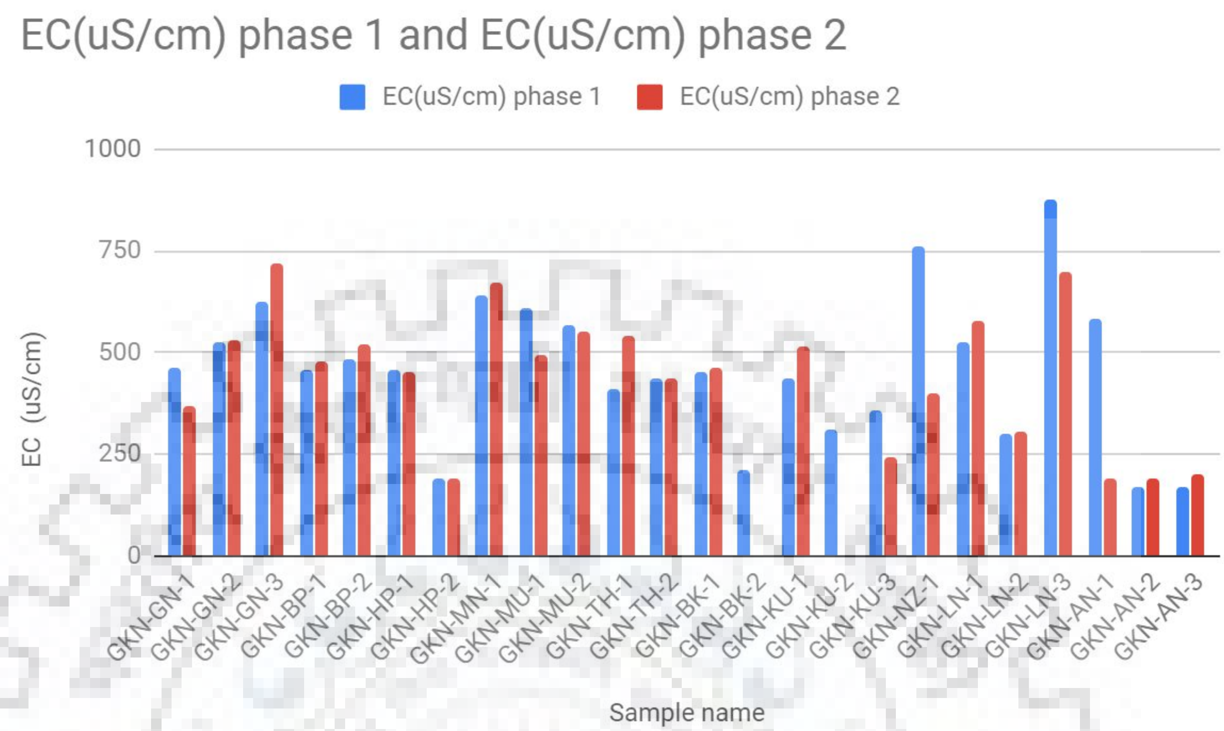


Fig 4.3 EC variation in the two phases of sampling for all locations. Source: Made by Gautam Yadwani

4.1.4 Heavy Metal Concentrations Phase 1:

The values obtained by the ICP-MS analysis of the heavy metals are shown in the below tables. The permissible values are mentioned in the parenthesis of each element. The values shown are in ppb(parts per billion). The values exceeding the permissible limits are highlighted in red.

Table 4.7 Names of the samples along with heavy metal values in ppb for phase 1

Sample name	Depth(in ft.)	Au(2.2)	As(10)	Ca(75000)	Cr(50)
GKN-GN-1	50-100	0.159	1.118	10608.689	1.257
GKN-GN-2	0-50	0.244	0.543	22422.465	2.209
GKN-GN-3	150-200	0.17	0.688	13735.577	2.175
GKN-BP-1	100-150	0.071	0.983	33848.672	2.104
GKN-BP-2	100-150	0.076	0.881	11723.969	1.641

GKN-HP-1	100-150	0.108	1.95	55446.958	2.515
GKN-HP-2	150-200	0.1	1.454	13343.159	1.614
GKN-MN-1	100-150	3.43	1.27	19406.41	2.023
GKN-MU-1	50-100	0.158	0.745	10521.264	1.301
GKN-MU-2	50-100	0.078	0.552	61896.145	1.504
GKN-TH-1	100-150	0.053	2.544	9856.023	0.872
GKN-TH-2	150-200	0.07	0.866	8780.465	0.875
GKN-BK-1	100-150	0.14	0.819	9235.811	1.62
GKN-BK-2	100-150	0.148	0.588	13425.488	1.319
GKN-KU-1	0-50	0.136	0.724	17304.897	1.998
GKN-KU-2	50-100	0.083	1.892	10883.871	1.388
GKN-KU-3	50-100	0.161	3.678	6668.017	0.926
GKN-NZ-1	50-100	0.1	0.435	15324.42	1.056
GKN-LN-1	150-200	0.134	0.508	10343.703	1.943
GKN-LN-2	200-250	0.066	2.722	16801.415	1.9
GKN-LN-3	150-200	0.199	1.108	23077.72	1.964
GKN-AN-1	100-150	0.246	0.501	20686.208	1.65
GKN-AN-2	100-150	0.164	0.428	9898.48	1.199
GKN-AN-3	100-150	0.152	0.411	11715.092	1.252

Table 4.8 Names of the samples along with heavy metal values in ppb for phase 1

Sample name	Depth(in ft.)	U(15)	Ba(700)	Cd(3)	Ni(20)
GKN-GN-1	50-100	0.16	17.273	0.022	0.819
GKN-GN-2	0-50	0.163	26.517	0.044	1.368
GKN-GN-3	150-200	0.376	23.019	0.053	0.852
GKN-BP-1	100-150	0.392	51.946	0.033	1.368
GKN-BP-2	100-150	0.36	18.608	0.037	1.039
GKN-HP-1	100-150	2.162	66.945	0.038	14.231
GKN-HP-2	150-200	0.259	22.781	0.025	0.751
GKN-MN-1	100-150	1.637	42.982	0.02	0.885
GKN-MU-1	50-100	0.423	20.522	0.026	0.553
GKN-MU-2	50-100	0.784	51.263	0.119	2.493
GKN-TH-1	100-150	0.215	37.785	0.072	0.518

GKN-TH-2	150-200	0.864	13.143	0.02	0.917
GKN-BK-1	100-150	0.356	20.925	0.017	0.496
GKN-BK-2	100-150	0.334	17.124	0.038	1.014
GKN-KU-1	0-50	0.4	25.363	0.025	0.828
GKN-KU-2	50-100	0.691	21.933	0.409	1.335
GKN-KU-3	50-100	0.217	14.809	0.019	0.585
GKN-NZ-1	50-100	0.384	14.866	0.017	0.748
GKN-LN-1	150-200	0.607	12.358	0.015	1.062
GKN-LN-2	200-250	0.723	39.169	0.017	0.789
GKN-LN-3	150-200	2.514	58.17	0.038	1.341
GKN-AN-1	100-150	0.576	42.247	0.146	1.133
GKN-AN-2	100-150	0.067	10.368	0.015	0.664
GKN-AN-3	100-150	0.063	12.17	0.036	0.706

Table 4.9 Names of the samples along with heavy metal values in ppb for phase 1

Sample name	Depth(in ft.)	Cu(50)	Fe(300)	Mn(100)	Pb(10)
GKN-GN-1	50-100	0.48	139.425	1.563	0.202
GKN-GN-2	0-50	0.556	193.674	1.294	0.199
GKN-GN-3	150-200	0.658	128.13	1.291	0.193
GKN-BP-1	100-150	1.109	207.235	1.194	0.146
GKN-BP-2	100-150	1.153	140.377	1.478	0.342
GKN-HP-1	100-150	0.28	208.871	6.202	0.12
GKN-HP-2	150-200	0.299	138.019	1.844	0.221
GKN-MN-1	100-150	0.304	167.22	1.627	0.135
GKN-MU-1	50-100	0.365	101.549	2.553	0.166
GKN-MU-2	50-100	0.532	236.545	31.161	0.184
GKN-TH-1	100-150	0.447	100.222	1.326	0.301
GKN-TH-2	150-200	0.305	91.319	1.198	0.229
GKN-BK-1	100-150	0.398	94.348	0.868	0.157
GKN-BK-2	100-150	0.493	129.507	2.252	0.276
GKN-KU-1	0-50	0.228	150.043	2.564	0.129
GKN-KU-2	50-100	2.022	105.642	3.194	0.336
GKN-KU-3	50-100	0.177	86.717	1.337	0.122
GKN-NZ-1	50-100	0.245	134.015	2.047	0.102

GKN-LN-1	150-200	0.216	108.755	0.533	0.093
GKN-LN-2	200-250	0.203	149.046	33.296	0.254
GKN-LN-3	150-200	0.468	192.638	6.56	0.128
GKN-AN-1	100-150	0.364	180.399	4.059	0.527
GKN-AN-2	100-150	0.172	102.489	1.788	0.133
GKN-AN-3	100-150	3.186	109.298	2.846	0.142

Table 4.10 Names of the samples along with heavy metal values in ppb for phase 1

Sample name	**Depth(in ft.)**	**Se(10)**	**K(10000)**	**Mg(30000)**	**Na(20000)**
GKN-GN-1	50-100	0.56	4853.791	17583.117	3657.15
GKN-GN-2	0-50	1.229	13714.719	46871.837	21804.809
GKN-GN-3	150-200	0.814	6624.525	56155.09	10028.243
GKN-BP-1	100-150	0.695	5364.83	34111.138	6165.847
GKN-BP-2	100-150	0.729	4829.48	36209.287	8355.024
GKN-HP-1	100-150	2.917	6173.585	32907.241	6183.276
GKN-HP-2	150-200	0.746	5010.361	11653.513	3709.427
GKN-MN-1	100-150	1.255	6575.087	52042.538	16699.043
GKN-MU-1	50-100	1.153	61188.656	35431.849	5806.962
GKN-MU-2	50-100	0.89	6375.818	38484.672	12188.37
GKN-TH-1	100-150	2.298	6491.392	18181.92	9358.982
GKN-TH-2	150-200	1.518	5329.809	26180.225	11041.806
GKN-BK-1	100-150	0.712	8007.639	31686.81	8766.892
GKN-BK-2	100-150	1.06	2751.036	13217.591	3223.795
GKN-KU-1	0-50	0.873	4807.107	27955.789	10502.475
GKN-KU-2	50-100	0.653	5840.951	22588.841	5579.985
GKN-KU-3	50-100	0.865	58168.408	16236.277	4123.973
GKN-NZ-1	50-100	0.619	5851.46	50899.923	26668.724
GKN-LN-1	150-200	1.153	20495.463	31153.448	7744.853
GKN-LN-2	200-250	0.585	6765.687	21005.031	5576.829
GKN-LN-3	150-200	10.225	96807.823	55061.357	16731.525
GKN-AN-1	100-150	1.543	6088.091	40806.165	8048.541
GKN-AN-2	100-150	0.712	828.27	12171.367	3677.569

GKN-AN-3	100-150	0.534	854.099	12680.117	3836.424

4.1.5 Heavy Metal Concentrations Phase 2:

The values obtained by the ICP-MS analysis of the heavy metals are shown in the below tables. The permissible values are mentioned in the parenthesis of each element. The values shown are in ppb(parts per billion). The values exceeding the permissible limits are highlighted in red.

Table 4.11 Names of the samples along with heavy metal values in ppb for phase 2

Sample name	**Depth(in ft.)**	**Au(2.2)**	**As(10)**	**Ca(75000)**	**Cr(50)**
GKN-GN-1	50-100	0.05	3.333	54236.004	1.765
GKN-GN-2	0-50	0.069	0.567	48813.792	2.523
GKN-GN-3	150-200	0.068	0.793	98320.54	4.027
GKN-BP-1	100-150	0.023	0.605	75503.998	3.252
GKN-BP-2	100-150	0.026	1.945	83569.402	3.571
GKN-HP-1	100-150	0.027	5.213	71553.489	3.796
GKN-HP-2	150-200	0.022	2.254	26810.002	1.623
GKN-MN-1	100-150	0.067	3.741	90037.273	4.261
GKN-MU-1	50-100	0.037	0.731	81901.169	2.267
GKN-MU-2	50-100	0.024	0.461	88458.763	2.5
GKN-TH-1	100-150	0.017	3.96	76309.108	2.32
GKN-TH-2	150-200	0.022	1.413	70222.771	2.13
GKN-BK-1	100-150	0.039	1.451	69790.294	2.557
GKN-BK-2	100-150				
GKN-KU-1	0-50	0.047	0.995	77740.217	3.748
GKN-KU-2	50-100				
GKN-KU-3	50-100	0.025	5.784	36043.711	2.147
GKN-NZ-1	50-100	0.027	0.612	61349.422	1.964
GKN-LN-1	150-200	0.038	0.668	86853.827	3.236
GKN-LN-2	200-250	0.022	4.803	45314.02	2.216

GKN-LN-3	150-200	0.03	1.047	108117.952	3.218
GKN-AN-1	100-150	0.044	1.857	26287.228	1.588
GKN-AN-2	100-150	0.044	1.962	26818.105	1.456
GKN-AN-3	100-150	0.041	1.931	26170.17	1.623

Table 4.12 Names of the samples along with heavy metal values in ppb for phase 2

Sample name	Depth(in ft.)	U(15)	Ba(700)	Cd(3)	Ni(20)
GKN-GN-1	50-100	0.428	87.111	0.058	1.087
GKN-GN-2	0-50	0.198	40.838	0.117	1.83
GKN-GN-3	150-200	0.909	174.62	0.182	1.883
GKN-BP-1	100-150	0.405	114.787	0.126	2.464
GKN-BP-2	100-150	0.803	125.289	0.083	1.621
GKN-HP-1	100-150	3.002	132.627	0.112	1.868
GKN-HP-2	150-200	0.294	33.979	0.241	0.703
GKN-MN-1	100-150	4.588	177.829	0.162	1.267
GKN-MU-1	50-100	1.219	104.339	0.079	1.766
GKN-MU-2	50-100	1.039	118.886	0.051	1.877
GKN-TH-1	100-150	0.791	166.817	0.065	1.603
GKN-TH-2	150-200	1.814	96.224	0.148	1.598
GKN-BK-1	100-150	0.905	128.961	0.125	1.287
GKN-BK-2	100-150				
GKN-KU-1	0-50	1.045	92.816	0.071	1.376
GKN-KU-2	50-100				
GKN-KU-3	50-100	0.483	54.518	0.04	0.996
GKN-NZ-1	50-100	0.794	53.119	0.081	1.069
GKN-LN-1	150-200	2.06	120.216	0.071	1.482
GKN-LN-2	200-250	1.031	76.098	0.077	0.961
GKN-LN-3	150-200	5.267	262.083	0.103	1.846
GKN-AN-1	100-150	0.65	21.91	0.073	0.503
GKN-AN-2	100-150	0.668	26.322	0.074	0.897
GKN-AN-3	100-150	0.665	24.293	0.055	0.849

Table 4.13 Names of the samples along with heavy metal values in ppb for phase 2

Sample name	Depth(in ft.)	Cu(50)	Fe(300)	Mn(100)	Pb(10)
GKN-GN-1	50-100	0.387	160.469	6.628	0.157
GKN-GN-2	0-50	0.964	122.644	3.753	0.208
GKN-GN-3	150-200	2.78	200.798	8.653	0.164
GKN-BP-1	100-150	4.438	175.479	7.092	0.302
GKN-BP-2	100-150	4.544	178.915	2.783	0.196
GKN-HP-1	100-150	0.95	157.272	6.629	0.279
GKN-HP-2	150-200	0.868	84.217	0.187	0.272
GKN-MN-1	100-150	0.935	191.298	4.128	0.161
GKN-MU-1	50-100	2.047	184.447	18.914	0.177
GKN-MU-2	50-100	0.568	214.9	100.476	0.174
GKN-TH-1	100-150	1.474	170.916	33.991	0.186
GKN-TH-2	150-200	1.085	157.663	14.53	0.173
GKN-BK-1	100-150	1.82	156.376	4.376	0.218
GKN-BK-2	100-150				
GKN-KU-1	0-50	1.156	169.725	14.941	0.167
GKN-KU-2	50-100				
GKN-KU-3	50-100	0.515	96.614	11.039	0.145
GKN-NZ-1	50-100	0.684	140.919	2.971	0.132
GKN-LN-1	150-200	0.592	191.219	3.628	0.182
GKN-LN-2	200-250	1.05	115.806	58.366	0.202
GKN-LN-3	150-200	0.974	227.564	42.672	0.207
GKN-AN-1	100-150	0.648	80.746	0.844	0.211
GKN-AN-2	100-150	0.59	83.941	3.987	0.215
GKN-AN-3	100-150	0.96	84.63	1.65	0.246

Table 4.14 Names of the samples along with heavy metal values in ppb for phase 2

Sample name	Depth(in ft.)	Se(10)	K(10000)	Mg(30000)	Na(20000)
GKN-GN-1	50-100	1.005	3337.493	16524.125	5919.521
GKN-GN-2	0-50	1.893	1211.531	30634.05	24545.096
GKN-GN-3	150-200	1.449	5472.418	39636.487	13549.476
GKN-BP-1	100-150	1.321	3525.267	23380.625	S
GKN-BP-2	100-150	1.25	3432.221	25580.147	9908.438

GKN-HP-1	100-150	5.119	3837.979	21179.993	6745.301
GKN-HP-2	150-200	1.169	1839.547	7273.348	3977.584
GKN-MN-1	100-150	1.513	4739.79	37209.239	20183.621
GKN-MU-1	50-100	1.689	5109.498	23672.488	8189.948
GKN-MU-2	50-100	1.081	4598.585	26707.618	15039.129
GKN-TH-1	100-150	5.481	4752.388	14732.355	12009.65
GKN-TH-2	150-200	1.922	3730.776	18275.302	12528.614
GKN-BK-1	100-150	1.385	3750.284	20408.799	9924.517
GKN-BK-2	100-150				
GKN-KU-1	0-50	1.642	3406.506	21200.483	13313.67
GKN-KU-2	50-100				
GKN-KU-3	50-100	1.186	2818.077	11231.278	4759.357
GKN-NZ-1	50-100	1.315	2250.806	23068.883	5885.732
GKN-LN-1	150-200	1.87	3874.611	25658.388	15001.67
GKN-LN-2	200-250	0.912	4491.168	12970.239	6607.427
GKN-LN-3	150-200	15.748	6842.151	35831.22	18107.972
GKN-AN-1	100-150	0.988	1451.836	8686.419	3926.949
GKN-AN-2	100-150	1.075	1417.267	9035.976	4055.984
GKN-AN-3	100-150	1.198	1503.342	8954.015	4062.885

4.1.6 Heavy Metal Concentration comparison for each element in Summer and Winter phases of sampling:

- Fig 4.4 shows the concentration variation of the elements As and Mn, in this As and Mn shows very little change in its values within the seasons, the values increase as a general trend though and both these elements are within the maximum permissible limit prescribed by BIS. There are a few exceptions in values of Mn in both the phases, shown by black diamonds in these figures. These outliers had values upto 40 in phase winter and these shifted to a 100 in phase summer.

Fig 4.4 As and Mn Concentration variations in the two phases of sampling, box plot. Outliers are shown as black diamonds. Source: Made by Gautam Yadwani

Fig 4.5 shows the concentration variation of the elements Au, Cu, Cd and Pb, in this Au and Pb shows very little change in its values within the seasons and both have decrease in the concentrations. While Cu and Cd have a increase. All these elements are within the maximum permissible limit prescribed by BIS. There are a few exceptions in values of Au, Cd and Cu in both the phases, shown by black diamonds in these figures. These outliers had maximum value variation for copper.

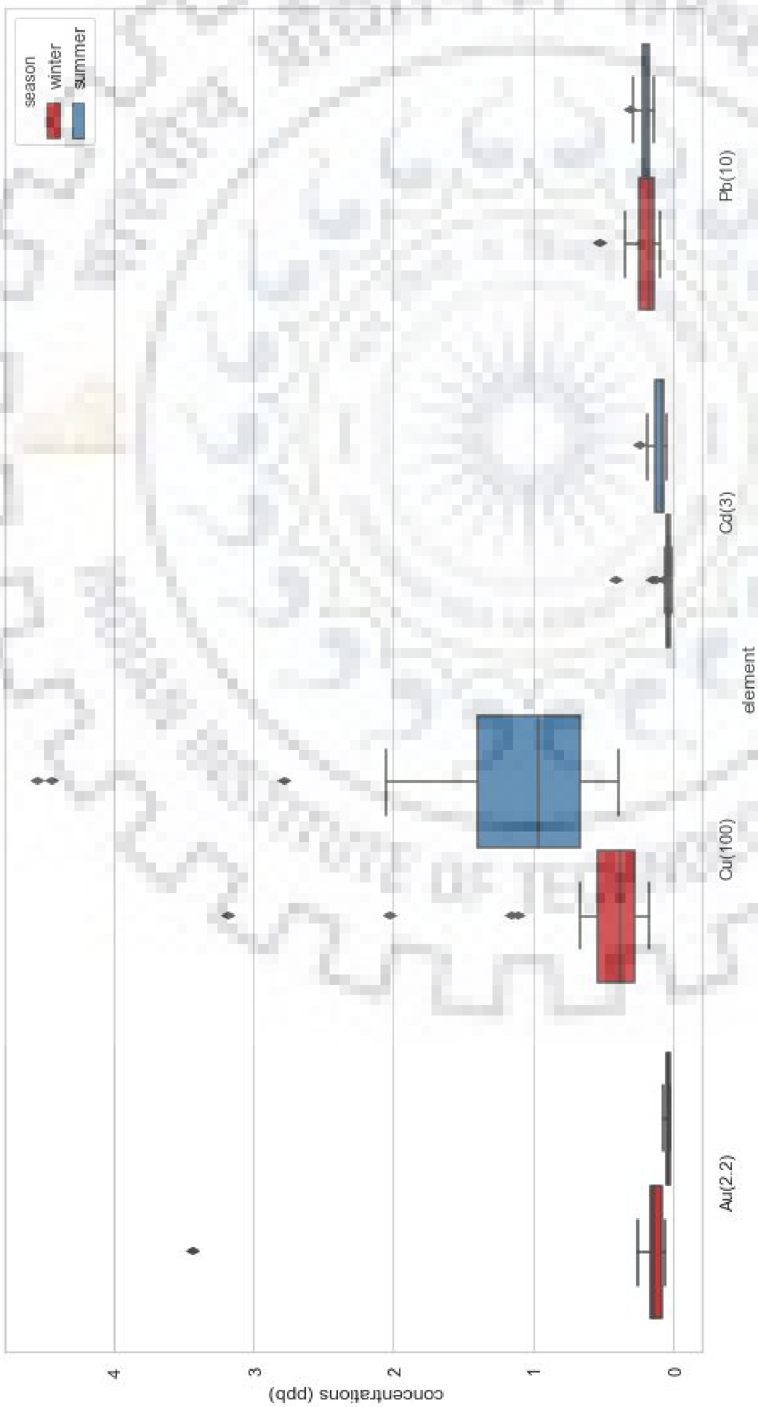


Fig 4.5 Au, Cu, Cd, Pb Concentration variations in the two phases of sampling, box plot. Outliers are shown as black diamonds. Source: Made by Gautam Yadwani

- Fig 4.6 shows the concentration variation of the elements Fe and Ba, in this Fe shows very little increase in its values within the seasons while Ba shows significant increase but both these elements are within the maximum permissible limit prescribed by BIS. There are one exception in values of Ba shown by black diamond. The value of this is ~260 ppb

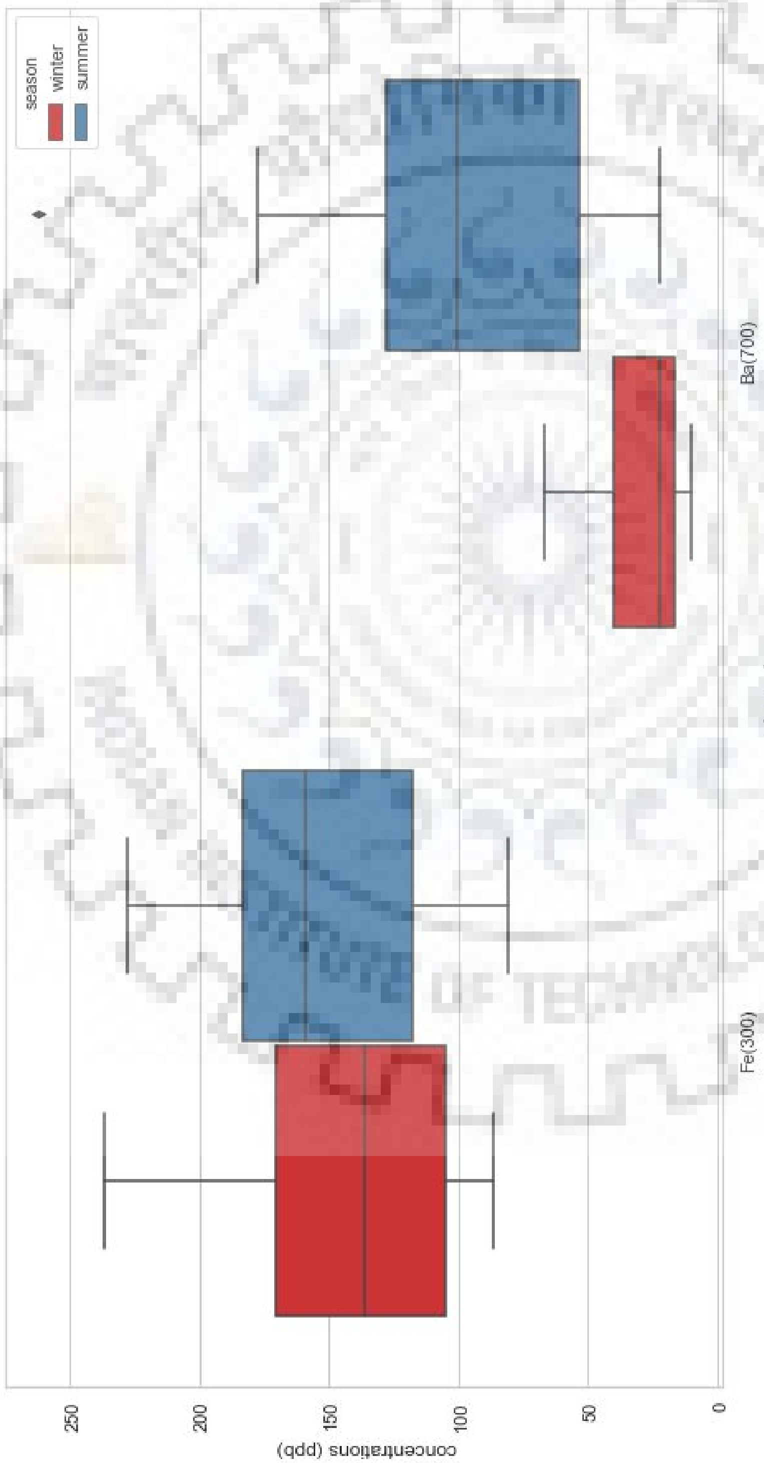


Fig 4.6 Fe and Ba Concentration variations in the two phases of sampling, box plot. Outliers are shown as black diamonds. Source: Made by Gautam Yadwani

- Fig 4.7 shows the concentration variation of the elements K, Mg, Na, Ca, in this K and Mg shows a drop in their concentrations within the seasons while Ca and Na show a jump. While other three elements have nominal changes, Ca has quite a lot of increase. All these elements do exceed maximum permissible limit prescribed by BIS in some of the samples.

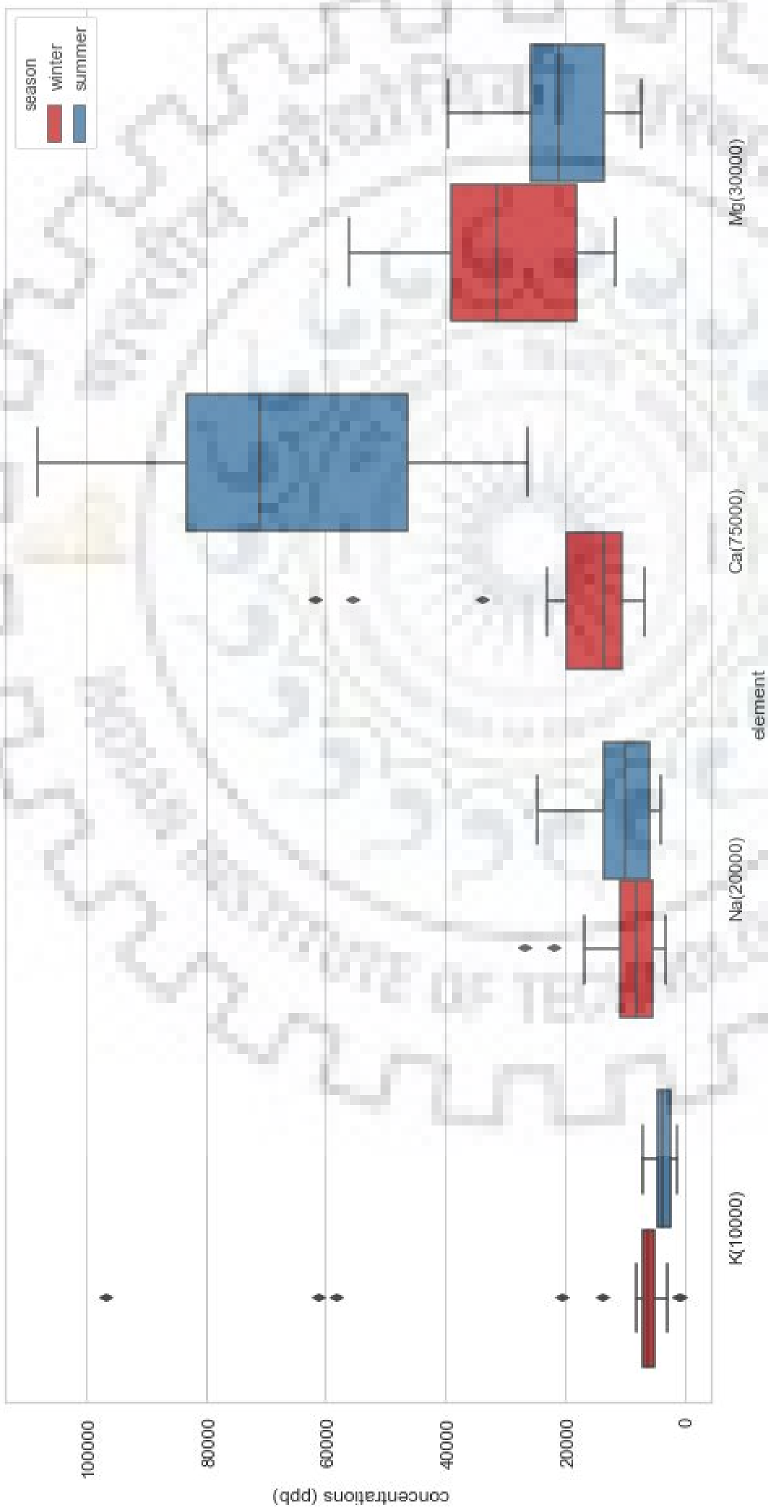


Fig 4.7 K, Na, Ca, Mg Concentration variations in the two phases of sampling, box plot. Outliers are shown as black diamonds. Source: Made by Gautam Yadwani

- Fig 4.8 shows the concentration variation of the elements U, Cr, Cu, Se, in this all four elements show very little increase in its values within the seasons and all these elements are within the maximum permissible limit prescribed by BIS. There are a few exceptions in values of U and Se in both the phases, shown by black diamonds in these figures. These outliers had values upto 16 ppb for Se in phase Summer.

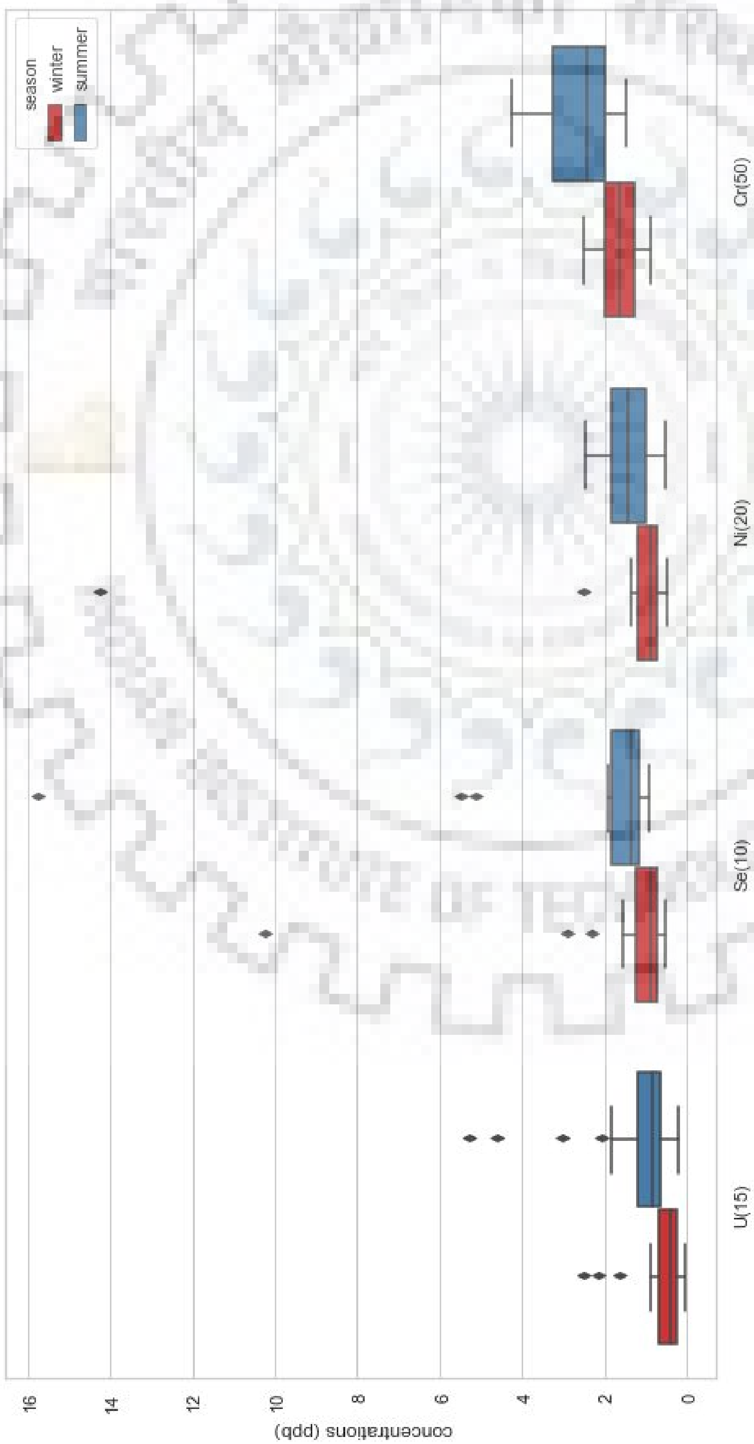


Fig 4.8 U, Se, Ni, Cr Concentration variations in the two phases of sampling, box plot. Outliers are shown as black diamonds. Source: Made by Gautam Yadwani

Chapter 5: CONCLUSION

The results obtained from the ICP-MS analysis are summarised for each element in the table below.

Table 5.1 Summary for phase 1 and 2

Element	Phase1 mean	Max value phase1	Min value phase1	Phase2 mean	Max value phase2	Min value phase2
Au(2.2)	0.2685833333	3.43	0.066	0.0367727272 7	0.069	0.017
As(10)	1.142	3.678	0.411	2.096636364	5.784	0.461
Ca(75000)	18206.45492	61896.145	6668.017	65010.05714	108117.952	26287.228
Cr(50)	1.596041667	2.515	0.872	2.626727273	4.261	1.456
U(15)	0.613625	2.514	0.063	1.320818182	5.267	0.405
Ba(700)	28.42858333	66.945	10.368	101.531	262.083	21.91
Cd(3)	0.05420833333	0.146	0.015	0.0997272727	0.241	0.04
Ni(20)	1.520625	14.231	0.496	1.4015	2.464	0.503
Cu(50)	0.6108333333	3.186	0.172	1.364954545	4.544	0.515
Fe(300)	141.4784583	236.545	86.717	152.1162727	227.564	80.764
Mn(100)	4.753125	33.296	0.533	16.01081818	100.476	0.187
Pb(10)	0.2015416667	0.527	0.093	0.1988181818	0.279	0.132
Se(10)	1.43075	10.225	0.534	2.373227273	15.748	0.912
K(10000)	14574.92029	96807.823	828.27	3517.888227	6842.151	1211.531
Mg(30000)	30886.46429	55061.357	11653.513	20993.24895	39636.487	7273.348
Na(20000)	9145.021833	26668.724	3223.795	9920.1155	24545.096	3926.949

5.1 Discussion:

5.1.1 In-Situ parameters:

Based on new measurements during two sampling campaigns during December (2018) and April (2019) respectively, parameters such as pH and the EC were found to be well under the WHO permissible limits for drinking water (pH 6.5-8.5; EC 0-1400; WHO, 2001). Except a few samples for which values of pH were found to be touching the upper limit of 8.5 (Sample GKN-HP-2 Table 4.3), the rest are within the WHO permissible limits for drinking water (WHO, 2001). Some samples were found to have values of EC lesser than 200 uS/cm (GKN-AN-1, GKN-AN-2, GKN-AN-3; Table 4.5). This may be an indicator of pollution by external sources, but the source of that pollution cannot be determined with the present data.

Also major elements like Calcium, Magnesium, Sodium and Potassium were found to be present in concentrations exceeding the permissible values in a few samples (GKN-GN-2 GKN-BP-1 GKN-MN-1 GKN-MU-1 GKN-BK-1 GKN-MU-2 GKN-NZ-1 GKN-LN-3 GKN-AN-1 GKN-BP-1 GKN-MU-1 Tables 2.10, 4.12, 4.13, 4.14). Calcium and magnesium are found in groundwater that has come in contact with certain rocks and minerals, especially limestone and gypsum. When these materials are dissolved, they release calcium and magnesium(WHO Guidelines for Drinking-water Quality 2011)

5.1.2 Heavy Metal Concentrations:

This study is aimed at quantifying the heavy metal pollution, if any, in groundwater in Gurukul Narsan block of Haridwar district, to provide the current status of heavy metal pollution in this area. Additionally, since there is a severe lack of such data for this area, this study would be the first systematic study done in this regard for the said area (Water Quality, Pollution Source Apportionment and Health Risk Assessment of Heavy Metals in Groundwater of an Industrial Area in North India, 2016). In light of the emphasis and major incentives given out by the Uttarakhand state government during the last fifteen years to set up industries in this area, it has been suggested that this would also lead to pollution of groundwater (Assessment of heavy metal pollution in water using multivariate statistical techniques in an industrial area: A case study from Patancheru, Medak District, Andhra Pradesh, India 2009). This environmental concern needed to be addressed by proper facts based on geochemical analysis of groundwater from this area. This is what is tried in this study. For the observations of concentrations of heavy metals in the groundwater in the Gurukul Narsan area of Haridwar district we can say that, the concentration values for majority heavy metals studied in this dissertation are under the permissible limits by the WHO Guidelines for Drinking-water Quality 2011. From the obtained results it can conclusively be said that the current levels of these heavy metals are not hazardous to human beings on consumption. The values of a few elements like Selenium and Gold are exceeding the values in one sample each for one season. The groundwater state may not be alarming now, but the area does contain a few harmful industries that may increase the damage in the future. The harm can be prevented before the damage is done and that is possible by proper government regulations and individual awareness in the area. The conditions of Bangladesh and the Indian state of Assam, can be a wakeup call for the authorities to prepare for the future.

REFERENCES

1. Adepoju-Belo, AA & Abali OM,. Heavy metals: A deep review. The Nig. J. Pharms., (2005) 37: 41-45.

2. Agency for Toxic Substance and Diseases Registry, ATSDRO. (1999). http://www.atsdr.cdc.gov.

3. Chopra, R.P. and Krisan, Gopala. 2014b. Assessment of groundwater quality in state of Punjab. Journal of Earth Sciences and Climate Changes. 5(10):243

4. Central Ground Water Board (CGWB).

5. Dipali, Joshi N.A. (2012) Study of ground-water quality in SIDCUL Industrial Area, Haridwar, Uttarakhand, India. J Apple Technolo Environ Sainit 2(2):129–134

6. Gauri S, Joshi MC, Saxena S.K., Dutta HK (2011) Analytical study of water in ground water samples of Uttarakhand state in India. J Apple Pharm Sci 01(09):166–169

7. Guidelines for Drinking Water and its Quality index, 4th Edition, WHO 2011.

8. Singh PR., Dobal R., Sethi R., Asawal R.S., Singh RP., Uniyaal D.P. and Sharma B. 2015. Variations in Surface Water Quality of Pithoragarh District, Uttarakhand (India), with respect to time and space. Analytical Chemistry Letter, 5,8, 265-280.

9. Jarupa, L. (2003). Hazards of heavy metal contamination. British Medias Bulletin, 63(1), 167–182.

10. A Special Report on India (2006); Creaking, Groaning: Infrastructure is India’s Biggest Handicap -The Economist

11. Naiik, P. K., Dehuri, B., & Tiwari, A. (2007). Ground-water pollution around industrial area in the coastal stretch of Maharashtra state, India. Environmental Monitoring and Assessment, 132(1–3), 207–233.

12. WHO (2011). Guidelines for quality of drinking water standards—I, recommendation (2nd edition). Geneva: WHO.

13. V. Balram, Characterisation of trace elemental presence in environmental sample

by ICP-MS, AAS 6 (1996) 174–179.

14. BIS, Specifications for drinking water. Bureau of Indian Standards, New Delhi 1997, 171-178.

15. Bhutiani, R., Kulkarni, D.B., Khanna, D.R. et al. Expo Health (2016) 8: 3. https://doi.org/10.1007/s12403-015-0178-2

16. B. Dasaram, M. Satyanarayanan, V. Sudarshan and A. Keshav Krishna. Assessment of heavy metal pollution in water using multivariate statistical techniques in an industrial area: a case study from Patancheru, Medak District, Andhra Pradesh, India. Data Journal of hazardous materials, ISSN: 1873-3336, Vol: 167, Issue: 1-3, Page: 366-73