Groundwater Contamination by Heavy Metals for Bhagwanpur, Haridwar

A Dissertation

Submitted in partial fulfilment of the

Requirements for the award of the degree

Of

Integrated Masters of Technology

In

Geological Technology

By

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May, 2019

CANDIDATE'S DECLARATION

The thesis with the title "GROUNDWATER CONTAMINATION BY HEAVY METALS FOR BHAGWANPUR, HARIDWAR" is conducted under the guidance of Dr Nachiketa Rai, an assistant professor at Department of Earth Sciences, IIT Roorkee.

I declare that all the work included in this thesis is my own original work except for the places where a reference has been given. This dissertation thesis has not been acknowledged for any degree and isn't simultaneously submitted to some other candidature for any degree or certificate.

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CERTIFICATE

This is to certify the work presented in this thesis titled "GROUNDWATER CONTAMINATION BY HEAVY METALS FOR BHAGWANPUR, HARIDWAR" submitted by Mr. Nikhil Goyal 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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ACKNOWLEDGEMENT

First, I want to offer my true thanks to my supervisor ***Dr Nachiketa Rai*** *for the persistent help of my Dissertation study and research, for his understanding, inspiration, energy, and gigantic learning. His direction helped me in all the season of research and composing of this thesis. I couldn't have envisioned having a superior guide and tutor for my Dissertation studies. His dedication and keen interest above all his attitude to help his students are unmatchable.*

I am thankful to ***Dr Sunil Bajpai****, Head of the Department, Department of Earth Sciences, IIT Roorkee and* ***Dr GJ Chakrapani****, the O.C. Dissertation for the batch of Geological Technology(2014-19), for providing inspiration in the form of administrative support without which this work would not have been completed.*

I would like to thank ***Dr AK Sen****, Head, Institute Instrumentation Centre and* ***Mrs Poonam****, supervisor of the ICP-MS lab at the Institute Instrumentation Centre, IIT Roorkee, for their help during measurements of all the heavy metals. Without their guidance and support that work would not have been completed.*

I would be grateful to my friend and colleague ***Mr*** *Gautam Yadwani for showing me the way for all the work and aiding* ***me with the analysis*** *and* ***all the hands-on work associated with this dissertation.***

Lastly, I wish to thank my friends and family for being extremely supportive in this venture and supporting me every time I was in problem.

Nikhil Goyal

CONTENTS

ABSTRACT

In recent times a major concern is the rising number of human casualties due to the water pollution. Groundwater is found to be a major water source for all our daily needs including domestic, industrial and agricultural usage. Contaminated groundwater can easily find its way into our bodies. Contamination of groundwater by heavy metals is particularly life-threatening with various serious diseases occurring if consumed in excess. The present study was aimed to create facts for a hypothesis that groundwater in the surrounding region of Bhagwanpur Industrial Area could be polluted with heavy metals because of many industrial effluents discharge in the region. The facts are numerical and created by measuring the heavy metals present in the water samples in the region alongside some in-site measurements : Temperature, pH and EC. 16 elements were analyzed :A total of 16 elements were analyzed: 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). A total of 23 samples were taken during 2 phases of sampling(Pre Monsoon and Post Monsoon). Depths were noted to check variation of contamination with depth. Results have shown that the water in the region is safe for all kinds of use barring a few exceptions for metals like sodium, calcium, magnesium, etc. Bhagwanpur being developed as a heavily industrialised area, strict regulations for the treatment and monitoring of waste disposal should be a benchmark for the industries in the area to stop any future danger.

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1. INTRODUCTION

Water is undeniably the most important and precious of all natural resources. Life started in the water and life was fed with water. 97% of the world's water is found in oceans. But that is saline and cannot be used for drinking. Only 2.5% is present as non-saline water. No life form can sustain without water. In India, groundwater is the main source of water used to meet domestic, agricultural and industrial needs. This source has two different functions. On the one hand, it is an important source of water for the city and the countryside, and on the other, it helps in irrigation. Since ages, people live in places where the quality and quantity of water available is good. Our industries also use water for various nation-building activities which contribute to our Growth Domestic Product (GDP). The processes in which the water is used are processing, cleaning, transport, dilution and cooling in production facilities. Among all, industries such as chemical, steel and oil refineries use vast amounts of water.

Water has unique chemical properties due to its polarity and hydrogen bonds. This implies it can break down, assimilate, adsorb or suspend a wide range of mixes **(WHO, 2007)**. Thus, water isn't pure in nature, as it gets dirtied in the environment and from human and animals inferred and other organic exercises **(Mendie, 2005)**.

Groundwater contamination today, has got much attention. The use of water is everywhere and in everything. Polluted water can create many forms of diseases in humans or animals. Heavy metal in particular, even in small concentrations can make the water hazardous**(Marcovecchio et al., 2007)**. Thus, they are of primary concern.

Activities, be it land-based or water-based can cause water pollution if the waste disposal is not taken care of. The areas of high population density and excessive land use by humans, groundwater becomes particularly vulnerable. Industries, where chemicals or waste materials are released to the environment, can cause the surrounding groundwater to get contaminated. If the groundwater is contaminated by pollutants, it causes disease and is very difficult to clean. On the off chance that inappropriately dealt with, this waste can present risky wellbeing and ecological outcomes.

Groundwater is mainly composed of the rainfall and the subsequent penetration of water into the earth. One more significant factor is soil quality. The heavy metals assume a significant job in the typical working of the human body. The imbalance of these heavy metals can cause dysfunction in our normal body processes. Both natural and artificial ways can add heavy metals to the water. Heavy metals are called **trace metals** because they are generally present in very small quantities. These are toxic in nature. Heavy metals are generally metallic and are thus heavy and dense. They usually accumulate. The major anthropogenic sources of heavy metals are industrial waste from mining facilities, production and metal refining facilities, domestic sewage and the drainage of roads. A considerable lot of these heavy metals are exceedingly harmful to people, for example, Arsenic, Cadmium, Mercury, Lead, Nickel and Tin. Their measures in surface and groundwater over fixed concentrations is unwanted. Some heavy metals, for example, Hg, Pb, As, Cd, Fe, Co, Mn, Cr, and so forth have been called to be hazardous to the oceanic environment and human wellbeing. They are found in colloidal, particulate, and dissolved phases in water **(Adepo ju-Bello et al., 2009)**, where their occurrence in water bodies is either of natural origin (eg, eroded minerals in sediments, leaching of ore deposits, and extruded products) or of anthropogenic origin (ie disposal of solid waste, industrial or domestic effluents, dredging dredging) **(Marcovecchio et al., 2007).**

Heavy metals in groundwater have also been reported previously in India, showing that metal contaminated water is present in industrialized areas **(Yadav et al., 2011)**.

1.1 Statement of Problem

Bhagwanpur is a town or tehsil located in the district of Haridwar, Uttarakhand, India. Among the total six, it is one of the development blocks of Haridwar district. It is also the commercial centre of the Garhwal region of the state of Uttarakhand in India. Over 2 lakh people live in the total block area. The block has over hundreds of industries all producing a diverse range of products. These enterprises work in diverse sectors including manufacturing, electric batteries, paints and chemicals, metal and repairing, automobile spare parts, pharma etc.

These industries discharge their waste materials in the surrounding area which may then percolate to the groundwater through mixing with surface water or through the soil. The waste material consists of an oil discharge, metal pieces and leftover scrap and other harmful chemical effluents which may come through paint, pharma and electric battery industries. All these wastes may include heavy metals in them which may then mix with surface water and percolate to mix with groundwater eventually and contaminate it.

The block has various hand pumps dug in the whole area and a lot of people are using the water to drink, and use the same for other domestic purposes. Thus groundwater use is a common practice here. This has raised huge concerns as there is a possibility that groundwater in the surrounding region may be contaminated with heavy metals of surrounding regions.

1.2 Objectives

The purpose of this dissertation is:

- To measure the various in situ physicochemical parameters present in the groundwater available through hand pumps and domestic boreholes. These physicochemical parameters are
    - pH
    - Electrical Conductivity
    - Temperature
- To measure the concentration of all the harmful heavy metals present in the groundwater collected through hand pumps and domestic boreholes. These elements are
    - Arsenic

    - Mercury
    - Tin
    - Copper
    - Calcium
    - Chromium
    - Cadmium
    - Lead
    - Antimony
    - Nickel
- To establish the variation in heavy metal contamination with respect to the depth of different sources
- To get the time variation of the heavy metal contamination in groundwater with respect to different seasons i.e. summer, winter and rainy.

1.3 Justification of the study

Nearly 2 million people die each year because of diseases arising from drinking contaminated water. With the population of the world on the rise and rapid process of industrialisation and urbanizations, a large number of population is expected to drink such contaminated water. The dependency of groundwater for drinking and other domestic purposes has also increased in recent time.

Some of the previous studies done near **industrial regions** have shown negative results toward groundwater contamination. Among regions where heavy metals come from the natural sources, some major cases have come from areas near Ganga River Basin, previous research**(Chakraborti, Dipankar et al)** has suggested that. Our study area “Bhagwanpur Block” is a heavily industrialised area of Uttarakhand. Not only that, but it is also surrounded by canals which contains water from upper Ganga. This water is used for various irrigation purposes. Thus there is a high possibility that this area may contain contaminated groundwater. A study which measures these contamination measurements is significant enough to raise awareness and thus help future researchers and governments to prevent future health diseases in the area.

2. LITERATURE REVIEW

2.1 Sources of water

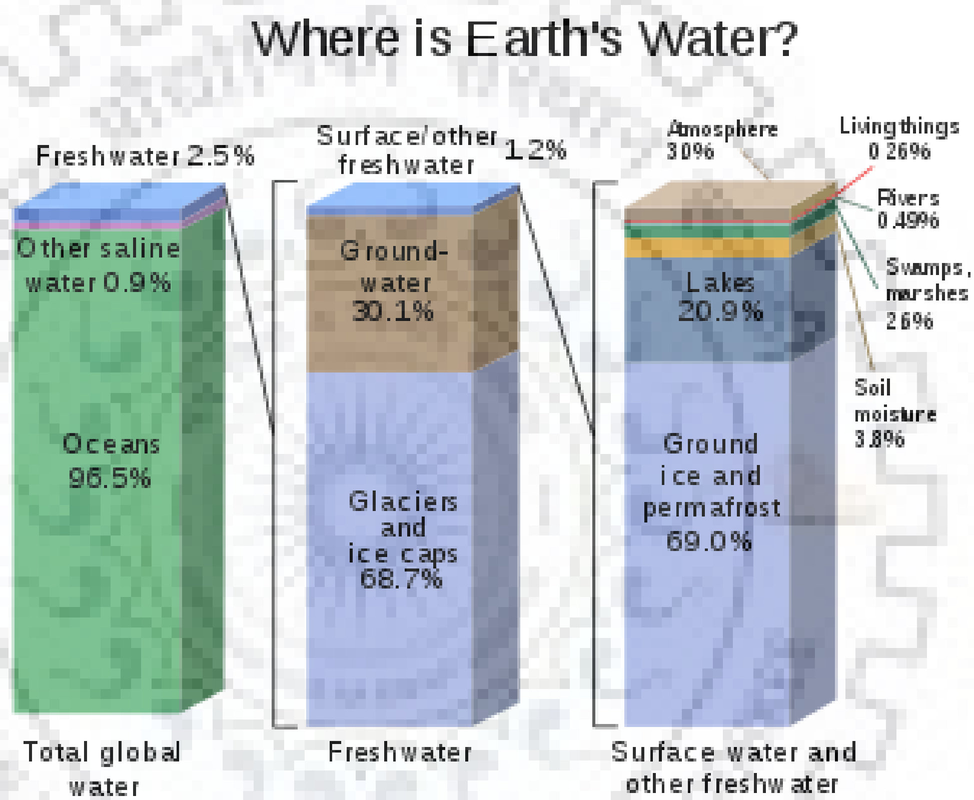

Fig 2.1 Water sources on Earth Image source: https://en.wikipedia.org/wiki/Water_resources

There are uncountable uses of water and it is very essential for many daily chores. Some major uses of water are Domestic, Industrial and agricultural use. But this usable water is very little proportion of total water present on earth. Out of all the water, only 2.5% is resourceful water i.e. water that can be used in some meaningful activity. This water is called “Freshwater”. Rest of the water is “Saline” is mostly found in oceans. Nearly 67% of this freshwater is in the frozen form in the form of glaciers and ice caps. Thus, it is also considered as non-usable. Thus, most of our needs are fulfilled through groundwater only which is 30% of all the freshwater. There are surface water sources like rivers, ponds, lands, etc. These water mostly either get dried, contaminated or gets to the oceans through drainage.

Water has unique chemical properties due to its polarity and hydrogen bonds. This implies it can break down, assimilate, adsorb or suspend a wide range of mixes **(WHO, 2007)**. Thus, water isn't pure in nature, as it gets dirtied in the environment and from human and animals inferred and other organic exercises **(Mendie, 2005)**.

2.1.1 Groundwater

More than half of the population of this world uses groundwater as their primary source of usable water. It's the biggest use is in irrigation and agricultural purposes.

Groundwater basically seeps through soil gaps and pores and resides in these spaces. This is called Groundwater Storage. When all the soil pores get filled up by the groundwater or in other words they get saturated, it is called **saturated zones** or **aquifers**. The top of this aquifer is known as the **water table.** These aquifers are generally made of rocks which have large gaps or large soil pores between there rocks particles. This makes the rock permeable. This allows the water to seep easily. Examples of such rock types are sand, gravel, sandstone, or limestone. In any water aquifer, its ability to store groundwater depends on how easily it allows the groundwater to flow through its gaps and how well connected it gaps are which is also known as the permeability of the rock **(USGS, 2009)**.

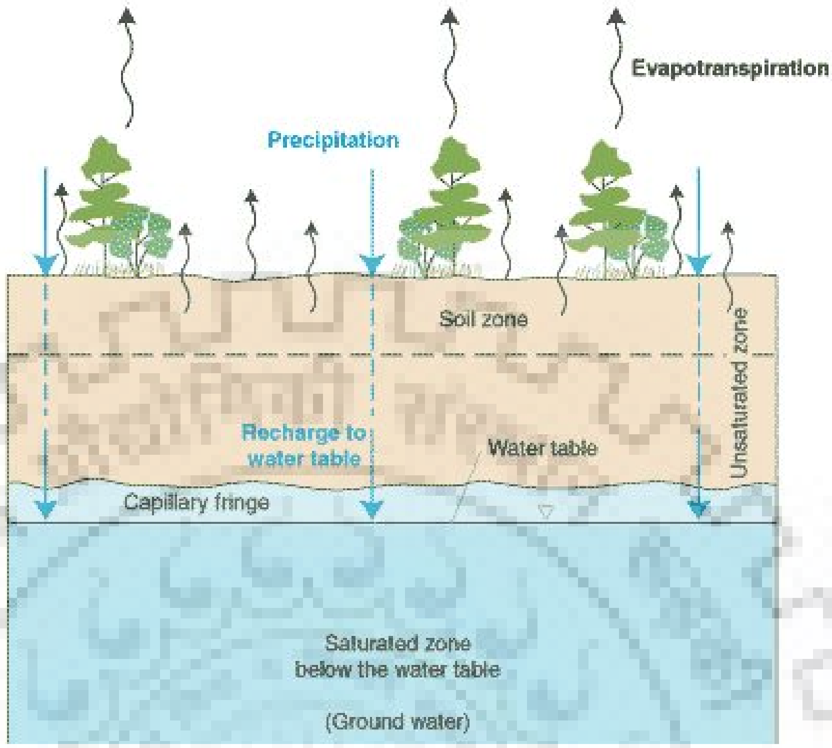

Fig 2.2 Water sinking to form groundwater Source: USGS

In the regions where surface water is not present, groundwater helps in their development in the form of supporting new industries and agricultural purposes like irrigation. However, the very same industry and use cases can destroy this very boon that helped to create them. In regions of high permeability, along with water, some harmful pollutants can also permeate into the groundwater. Thus it is susceptible to contamination. Groundwater contamination can occur through landfills, septic tanks, leaking underground gas tanks and excessive use of fertilizers and pesticides. These things release man-made things such as gasoline, oil, road salts and chemicals in the groundwater.

Hazardous objects from the land surface can move through the soil and seep into the groundwater. For e.g., pesticides and fertilizers may enter the groundwater supply over time. Road salt and other harmful chemicals from mining and used motor oil can also get into the groundwater. In addition, untreated waste from septic tanks and toxic chemicals from underground storage tanks and leaky landfills can pollute the groundwater.

These whole set of activities end making groundwater not usable for human purposes and is also difficult to rectify.

2.1.2 Surface Water

The water that is present on the surface of the earth within continents in the form of rivers, lakes, ponds or wetlands etc. is called surface water. It is different than groundwater. This water can seep through the soil to form groundwater. Surface water can evaporate or it can seep into the ground. This could also be extracted by humans for various purposes such as drinking or agricultural purposes. The same water can be refilled through rainwater.

Precipitation, which does not evaporate or penetrate the soil, flows as surface water, which can accumulate into streams and connect to rivers. A lake is in a basin surrounded by land, which is filled with water, with the presence of rivers or other bodies which serve to supply or drain the lake. Ponds similarly to lakes are water storage inland depressions, however, they are much smaller in size and usually support some flora nearby **(Mallard, 1982)**.

As discussed, earlier, surface water can seep into the soil to form groundwater. And so can chemicals which are also mixed with surface water. It is this interconnected nature that they both cannot be said independent. If the surrounding surface water is hazardous for health, then, so can b said for the underground groundwater near the region.

Fig 2.3 Groundwater contamination through industries Source: https://www.constantinealexander.net/2012/11/report-cleanup-of-some-contaminated-groundwater-sites-in-the-us-unlikely-for-decades.html

2.2 Water Pollution

Any change in the physical, chemical or biological aspects of water which can be harmful to any living beings including human beings, plants, animals and aquatic life can be termed as water pollution. When harmful and toxic substances from industrial wastes, or agricultural pesticides and other chemicals or any other waste from septic tank leakages mixes with water and makes water no use for the humans or the environment, it is termed as water pollution.

Fig 2.4 Disposal of industrial waste in fresh water
Source: https://www.nrdc.org/stories/water-pollution-everything-you-need-know

Water has unique chemical properties due to its polarity and hydrogen bonds. It is a universal solvent. This implies it can break down, assimilate, adsorb or suspend a wide range of mixes **(WHO, 2007)**. Thus, water isn't pure in nature, as it gets dirtied in the environment and from human and animals inferred and other organic exercises **(Mendie, 2005)**. The hazardous substances from farms, cities and factories dissolve and mix with them, causing water contamination. One more unique characteristic of water is that it can also easily clean itself by breaking down the particles of contamination or by helping them settle at the bottom and thus keeping itself free of the pollution or just by dissolving it with more of water itself, thus reducing the toxicity. However, this all takes time.

Water pollution is called such when the water is not available for drinking for humans or it is not good for aquatic lives to survive in it. It can be caused either by man-made activities or by natural processes such as volcanic eruptions and emission, earthquakes, storms etc.

Water pollution is said to be the leading cause of the world's death numbers with 14,000 dying because of it daily**(Larry, 2006)**. About 60 per cent of Indian Population has no access to pollution-free water. Thousands of Indian children die due to Diarrhea. Some 90% of China's cities suffer from some degree of water pollution. Almost all of China receives polluted water. Industrialized nations keep on battling with contamination issues also. In the latest national report on water quality in the US, about half of assessed stream miles and assessed lake acres, and 32 percent of assessed bay and estuarine square miles were termed as polluted **(USEPA, 2007)**

2.3 Categories of Water Pollution

2.3.1 Groundwater

When rainfall occurs, Not all water is stored on the surface. Some of it can permeate into underground rocks through gaps and pores in the soil. This then gets stored as groundwater. It is our most important resources as a source of drinking water. Almost all rural population in India drinks groundwater and use it for different purposes. However, this water can get contaminated as well. n regions of high permeability, along with water some harmful pollutants can also permeate into the groundwater. Groundwater contamination can occur through landfills, septic tanks, leaking underground gas tanks and excessive use of fertilizers and pesticides.

2.3.2 Surface water

Most of the drinkable water on earth is from freshwater sources which are 2.5 per cent of the total water. Surface water makes only 1.5% of these portions which is mainly stored in the form of rivers, lakes, ponds and wetlands. Surface water pollution includes pollution of rivers, lakes and oceans. This water can get polluted as fertilizers and pesticides from farms can find their way into these water sources as runoff. Many industries and factories also, dump their wastes directly into these sources thus making it hazardous for any use.

Fig 2.5 Depiction of water pollution Source: https://en.wikipedia.org/wiki/Water_pollution

2.4 Sources of Water Pollution

There is 2 major water resource as per human needs are concerned. We define them as different sources, however, both of them are interrelated. Groundwater is basically the surface water which seeps into the earth through spaces and pores. Conversely, Groundwater can also feed surface water. There are 2 distinct sources of water pollution based on their origin:

2.4.1 Point Based Sources

In point-based sources, the contamination enters into the water through a single gateway. This contamination is usually through a pipe or ditch. This kind of pollution is done factory/industry waste dumpage into the water bodies. Septic tank waste is also an example of the same. Wastewater treatment facility also dumps their waste this way. EPA regulates this point based on pollution by imposing rules such as putting limits on the waste discharge and also only allowing a certain kind of pollutants into the water bodies. Although, coming from a single point these pollutants can get mixed in the whole of the water body gradually.

2.4.2 Non-Point Based 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 a 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.

2.5 Heavy Metals

Heavy metals are the elements which generally have a high density as compared to other elements and are generally toxic or hazardous even at very low concentrations. The examples of heavy metals are Mercury(Hg), Cadmium(Cd), Tin(Sn), Lead(Pb), Arsenic(As), etc. They are a group of metals or metalloids with an atomic density greater than $4 g/cm^3$ or are 5 times heavier than water.

Fig 2.6 Metal Arsenic

Fig 2.7 Metal Lead

https://en.wikipedia.org/wiki/Heavy_metals#Toxicity

Heavy metals can find their way into our body through drinking water, food intake, medicines etc. At small concentrations, they are necessary for some body activities examples of such are Copper, Zinc, etc. But at large concentrations, they could become life-threatening. Drinking water through pipes can infuse Lead in our bodies as the tap could have Lead in them. Or they can enter via air near factories which emit highly toxic metals in the air.

Heavy metals are dangerous because of one distinctive property. They bioaccumulate which means their concentration increases over time and becomes larger than surrounding regions. The process is taken up at a faster rate than excreting them and are stored at high speeds than the counter speed of breaking them apart. They can find their way into the water supply through industrial waste or household waste dumpage. They can also come through the soil as it breaks due to the pouring of acid rain over it.

Bangladesh has in some areas, a very large concentration of Arsenic mixed in groundwater and that has turned out to be catastrophic(Tuzen and. Soylak, 2006).

2.5.1 Essential Heavy Metals

Not all heavy metals are harmful. In fact, at small concentrations, some of them are vital for the normal functioning of our body. They are also important for normal growth and development of our body. Without them, our health would be in danger. Some examples of these nutritionally important elements/heavy metals are (e.g., iron, copper, manganese, and zinc). Also, cobalt, copper, iron, manganese, molybdenum and zinc at lower concentrations act as a catalyst for enzyme activities **(Adepoju-Bello et al., 2009)**, However exposure or intake of these at quantities larger than required is fatal and can be life-threatening.

They can found their way into our bodies in many ways. Most common of them are food, fruits and vegetables or through vitamin products. Heavy metals like Gallium, Lead and chromium could be injected in our bodies in the diagnosis of many diseases or through X-ray radiations. 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.

2.5.2 Hazardous Heavy Metals

Heavy metals can become harmful when they are not excreted or disposed of by the body. This way they tend to accumulate and become hazardous. Heavy metals can enter our body through food, water or air. They can also get in through exposure of our skin to environments like industrial, agricultural or medicinal where concentrations of these metals are much more. Drinking water through pipes can infuse Lead in our bodies as the tap could have Lead in them. Or they can enter via air near factories which emit highly toxic metals in the air**(Lenntech, 2005)**. There are metals which are of no value for our body and their intake even in small quantities is life-threatening. Examples are Argon, Cadmium or Lead**(Yahaya et al., 2010)**. In adults, heavy metals generally find a path through the exposure of industrial activity near them life-threatening while for children most common route is eating non-edible items near such as soil. Among less general cases are the ones related to radiological procedures like that in hospitals. Heavy metals enter the water by industrial and commercial waste, or even from acid rain breaking down soil and releasing heavy metals into groundwater **(Lenntech, 2005)**.

2.6 Mobility of Heavy Metals

Heavy metal is in the groundwater both in the dissolved as well as the suspended state. Their solubility and transportation can be different for different metal. The basis of this existence depends on two major factors. Sorption and precipitation define 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. For example, some chemical processes such as aqueous complexation often make an element more soluble.

2.7 Heavy Metals in Groundwater

Groundwater is the main source for many of our daily water needs. However, in the wakening of large urbanization and industrialisation activities, these sources have become contaminated. This is especially vulnerable in areas of high population. Many wastes are being directly dumped into the ground and water. These contaminants can leach through soil and find their way to groundwater. Unconfined aquifers with shallow water tables overlain by permeable soils are especially vulnerable to various contaminants. **(USEPA, 2002)**.Water is a universal solvent can be easily contaminated. When groundwater becomes polluted, it is difficult to clean and rectify. Heavy metals even at very low concentration can lethal for our lives. They can get stored in our soft tissues and get accumulated over time.

2.8 Naturally occurring heavy metals

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 the population.

Rocks and minerals present underground may contribute to 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 federation 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 on consumption. The results of these natural sources of pollutants of groundwater rely on the type of pollutant and its quantity **(USEPA, 2002)**.

2.9 Heavy Metals Occurring through manmade activities

Groundwater Pollution can occur in many ways. Most dangerous among them are the ones through industrial waste, agricultural waste or through septic tank leakages. The waste material consists of an oil discharge, metal pieces and leftover scrap and other harmful chemical effluents which may come through paint, pharma and electric battery industries. These industries discharge their waste materials in the surrounding area which may then percolate to the groundwater through mixing with surface water or through the soil. Mechanical waste might be poisonous, ignitable, destructive or receptive. If not handled they can be dangerous for many lives.

Bhagwanpur, Haridwar, India has many industries releasing a variety of toxic substances. These heavy metals further can come through various man-made activities. The below table summarises the same.

Table 2.1 Sources of heavy metals

Heavy Metal	**Man-Made Source**
Arsenic(As)	Pesticides, fungicides, metal smelters
Cadmium(Cd)	Welding, electroplating, Batteries,
Chromium(Cr)	Mining, textile, electroplating
Copper(Cu)	Electroplating, pesticides, Mining
Lead(Pb)	Paint, batteries, automobile emissions, burning of coal, mining
Manganese(Mn)	Welding
Mercury(Hg)	Pesticides, batteries, paper industries
Nickel(Ni)	Zinc base casting, battery industries
Zinc(Zn)	Brass manufacturer, metal plating

2.10 Effects of heavy metals on humans and the environment

Fig 2.8 Heavy metal poisoning Source -https://www.ncbi.nlm.nih.gov/pmc/articles/PMC4427717/

2.10.1 Antimony(Sb)

Antimony is used as a compound in a flame resistant. Batteries, pigments, and ceramics and glass often contain Antimony. Being in the presence of Antimony of high concentration even for a small time can cause diarrhoea, nausea or vomiting. Little is known on its long term effects but it could cause cancer.

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2.10.2 Cadmium(Cd)

Cadmium is important for plants, humans and animals. However, cadmium tends to accumulate easily and is said to remain in the body for a long period of time.

This can cause renal dysfunction in humans if exposed for long term. It is suspected of causing lung cancer and can cause obstructive lung disease. There are some bone defects which can also occur because of cadmium. In addition, it increases blood pressure and effects on the myocardium in animals, although most human data do not support these findings.

The normal every day admission for people is evaluated as 0.15µg from air and 1µg from water. Smoking 20 cigarettes can give 2-4µg of cadmium.

2.10.3 Chromium(Cr)

Cr is utilized in metal alloys and in many industries like paints, cement, paper, rubber, etc. Exposure to Chromium can cause skin irritation and ulcer. Long haul presence can cause kidney and liver harm and harm excessively circulatory and nerve tissue. It can get accumulated in aquatic life which can be passed on to others through the food chain.

2.10.4 Copper(Cu)

Copper is an important heavy metal which can be used in many places, however, it can also cause liver and kidney damage. Stomach and intestinal irritation can also occur. Copper can found their way in our body through drinking water through copper pipes.

2.10.5 Lead(Pb)

Lead has diverse effects on our body depending on the amount consumed. Its effects on the human body are also diverse including liver, kidney, gastrology tract, reproductive organs, etc.

Lead can have psychological developments in children in small subtle amount when taken in intermediate concentrations. A rise of 10µg to 20µg of Lead can lead to dropping of 2IQ points in young ones.

Most people get lead through food exception being the ones with drinking water through lead pipes or people living in regions with industries releasing lead emission in water and air. Lead in the air can deposit on food and thus find its way to our bodies.

Fig 2.9 Diseases caused by Heavy metals. Source: https://www.ncbi.nlm.nih.gov/pmc/articles/

2.10.6 Mercury(Hg)

Mercury has no use in our body however its effects and side effects are large. It can cause tremors. Some abnormal effects on the psychology of beings with other effects like spontaneous abortion and congenital malformation can also be seen.

Monomethylmercury causes damage to the brain and the central nervous system, while foetal and postnatal exposure has given rise to an abortion, congenital malformation and development changes in young children.

2.10.7 Nickel(Ni)

Nickel is useful for our body in small amounts to create red blood cells, however, in large amounts, they can adversely affect on liver, kidney, liver and can cause skin irritation. Nickel currently is not considered that harmful as it does not accumulate in aquatic life and thus EPA does not regulate it.

2.10.8 Arsenic(As)

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 a 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 colour the skin, produce slight to major tingling and loss of sensation in 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 severe damage of the blood vessels in them, which might result in the formation of gangrene. Arsenic poisoning has the strongest impact on blood pressure and may result in heart attacks and other cardio diseases. The studies for diabetes and reproductive effects not available.

Fig 2.10 Arsenic causing black foot. Link -https://www.ncbi.nlm.nih.gov/pmc/articles/PMC4427717/

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 2.11 Heavy Metals, their effects and permissible levels.
Source: https://www.researchgate.net/figure/Types-of-heavy-metals52

2.11 In Situ Properties

2.11.1 Temperature

Water Temperature is an important factor for aquatic life as it controls there metabolic activity and reproductive activity. Temperature change depends on many factors. It can change seasonally, monthly, daily or even hourly. Stream vegetation helps balance the same by providing the shade and act as a buffer. Water temperature can be affected by the quantity and speed of stream flow and the temperature of discharges put into it. The sun has much less effective in warming the waters of streams with greater and swifter flows than of streams with smaller, slower flows. Temperature changes can also affect the quantity of some gases dissolved in water, for example, oxygen is more dissolved in colder water **(Missouri Department of Natural Resource, accessed on May 9th, 2012).**

2.11.2 pH

pH is a scale of acidity from 0 to 14. It tells how acidic or alkaline a substance is. More acidic solutions have a lower pH. More alkaline solutions have a higher pH. Substances that aren't acidic or alkaline (that is, neutral solutions) usually have a pH of 7. Too acidic or basic water can destroy the aquatic life living in it thus pH of water has an important effect. pH values of streams between 6 and 9.

In a lake or pond, the water's pH is affected by its age and the chemicals discharged by communities and industries. Lakes become acidic with time because of increment of organic content in it over time. Low pH water along with some chemicals and metals can become really toxic. become

2.11.3 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 aluminium 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 (µmhos/cm) or micro siemens per centimetre (µS/cm). **(Missouri Department of Natural Resource, accessed on May 9th, 2012).**

3. MATERIALS AND METHODS

3.1 Study Area

Bhagwanpur is one of the six administrative blocks of the district of Haridwar which is a district in the southwestern part of Uttarakhand State. Haridwar which is India's one of holiest cities is also the headquarter city of Uttarakhand. 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. It has been the centre of India's culture representation from centuries.

Bhagwanpur is a town or tehsil located in the district of Haridwar, Uttarakhand, India. The block is located at 30.06941°N and 77.83997°E. It is also the **commercial centre** of the Garhwal region of the state of Uttarakhand in India. Bhagwanpur Block Headquarters is Bhagwanpur It is located 39 KM towards west from District head quarters Haridwar. 54 KM from State capital Dehradun towards North. Bhagwanpur Block is bounded by Roorkee Block towards South, Punwarka Block towards west, Muzaffarabad Block towards North, Ballia Kheri Block towards west. Roorkee City, Manglaur City, Saharanpur City, Purquazi City are the nearby Cities to Bhagwanpur.

It's the Its area is about Over 2 lakh people live in the total block area. The altitude of the region is 264 meters above the sea level. The block has over hundreds of industries all producing a diverse range of products. These enterprises work in diverse sectors including manufacturing, electric batteries, paints and chemicals, metal and repairing, automobile spare parts, pharma etc. The city is well connected to the nearby cities and villages through roads network, however, there is no direct railway connectivity with the nearest railway station being 7km away i.e. Iqbalpur Railway Station

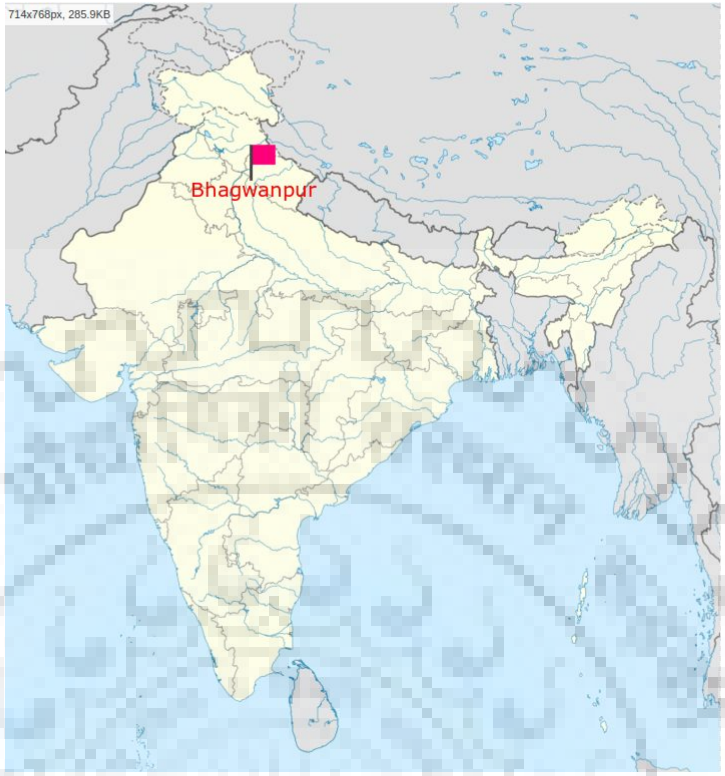

Fig 3.1 Indian map showing Bhagwanpur. Source: Adapted from Wikipedia

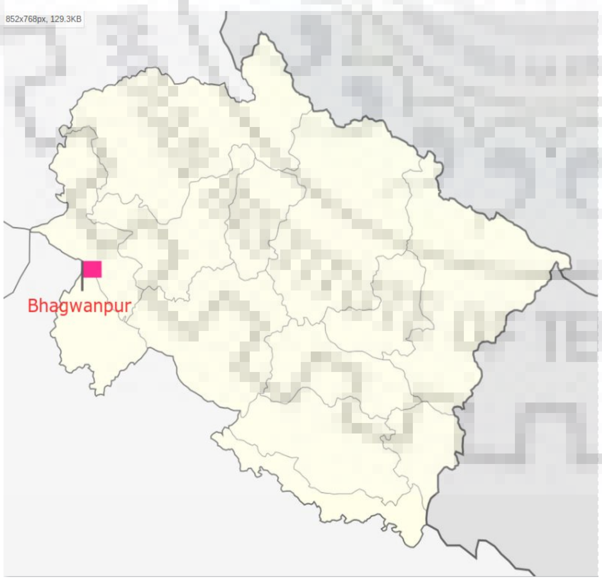

Fig 3.2 Uttarakhand map showing Bhagwanpur
Source: Adapted from Wikipedia

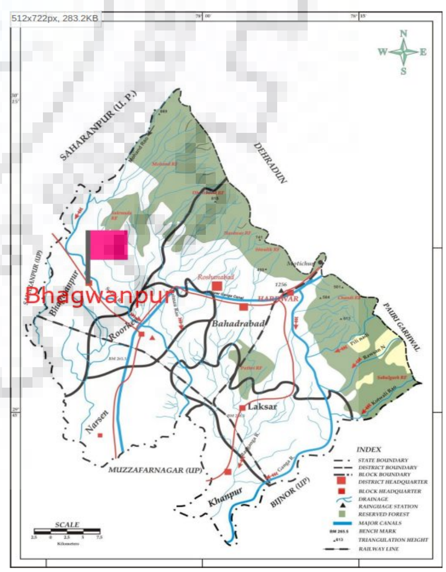

Fig 3.3 Administrative map of Haridwar

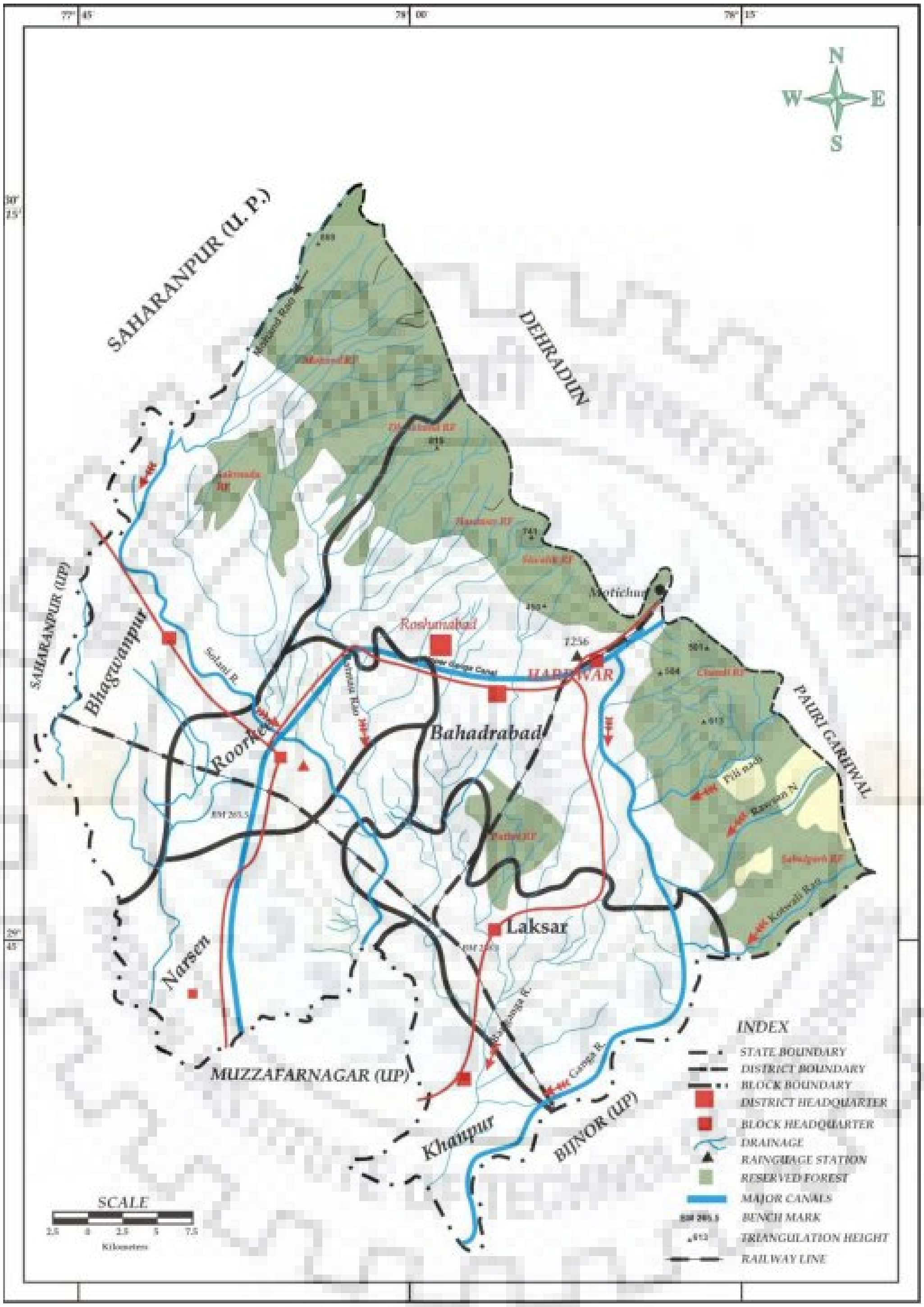

Fig 3.4 Administrative map of Haridwar.
Source: http://cgwb.gov.in/AQM/NAQUIM_REPORT/Uttarakhand/Haridwar.pdf

3.1.1 Climate

Bhagwanpur is located in the district Haridwar of Uttarakhand state in India. This region has sub-humid and hot climate. The region is spread across all of northern Indo-Gangetic Plain that also includes Piedmont Plain in Western Himalayas. Haridwar has three different seasons each of almost 4 months. With Summers in April - July, followed by Rainy Season in July - October and Winters in November - March. The data related to climatological and monthly rainfall can be seen in table no.3.1 below.

June is the hottest season with Maximum temperature touching almost 40 degree Celsius which start rising in March from 27 degree Celsius. In winters, the Temperature could range anywhere between 10-degree Celsius to 22-degree Celsius with January being the coolest. Wind speed is highest in the month of Summers which are May-June. It can reach up to 2.5km/hr. The same is about 0.5km/hr during the months of November. The evaporation is maximum in May at 156 mm and a minimum of 24.5 mm in January.

3.1.2 Rainfall

The rainfall on average in the district of Haridwar is 1174 mm with almost 80 per cent of it being in the monsoon and the rest 20 in remaining non-monsoon months. The rainfall is highest in the north which gradually decreases towards the south. The month of August receives the highest rainfall i.e. 412mm with June and July also being among the wettest months. The monsoon retreats in the month of with very little rainfall of 24mm. All this data has been given in Table No 3.1.

Table No. 3.1: Monthly Rainfall data of Bhagwanpur

Sn	Agroecological Zone	Avrage monthly rainfall (mm)	No. of Rainy Days (No.)	Maximum Rainfall intencity			Avrage weekly tem									Potencial Evapo transpiration		
				up to 15 minute (mm)	Beyond 15 but up to 30 min (mm)	Beyond 30 but up to 60min (mm)	Period									Period		
							Summer(April may)			Winter (Oct-March)			Rainy (June Sep)					
							Min	Max	mean	Min	Max	mean	Min	Max	mean	Summer	Winter	Rainy
Name of Block- Bhagwanpur																		
1	Hot Sub humid (Dry)	1141	45	92	45	15	9.3	23.7	16.5	1.1	19.9	10.5	13.1	23.4	18.3	4.04	1.92	3.8

3.1.3 Physiography

The physiography of Haridwar is structurally divided into three units:

1. Structural Hills: The District in the north and northwestern part is surrounded by structural hills called The Siwaliks. These hills are the ones which have high relief and sharp steep slope. There is more runoff in these regions because of the rough and broken topography and homogenous lithology. The major rocks found in the region are clay, conglomerates, sands, silt, Sandstone etc.. The hills are intersected by faults.

2. Upper Piedmont Plains | The Bhabar: This is the second unit and is just below the Siwaliks. This is The Bhabar. The Bhabar has a large rock with Boulders, cobbles, pebbles, clays and sands etc. Located at a higher elevation as compared to plains they have steeper slopes of 10 to 20 meters/km. These terms have thus geographic and geomorphological connection. Our study area Bhagwanpur and a nearby local town called Bahadrabad has The Bhabhar surrounding them.

3. Lower Piedmont Plains | Tarai: This unit or zone is further below the Bhabar Zone and is called The Tarai. This unit is almost planer and has a low slope with 1.2meters/km. The region has even finer rock grains with gravel and sand being the major rock types. This unit has sediments brought by the rivers Ganga and Solani.

3.1.4 Geomorphology

It is divided and segmented into two parts:

1. Banger: It is also called the Varanasi Uplands. It is the region free of the flood. This has two parts:

- Piedmont Zone: It is called Bhabar. It is the northern part of the raised land which is located adjoining the Siwaliks. Its slope is slightly southern. The fluvial channels are seasonal and die out at places. They reappear at a distant location when the structure converges with Varanasi Plain.
- Varanasi Plain: Varanasi Plain has a low gradient which south easterly inclined. It has low sandy mounds and ridges in the northern part (Bhur surface) and wide extensive clayey southern part accompanying soil alkalization, heavy fluvial features such as paleochannels with meander cutoffs, ox-bow lakes and tals.

2) Flood Plain (Khadar). This is further divided in:

- Old Flood Plain: Defined by palaeobanks with bluffs and showing exploitation of patio, the highest locally developed/preserved is erosional and did not receive alleviation while lower, filled up by Terrace alluvium, gets flooded during high outpouring. Characterized by the levee, meander scrolls, wild oxbow lakes and abandoned channels
- Active Flood Plain: Oscillating/migratory active channel defined by banks with point-bar, channel bar sands and silts

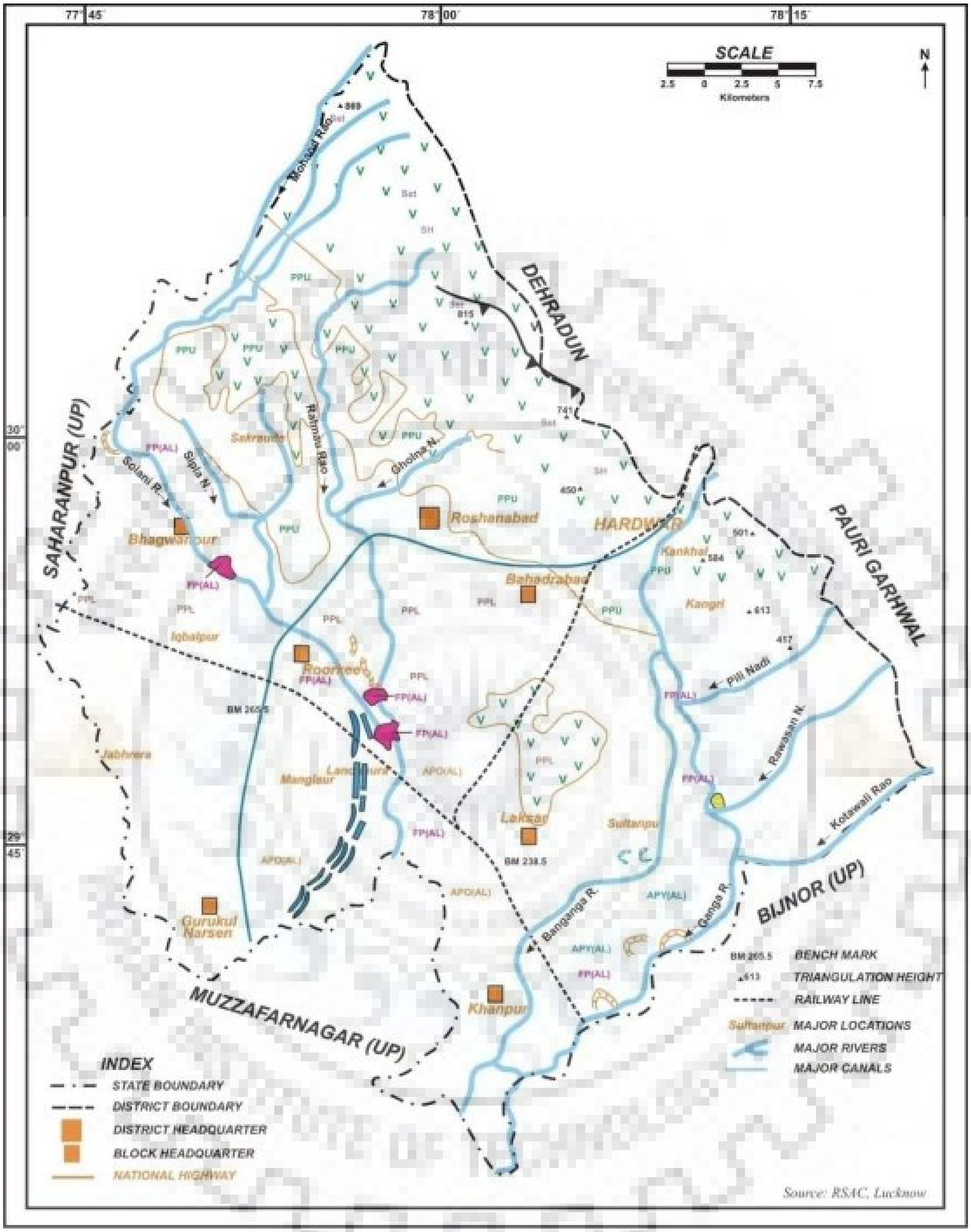

Fig 3.5 Geomorphological map of Haridwar
Source: http://cgwb.gov.in/AQM/NAQUIM_REPORT/Uttarakhand/Haridwar.pdf

Table 3.2 Stratigraphy of Haridwar district

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 cutoffs, ox-bow lakes and tals.

3.1.5 Soils

Soils assume a significant job in groundwater refilling and the agribusiness of the region. It is also highly fertile.

- Ultisols, one of the three major soil types is dark brown coloured soil, spread all across the north part of Siwaliks.

- The Entisols are known as the Bhabar soil is found up and down the lower regions of Siwaliks and stretches out up to Tarai. They have pedogenic horizons. In spite of the fact that these soils comprise of rocks, stones, sand, sediment and mud but they are still very fertile.

- Molisols soil happens in the southern piece of the area likewise called the Tarai soil, which comprised principally of the fine-picked up sand, clay and silt. These are soils with an almost dark; natural rich surface horizon and high base supply. These are the most fertile soils of the whole district with only one-fourth of the total being organic.

3.1.6 Drainage

The main river of the region is river Ganga. Entering from the corner, it flows southward while draining the whole of eastern Haridwar. One stream rises up out of waterway Ganga at close Shahpur Sheetlakhera and goes 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 tributaries of River Ganga River Ganges and Solani are the enduring waterways. Solani is one important regional drainage source which drains the central part of the district. Many seasonal and regional rivers contribute to river Solani. The drainage design in the area is sub dendetric to dendetric and trills. The drainage courses of the vast majority of the nalas out falling in the different tributaries are expansive, level and busy with cobbles, rocks and rock. Significant drainage is relied upon to happen from such streams amid the rainstorm time frame. Past the storm season, the vast majority of these nalas just as tributaries go dry. But, in Tarai belt, the drainage is pretty much lasting as it gets emanating drainage through the groundwater body-offering ascend to a number of springs on dejections along the nalas.

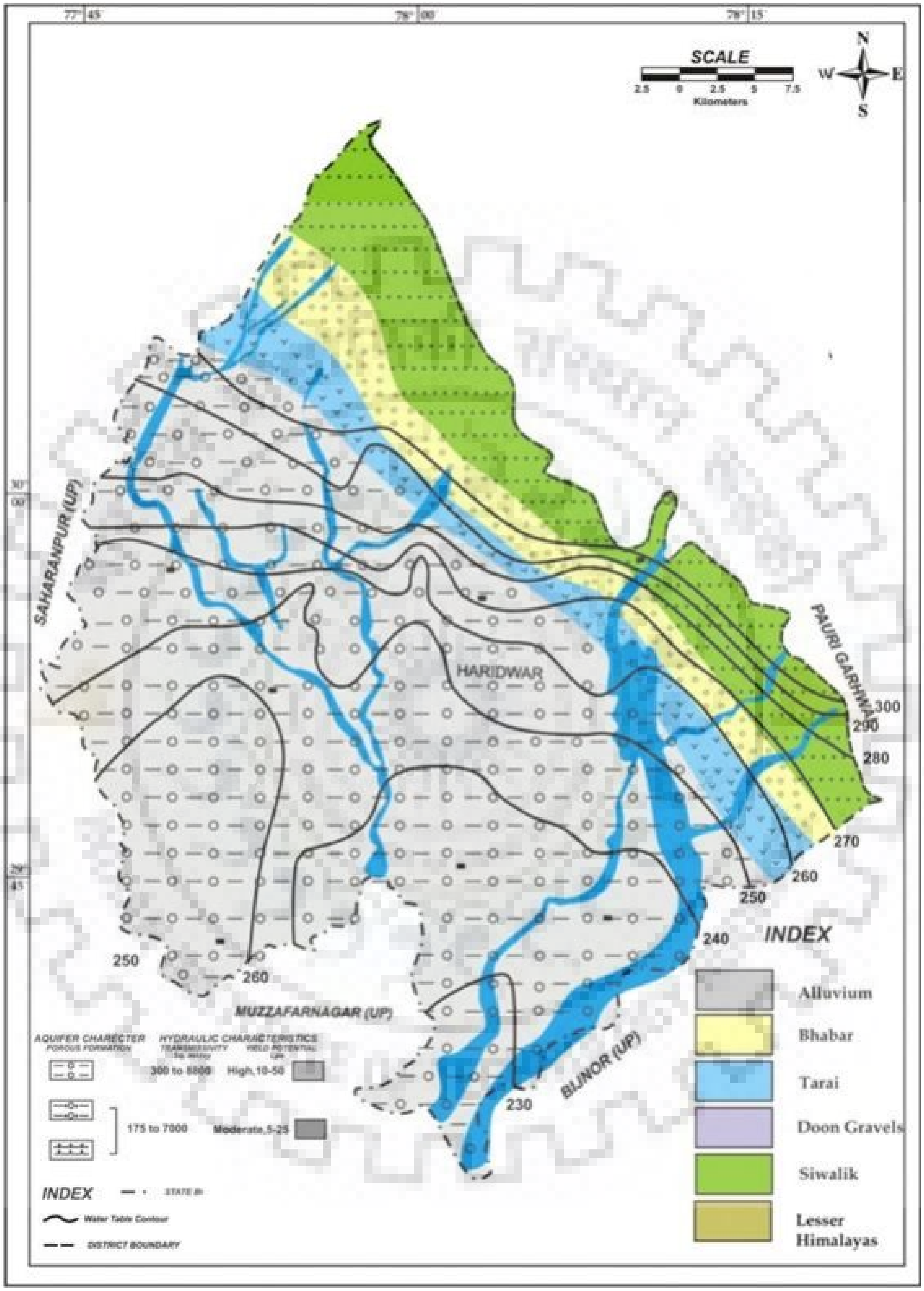

Fig 3.6 Drainage map of Haridwar
Source: http://cgwb.gov.in/AQM/NAQUIM_REPORT/Uttarakhand/Haridwar.pdf

3.1.7 Land Use

Table 3.3 Land usage in Bhagwanpur block

S.No.	Block Name	Total Geographical Area	Area Under Agriculture				Area Under Forest	Area under Wasteland	Area Under Others uses
			Gross Cropped Area (1)	Net Shown Area (2)	Area Sown more than once (1-2)	Cropping intensity (%)			
1	BHAGWANPUR	30276	27696	23080	8709	153	275	2004	4564

3.1.8 Geology

Northern part: High slope hills called the Siwalik Range. 600-900 meter is their elevation of the highest peak. Upper Siwaliks are then followed up by Middle Shivaliks

Middle Siwaliks: This region is to a great extent comprises of lower adjustments of earth and sandstone and an upper succession of huge. The upper part is every now and again part up by muds into an increasingly argillaceous succession. The thickness of the middle Siwaliks is around 2000 meters.

Upper Siwaliks: These are for the most part redaceous comprising of sandstone, rocks, stones, aggregates, shale, cut and mud. The most extreme thickness of upper Siwaliks is around 1000 meters. Middle Siwaliks have soak slopes which are plunging towards south up to 200 to 600. These Middle Siwaliks has navigated by numerous minor faults.

The alluvium has been extended down to the south in the complete district. The surface has also changed as we go from north to south dependent upon the term, detachment of transportation and nature of affirmation of sediment.

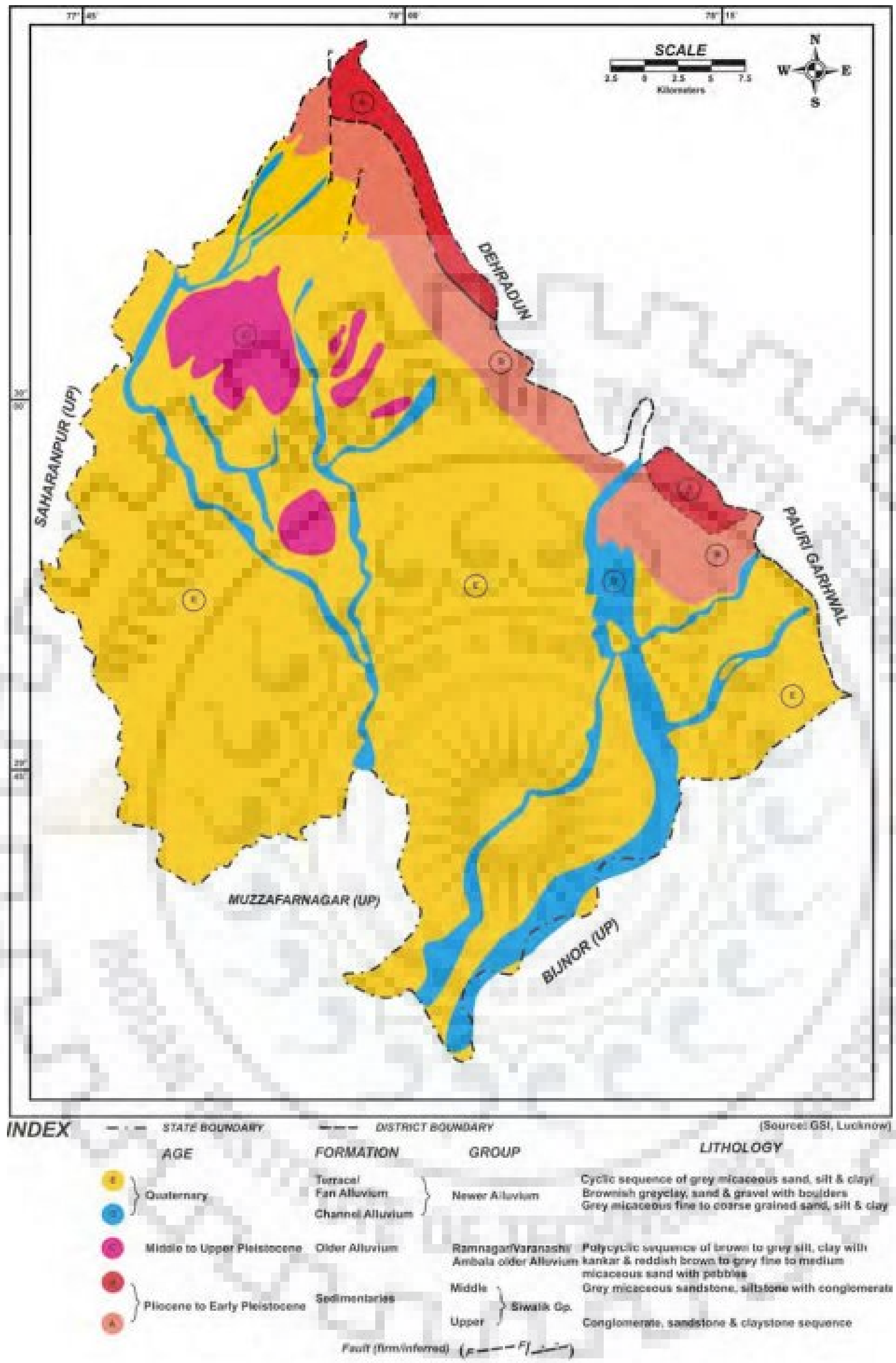

Fig 3.7 Geological map of Haridwar
Source: http://cgwb.gov.in/AQM/NAQUIM_REPORT/Uttarakhand/Haridwar.pdf

3.1.9 Hydrogeology

The block of Bhagwanpur is located from north to northwestern part of the district of

Haridwar. Its total area is about 315 km² which does not include forest. Currently, the main source of occupation for the families is agriculture however there has been an increasing number of industries being set up in the region. It can be divided into three units:

In the north upper and middle Siwaliks cover, most of the region and their elevation above the sea is 400-800m.

Further down of the structural hills of Siwalik there is upper piedmont plain wich s comprised of rock debris, and it occurs over the south of Siwalik hill in variable lateral and areal extent formed at the foothills by the consolidation of many alluvial fans consisting of boulders, cobbles, sands, gravel and clay.

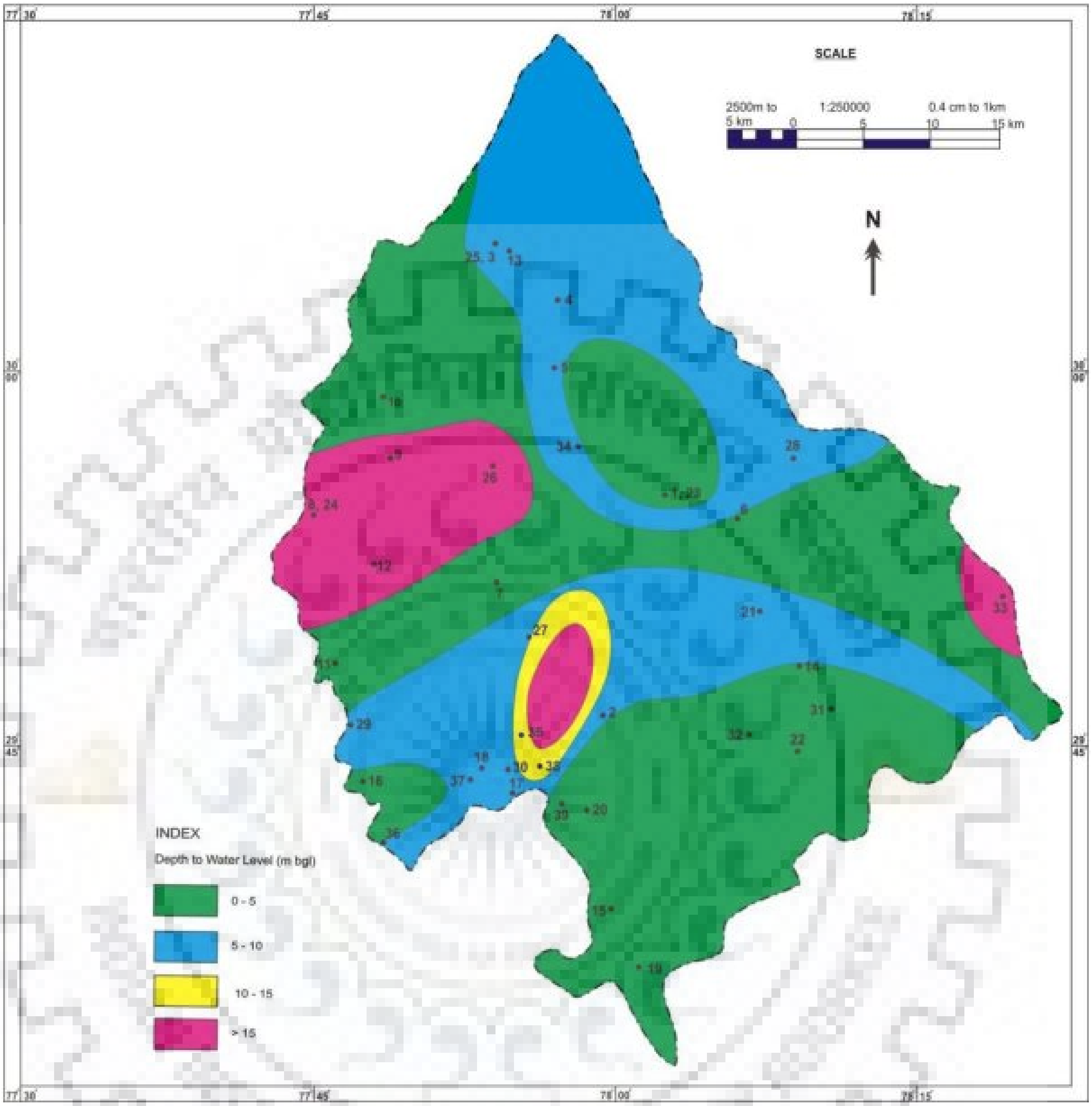

Fig 3.8 Hydrogeological map of Haridwar
Source: http://cgwb.gov.in/AQM/NAQUIM_REPORT/Uttarakhand/Haridwar.pdf

3.2 Sampling

All the samples are taken from the industrial region of the Bhagwanpur block. A total of 23 samples are taken. The main locations of these samples are Sikandarpur, Bhagwanpur, Raipur, Sisona etc. with each location having 3-4 samples on average. Most of the samples are taken from the government hand pumps with some of them being from the domestic water lines. The samples were taken for two different time series:

- One during the month of December which are the peak of winters in this part of India(Post Monsoon)
- Other during the month of April which is usually summers(Pre Monsoon)

A major point was kept in mind during the selection of sampling sites to keep the site's characteristics a bit diverse on the basis of the number of factors

1. Depth of the hand pumps
2. Surrounding Environment: Residential, Agricultural or Industrial
3. Groundwater Source: Handpumps or Domestic Pipes

Sampling Process

- First, the selection of the sampling site was done by roaming around the region and selecting the site based on the above factors
- Geolocation was noted and marked on the map using GPS (Global Positioning System). 2 Mobile apps were used for the same purpose: Google Maps and Compass
- At least 5-10 L of water from each site was drained out before collecting the sample to keep the water which is fresh groundwater.
- Sampling bottles of 120ml capacity were used to collect the samples.
- Sample bottles were first cleaned with Milli Q water and then filled up with the sample.
- A simple and unique naming convention was decided based on which samples were given names.
- After those in-situ measurements were carried upon the samples and the results were noted down in a notebook. The measurements were done for\
    - Temperature
    - Electrical Conductivity
    - pH

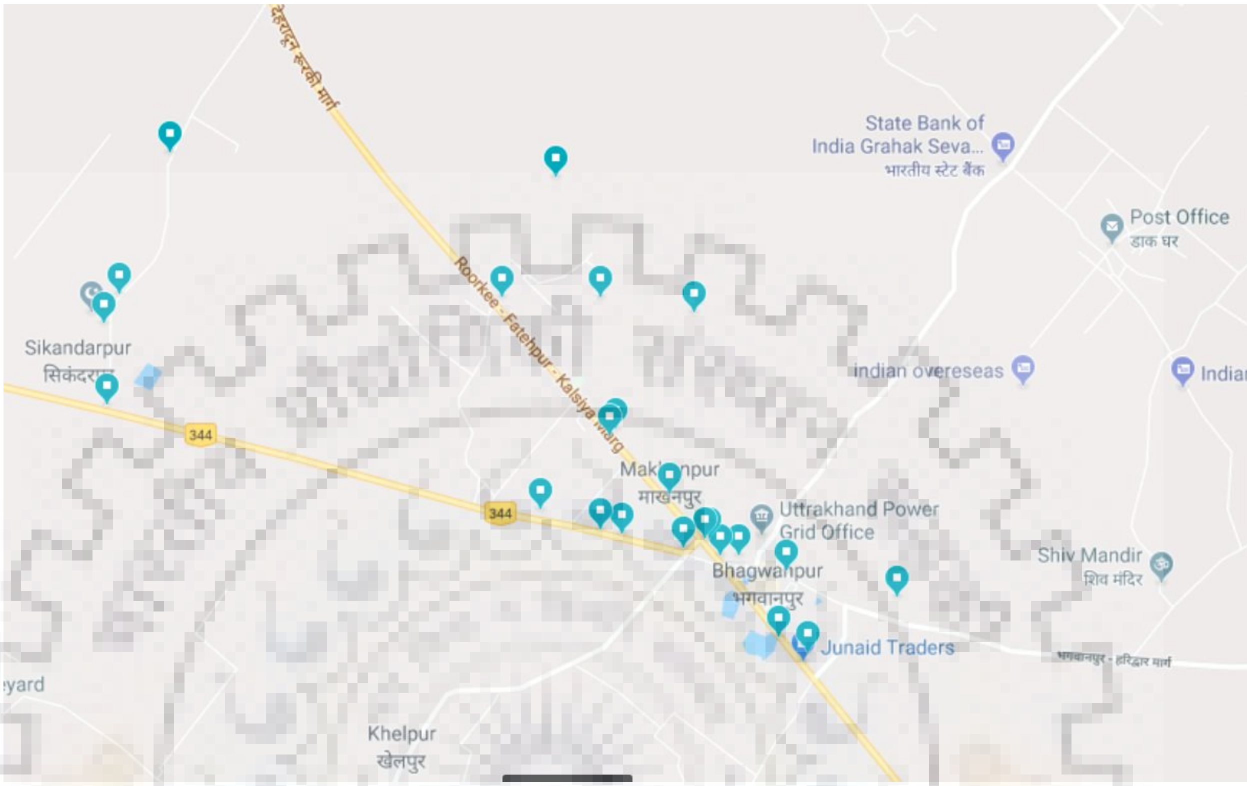

Fig 3.9 Map with all the sampling sites marked

Source: Adapted Google maps

Table 3.4 Sampling Locations in Bhagwanpur

Sample number	Sample name	Latitude	Longitude
1	BGP-BP-1	29°5633"	77°4839"
2	BGP-SP-1	29°5636"	77°4829"
3	BGP-SP-2	29°5631"	77°4828"
4	BGP-SP-4	29°5633"	77°4831"
5	BGP-MP-1	29°5222"	77°5236"
6	BGP-MP-2	29°5631"	77°4828"
7	BGP-RP-1	29°5643"	77°4734"
8	BGP-MP-3	29°5645"	77°4820"
9	BGP-MP-4	29°5658"	77°486"
10	BGP-RP-2	29°5723"	77°4737"
11	BGP-BP-2	29°5631"	77°4828"
12	BGP-BP-3	29°5616"	77°4847"
13	BGP-BP-4	29°5635"	77°4825"
14	BGP-SK-1	29°578"	77°4556"
15	BGP-SK-2	29°5717"	77°4543"
16	BGP-SK-3	29°5727"	77°4552"
17	BGP-SK-4	29°5756"	77°4622"
18	BGP-SI-1	29°5712"	77°4758"
19	BGP-SI-2	29°5751"	77°4754"
20	BGP-SI-3	29°5723"	77°4827"
21	BGP-RP-3	29°5636"	77°488"
22	BGP-BP-5	29°5615	77°4851"
23	BGP-BP-6	29°5624"	77°4916"

Fig. 3.10 Photographs of a sampling site
Source: Nikhil Goyal

Fig. 3.11 Soldering activity at one of the industries near a sampling site. Source: Nikhil Goyal

Fig. 3.12 Oil spills from a truck workshop near a sampling site. Source: Nikhil Goyal

3.3 Measurements

3.3.1 Temperature

The temperature was recorded on the sampling site. A very small pocket thermometer machine was used for the same. Before each measurement thermometer was cleaned with Milli Q water to prevent any contamination of the sample. Wait time was set until reading gets stable. The reading was noted.

Fig. 3.13 Temperature meter used for the readings Source: Nikhil Goyal

3.3.2 pH measurements

pH measurements were done using a small pH meter machine of the company HANNA. The instrument was small and light and thus easily portable. The meter was first calibrated using buffer solutions of pH 4 and pH9. The reading of the meter was set as the same pH of buffer solutions during calibration. This activity is done to have standard results during actual measurements. Before actual sampling, the meter was washed with Milli Q water to keep the reading free of contaminants and also preventing the sample from outside contamination. The reading was noted at last when they get stabilised.

Fig. 3.14 pH meter photo taken on the ground

3.3.3 Electrical Conductivity

For EC measurements again, a small portable machine was used to measure, however, all the EC measurements were done off site within 24 hours of sample collection. The machine was first calibrated with a standard solution of the known conductivity 1413 µS/cm. The reading was readjusted with accordance to the standard. The EC measurements were done in the same process as that of pH with readings with noted after stabilisation in micro Siemens per cm.

Fig 3.15: EC meter used in this study Source: Flipkart

3.3.4 Heavy Metal Contamination Measurements

For heavy metal measurements, Inductively coupled plasma mass spectrometry (ICP-MS) lab facility of Indian Institute of Technology, Roorkee was used. Before taking samples to the lab, they were filtered with filter paper.

After filtration, 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

4. RESULTS AND DISCUSSIONS

4.1 Obtained values:

4.1.1 Temperature measurements:

The in-situ on ground temperature values obtained for the samples collected for both the phases are mentioned in the table below. The mean temperature for phase 1 of sampling was found to be 24.186 and the standard deviation of 0.588. For phase 2 the mean obtained is 27.332 and the standard deviation 0.726.

Table 4.1 Temperature values for both phases

Sample number	Sample name	phase 1 Temperature(°C)	phase 2 Temperature(°C)
1	BGP-BP-1	24.4	28.5
2	BGP-SP-1	24.6	27.5
3	BGP-SP-2	24.6	26.8
4	BGP-SP-4	24.9	28
5	BGP-MP-1	25	27.6
6	BGP-MP-2	24.8	damaged
7	BGP-RP-1	24.5	27
8	BGP-MP-3	25.2	25.8
9	BGP-MP-4	24.7	28.8
10	BGP-RP-2	25	27.8
11	BGP-BP-2	24.3	27.2
12	BGP-BP-3	24.1	27.3
13	BGP-BP-4	23.7	27.1
14	BGP-SK-1	23.6	27.1
15	BGP-SK-2	23.6	27.6
16	BGP-SK-3	23.7	25.6
17	BGP-SK-4	23.3	26.8
18	BGP-SI-1	23.8	27.2
19	BGP-SI-2	23.5	27.4
20	BGP-SI-3	23.7	27.9
21	BGP-RP-3	24.2	27.3

22	BGP-BP-5	23.5	27.2
23	BGP-BP-6	23.6	27.8

Table 4.2 Temperature mean, SD and Range

Phase	Mean±S.D.	Range
1	24.186±0.588	23.3-25.5
2	27.332±0.726	25.6-28.8

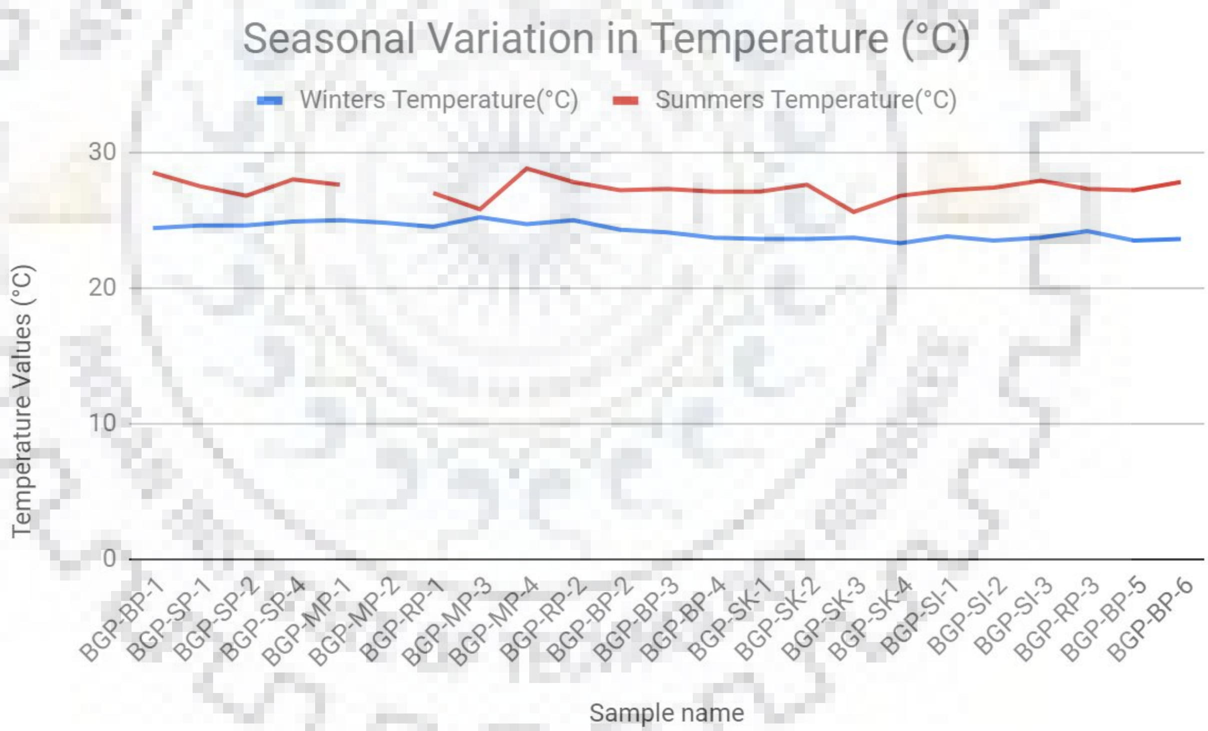

Fig 4.1 Chart showing seasonal variation in temperature values at sample site

The above figure shows the variations in Temperature values for all the sampling site for 2 seasons: Winters and Summers. It is deduced that the Temperature values are higher during summers as compared to winters by an average measure of 3-4 (°C).

4.1.2 pH measurements:

The in-situ on ground pH values obtained for the samples collected for both the phases are mentioned in the table below. The mean pH for phase 1 of sampling was found to be 7.465 and the standard deviation of 0.148. For phase 2 the mean obtained is 7.768 and the standard deviation 0.210.

Table 4.3 pH values for both phases

Sample number	Sample name	pH phase 1	pH phase 2
1	BGP-BP-1	7.53	7.6
2	BGP-SP-1	7.56	7.8
3	BGP-SP-2	7.36	7.6
4	BGP-SP-4	7.46	7.7
5	BGP-MP-1	7.5	7.7
6	BGP-MP-2	7.3	
7	BGP-RP-1	7.64	8.1
8	BGP-MP-3	7.53	7.8
9	BGP-MP-4	7.52	7.7
10	BGP-RP-2	7.54	7.8
11	BGP-BP-2	7.5	7.6
12	BGP-BP-3	7.15	7.3
13	BGP-BP-4	7.65	8.1
14	BGP-SK-1	7.5	7.4
15	BGP-SK-2	7.6	7.8
16	BGP-SK-3	7.23	8.1
17	BGP-SK-4	7.54	7.8
18	BGP-SI-1	7.14	7.7
19	BGP-SI-2	7.45	7.8
20	BGP-SI-3	7.67	8.1
21	BGP-RP-3	7.34	7.7
22	BGP-BP-5	7.54	7.9
23	BGP-BP-6	7.44	7.8

Table 4.4 pH mean, SD and Range

Phase	Mean±S.D.	Range
1	7.465±0.148	7.14-7.67
2	7.768±0.210	7.3-8.1

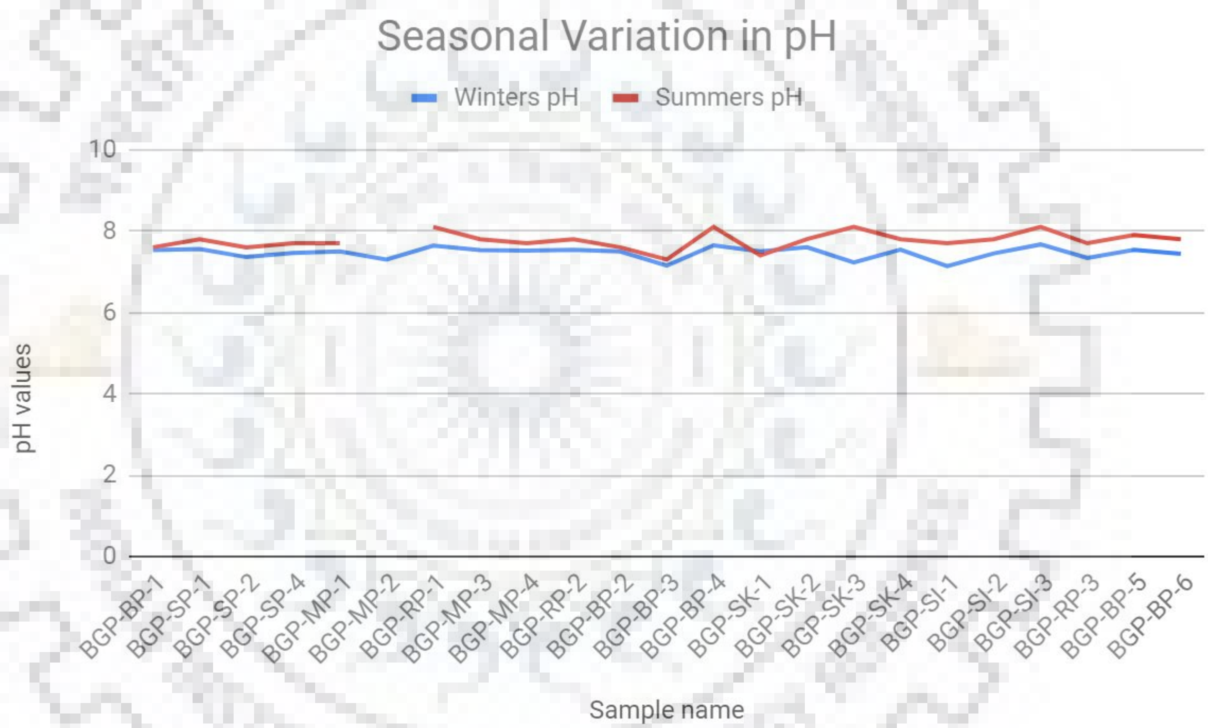

Fig 4.2 Chart showing seasonal variation in pH values at sample site

The above figure shows the variations in pH values for all the sampling site for 2 seasons: Winters and Summers. It is deduced that the pH values are higher during summers as compared to winters by an average measure of .3.

4.1.3 EC measurements:

The in-situ on ground EC values obtained for the samples collected for both the phases are mentioned in the table below. The mean EC for phase 1 of sampling was found to be 499.826 and the standard deviation 123.831. For phase 2 the mean obtained is 512.318 and the standard deviation 157.736.

Table 4.5 EC values for both phases

Sample number	Sample name	EC(uS/cm) phase1	EC(uS/cm) phase 2
1	BGP-BP-1	621	583
2	BGP-SP-1	472	474
3	BGP-SP-2	603	686
4	BGP-SP-4	465	490
5	BGP-MP-1	452	457
6	BGP-MP-2	634	
7	BGP-RP-1	410	415
8	BGP-MP-3	466	482
9	BGP-MP-4	459	476
10	BGP-RP-2	433	453
11	BGP-BP-2	616	517
12	BGP-BP-3	901	1140
13	BGP-BP-4	374	388
14	BGP-SK-1	676	611
15	BGP-SK-2	366	410
16	BGP-SK-3	361	354
17	BGP-SK-4	414	427
18	BGP-SI-1	466	491
19	BGP-SI-2	459	494
20	BGP-SI-3	460	475
21	BGP-RP-3	461	470
22	BGP-BP-5	465	487
23	BGP-BP-6	462	491

Table 4.6 EC mean, SD and Range

Phase	Mean±S.D.	Range
1	499.826±123.831	361-901
2	512.318±157.736	354-1140

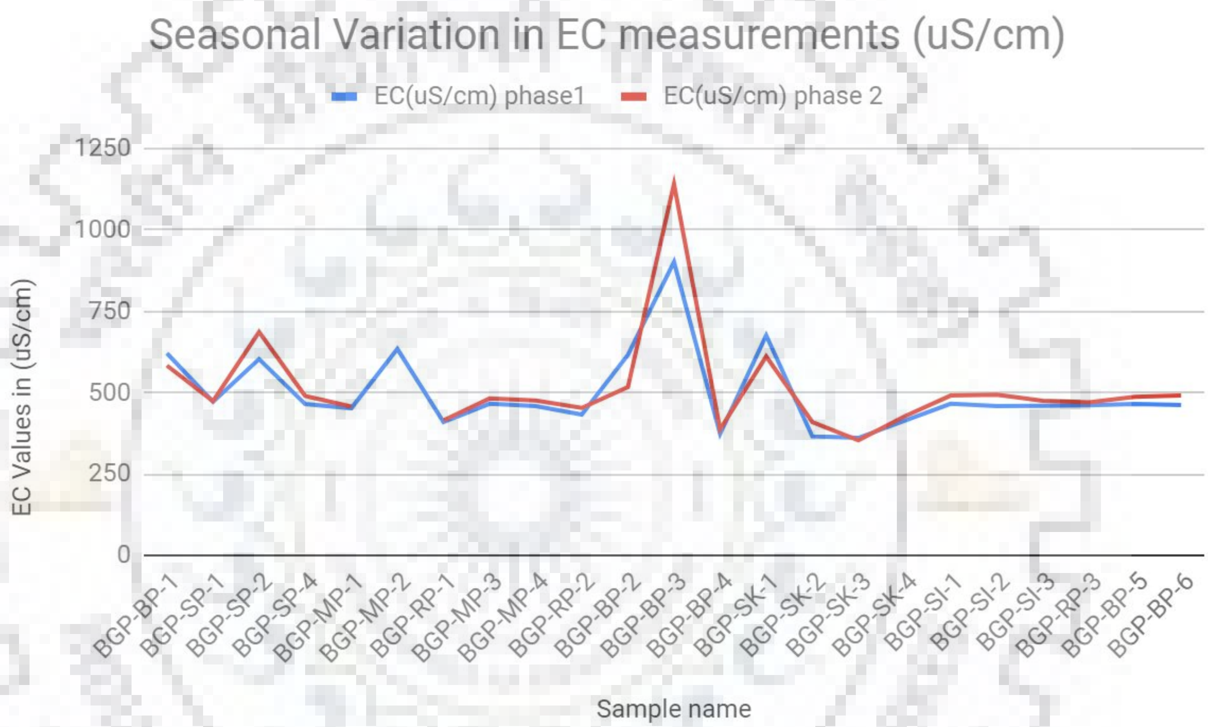

Fig 4.3 Chart showing seasonal variation in EC values at sample sites

The above figure shows the variations in EC values for all the sampling site for 2 seasons: Winters and Summers. Nothing can be said conclusively about the variation trend. At some locations have higher values in summers while others have higher values in winters. While for most values EC values are higher in Summers. This could be because of warmer water in Summers and Conductivity increases with Temperature.

4.1.4 Heavy Metal Conc Phase 1:

Below tables mention the values obtained for the heavy metals analyzed using the

ICP-MS probe. With each element heading their maximum permissible values as prescribed by the BIS is mentioned included in the parenthesis. The unit for these concentrations are parts per billion. The values more than the prescribed value are highlighted.

Table 4.7 Heavy metal concentrations for phase 1 of sampling

Sample number	Sample name	Sample acronym	Depth(Reported by locals in ft)	Au(2.2)	As(10)	Ca(75000)	Cr(50)
1	BGP-BP-1	BB1	200	0.159	1.118	10608.689	1.257
2	BGP-SP-1	BP1	200	0.244	0.543	22422.465	2.209
3	BGP-SP-2	BP2	100	0.17	0.688	13735.577	2.175
4	BGP-SP-4	BP4	200	0.071	0.983	33848.672	2.104
5	BGP-MP-1	BM1	200	0.076	0.881	11723.969	1.641
6	BGP-MP-2	BM2	150	0.108	1.95	55446.958	2.515
7	BGP-RP-1	BR1	100	0.1	1.454	13343.159	1.614
8	BGP-MP-3	BM3	200	3.43	1.27	19406.41	2.023
9	BGP-MP-4	BM4	200	0.158	0.745	10521.264	1.301
10	BGP-RP-2	BR2		0.078	0.552	61896.145	1.504
11	BGP-BP-2	BB2		0.053	2.544	9856.023	0.872
12	BGP-BP-3	BB3	100	0.07	0.866	8780.465	0.875
13	BGP-BP-4	BB4	100	0.14	0.819	9235.811	1.62
14	BGP-SK-1	BK1	100	0.148	0.588	13425.488	1.319
15	BGP-SK-2	BK2	100	0.136	0.724	17304.897	1.998
16	BGP-SK-3	BK3		0.083	1.892	10883.871	1.388
17	BGP-SK-4	BK4	200	0.161	3.678	6668.017	0.926
18	BGP-SI-1	BI1	200	0.1	0.435	15324.42	1.056
19	BGP-SI-2	BI2		0.134	0.508	10343.703	1.943
20	BGP-SI-3	BI3		0.066	2.722	16801.415	1.9
21	BGP-RP-3	BR3	200	0.199	1.108	23077.72	1.964
22	BGP-BP-5	BB5		0.246	0.501	20686.208	1.65
23	BGP-BP-6	BB6		0.164	0.428	9898.48	1.199
Mean values for all samples				0.26225	1.124875	17718.32608	1.543875

Table 4.8 Heavy metal concentrations for phase 1 of sampling

Sample number	Sample name	Sample acronym	Depth(Reported by locals in ft)	U(15)	Ba(700)	Cd(3)	Ni(20)
1	BGP-BP-1	BB1	200	0.16	17.273	0.022	0.819
2	BGP-SP-1	BP1	200	0.163	26.517	0.044	1.368
3	BGP-SP-2	BP2	100	0.376	23.019	0.053	0.852
4	BGP-SP-4	BP4	200	0.392	51.946	0.033	1.368
5	BGP-MP-1	BM1	200	0.36	18.608	0.037	1.039
6	BGP-MP-2	BM2	150	2.162	66.945	0.038	14.231
7	BGP-RP-1	BR1	100	0.259	22.781	0.025	0.751
8	BGP-MP-3	BM3	200	1.637	42.982	0.02	0.885
9	BGP-MP-4	BM4	200	0.423	20.522	0.026	0.553
10	BGP-RP-2	BR2		0.784	51.263	0.119	2.493
11	BGP-BP-2	BB2		0.215	37.785	0.072	0.518
12	BGP-BP-3	BB3	100	0.864	13.143	0.02	0.917
13	BGP-BP-4	BB4	100	0.356	20.925	0.017	0.496
14	BGP-SK-1	BK1	100	0.334	17.124	0.038	1.014
15	BGP-SK-2	BK2	100	0.4	25.363	0.025	0.828
16	BGP-SK-3	BK3		0.691	21.933	0.409	1.335
17	BGP-SK-4	BK4	200	0.217	14.809	0.019	0.585
18	BGP-SI-1	BI1	200	0.384	14.866	0.017	0.748
19	BGP-SI-2	BI2		0.607	12.358	0.015	1.062
20	BGP-SI-3	BI3		0.723	39.169	0.017	0.789
21	BGP-RP-3	BR3	200	2.514	58.17	0.038	1.341
22	BGP-BP-5	BB5		0.576	42.247	0.146	1.133
23	BGP-BP-6	BB6		0.067	10.368	0.015	0.664
Mean values for all samples				0.611	27.9215	0.052708333	1.491208333

Table 4.9 Heavy metal concentrations for phase 1 of sampling

Sample number	Sample name	Sample acronym	Depth(Reported by locals in ft)	Cu(50)	Fe(300)	Mn(100)	Pb(10)
1	BGP-BP-1	BB1	200	0.48	139.425	1.563	0.202
2	BGP-SP-1	BP1	200	0.556	193.674	1.294	0.199
3	BGP-SP-2	BP2	100	0.658	128.13	1.291	0.193

4	BGP-SP-4	BP4	200	1.109	207.235	1.194	0.146
5	BGP-MP-1	BM1	200	1.153	140.377	1.478	0.342
6	BGP-MP-2	BM2	150	0.28	208.871	6.202	0.12
7	BGP-RP-1	BR1	100	0.299	138.019	1.844	0.221
8	BGP-MP-3	BM3	200	0.304	167.22	1.627	0.135
9	BGP-MP-4	BM4	200	0.365	101.549	2.553	0.166
10	BGP-RP-2	BR2		0.532	236.545	31.161	0.184
11	BGP-BP-2	BB2		0.447	100.222	1.326	0.301
12	BGP-BP-3	BB3	100	0.305	91.319	1.198	0.229
13	BGP-BP-4	BB4	100	0.398	94.348	0.868	0.157
14	BGP-SK-1	BK1	100	0.493	129.507	2.252	0.276
15	BGP-SK-2	BK2	100	0.228	150.043	2.564	0.129
16	BGP-SK-3	BK3		2.022	105.642	3.194	0.336
17	BGP-SK-4	BK4	200	0.177	86.717	1.337	0.122
18	BGP-SI-1	BI1	200	0.245	134.015	2.047	0.102
19	BGP-SI-2	BI2		0.216	108.755	0.533	0.093
20	BGP-SI-3	BI3		0.203	149.046	33.296	0.254
21	BGP-RP-3	BR3	200	0.468	192.638	6.56	0.128
22	BGP-BP-5	BB5		0.364	180.399	4.059	0.527
23	BGP-BP-6	BB6		0.172	102.489	1.788	0.133
Mean values for all samples				0.478083333	136.924375	4.634541667	0.195625

Table 4.10 Heavy metal concentrations for phase 1 of sampling

Sample name	**Sample acronym**	**Depth(Reported by locals in ft)**	**Se(10)**	**K(10000)**	**Mg(30000)**	**Na(20000)**
BGP-BP-1	BB1	200	0.56	4853.791	17583.117	3657.15
BGP-SP-1	BP1	200	1.229	13714.719	46871.837	21804.809
BGP-SP-2	BP2	100	0.814	6624.525	56155.09	10028.243
BGP-SP-4	BP4	200	0.695	5364.83	34111.138	6165.847
BGP-MP-1	BM1	200	0.729	4829.48	36209.287	8355.024
BGP-MP-2	BM2	150	2.917	6173.585	32907.241	6183.276
BGP-RP-1	BR1	100	0.746	5010.361	11653.513	3709.427
BGP-MP-3	BM3	200	1.255	6575.087	52042.538	16699.043
BGP-MP-4	BM4	200	1.153	61188.656	35431.849	5806.962
BGP-RP-2	BR2		0.89	6375.818	38484.672	12188.37

BGP-BP-2	BB2		2.298	6491.392	18181.92	9358.982
BGP-BP-3	BB3	100	1.518	5329.809	26180.225	11041.806
BGP-BP-4	BB4	100	0.712	8007.639	31686.81	8766.892
BGP-SK-1	BK1	100	1.06	2751.036	13217.591	3223.795
BGP-SK-2	BK2	100	0.873	4807.107	27955.789	10502.475
BGP-SK-3	BK3		0.653	5840.951	22588.841	5579.985
BGP-SK-4	BK4	200	0.865	58168.408	16236.277	4123.973
BGP-SI-1	BI1	200	0.619	5851.46	50899.923	26668.724
BGP-SI-2	BI2		1.153	20495.463	31153.448	7744.853
BGP-SI-3	BI3		0.585	6765.687	21005.031	5576.829
BGP-RP-3	BR3	200	10.225	96807.823	55061.357	16731.525
BGP-BP-5	BB5		1.543	6088.091	40806.165	8048.541
BGP-BP-6	BB6		0.712	828.27	12171.367	3677.569
Mean values for all samples			1.4085	14539.33283	30358.12608	8985.170833

4.1.5 Heavy Metal Conc Phase 2:

Below tables mention the values obtained for the heavy metals analyzed for the phase 2 samples, using the ICP-MS probe. With each element heading their maximum permissible values as prescribed by the BIS is mentioned included in the parenthesis. The unit for these concentrations are parts per billion. The values more than the prescribed value are highlighted.

Table 4.11 Heavy metal concentrations for phase 2 of sampling

Sample number	Sample name	Sample acronym	Depth(Reported by locals in ft)	Au(2.2)	As(10)	Ca(75000)	Cr(50)
1	BGP-BP-1	BB1	200	1.209	0.866	47436.731	3.01
2	BGP-SP-1	BP1	200	0.077	1.365	36795.555	3.541
3	BGP-SP-2	BP2	100	0.156	2.931	79628.668	3.459
4	BGP-SP-4	BP4	200	0.062	1.689	38330.794	3.189
5	BGP-MP-1	BM1	200	0.089	0.75	33902.724	4.07
6	BGP-MP-2	BM2	150				
7	BGP-RP-1	BR1	100	0.083	1.075	31218.236	3.396
8	BGP-MP-3	BM3	200	0.094	0.771	34264.708	3.625

9	BGP-MP-4	BM4	200	0.075	2.014	39375.529	3.797
10	BGP-RP-2	BR2		0.097	0.661	28056.966	3.796
11	BGP-BP-2	BB2		0.868	1.179	54300.017	2.663
12	BGP-BP-3	BB3	100	1.023	1.14	99560.499	4.219
13	BGP-BP-4	BB4	100	0.341	0.978	19822.621	2.861
14	BGP-SK-1	BK1	100	0.228	8.312	86138.058	2.979
15	BGP-SK-2	BK2	100	0.11	1.018	47007.598	3.214
16	BGP-SK-3	BK3		0.116	1.21	27651.967	2.605
17	BGP-SK-4	BK4	200	0.134	2.179	27860.93	3.296
18	BGP-SI-1	BI1	200	0.14	1.395	38331.463	2.935
19	BGP-SI-2	BI2		0.121	1.249	36812.111	3.048
20	BGP-SI-3	BI3		0.114	1.317	39714.923	3.157
21	BGP-RP-3	BR3	200	0.064	1.76	42511.025	4.29
22	BGP-BP-5	BB5		0.221	1.263	29553.585	3.188
23	BGP-BP-6	BB6		0.197	1.335	31501.13	3.548
Mean values for all samples				0.234125	1.519041667	39573.99325	3.078583333

Table 4.12 Heavy metal concentrations for phase 2 of sampling

Sample number	**Sample name**	**Sample acronym**	**Depth(Reported by locals in ft)**	**U(15)**	**Ba(700)**	**Cd(3)**	**Ni(20)**
1	BGP-BP-1	BB1	200	4.737	168.333	0.07	1.41
2	BGP-SP-1	BP1	200	3.538	116.348	0.065	1.477
3	BGP-SP-2	BP2	100	3.57	267.382	0.076	1.851
4	BGP-SP-4	BP4	200	4.126	124.819	0.05	0.759
5	BGP-MP-1	BM1	200	3.526	96.351	0.052	1.489
6	BGP-MP-2	BM2	150				
7	BGP-RP-1	BR1	100	8.418	152.489	0.076	1.043
8	BGP-MP-3	BM3	200	4.658	82.005	0.807	1.812
9	BGP-MP-4	BM4	200	3.388	116.25	0.084	0.853
10	BGP-RP-2	BR2		3.042	64.115	0.06	0.805
11	BGP-BP-2	BB2		3.984	199.103	0.116	1.802
12	BGP-BP-3	BB3	100	10.227	445.815	0.391	2.669
13	BGP-BP-4	BB4	100	5.842	66.189	0.488	1.044
14	BGP-SK-1	BK1	100	0.313	198.389	0.065	1.603
15	BGP-SK-2	BK2	100	2.91	120.839	0.135	1.079

16	BGP-SK-3	BK3		6.735	49.894	0.089	0.73
17	BGP-SK-4	BK4	200	2.564	69.496	0.102	1.121
18	BGP-SI-1	BI1	200	4.093	130.281	0.084	0.837
19	BGP-SI-2	BI2		3.966	125.695	0.101	0.861
20	BGP-SI-3	BI3		4.238	133.336	0.307	1.049
21	BGP-RP-3	BR3	200	3.136	132.131	0.053	1.582
22	BGP-BP-5	BB5		3.767	88.158	0.418	2.886
23	BGP-BP-6	BB6		4.007	96.349	0.136	3.279
Mean values for all samples				3.949375	126.823625	0.159375	1.335041667

Table 4.13 Heavy metal concentrations for phase 2 of sampling

Sample number	Sample name	Sample acronym	Depth(Reported by locals in ft)	Cu(50)	Fe(300)	Mn(100)	Pb(10)
1	BGP-BP-1	BB1	200	0.823	147.226	38.161	0.19
2	BGP-SP-1	BP1	200	1.184	99.865	83.561	0.275
3	BGP-SP-2	BP2	100	0.815	173.844	167.666	0.198
4	BGP-SP-4	BP4	200	0.56	104.897	91.556	0.291
5	BGP-MP-1	BM1	200	0.823	110.216	79.29	0.219
6	BGP-MP-2	BM2	150				
7	BGP-RP-1	BR1	100	0.828	91.125	28.009	0.185
8	BGP-MP-3	BM3	200	0.667	105.412	97.748	0.975
9	BGP-MP-4	BM4	200	0.76	107.128	78.387	0.363
10	BGP-RP-2	BR2		0.874	85.07	89.414	0.143
11	BGP-BP-2	BB2		0.799	150.757	107.289	0.206
12	BGP-BP-3	BB3	100	0.861	248.847	2076.837	0.247
13	BGP-BP-4	BB4	100	0.828	77.886	23.294	0.186
14	BGP-SK-1	BK1	100	0.715	289.15	537.211	0.28
15	BGP-SK-2	BK2	100	0.573	123.222	31.472	0.171
16	BGP-SK-3	BK3		0.694	99.471	41.555	0.256
17	BGP-SK-4	BK4	200	0.993	100.449	94.616	0.215
18	BGP-SI-1	BI1	200	1.227	112.647	63.986	0.434
19	BGP-SI-2	BI2		1.146	106.052	58.565	0.222
20	BGP-SI-3	BI3		1.101	107.086	62.808	0.222
21	BGP-RP-3	BR3	200	1.139	110.524	67.914	0.233
22	BGP-BP-5	BB5		1.066	90.627	4.974	0.313

23	BGP-BP-6	BB6		1.4	92.765	1.734	0.359
Mean values for all samples				0.828166666	113.92775	163.5852917	0.257625

Table 4.14 Heavy metal concentrations for phase 2 of sampling

Sample number	Sample name	Sample acronym	Depth(Reported by locals in ft)	Se(10)	K(10000)	Mg(30000)	Na(20000)
1	BGP-BP-1	BB1	200	2.18	1689.658	25336.873	44502.6
2	BGP-SP-1	BP1	200	2.326	3493.742	30912.309	23132.504
3	BGP-SP-2	BP2	100	2.326	3493.742	30912.309	23132.504
4	BGP-SP-4	BP4	200	1.139	1692.168	20864.085	55180.424
5	BGP-MP-1	BM1	200	0.865	1642.745	18259.42	55461.542
6	BGP-MP-2	BM2	150				
7	BGP-RP-1	BR1	100	0.9	2860.378	29526.96	33257.101
8	BGP-MP-3	BM3	200	0.836	1333.43	17505.719	62840.734
9	BGP-MP-4	BM4	200	1.058	1694.45	21066.435	46129.378
10	BGP-RP-2	BR2		1.139	1164.724	13615.88	82210.269
11	BGP-BP-2	BB2		1.765	2451.907	22135.544	18760.39
12	BGP-BP-3	BB3	100	2.629	4098.405	50313.415	62262.42
13	BGP-BP-4	BB4	100	1.554	2069.271	17085.028	43512.228
14	BGP-SK-1	BK1	100	1.449	2492.563	14233.867	18649.2
15	BGP-SK-2	BK2	100	1.081	2398.459	16496.582	20550.74
16	BGP-SK-3	BK3		1.175	2045.365	19281.94	29104.306
17	BGP-SK-4	BK4	200	1.075	1400.019	12351.308	63587.481
18	BGP-SI-1	BI1	200	1.11	1771.199	20130.763	43655.643
19	BGP-SI-2	BI2		1.058	1694.073	19809.137	42590.692
20	BGP-SI-3	BI3		1.11	1824.224	21162.667	45986.848
21	BGP-RP-3	BR3	200	0.906	1946.259	22545.962	48867.372
22	BGP-BP-5	BB5		1.087	1466.838	15479.227	57268.073
23	BGP-BP-6	BB6		1.157	1656.425	16467.151	60995.418
Mean values for all samples				1.246875	1932.501833	19812.19088	40901.57779

4.2 Seasonal Variation in Heavy Metal Concentrations

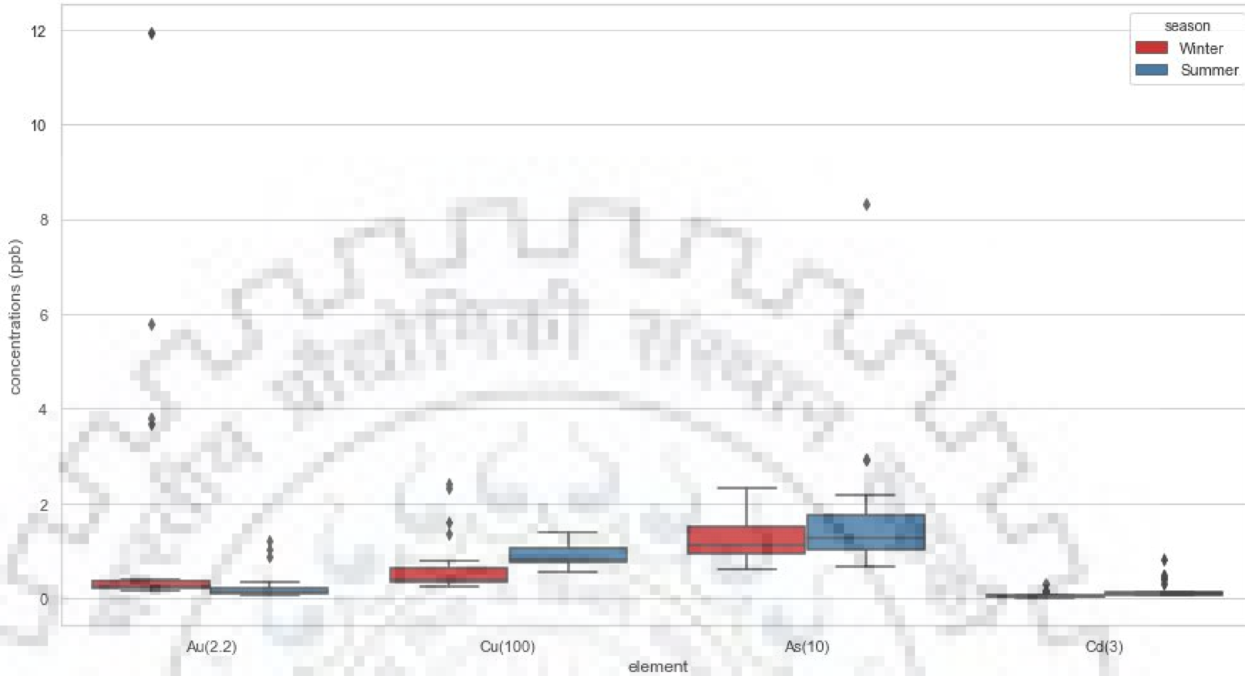

Fig 4.4 Seasonal Variation in Concentration of Heavy Metals Au, Cu, As and Cd for all sampling sites. Black diamond shows outlier values.

The concentrations of Cu, As and Cd are higher for the summer season while Au has higher values in winter season. Au and As have outlier values of at 12 and 8 while there permissible limits are 2.2 and 10 respectively.

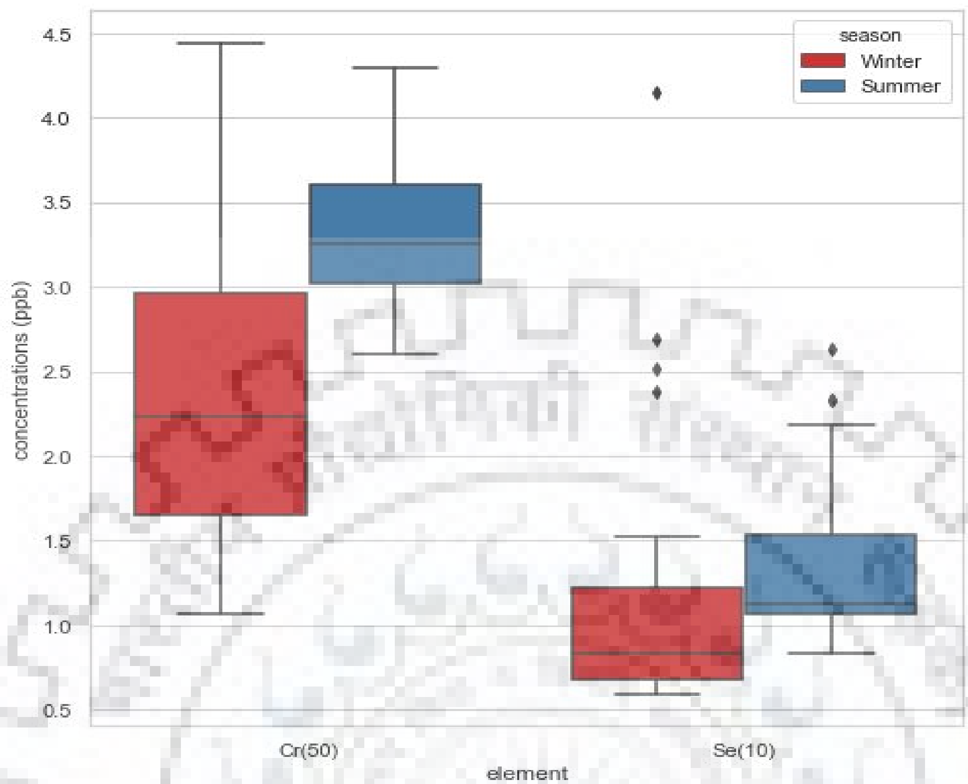

Fig 4.5 Seasonal Variation in Concentration of Heavy Metals Cr and Se for all sampling sites. Black diamond shows outlier values.

The concentrations of both Cr and Se are higher for the summer season. Se has outlier values of 4.2 for the winter season while its permissible limit is 10.

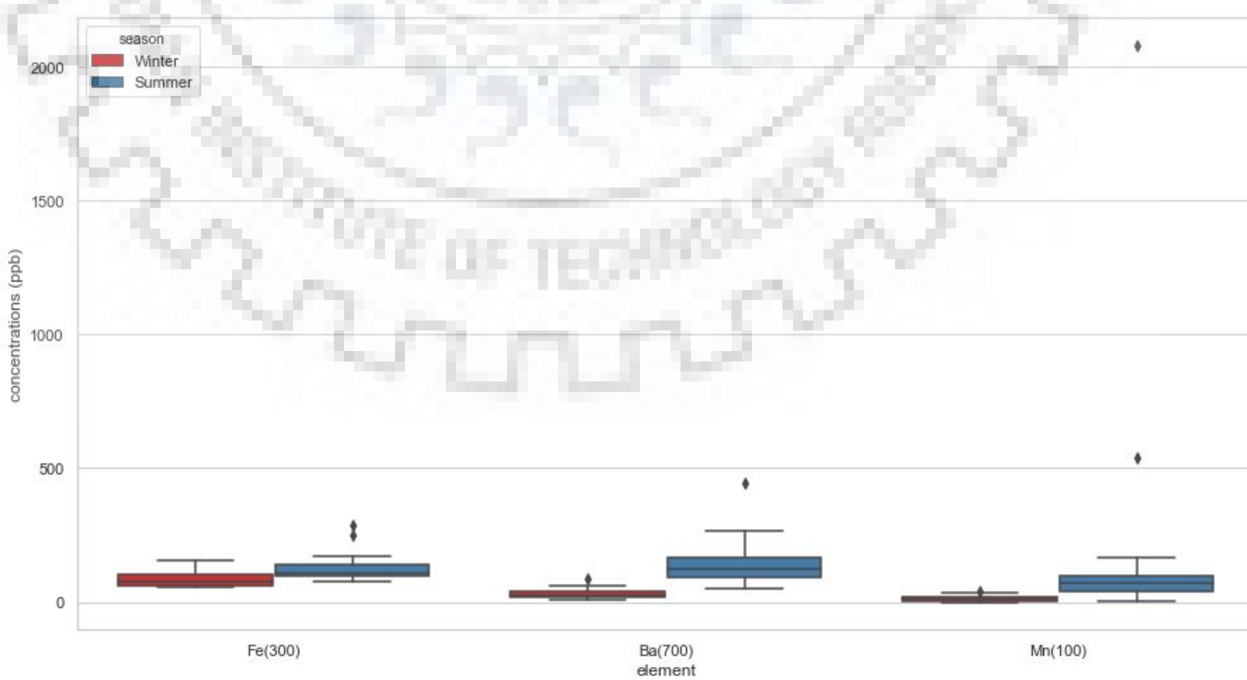

Fig 4.6 Seasonal Variation in Concentration of Heavy Metals Fe, Ba and Mn for all sampling sites. Black diamond shows outlier values.

The concentrations of Fe, Ba and Mn are higher for the summer season. Mn has considerably large outlier values for the summer season at above 2000 while its permissible limit is 100.

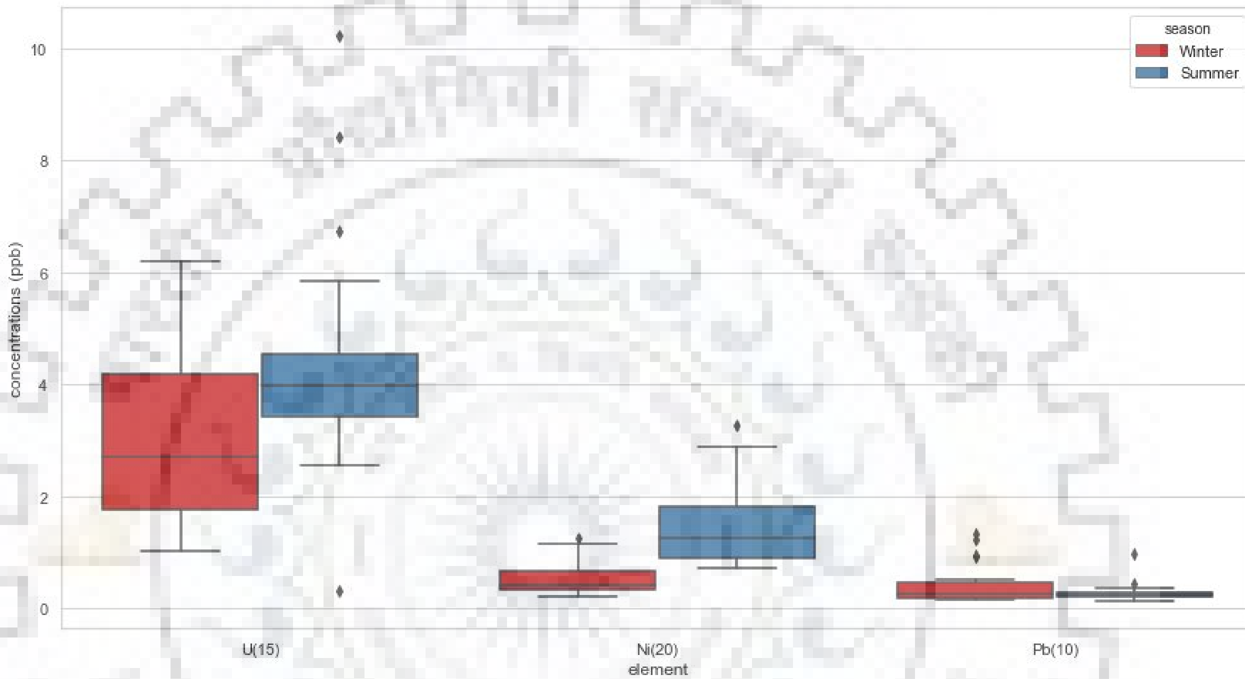

Fig 4.7 Seasonal Variation in Concentration of Heavy Metals U, Na and Pb for all sampling sites. Black diamond shows outlier values.

The concentrations of U and Na are higher for the summer season while Pb has higher values in winter season. U has outlier values of above 10 for the summer season while its permissible limit is 15.

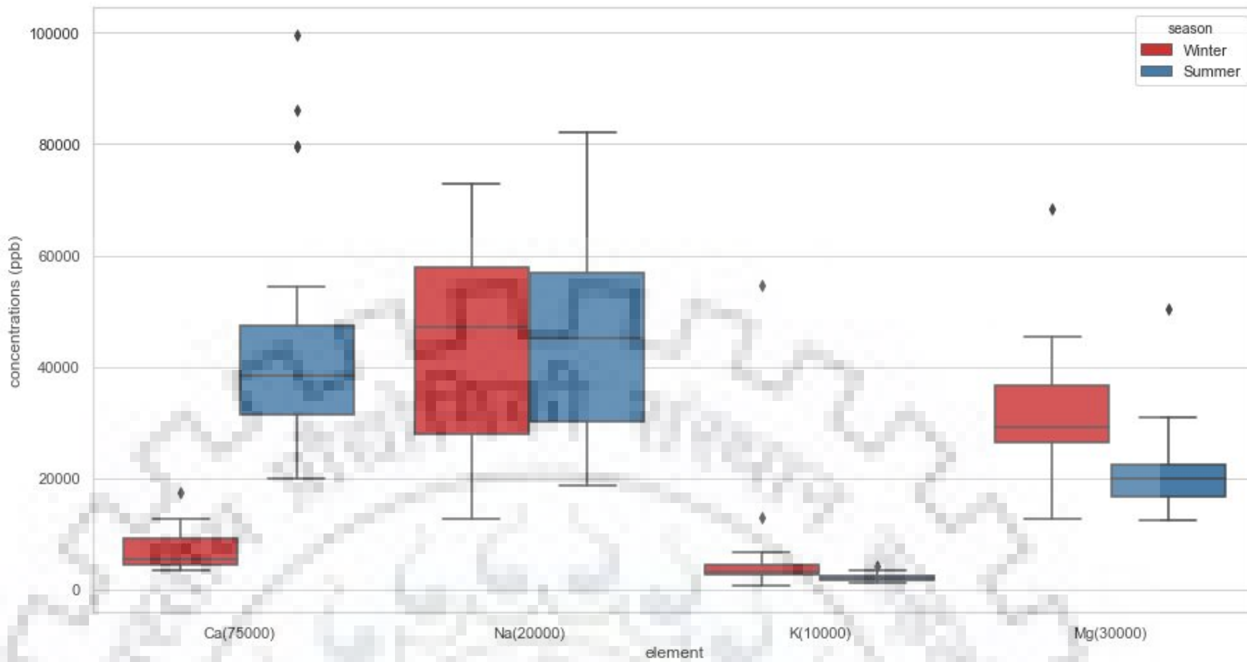

Fig 4.8 Seasonal Variation in Concentration of Heavy Metals Ca, Na, K and Mg for all sampling sites. Black diamond shows outlier values.

The concentrations of all Ca, Na, K and Mg are higher in the winter season. Ca has outlier values in summers at above 100,000 while its permissible limit is 75,000.

In general, 9 out of 16 elements showed higher values in summers and the rest 7 showed higher values in winters.

5. CONCLUSION AND FURTHER WORK

Aim of this study was to quantify the problem of groundwater contamination in the Bhagwanpur Industrial Area in the district of Haridwar, Uttarakhand. For that aim, various measurements were done including in-situ measurements for Temperature, Electrical Conductivity, pH and finally lab measurements for Heavy Metal analysis which were done using ICP-MS facility. The following conclusions can be made after obtaining the results:

- Temperature values were found to be in the range of 23 - 26(degree Celsius) for the month of December 2018 and 25 - 29(degree Celsius) for the month of April 2019**(Table No. 4.1)**. The values obtained from the study meet the expectations.
- The permissible values for pH in drinking water are 6.5 - 8.5**(BIS, 1997)**. The values found in the samples are all well within safe limit with the mean value being 7.46(Range: 7.14 - 7.67) and 7.76(Range: 7.3 - 8.1) for phases 1 and phase 2 respectively**(Table No. 4.4)**. Point to be noted is pH values are found to be larger for Pre Monsoon phase i.e. phase 2**(Fig No. 4.2)**.
- Electrical Conductivity: The mean EC value for phase 1 of sampling was found to be 499.826 and the standard deviation 123.831**(Table No. 4.6)**. For phase 2 the mean value obtained is 512.318 and the standard deviation 157.736**(Table No. 4.6)**. Anything below 800 uS/cm**(Water-Quality-Salinity-Standards, MRCCC, 2013)** is said to be safe for drinking water unless otherwise polluted. All values were found to be within the safe limit except for one site**(Sample BGP-BP-3, Table No. 4.5)**. This could be because of failing sewage system which would raise the conductivity in the region because of the presence of chloride, phosphate, and nitrate **(Iyasele, J.U1 , David J. Idiata, D.J, 2015)**. Point to be noted is that the values in phase 2 are found to be little larger than phase 1**(Fig No. 4.3)**. This may be because of the warmer climate and water and Electrical Conductivity increases with Temperature**(Masaki Hayashi, 2003)**.

- Heavy Metal analysis: The aim of this study was to find facts to support a hypothesis. This hypothesis was that Bhagwanpur, being an industrial area with a good amount of population living in it could have contaminated groundwater**(Mohankumar, K. 2016)**. This puts a lot of people in danger. To support this hypothesis, we needed well diverse and multiple measurements spread all over the region without which nothing could be conclusively said. After doing a detailed analysis of results, it could be safe to state that the water in the region is well within safe permissible limits by WHO **(WHO, 2011)** and Bureau of Indian Standards **(BIS, 1997).** However, there are few exceptions for some major elements like Calcium, Sodium, Potassium, Manganese and Magnesium**(Table No. 4.10, 4.11, 4.13 and 4.14).** Although these elements are not hazardous however, some diseases could occur with their excess in the body**(Sengupta P., Potential health impacts of hard water, 2013)**. There is no conclusive trend as per season, time and depth variations are concerned.

Bhagwanpur region is growing economically at a very fast pace. New industries are being set up there each day. Government is planning to make this area an industrial hub. These industries may emit harmful and hazardous substances into our environment that can pollute the water. That is a potential future threat. Although the situation right now is safe fortunately, however, nothing can be said about its future possibilities. Thus, the region should be kept in check for any future danger to avoid any casualties.

6. REFERENCES

Belkhiri, Lazhar & Tiri, Ammar & Mouni, Lotfi. (2018). Assessment of Heavy Metals Contamination in Groundwater: A Case Study of the South of Setif Area, East Algeria.

Abdul Jameel, A. J. Sirajudeen and R. Abdul vahith., Studies on heavy metal pollution of groundwater sources between Tamilnadu and Pondicherry, India. Advances in Applied Science Research, 2012, 3, 424-429

Momodu, M.A. & Anyakora, Chimezie. (2010). Heavy Metal Contamination of Ground Water: The Surulere Case Study. Res J Environmental Earth Scis. 2. 39-43.

Mohankumar, K. (2016). Heavy Metal Contamination in Groundwater around Industrial Estate vs Residential Areas in Coimbatore, India. JOURNAL OF CLINICAL AND DIAGNOSTIC RESEARCH. 10. 10.7860/JCDR/2016/15943.7527.

Mendie, U. (2005) The Nature of Water. The Theory and Practice of Clean Water Production for Domestic and Industrial Use. Lacto-Medals Publishers, Lagos, 1-21.

A B West, Larry (March 26, 2006). "World Water Day: A Billion People Worldwide Lack Safe Drinking Water".

Adepoju-Bello, A.A. and Alabi, O.M. (2005). Heavy metals: A review. The Nig. J. Pharm., 37: 41-45. Adepoju-Bello, A.A.; O. Ojomolade, G. Ayoola, and H. Coker. (2009).

Quantitative analysis of some toxic metals in domestic water obtained from Lagos metropolis. The Nig. J. Pharm. 42(1): 57-60.

Central groundwater board ministry of water resources, river development and Ganga rejuvenation government of India(October–2016). “AQUIFER MAPPING AND GROUND WATER MANAGEMENT PLAN Haridwar District, Uttarakhand”.

Chakraborti, Dipankar et al. “Groundwater Arsenic Contamination in the Ganga River Basin: A Future Health Danger.” International journal of environmental research and public health (2018).

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

Sengupta P. Potential health impacts of hard water. Int. J. Prev. Med. 2013;4:866–875.