Prediction of quality of water emphasizing on nutrient dynamics in Kosi watershed, Uttarakhand

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THE AWARD OF THE DEGREE OF

DOCTOR OF PHILOSOPHY IN FORESTRY
(Forest Influence and Climate Change)

By

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2021

DECLARATION

I hereby declare that the thesis **"Water Quality Prediction Emphasizing on Nutrient Dynamics in Kosi watershed, Uttarakhand" s**ubmitted by me, **Ms. Pooja Rani Sinha** (Reg.no. 16Ph.D422) to Forest Research Institute (Deemed to be) University, Dehradun, for the award of the degree of **Doctor of Philosophy in Forestery (Forest Influence and Climate Change)**,embodies the research work carried out by myself under the supervision of Dr. V.P Uniyal and Er.Kireet Kumar. The thesis has been duly checked through 'URKUND' a plagiarism detection tool approved by F.R.I Deemed to be university and thesis has plagiarism to the acceptable limits. No part of the thesis has been submitted for any other degree/diploma of the same institution where the work was carried out, or to any other institution and it fulfils the requirements of the ordinance governing award of PhD Degree of F.R.I Deemed to be University.

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EXECUTIVE SUMMARY

The study of this research is an attempt to understand the water quality of the region. The region is blessed to have underground water as springs in the region. These springs are the only source of water in the region. Groundwater is fresh water (from rain or melting ice and snow) that soaks into the soil and is stored in the tiny spaces (pores) between rocks and particles of soil. This groundwater which accounts for nearly 95 percent of the nation's fresh water resources. It can stay underground for hundreds of thousands of years, or it can come to the surface and help fill rivers, streams, lakes, ponds, and wetlands. Groundwater can also come to the surface as a spring or be pumped from a well. Both of these are common ways we get groundwater to drink. About 50 percent of our municipal, domestic, and agricultural water supply is groundwater.

The management of river water quality is a major environmental challenge. Monitoring different sources of pollutant load contribution to the river basin is quite a difficult, laborious and expensive process which sometimes leads to analytical errors also. The region selected for study is a central Himalayan spring fed basin in which springs are only source of water in the region. The contamination of the springs in the region leaves the region with no alternate source of drinking water.

General statistical results of the physicochemical parameters for the springs were studied to carry out the interrelationships among the various parameters. The correlation between various parameters were studied and analysed for the samples collected and general statistical analyses of the bio-physico and chemical parameters of the basin's surface water quality have been carried out to find the interrelationships among them, which constitute the first phase of the present study. By this study it is found that a strong correlation exists between Ca and EC. Maximum correlation is obtained between TDS and EC($r = 0.86$). Regression equation has been derived for surface water quality parameters corresponding to the correlation coefficient value of more than 0.8. Similarly, a systematic correlation and regression study on ground water quality, in the second phase of work, shows the linear relationship among the different water quality parameters. High correlation coefficients have been observed from TDS with Mg and Ca, from Cl with Ca and from SO4 with EC, Mg, Ca and TDS.

The Groundwater analysis (springs) of the samples showed the high contamination of the springs with nitrate and sulphate, whereas considerable amount of decrease in dissolved oxygen was seen inthe samples. Water quality performs important role for all living beings. The quality of surface water within a region is governed by both natural processes such as precipitation rate, weathering processes and soil erosion and anthropogenic effects such as urban, industrial and agricultural activities and the human exploitation of water resources. Ground water quality has become an important water resources issue due to rapid increase of population, rapid industrialization, unplanned urbanization, flow of pollution from upland to lowland, and too much use of fertilizers, pesticides in agriculture.

The study emphasizes on the analysis of such springs and spring fed river in the watershed as second and third objective of the research. The motive of the study is to analyze the entire water quality of the region. The water is present in the region is only in the form of springs. The other source of water is river Kosi which too is a spring fed river. Hence the water quality analysis incorporates the study of the springs as well as the river Kosi which merges out to be the summation of various perennial and non perennial springs of the region. The research further extends to study the simulation pattern of the water quality of river Kosi with the various input parameters demanded by the model.

The model WASP (Water Quality Simulation Program) helps to simulate the water quality of the surface water hence detailing the effect of contamination of the springs after merging into river Kosi. The water quality of the springs was studied and analyzed as a component and objective of the project. The area selected for studying the springs of the region was Almora which is considered to be most densely populated town and is a district headquarters of the region. The water quality analysis was incorporated and compared to study the water quality analysis in early 90s for the springs of Almora. The component studied was for the surface water quality for the surface water inthe entire stretch which helped the execution of the model WASP (Water quality Analysis and Simulation Program) suggested by EPA (Environmental Protection Agency).The springs that originate as river from Buddha peenath near Kausani and extends in the entire stretch to merge in Ramganga near Ramnagar. The Plate 1 illustrates one of the selected stations as for second objective in which 31 sampling points were selected in the entire stretch. The stations that were selected for fulfillment of

fourth objective were analysed for water quality along with hydrometeorological and meteorological data, to sum up the simulation pattern of water quality parameters in the region for the surface water.

Plate 1 River Kosi before Kosi barrage

The extract of the three objectives of the research suggests that when the springs of Almora was analysed, it was observed that the contamination of the springs were beyond the permissible limit for most of the parameters as nitrate, sulphate, hardness, Dissolved Oxygen, BOD and MPN. But the contamination levels of the parameters were not analysed to be that high end as to be a matter of concern in river Kosi. The probable reason for this contamination to be not found in the river Kosi was the dilution of contaminants.

The contamination however was found comparatively high at Kwarab (Point after river Kosi crosses Almora) station than in comparison to Kosi barrage (Before the river Kosi crosses Almora). However with the increasing population and urbanization with slapdash clustering of the concrete buildings may pose contamination of the river in forecoming years for the river Kosi too. However Ramnagar barrage (which was last sampling point in the stretch) was observed to be full of filth and plastic bottles (Plate 2).

Plate 2 Ramnagar barrage filth as bottles and plastics

The condition is not at present that alarming for the river Kosi but it is certainly going to be alarming if the precautions and preventive measures are not taken. The condition may get worsened as we have seen in the case of the river Ganga contamination, which over the years has got contaminated to that extent that now government is taking measures to clean and purify it, to restore its serenity. It is certainly a tedious task to get a river purified after it is contaminated. It would be rather beneficial if measures are taken prior the contamination reaching distressing levels.

This research is submitted within the domain "climate change and forest influence" in order to see the effect of change in water quality in the region and its futuristic consequences.

Chapter 1

Introduction

1.1 Introduction

The unmanageable human desire and voracious thirst for knowledge has led to the giant scientific development hence challenging the natural resources and keeping all their sustainability on stake. This irrational development of technology and science has urged for elevation of greed of more comforts and standard of living of human beings outlaying the environment and its well being. The rapidly increasing urbanization and unplanned structuring of the buildings have posed a threat to the various environmental factors of which water is the major component. The survival without food would be for a few days but survival without potable water in any region is question to be addressed at alarming state.

On one hand where the technology and science has led to the development in the region on the other hand these developments have challenged the environment sustainability in entire living space in the region. The technological development has led to following changes in the living standard of the people

a) Production and quantifying better quality food, b) Remedies for various infectious diseases, c) Better communication systems d) Transportation have become faster and comfortable e) Generation of more job opportunities f) Development of more systematic and efficient machines has decreased the human as well as animal effort g) The development of advanced water filtering units which are now very commonly available has decreased the diseases caused due to impure water, hence water treatment technology has turned into boon for the health well being of the people. h) Immediate recovery from the catastrophic events as floods, volcanic eruption, landslides, droughts etc. In one way where the life of human beings in due course of time is facilitated with various comforts by rectifying the various man generated or nature generated challenges on the other hand the environment and nature which was supposed to go hand in hand with the development, but in contrary, the environment has detetoriated to such extent that the ultimate flag bearer for all and most of the disaster comes in the lap of human beings for all the unquestioned concrete jungles and other development works.

Nowadays we continuously hear the new cry for the environment and its conversation in different aspects all over the world without improper steps related to its preserving and well being. We have been continuously, since decades disturbing the nature and its balance for our own selfish needs and comfort. Le-Chatelier's principle comes into play here which illustrates that "whenever a system at equilibrium is subjected to stress, it will react in such a way so as to relieve that stress." Hence the principle is explained as when a system is under overestimated stress, it bears that for some time but then when it exceeds its threshold limit, it relieves its stress by retaliating back, to subject back to the equilibrium (Horne 1978). This retaliation would be in the form of any disastrous and catastrophic event. So in order to save ourselves, we need to take immediate steps, so that cry for environmental pollution could be taken to right pathway for the sustainable existence of human beings with the nature.

The concern over pollution in most of the developing countries is growing, and rather the industrial pollution is the most talked about concern today. The effluents generated from the industries have dragged the concern for pollution control in a very aesthetic manner because of its disastrous and violent effect. It is now believed that, only in the light of long term and short term environmental impact of the industrial units, any development activity would take place.

The release of loathsome industrial waste from the industries has increased due to monstrous increase in industrial activities which has become a major environmental concern. According to a report of NEERI (2015) near about 61754 MLD is the estimated sewage generation in the country as against the developed sewage treatment capacity of 22963 MLD (Central Pollution Control Board (2015). The pollution and contamination exposes the water resource both scarce in quantity and unsafe in quality day by day. Although many agencies have although taken the responsibility to keep it as pristine as possible. Pollution exposes environment to irreparable harm which can be mended only with religiously and consistent effort. Water is most important and significant part of environment and is the basis on which survives life. Our body is 70 percent made up of water and hence plays vital role in sustenance of life on the earth. The matchless physical and chemical property of water has allowed life to evolve in it.

As illustrated by Szent Gyorgvi (1958) "That water functions in varieties of ways within the cell cannot be disputed. Life originated in water, is thriving in water, water being it's

solvent and medium. It is the matrix of life." The biological reactions take place in water which is an incorporated system of a metabolic activity of biology taking place in an aqueous solution that is important for upholding of the life. Our planet is 71 percent water of which only 3 percent is fresh water and of this 3 percent ,75 percent is packed in up with glaciers and icebergs. Of that 24 percent exists as ground water and only 1 percent is in form of rivers, lakes and ponds that is available for drinking (Dugan 1972).This 24 percent of groundwater and 1 percent of surface water of 3 percent total available fresh water is exploited for drinking needs , domestic needs as well as industrial purposes. Along with the requirement, such rare water resource is also polluted by industries, solid waste dumping and municipal waste dumping and by many other ways.

The importance of fresh water as a vital resource needs to be conserved and needs to be used prudently by man. But unfortunately the fresh water bodies do not witness this initiative of preservation and conservation all through the world.
According to CPCB (2015) 80 percent of the available freshwater sources in India are polluted. The pioneer step needs to be taken by industries by thoroughly treating their wastewater before disposal, Government needs to be aware for taking stringent laws on violation of environmental laws and also general public needs to be aware so that all the kinds of waste that they generate at an individual level is seen that is disposed well and also recycled. The countries worldwide have passed various and laws and regulation looking on to the seriousness of the problem of pollution. In India in order to conserve water and its serenity have passed its first law in 1974 which is amended in time to time and made more stringent.

In 1976 (HABITAT) which was a United Nations conference on human settlements came out with the theme of "Clean water and sanitation for all by 1990" which was reframed by United Nations water conference that was held in Mar del Plata, Argentina , in March 1977.This conference dedicated the entire decade of 1980-1990 for water resource management and its conservation under the theme titled as International Drinking Water Supply and Sanitation Decade and hence reaffirmed the seriousness of the theme made at HABITAT in 1976. The conference emphasized on the programs to be adopted so that water could be made safe as high as 100 percent for rural as well as urban population by

1990 and this was officially announced in United Nations General Assembly in November 1980 in a special session (Subramanyam 1983). Few of the supporting agencies along with the International organizations have requested to opt for technologies that would minimize pollution in the water bodies. Efficient technology and adequate finances were the two important prerequisites for achieving the goal for conservation of water resources for the decade.

According to WHO review of national baseline data report by 86 countries/territories for the end of the year 1980, 75 percent of urban residents of 100 have access to potable water WHO(1984). Most of the diseases say 80percent comes from unhygienic water and sanitation system, diarrheal diseases is the major culprit to kill about 6 million children in major 4 developing counties every year (Lee 1984) which has increased to 20 million in 2005 whereas more than 600 million people have gastroenteritis.

The reported incidence of water borne disease was 800 cases per 10000 annually reported by Indian National Scenario WHO (1984).The Indian Planning Commission, has stated that water borne disease constitute nearly 80 percent of country's Public health problem Govt of India (2011). Late in by the end of 1980 near about 59 percent of population of India (23 percent urban and 69 percent rural) could not access safe potable water. The First Five year plan emphasized on potable drinking water hence a national rural water supply scheme was initiated which later extended for hygienic sanitation schemes in forecoming five year planning. Although emphasis on water and sanitation was given right in from the first five year planning of the country but still, yet many villages and towns are deprived of potable drinking water. The drinking water crisis are now a days have hit villages too as the water table has lowered down to such an extent that it is hardly left for the people to drink or for agriculture purpose.

Late back in March 1980 about 200,000 villages with a grand population of 160 million were yet to be provided with potable water supply facilities. The urban areas are comparatively at better position in comparison to the rural areas and small towns. By the end of the Fourth Five year Plan means in the duration between the years 1954-1974, the water supply and sanitation programs were not given so much of importance which was due to constraint in the resources. The necessity of clean water and hygienic sanitation was later realized in draft of Fifth Five Year Plan (1974-1979) which included potable drinking water as a minimum requirement for rural as well as urban areas. The Sixth Five Year Plan 1980-1985 was a step forward in context of developing awareness for drinking water both

nationally and internationally, which helped in understanding the global approach towards water as an important resource and using it in a way for sustainably existing it with human economic development. The plan provided a huge amount for systematic and channelized use of water as for Rs 15,540 million (States) and 6,000 million (Central) for rural water supply and 17,530 million for urban water supply sanitation amongst the country. By the sixth five year plan the nation became more serious for the overall resource scarcity and started to understand the importance of cheaper technologies for preserving such resources.

Despite of enormous development in science and technology our country is not yet able to conserve our natural resources and provide potable water for many urban as well as rural areas.

The Government of India is firm to provide water to all the rural and urban areas under the mission termed as "Technological Mission". Government of India identified 1,61,722 villages which were covered with safe drinking water facilities by the end of 8th Five year Plan (1992- 1997).The 9th Five Year plan was then an extension of the 8th five year plan in which government targeted all the villages of rural areas as well as urban towns to get replenished with water within the stipulated time of the period and also the decision regarding sanitation facilities to be improved and expanded was incorporated for the nation. The 10th Five Year plan (2002-2007) came with the seriousness of pollution of the rivers. Hence the major rivers were identified and the measures for cleaning of these rivers were implemented within the plan period. Hence the pollution of water and rivers is not a new topic to be discussed upon .With the increasing population urbanization, industrialization, and exploitation of underground water sources have taken the problem to new dimension. Man finds easiest way to dump their waste into the rivers and all the waste that is dumped on to the soil too along with polluting the soil and air prominently pollutes the water too. The domestic discharge in the early history of human did not pose any problem as the nature had its own capacity to degrade the waste and rejuvenate it into normal condition. Nature still has that capacity to rejuvenate itself but the system because of overpopulation and various other reasons have brought the nature to threshold limit. The recent lockdown in 2020 due to pandemic have also proved this that nature rejuvenates itself. The Ganga river got pure for the first time in city like Kanpur too. The air quality was improved in miraculous manner. The air quality was improved to such a extent that Jalandhar could view the Himalayas in Dharamshala. Hence nature still has the capacity to rejuvenate itself provided we don't overload the system that more that the purification

capacity of the nature we are polluting the nature. We have been continuously adding up upon simply many other kinds of toxic wastes which the nature simply cannot handle and tackle.

Hence ultimately we are polluting the rivers, lakes streams as well as underground water sources to threatening levels that our nature cannot handle which is a threat to the existence of the mankind. Pollution is defined as a process in which certain harmful substances that are added to the environment is not let out and is returned to us in some or other form. Water is said to be "Polluted" when its properties and composition are changed due to infringement of foreign substances that it becomes comparatively less suitable for drinking and for other domestic purposes than otherwise that is found in its natural state. The pollutant is generally toxic or unfavorable for the organisms that are producing it. These pollutants need to be transported away from the point it is originated. Since man finds water bodies as easiest option to get rid of the wastes generated since they are carried away from the point of generation. In the contrary most of the radioactive wastes and sometimes chemicals also remains at the source (Mishra, A, J.S. Datta & Munshi 1994).

However, since water is a medium hence once it is polluted be it anywhere it poses problem and hence simply by just getting the waste transported doesn't mean that we have got rid of the waste that was generated by the man. Also greater the medium has mobility larger the area the water body covers with the waste and hence greater is the contamination levels and area covered. Only when the pollutant adversely effects the organisms is when it is posed as a contaminant, e.g., when the fishes in 1956 were killed and people got affected due to the outbreak of Minamata disease and Itai Itai disease in Japan due to mercury and cadmium contamination. According to a survey by WHO in 1980 about 25 million people die of drinking contaminated and unsafe drinking water (Agrawal 1980), which has now increased to 485 million in 2019. The major sources of pollution are broadly classified into 3 major parts as domestic, industrial and agricultural. The point sources of pollution as industrial and municipal could be controlled at the site of generation whereas the non point sources as agricultural waste that are carried away with the runoff is hard to tackle and control. The pollutants that are contributed to the aquatic environment by various point and non point sources can be classified as in Table 1.1

S.N	Reasons for contamination	Sources of Contamination
1.	Disease causing organism	Human and animal waste
2	Synthetic organic compound	Household and industrial chemicals and pesticides
3	Inorganic compounds	Acids, Akali, heavy metals form industrial effluents
4	Radioactive substances	Nuclear power plant
5	Oxygen demanding wastes	Sewage from industrial effluents
6	Plant nutrients	Through sewage and agricultural run off
7	Sediments	Soil erosion
8	Thermal discharges	Power plant

Table 1.1 Aquatic environment pollutants and its causes

(Odum 1971) from ecological point of view classified pollutants into three major classes as

1. Non biodegradable

Biodegradable and

Thermal

Non biodegradable wastes include 7 major kinds of pollutants as DDT, mercurial salts, heavy metals, phenolic chemicals, DDT etc. Biodegradable pollutants comprises of domestic sewage and other chemical pollutants. The dilemma exists with the biodegradable waste, when its contribution into the system exceeds the dispersal capacity. It is the natural property of any natural system to reshift to the normal condition after set in a stressed condition, hence the nature to retaliates, but when the pollutant input is beyond the capacity of the system's dispersal capacity, then this poses the major problem

The organic matter when disposed into the water, the microorganisms present in the organic matter uses the oxygen present in the water and hence the amount of oxygen required for the

oxidative degradation of organic matter by the microorganisms is known as BOD (Biochemical Oxygen Demand).The importance of BOD comes in with its value decides the intensity of organic pollution in the water body. The decrease in level of oxygen adversely affects the aquatic plants as well as animals. Oxygen in water is a standard which ensures the quality of water for human use as well as aquatic life. Phosphate levels when boosts in water results in increase of phytoplankton biomass this too is not appreciably good of the aquatic environment as it increases the fishes that are phosphate tolerant and decreases the population of fishes that are not tolerant.

The concept of water quality is generally studied in respect to the human consumption, however because of multidimensional use of water and its broader perspective defines the entire aquatic environment health. As for example the well being of a fish or reproduction of lobster in the aquatic environment may not sound important but any imbalance in their health as aquatic animals would sooner or later would affect the other organisms of ecosystem and this is the adage of ecology. The considered parameters for checking the pollution are various physicochemical as well as biological parameters as temperature, pH, hardness, dissolved oxygen, conductivity, and also inorganic nutrients whereas biological parameter deals with microorganisms present in the water as MPN, E.coli and other pathogenic bacteria. If E.coli present in water shows that water is in contact of human feaces and has sewage intuition into it, their presence and colonies number specify the extent of contamination by the sewage. The pollution of river in India is one with a long list. Although the rivers in India are considered to be religious entities yet the pollution of these rivers has reached to a devastating extent.

Most of the rivers in not only India but also world are polluted. The dumping of the industrial waste, sewage has seriously polluted the rivers. The industries either do not treat their effluent before dumping it into the river or the treatment is insufficient to remove the toxics from the effluent. The improper or inefficient treatment and then dumping them into the river fulfills their motive to just get rid of all the effluent and waste that they have generated to some other place through the flow of the river. Even most cities lack proper sewerage system of sanitation. The sewerage plants are either inefficient in treating the waste water or believe in the concept of dilution. Raw sewage is simply carried away to rivers and in sea for the coastal areas. This sewage is organic matter and hence when it

reaches the water bodies, utilizes the dissolved oxygen in the river and hence gets oxidized. This oxygen which is used by the sewage is actually the oxygen that is meant for the aquatic plants and animals to sustain. In many towns and cities, due to lack of proper sanitary system the sewage generated in the cities are directly carried away to the nearest rivers which results in numerous water borne diseases.

The concept of proper sanitation was given wayback by Father of the Nation Mahatma Gandhi stating that "For India sanitation is more important than Independence" .With the due course of time there has been a progressive migration of people from the rural areas as well as semi urban areas to cities and towns from 27.8% in 2001 to 31.2% in 2011 census. Whereas the number of cities has magnified and increased from 5,161 in 2000 to 7,935 in 2011. The cities then have expanded and newly established to accommodate huge migrated population. This uncontrolled expansion of the population has overburdened the basic infrastructure facilities as water supply, solid waste management, sewerage system and sanitation facilities.

The expansion of slum areas have also posed a problem in various aspects, as the slum areas lack proper sanitation facilities and has indiscriminate disposal of the sewage. Even though a huge amount of municipal expenditure is allotted to the government and authorities, yet due to lack of services, planning and management the problem of sanitation and sewerage system remain unresolved for decades till now from the independence. The large portion of resources is being used up the operation and maintenance by the Urban Local Bodies (ULB's). In spite of using such a major amount in O&M still the services provided by the local bodies are not satisfactory and they fail to collect, transfer the waste, treat and finally safely dispose the waste. This ultimately challenges the well being of public health and environment. Most of the cities and towns in India yet have unattended sewerage and sanitary conditions especially in the slum areas. They are yet handling their sanitation conditions with disposing their night soil in open, which in turn is increasing morbidity and in turn mortality due to pathogens and bacterial infestations. The sanitation and sewerage treatment is vital part of public health and sanitation and it falls within the guidelines and limits of State list according to the Indian Constitution. Since this is an essential and non- exclusive, the responsibility of providing the people with the services remains under the authority of public domain. A few cases although has privatized the

work for service delivery of sewerage facilities yet we are unable to encounter the increased pressure of excess population in an efficient manner. The major causes for the above issue are cited below:

1) The local bodies are not resourceful and cannot generate their own funds and hence they are dependent completely upon the state and central governments to provide them with grants.
2) Deficiency of will power, proper planning, implementation of the plan, procurement of the materials, operation and maintenance of the sewerage system to the desired efficiency.
3) The termination of the collected sewage and waste out of their boundaries leaves the ULB's with the concept of "out of sight out of mind". Simply getting rid of the waste by throwing it out of the boundaries doesn't mean the problem is resolved.
4) The cost of infrastructure investment, continual replacement and on-going O&M costs of centralized sewerage system (CSS) facilities are very high which leaves the ULB's handicapped as it is beyond its financial grip in the country.
5) It is also necessary to recognize that the practice of piped sewer collection is an inheritance from advanced countries with high water usages, which permit adequate flushing velocities.
6) Due to their high per capita water supply rates, the night-soil does not settle in pipes and hence no choking and no sulphide gas generation. Whereas, in the Indian scenario, the per capita water supply is low and inequitable in many cities and that too intermittent and this results in settling down of night-soil in the sewers, choking, gasification, etc., which necessitates very often the extreme remedies of cutting open the roads to access and break open the pipes for rectification and so on.

The conservation of water resources as well as sanitation facilities run hand in hand. Better the sanitation facilities and its management, rare is the contamination of the water resources. Once the sewage as well as effluent from industries is tackled well, this would help to conserve air, water as well as soil in an efficient way.

1.2 Present Study

Almora is a growing town in the fragile Himalayan region and the study of the water quality of the region would help to understand the contamination level in the region and also to

break the ceiling of the conception that the water sources in the Himalayan region are supposed to be pure and free from any intuition of the contaminants. Almora is although not having any industrial belt to contaminate the water sources but the major contaminations comes from the rapidly spreading of the structures and buildings without any proper sanitation arrangements.

Plate 3 Showing the vicinity of Karnatkula spring in Almora

On one hand where the conventional sewerage is an efficient source of sewage collection transportation and treatment, it is also resource inefficient technology. Hence with the time, high capital cost and consistent significant costs of operation and maintenance of such system prohibit its wide adoption in all sizes of the urban areas in the country. The general public also is insensitive and unaware with the effectiveness of using and consequences of not using the sewerage system.

The segregation of grey water from the waste water also is not opted in most of the cities and towns. Even in many of the cities and also towns no proper service connections have been provided to the toilets connecting to the sewers. Plate 3 shows the open drains carrying huge amount of municipal waste in the vicinity of the Karnatkula spring. Hence conservancy system of pollution is still major drawback the town is facing. The conservancy system of sanitation conserves the waste in the septic tanks from which the leachates are formed which slowly leaches down into the spring water. The town boldly accepts conservancy system of sanitation with day to day increasing clustering of buildings and population. Only a part of the town is connected with inefficient sewerage treatment plant which partially treats the

sewer water to dispose it into river Suyal which is a tributary spring fed river before it merges into river Kosi (As illustrated in Plate 4). The topographical constraints is said to be constraint for the sewerage connection of most of the houses inthe town. According to census GOI 2011, near about 81.4% households have toilet facilities within their premises. This incorporates the 70.9% households having water closets, 8.8% having pit latrines, 1.7% have other toilets (as connected open drains, night soil removed later by humans). Out of these 70.9% households, 32.7% households have water closets connected to sewer system and 38.2% households are having water closets with septic tank. The household pit latrines have increased percentage to 70.12 percent in Almora.

Hence the water contamination in the region of the natural springs has increased in from the previous decades. Because the river Kosi is the spring fed river hence the contamination of the river Kosi is the concerned threat in the region.

Plate: 4. The wastewater treatment plant disposing the partially treated water into river Kosi

1.3 Objectives Of the research:

The objectives of the research carried out from March 2017 to December 2019 expanded to study the water quality of the entire region. The spring fed river is approximately 170 km originating near Kausani to Ramnagar quenches the thirst of human beings as well is source of water for the animals in Jim Corbett National Park.

The research comprises of 4 major objectives

1) The first objective is to see the contamination of the springs in Almora for the

physicochemical parameters and to compare it with the study parameters from 1991 and 2017/18.

2) The second objective is to study the surface water quality and for the 31 sampling points from the origination of the springs.
3) The surface water quality data is fed to WASP model to see the water quality prediction in the region.
4) To suggest the mitigation measures for conserving the water quality of the region.

Chapter 2

Review Of Literature

2.1 Review of literature

Not very appreciable amount of work is done in the region regarding the water quality. The population and urbanization with drastically increase in tourism in summers as well as in winters are therefore throwing more pressure on the water requirement. The water requirement increases in summers because more national tourists entering in the region. Nainital is the popular tourist point for the tourism and as Almora lies in between Nainital and Kausani, it too is emerging as a popular tourism destination for both national and international tourists. This imparts an additional load for the water requirement of the region in the season when the water quality as well as quality both of the region is challenged. On the other hand the river Kosi which merges from the summation of the various springs in the region decreases with its flow in summers as well as winter seasons as many of the seasonal springs perishes in the season. The challenges for the requirement of the water bring many water borne diseases in pre-monsoon as well as monsoon season. The topographical constraints and challenges with the terrain have brought less awareness. The limited health facility worsens the scenario to a greater extent.

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constraints and challenges with the terrain have brought less awareness and development in the region. The limited health facility worsens the scenario to a greater extent.


03 हिन्दुस्तान

27° 20°

अल्मोड़

पीने लायक नहीं है अल्मोड़ा के धारे और नौलों का पानी

सैम्पल फेल

365 नौले हुआ करते थे कभी

नालों का पानी पहुंच रहा

Plate: 5 "Hindustan" hindi local newspaper of 10th of July 2018 specifying the critical condition of springs of Almora

The newspaper which is circulated locally published on 10 th July 2018 from the editorial desk states that the problem with the springs is left as an social issue and people are made aware of this prevailing scenario (Plate 5). Also an appeal is made for the local people to take measures to save their only source of water. The springs being the only source of water are exploited to an extent that that literatures say that the town was once gifted with 365 springs of which are left just 21 springs in the town. The water of the springs no more remaining fit for potable purposes.

2.2 Rationale of the study w.r.t Ground water

As the springs are the source of ground water, so the study of groundwater and its contamination becomes essential to understand the various ways of accumulation and oozing of springs from the aquifer. As the mountainous region does not have a defined water table due to its topographical constraints. But on other hand has scattered and unconfined aquifers which possess or holds the spring water. This groundwater that is

present in the water possessing rocks when released on the surface are termed as seeps or springs. The release of this water could be in form of concentrated discharge or point source groundwater discharge (that releases on the surface) hence forming a spring. When the discharge has no single opening from the source and water is released on the surface from a larger area is called seep. The aquifers are defined as the rock formations that hold the groundwater and nourish the springs. Depending upon the topography and geology the aquifers might exist in various different forms. If the land is flat that means if it is a plain then the aquifer might exist in large or expanded form. On the contrary if the landscape is surging once then the aquifer is comparatively smaller in size in both extent as well as thickness. So depending upon the landscape, their hydrogeological properties and geometry, aquifer varies with their storability as well as transmissivity. The Himalayas are fragile mountains that cause high degree of deformation, due to which it results in intense folding and faulting and hence development of fracture zones which results in discontinuity of aquifer in the mountain belts. Large numbers of springs are formed in mountain ranges of Himalayas under the same prevailing conditions. The complete knowledge of the local aquifers hence becomes essential to understand the impact and domino effect of local geology, structure and topography, that play key role in formation of such (mountain aquifers) and hence the springs too as these are discharge from such aquifers. Such rushed termination of the aquifers along the slopes of mountain and then exposure into the valley portion results in discharge of the groundwater in the form of springs. Hence it could be stated that most of the springs owe their genesis from such structural features as faults, fractures as well as weak planes. Groundwater is estimated to fulfill 85% of all rural water requirements in India (The Work Bank 2011) and so it is supposed to be the backbone of the India's water supply. On one hand where wells are groundwater sources of water in rural areas (sometimes urban) of plain region, springs are projected as major water source in most Himalayan region The Himalayas are huge and vast mountains that expand over 2500 km all along the northern boundaries of India and also form India's seven international boundaries. According to man estimate (Census 2011) approximately 40 million people reside in the Indian Himalayan Region (IHR). The Himalayas are further classified for the purpose of study into west to east into following discrete regions: The Western, The Central and The Eastern Himalayas. The central Himalayas comprises of Nepal Himalaya which on either sides are bordered by Western and Eastern Himalayas on its respective sides. Thakur and Rawat (1992).

Himalayan region depends on springs for their daily water requirement. But due to change in climatic conditions and rainfall pattern, a large number of villages and settlements that are scattered face immense shortage of water.

Plate 6: Women worshipping "dhara" (flowing spring)

The climatic conditions and urbanization have resulted in drying up of most of the perennial springs and these springs are turned up to be seasonal now, due to which near about 8000 villages are facing scarcity of water even for drinking purpose Rana Gupta (2009).The depletion of springs in the Himalayan region which is majorly due to climatic changes and increase in population with its consequences is detailed by Valdiya and Bharitariya (1989) and Kumar (2006) studying the hydrological aspects of Gula river and Almora and is been expressed in various works. Springs are exfiltration of groundwater onto the surface through the points through which the water merges and flows. However these springs were most significantly used by the mountain people since ancient times, to meet their daily requirement. These springs were also religiously worshipped (As demonstrated in Plate 6) and so we find most of the springs in the vicinity of the temples. But change in climate , increase in population ,advance upcoming technology, changes in the rainfall pattern and most importantly poor and inefficient legal policy framework for managing the groundwater resources has led for a necessity for efficient model development on spring management in the Himalayas. The prototype ought to include science and community based approach for managing the Himalayan springs.

Unless the argument for an overarching groundwater management gains momentum in the Himalayan region, spring-water management may remain a small argument within the overall hydrology and climate change paradigm, without capturing the essence and substance of groundwater management, an approach that needs to gain strength in the overall water management strategy for this region. This research along with studying the spring water quality, hydrogeology, which is important in understanding springs and also to know how it can significantly contribute in the planning, implementation and monitoring processes of programmes that most importantly functions upon spring restoration its management in Almora as well as across Himalayan region and its few towns.

Water quality of various sources as groundwater has been analysed from different sources e.g. Tube well, Dug well, Bore well etc. by many researchers. The contamination of water sources and its consequences have always attracted the interest of researchers from decades. The ground water characteristics, importance and its retention storage capacity was studied to understand the groundwater criteria. The various researchers and their work were studied and research work related to mountainous region as well as non mountainous region. A few which served as a torchbearer in the research are listed below.

According to Baker, R.M and Mooty W.S(1993) stated that groundwater contamination occurs when ground water intuitive contamination from the natural or environmental sources of contamination or anthropogenic sources of contamination. The contaminants that occur naturally in the soil and rocks affect the general properties of water and might include iron, aluminium, selenium, arsenic, manganese, lead, salty water, etc. The contaminants that could be present due to anthropogenic activities might include petroleum products, natural as well as synthetic compounds, fertilizers, pesticides, insecticides, bacteria and microorganisms, and septic disposal when conservancy system of sanitation is used for waste disposal. If properly planned, maintained and used, the septic system does not establish risk to the water quality. The consequences and effect of this contamination can extend beyond the owner's possessions. In case if the septic system malfunctions, then the contaminated wastewater in the tank would enter the shallow aquifer, hence contaminating the water resources. When the contaminated wastewater from the malfunctioning septic

system, leaches out after saturating the soil, it would pose rather health hazard and is also not allowable by the state law. India in the current scenario is ghastly moving towards a crisis of overusing the ground water and its contamination. The concept of groundwater reuse or exploitation is defined as a situation in which, over a stipulated period of time, average extraction rate of aquifers is greater than they getting recharged. The availability of surface water is more than in comparison to the groundwater in India. However in the case of accessibility to the decentralized availability of the groundwater, it is more easily available and also forms huge share of India's agriculture and drinking water demands. Approximately 89% of the groundwater that is extracted is used in irrigation sector, terming it as highest user category in the country. This is extended to 9% of the groundwater extraction which is done for domestic use. Then comes industrial use of groundwater which is 2% of the extraction and 50% is done for fulfilling the urban water requirements. 85%of the rural domestic requirements is fulfilled by the groundwater.(Deep Wells and Prudence: Towards Pragmatic Action for Addressing Ground water Overexploitation in India.)

According to Garfias. J The mountain terrain covers the 20% of the earth's land surface yet the details of groundwater flow at the depth of mountain massif is very little known. Because, mountainous region promotes deep circulation of groundwater and this is why the regional investigation to access the groundwater is not very effective and accurate. In addition to this the mountainous region are very fragile and get frequently fractured and might be in an active state of compression or extension, suggest that fracture aperture may be functionally related to the state of stress in the earth's crust. Hence, this increase in water table may be intimately related to a fluctuating hydraulic conductivity of groundwater in mountainous region.

The literature by (Meenu Rani & Himanshu Joshi et.al 2019) states that the behavior of the groundwater in the Himalayan region due to varied geological formations, lithological and sequential variations as well as due to complex tectonic framework is highly complex. The increase in demand of groundwater in the dry weather imparts the need to define the recharge potential sites and their spatial distribution accurately from the available information with government or NGO's which can help examine not only the limits of their

resource but also help in probability of treatment so that the recharge of the groundwater increases along with the continuous increasing demand. In the current prevailing scenario the quality as well as quantity of the groundwater is continuously deteriorating and reducing due to imbalance between the recharge and exploitation of the groundwater. A huge amount of water that comes from rain is simply lost as surface run off CGWB (2014). Hence the researchers have laid stress on the need of recharging the aquifer artificially so that a sustainable coexistence may occur between the water resource and human population Tan *et al.* (2013); Chinnasamy *et al.* (2015)

The literature by Menció A, Mas-Pla J, *et.al* (2016) stated that the biggest dilemma with the groundwater pollution is that it is not visible but rather difficult to clean or treat in comparison to the rivers or lakes. One of the greatest contaminant in the ground water is nitrate (NO_3^-) that is naturally present in the water body and most commonly occurring anion that contaminates the groundwater. The condition of groundwater is getting more crucial as it is diminishing continuously with increasing population and agricultural requirements. The assessment of pollution is an vital factor for making policy in any country and also it is a basis for initiating measures for protecting the groundwater resources. It is important to isolate nitrogen and the procedure that affects the nitrate pollution in order to improve the water quality of ground. Groundwater is supposed to be vital source of potable drinking water in India and supplies more than 50% of public and find its way for almost all water requirements in rural households, hence poses serious problem when contaminated.

The source for nitrate pollution in the groundwater can be both manmade and natural. The nitrogen fixation in the soil is the natural source of pollution which also effects the nitrates in the groundwater. Urban waste disposal, human waste through the absorption wells, municipal wastewater output of septic tanks, runoff from the agricultural fields, landfills seepage are the few sources of human induced pollution of the groundwater. The natural transformation through denitrification and nitrification also impacts the concentration of nitrate in the groundwater and hence poses to be most important reason for groundwater contamination. Nitrate is highly soluble in water and has high dispersion properties and so, it easily enters the groundwater and effects wide area. Inorganic nitrates that are used as

fertilizers also have high solubility and also biodegradability and enter the soil and then the groundwater easily and thus are major source of contamination.

Moreno-Corral R, Tetrahedron(2015) illustrated that groundwater is the major and valuable source of water which needs to be conserved and protected from agricultural runoff, anthropogenic activities, chemical intuition, sewage and animal waste, and many other such pollutants. The allowable limit of nitrates in water has been set at 40mg/l BIS(Standard #1053 of Iran) 50 mg/l by the World Health Organization WHO, Guidelines for Drinking-Water Quality, World Health Organization (WHO) (2017) and 45 mg/l by the US Environmental Protection Agency (U.S. EPA).

Since contamination of springs is majorly due to conservancy system of sanitation hence study of the presence of E.coli bacteria becomes essential for analysis of the samples. The presence of E.coli confirms that water system is in contact with the fecal contamination which poses serious risk when consumed. It is observed that water contaminated with E.coli gives a varied taste to the water and also is highly risky when consumed regularly. The water system is set up the advisory in the local body to study the parametric nature and fluctuations of the water and this water system if finds E.coli in the water it issues a “health advisory” to all people consuming it within 24 hours. The advisory clearly demonstrates and advises to boil the water before use. It also demonstrates to whether use the water for drinking, cooking or for any other domestic purposes. The water system in collaboration with efficient advisory body can do wonders in controlling the water quality of the region. This would outline the steps to correct and explain the demerits in the supply, responds to any health emergency immediately. Initiates to collect more water samples to keep monitoring and tracking the water quality of the region and also suggests measures to eliminate the potential reasons for contamination. It also takes step to solve and resolve the problem related to water and its purity. Immediately responding to the health emergency is the major role to be played by the advisory. It also outlines the steps underway to correct the problem and explains when the system expects to resolve the problem. More water samples will be collected to find and eliminate potential contamination sources, and a system not

normally disinfected will most likely be chlorinated and flushed. The health advisory will remain functional until the situation is resolved and water is safe for drinking.

The Mitchell valley is taken as an area for study wherein the project details as the groundwater receives the recharge from surface runoff and precipitation at higher elevations as mountains and discharges into the surface water in lower elevations or is lost in air by the process of evapotranspiration. The surface flows are normally generated by glacial or snow melt. Generally speaking the groundwater receives recharge from precipitation and surface runoff at higher elevations, and discharges into surface water in lower elevations, or evaporates into air as evapotranspiration. Surface flows are dominated by snowmelt and glacial melt that sustains the summer flows. In The Mitchell valley the quality of water is poor at the toe of the glacier and it is believed that it is due to groundwater coming in contact with the mineralized rock and hence getting the water contaminated. The poor quality water leaching out the ore deposits in the Upper Mitchell and Sulphurets valley are observed predominantly discharging into downstream into Mitchell and Sulphurets creeks at the premining condition. The difference in the water levels of monitoring wells and surface water and comparing their quality confirms the contamination and its probable source.(Chapter: Groundwater quality KMS Project)

2.3 Rationale of the study w.r.t Surface Water

The study of surface water quality becomes important in the region as the various springs sum up and merge to form a river and it is observed that water quality and quantity have significant relationship in most of the parametric study of water. The department hence had experimented on assessing the characteristics of water quality and volume of the water together. The study area taken by the department was Harvey river below the Sterling dam where the water quality was studied with respect to the water released in dam during hot and dry weather. This enabled the department to quantify the amount of water to be released in the dam to maintain health of the river downstream from the dam. This also helped to flow the quantified amount of water that could be made available for the human use along with sustaining the ecosystem of the river and its community associated services.

The literature by Galvin & Storer (2009) that flow regime plays vital role in driving the riverine ecosystem, when the flow reduces or the flow is low(at the lower end of the hydrograph) it can lead a huge number of changes in the riverine ecosystem that includes the identification of such impending ecological indicators for such multi-scale assessing the flow of low stress in surface water ecosystems. The tainted water quality that could be as an increased electrical conductivity, increased diurnal variation in water temperature and decreased dissolved oxygen (Lake 2003). Ecological consequences can include changes in the distribution and abundance of biota depending on differing species tolerances McNeil & Closs(2007); Miller *et al.* (2007); Chessman (2003).

According to the Act that came into the implementation for conserving the water resources in 1974 as The Water Prevention and Control of Pollution Act, 1974, aimed essentially to strengthen quality of water of various designated water bodies and their best uses. Kumar and Dobryial (1983) found that the physicochemical parameters were considered to isolate the probable beneficial use of the water bodies and for this a case study was observed on the banks of the rivers along with its probable the source of contamination. A considerable population as pilgrims, to fulfill their religious chants and sacred rituals visit holy places wherein they bath into the rivers through which they carry and communicate various skin diseases. Some pilgrims even settle down there in banks of the rivers for days and months together and hence their daily routine becomes the source of contamination for the rivers. Apart from bathing the pilgrims offer ghee, curd, flowers, idols, coins, body hairs ashes of the dead bodies and other religious offering into the river. These offerings are sometimes wrapped into a polythene bags and are thrown either into the river or on the banks of the rivers. These polythene bags do not degrade biologically and hence they either keep floating on the surface of the river or are accumulated at the bed of river stratum which poses health hazard to entire riverine system CPCB, Delhi (2005). To analyze the water quality of the river the critical parameters as total coliform which is a biological parameter is selected and studied in the laboratory, so that if the value crosses the desired limit then probable steps could be taken to restore the aesthetic quality of the water. The range of water quality for total coliform is as follows. (a) 50 MPN/100 ml for drinking water sources after disinfection, (b) 500 MPN/100 ml for outdoor organized bathing and (c) 5000 MPN/100 ml for drinking water source with conventional treatment followed by disinfection.

The major water source in Uttaranchal that feed the river is rainfall as well as snowmelt. The total dissolve solids in most of the Himalayan region that are fed by snow and river is 35- 151mg/l, which is in parallel to 90.23 to 121.33 mg/l. It was also analysed that the bicarbonate ranged from 28 to 76 ppm. The total alkalinity in the present study ranged from 37 to 96mg/l. If the unpolluted hill streams were seen then that ranged for NO3-N from 0-.13 ppm and phosphate PO4-P, 0.0122–0.068 mg/l. Hence concentration of nitrate nitrogen in the glacier fed rivers was seen in very low range. Also BOD in upland hill streams ranged between 0-3 ppm which is quite less when compared from the recent values as 9.9-12.87 ppm.

The literatures regarding the necessity of the models and kinds of the most accepted models were established by the Liangliang GAO1, Daoliang LI(2012) they confirmed that water quality models have become important tool to assess the variations in the quality of water which is important for the environmental management. A varied range of models are available nowadays each having its own benefits and limitation in available situations. The prime aim of the paper studied was to offer a clear idea to the researchers for selecting the model and its use for their study area. Out of which 8 renowned models were selected and reviewed. The models were SWAT,ELCOM-CAEDYM, MIKE11, WASP, CE-QUAL-W2 ,QUAL's, and EFDC. Each model was briefed to be used with their use, development, simulation elements, applicability i.e to be used in lakes, streams, rivers or estuaries and its basic principles. Presently the mostly trending models are

combination models- nowadays the trend for combining the models are into vogue which means when single model is not able to solve the problem then two models are combined to get desired output.

Application of models by combining artificial intelligence mechanistic models with non mechanistic models which are more accurate as the non mechanistic models provides more realistic results

Combination of models with remote sensing and geographical information system is more into trend these days which gives results with the help of (3S)-3S.

Yang C, Kuo J et a l. (2007), Geza M, Poeter E P, McCray et al.(2009) explained WASP as a surface water quality model and the version used for this research is version 8. It is a 1, 2, 3 dimensional and dynamic model. It is model suggested by EPA (Environmental Protection Agency) and can be downloaded free of cost from the website. WASP can help in visualizing various parametric features of nitrate, phosphate, BOD,DO, pH , phosphorus sand also organic phosphorus. Canu D M, Solidoro C(2004) Zhang M, Shen Y, Guo Y(2008).It can be used in various sorts of surface water bodies as lakes, rivers, streams, ponds, reservoirs, estuaries, and also the coastal waters. WASP can also be linked with hydrodynamic and sediment transport models that provide flows, depths, velocities, temperature, salinity and sediment f luxes. It comes in two kinetic modules and it is decided by the user the modules to be used for the study area. The TOXI module is for toxicants whereas the EUTRO module is for conventional water quality problems. It works on conservation of mass and momentum equations that calculates the river hydraulic characteristics (e.g., depth, velocity, top width and flow rate) Ambrose B, Wool T A, Martin J L. T.(2001) Yang C P, Kuo J T, Lung W S, Lai J S et al. (2007)

The continuity equation Eq. (1) and momentum equation Eq. (2) used in the WASP model are as follows:

$$\partial Q\ dt\ \text{þ}\ 1\ B\ \partial Q\ dx\ \text{¼}\ qs \quad \ldots(1)$$

$$\partial Q\ dt\ \text{þ}\ \partial\ \partial x\ QW\ A\ \text{þ}\ gA\ \partial z\ \partial x\ \text{þ}\ Q\ Qj\ j\ K2\ \text{¼}\ 0 \ldots\ (2)$$

where Z is the elevation of water surface whereas Q is the rate of flow water surface elevation, Q is the flow rate, B is the wetted cross sectional width, A is the wetted cross sectional area, t is the time, x is the distance along the channel, K is the conveyance of the channel, g is the gravitational acceleration, and q is the side discharge per unit channel length This model helps users interpret and predict water quality responses to natural phenomena and manmade pollution for various pollution management decisions. (Lai et al) combined the Integrated Watershed Management Model (IWMM) and the Water Quality Analysis Simulation Program model. . Although WASP can be run with 1, 2 or 3 dimensions as desired, the model has limitations: (1) it does not handle mixing zones or near

field effects, (2) it does not handle sinkable/floatable materials, and (3) it requires an extensive amount of data for calibration and verification.

WASP is a mechanistic or deterministic model and its major function is to react to the external uproar of the system. This modeling framework functions on contaminant fate and its transfer in the surface water precisely. It works on box model approach. The box model is flexible approach that helps the modeler to describe the kinetic process, its inputs and also geophysical morphology. Since the model works on conservative properties, so it gives the liberty to the modeler to understand that such properties are those that are not gained or lost through ordinary reactions as mass, momentum and heat. Thus it can explain well and also keep a track on the change and also its pathway. Extending to this fact WASP is also related to the source and its sinks of the waste accumulation (USEPA, 2006b). WASP along with describing all the sets of equations also describes well the pertinent mechanisms of the surface water body.

The user can provide input to WASP using options for constant or time-variable transport and kinetic processes, and point and non-point waste discharges. Some earlier WASP studies focus on eutrophication of Tampa Bay (Wang et al. 1999), phosphorus loading to Lake eutrophication of the Neuse river and estuary (Wool et al. 2003), eutrophication and Polychlorinated biphenyl (PCB) pollution of the Great Lakes Thomann et a l. (1979); Di Toro & Connolly (1980), eutrophication of the Potomac estuary (Thomann & Fitzpatrick 1982), kepone pollution of the James river estuary, volatile organic pollution of the Delaware estuary, heavy pollution of the Deep River, North Carolina (JRB, 1984) and evaluation of dissolved nitrogen in the Altamaha river, Georgia also reported on the application of the WASP water quality model. WASP in the present study is used to predict dissolved oxygen, phosphate, nitrate and chlorophyll-a and biochemical oxygen demand (BOD) concentrations in Akkulam Veli Lake, a tropical coastal lake. Efforts were made to derive specific conclusions from the model output (i.e. spatial variation maps and daily variation)

2.4 Relationships between the water quality parameters

Dirunal variations are an important aspect to study the physicochemical properties of water

The impact of diurnal variations in the various parametric study of water samples were studied and analysed through various literatures by the following researchers .Diurnal variation in physicochemical characteristics have been studied by Ganapati (1955), George (1961), George (1966), Khan and Siddique (1970), Vijayalaxmi and Venugopal (1973), Mishra et al. (1975, 1976), Bohra et al. (1978), Kumar et al. (1978), Rai and Dutta Munsi (1979), Sahu et al. (1995), Das et al. (1997), Jain (1999) in surface water systems like ponds, lakes, rivers and groundwater like Tube well, Bore well etc. of different parts of India. Dirunal variation in meteorology is defined as variation between high temperature and a low temperature that occurs in the same day. Temperature lag is a vital factor in diurnal temperature variation, peak temperature that generally occurs after noon and minimum temperature is generally occurs after midnight, or during early morning in the hour around before the sunrise. Temperature variations play key role in pH, DO, BOD, TDS and various other parameters.

As expected, the maximum water temperature was in the day time of summer. The study area selected in this paper is Rourkela specified that on analysis that the diurnal fluctuation in the temperature was 0.5, 1.5 and 3.0 ^{0}C respectively in summer, winter and Rainy seasons respectively. Whereas pH value ranged in between 7.4 to 7.6, 7.2 to 7.4 and 7.1 to 7.3 in Summer, Winter and Rainy season respectively indicating that throughout 24 hours of cycle the samples were slightly alkaline. The Dissolved Oxygen concentration also proved to be temperature dependent and ranged from 7.0 to 7.8 in Summer, 7.8 to 8.1 in Winter and 7.0 to 7.6 in Rainy season.

Correlation Coefficients among Water Quality Parameters

Correlation among the water quality parameters has been reported by Tiwari et al. (1988), Somasekhara Rao et al. (1994), Singh et al. (1994), Mariappan (2000), Jeyraj et al. (2002), Lingeswara Rao et al. (2002), Tyagi et al. (2003) and Mohanty et al. (2003).Not a very appreciable amount of work is done for the study area selected for the study by the researcher but the literature specifies that various water quality parameters significantly react with any changes that are environmental or anthropogenic and that is proved by various analysis going through the study area. A very little work has been done on assessing

the quality of groundwater, surface water and treated water of the industrial city of Rourkela and its periphery by Ali and Tiwari (1988), Naik et al. (1996), Patel et al. (1988) and Dasgupta Adak et al. (2001).

This research was done on the industrial as well as agricultural pollution of rivers It was alleged that due to immobile nature of the pesticides they were unlikely to pollute groundwater. But on analysis it was observed that pesticides are mobile in environment and does not remain in nature as left in as pollutant.

Also if the pesticides would not be mobile in nature it would not brought under microbial action and would cause pollution of the groundwater. But this is not the case and the groundwater under past several years has been subjected to pollution by agricultural wastes Rice *et al*. (1991). Regarding the study area selected by me for the research not very appreciable work is done in the region and regarding the water quality in the region. However pioneer but inconsistent monitoring of the springs of Almora are witnessed but the story for the water quality of river Kosi is not discussed in appreciable extent. Also the modeling part of the river is addressed for the first time in the region through the research. Hence generation of the data posed greatest challenge in the scenario.

S. Gupta, M. Bhatnagar, and R. Jain(2003), studied literature on Bikaner city and visualized that the water samples isolated from the different allotted station gave faint aroma, which specifies that the odour was due to various chemicals which were used as raw materials in the industrial units and the odor generated was due to the bacteria and microorganisms decomposing the plant debris, the waste disposal into the water body. This showed very unhealthy condition of the water body. The contaminants normally got diluted in the monsoon season and hence the odor disappeared. The other major role was played by the temperature which favorably facilitated the ongoing chemical reactions in the water body. River water pollution is not only a concerned aesthetic issue but also is a serious economic problem also challenging the public health of the residents. Ashish Kumar,and Yogendra Bahadur (2010) stated that the serenity of the river could be maintained by continuously monitoring the water quality which would be helpful in taking timely steps for taking preventive measures to avoid pollution. From the related research it is obvious that although the river water of Bikaner is polluted yet it is used for agricultural as well as pisciculture

purposes. Hence it is in urgent requirement that wastewater is treated well before disposing that into the river so that aquatic health could be retained along with the health of soil as well as human beings.

The literature by Ghada Mohamed Elamin Elfaki Taha(1989) states that because nitrate is fairly soluble into water and hence it travels easily from the soil into the groundwater. Ammonium which is also a constituent found in waste is readily soluble in water and has is easily moved in with water through the soil profile. Ammonium which might be a component in the waste is also soluble in water and has enhanced way of getting adsorbed at the exchange points. Ammonium nitrate gets rapidly converted into nitrate irrespective to its source of generation by the bacteria present in the soil when the soil temperature is above 50 degree Fahrenheit. As the nitrogen reaches soil from any of the sources be it organic or inorganic, it soon becomes part of the nitrogen cycle.

Nitrogen that is available in the environment in various forms changes its nature and moves in through the nitrogen cycle which is shown in natural and crop land system as well. In major platforms of the natural ecosystems, the nitrogen is at short supply and nitrogen recycles efficiently while in other ecosystem it might be abundant but potential loss would be high justifying the reason why groundwater gets contaminated with nitrate.

2.5 Nitrate dynamics in hydrology

Nitrate availability is typically greater in urban and suburban watersheds than in watersheds dominated by natural ecosystems due to various reasons as buildup and wash-off of atmospheric deposition, application of fertilizers, leaching from septic systems, and leaking sanitary sewers Kaushal et al, (2011); Divers et al.(2013). In stream biology serves as a proximal control on the nutrient concentrations, especially in the urban streams where increased nutrient availability can enhance primary production relative to undisturbed ecosystems Groffman et al. (2005) Quantifying the interaction between hydrology and in-stream ecology is critical for understanding controls on nutrient concentration-discharge (c-Q) patterns.

Watershed process that are merged from increasingly higher frequency water quality data have precisely been assumed to move hand in hand with those obtained from long term but less frequent sampling. In the past, sampling at higher frequencies has augmented understanding of storm event phenomena, antecedent conditions, and dial patterns However, recent work on nitrate c-Q in a forested watershed showed inconsistency between c-Q slopes derived from long-term weekly sampling versus high-frequency data. Reconciling and understanding of the nitrate export dynamics inferred from long-term weekly and high-frequency sensor data is required for advancing and understanding of the solute production, transformations, and transport at watershed scales as well as developing effective management strategies to reduce nonpoint source pollution. Many of these strategies are optimized for either high flows (e.g. detention basins) or low flows (e.g. stream restoration). Understanding when and how nitrate is being exported is critical for efficient decision making.

The mechanisms of N retention and possible timing of N breakthrough and increased leaching are subjects of practical and theoretical interest. Many of these experiments found that much of the added N was retained in the catchment, with only a small fraction leaching to surface waters. It is assumed that much of the added N remains in catchment soils and biomass. If this retained N were to be released, it would lead to N "breakthrough" and rapid reacidifícation of surface waters

Nitrate in water quality

The various papers for the study of nitrate in ground water as well as surface water was studied to understand the reason, causes and effects of behind the contamination of water with various nutrients especially nitrates

Arwenyo1, J. Wasswa et al. (2012) stated that spatial analyses of septic systems population and water quality were used to derive the impact of septic systems population on spring water quality. The software ArcGIS was into use to frame the thematic maps on septic tanks and population, water quality parameters as well as to exhibit the spatial analysis on the map layers via spatial overlay. The locations were determined by using eTrex as well as GPS device. This paper helped to correlate that the use of remote sensing and softwares related

could help to enhance the representation of the points as well as parameters. The water sample collected had nitrate concentration above the USEPA's drinking water standard of 10 mg L-1 (US EPA, 2014). The nitrate concentrations ranged from 0.01 to 11 mg L. The levels found in this study were however, below the Uganda's and World Health Organisation's guidelines whose maximum nitrate levels in drinking water are at 50 mg L-1 (UNBS, 2008; WHO, 1996). Studies by US Geological Survey (USGS) defined concentrations of nitrate in water beyond 2 mg L-1 as the level indicating human impact on water quality Durvey,Hanchar et.al (1997). The effect of septic tanks effluents on groundwater quality in Northern Williamson county and Southern Davidson County, Tennessee.

2.6 Phosphate and sulphate as nutrient in water

The phosphate concentration in the surface water is as common as nitrate but depending upon the region selected for study phosphate concentration as contamination is not witnessed but as in for groundwater contamination the sulphate concentration is seen in springs of Almora. The contamination is generally from the domestic use of the population concentrated near the springs.

According to studies made by Krzysztof Lejcus´ a Magdalena et.al(2013) the surface water when polluted by runoff from agricultural fields or sewage can impact the ecosystem and change the tropic state to highly productive and nutrient rich medium.

Phosphate is said to be the major culprit to stimulate eutrophication and to demonstrate this the study area was selected for seeing phosphate build up in surface water of Strzegomka River at the inflow and outflow from Dobromierz Reservoir Lower Silesia, Poland, Central Europe. Nearly 25000 people are dependent upon this reservoir for potable water. This reservoir was continuously monitored for keeping a check on phosphate concentration for hydrological year XI 2000– X 2001 and then for continuously 15 years from 2000 to 2014.Phosphate concentration varied from 1.70 mg to 4mg/l in the hydrological year and the mean concentration was .33mg/l for 15 years between 2000 to 2014 in Dobromierz Reservoir. Statistically decreasing trends for phosphate was not detected at the inflow of the Dobromierz Reservoir. Phosphate run off is seen to be maximum when during storms and run off generation. These are generally washed off during rains in from vegetation.

Phosphates are generally available for plant uptake and algal growth to protect it from the run off.

According to A.N. Sharpley, W.J. Gburek, et al.(1999) Phosphate increases in concentration when run off generated from the soil that are overgrown by plants even if the rainfall is low and hence causing remobilization of P from organic matter dying back after the vegetation season ends.

Sulphate as nutrient in water:

Sulphate as nutrient is within permissible limit in the region for the springs of Almora whereas for the surface water quality sulphate is not traced in the samples. The sulphate as a nutrient is not a problematic issue in the region. In springs named Thapalya and Sunehri are found sulphate contamination with 30-40mg/l. The contamination is due to domestic use which takes place at the source itself as illustrated in Plate 7. These springs are contaminated due to regular washing of clothes at the source and the detergent present in the washing powders seems to contaminate the springs. Also the springs are densely populated with buildings; also the dumping of the waste nearby the springs poses the contamination of the springs.

According to MPCA(1999) states that sulphate is found readily in surface and groundwater systems due to high solubility in water). Sulphate can be found in the large amount in atmosphere due to combustion activities or due to pollution rising standards. This sulphate reaches to the surface water sources through rainfall or dry deposition. Since this sulphate occurs as most abundantly occurring ion and is highly mobile in aquifer and highly soluble. The change from reductive to oxidative atmosphere sulphate becomes abundantly occurring ion on earth's surface**.**

The most stable form of sulphate is plus six oxidation state but other oxidation states as S+4,SO or S-2 are also stable states. According to Goldstein and Aizenshtat(1994) stated that sulphate along with finding its way naturally in the environment as through sulphur rich minerals dissolution, atmospheric deposition and oxidation of sulphur dominant minerals

Krouse and Mayer (1999) can be also found due to anthropogenic activities as through refineries and coal mines, sulphate is found in water from both in natural and anthropogenic sources.

Plate 7 Showing domestic use of water springs showing contamination of sulphate

The various natural sources incorporate the sulphur mineral dissolution, atmospheric deposition and sulphide oxidation from mineral. The human induced sources are from power plant, coal mines and metallurgical refinery.

Chapter 3

Area Under Study

3.1 Study Area

Almora town, the headquarters of Almora district is situated at a magnificent location (latitude 29°37'3" N and longitude 79°40'20'E) over saddle shaped ridge of 6 km in length running from north-east to south –west.

The town is spread over an area of 9.03km^3 including the cantonment area, which has been considered as a part of Almora town for the purpose of this study.

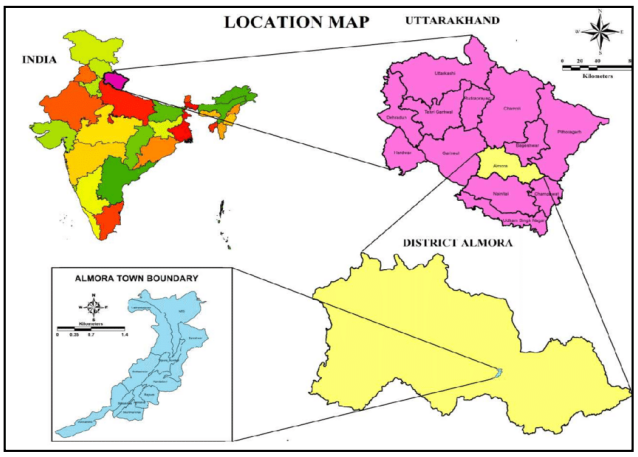


Fig 3.1 Map of Almora

This town is connected by metalled road with Kathgodam (the nearest railway station at about 90km) and with a number of famous tourist centers of this region, namely Nainital(65km) , Ranikhet (48km), Kausani(49km) and Pithorgarh(about 120km) Fig 3.1 shows the location map of Almora. Due to its historical, physical and cultural identity the town is the core of Kumaon Himalaya.

The relief and slope are significant factors in development of settlement in the region Situated on the ridge ,religiously Almora is said to be protected by three temples Kasar Devi on one side and siyahi and banari devi on the other two sides.

Almora town is located on saddle shaped ridge and its altitude varies from about 1500 meter to 1800meter above mean sea level.

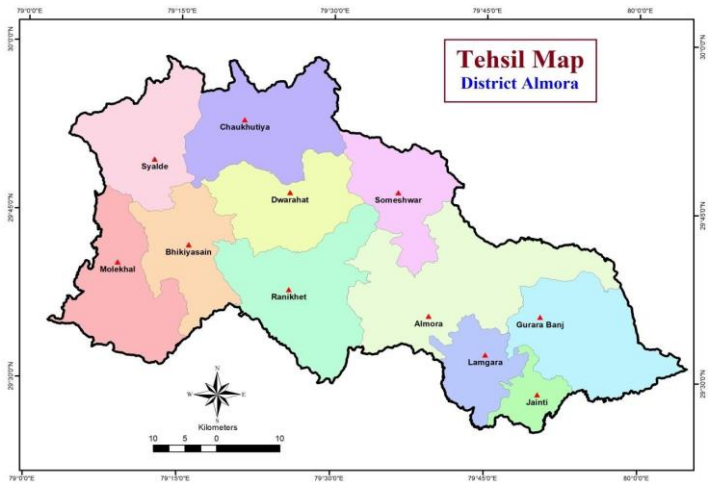


Fig 3.2 Tehsil map of Almora

Slope is an important part of landforms. The average slope of this town ranges from 5 degree to 35 degree. The lower value of average slope is found on the ridge. The top of the ridge is The surrounding ridges Simtola(1877mt) and Kalmatia (1945mt) from a col known as Mount Brown which in the present time is known as Hiradungari(1684m). Fig 3.2 shows the tehsil map of Almora.

The name is hiradungri is originated from micaceous rock which shines like a diamond (hira) in the morning sun. Another ridge known as Sitoli runs westward from hiradungri to Salidhar and is situated in the north of the Almora town crowded with houses from Paltan Bazar to Nandi Devi Temple. The slope gradually increases towards west and east directions.

3.2 Background Study and meteorological pattern

The Almora lies on 1633 meters above sea level and the climate of Almora is warm and temperate. On one hand where summers are with pleasant weather with good deal of rainfall, while the winters have very little rainfall. The climate here is classified as Cwb by the Köppen- Geiger system. The average temperature in Almora is perceived to be 14.4 °C or 57.9 °F. Climate may be defined as cumulative effects of the atmospheric conditions

that exist in any region over a long period of time. The elements that make up climate are temperature, precipitation, and humidity of the air, cloudiness, air pressure, and wind. These elements depend on the conditions of the atmosphere and vary greatly from place to place from season to season Worcester (1948). In Almora town, temperature starts rising from February every year and reaches the highest values in May and June. In general during the summer and rainy seasons (May to September) the temperature remains high. From mid September to November the temperature of the region is moderate whereas, the last month of year as December to second month of the year as February is the coldest months of the year. The humidity is very high during rainy season (mid July to mid September) and Almora receives about 75 percent of the total rains in this season. August is the month which receives maximum rainfall while in November and December the area receives negligible rainfall. In general, the main characteristics of the autumn and spring seasons are cloudless sky, transparent atmosphere, tranquil nights, heavy dew and great temperature variations. Pleasant nights and hot days are the principal characteristics of summer season in this town.

Physical Climatology is a science which deals with reasons for climate change and this involves collection and observations of atmospheric data related to rainfall, air temperature, humidity, solar radiations and wind patterns etc. Their distribution mainly depends on transfer of energy and mass in a closed climate system. This process of transfer is influenced by differences in altitude, latitude, surface characteristics of land and water, local topography and gross atmospheric features such as pressure centers, large air masses etc.

Regional climatology necessarily explains the spatial patterns of climate. It includes the identification of significant climatic changes across the world and classification of areas on the basis of different climatic patterns. Large scale or macro climatic and intermediate or mesoscale climatic zone are generally studied as subdivisions of regional climatology.

Applied climatology is the third division of climatology which relates to the exploration of interrelation between climate and other natural or manmade phenomena. It considers the potential impact of climatic change on human welfare and also includes the possible actions to modify climate according to human needs. Study of interdependence of water resources on climatic factors is also conducted under the science of applied climatology.

The specific heat of water which provides it the ability to exist in all three phases (i.e, solid,

liquid and gaseous) under natural conditions. Its capacity of storing or releasing latent heat with changes in its different locations and during different state is responsible for its impact on atmospheric processes. However, availability of water at different locations and during different periods is influenced by weather and climate of that region. Atmospheric changes are the governing factors in maintaining the hydrologic cycle of water redistribution on the earth surface.

Temperature Patterns

Surface air temperature, an index of sensible heat, is one of the important parameters to study in connection with the general climatology of any area. For applied climatology uses the surface temperature is required to be analyzed statistically to generate useful information. The average globe surface temperature is about 13 Degree centigrade. This value changes with place and the local average surface temperature varies due to several factors such as latitude, altitude, topography and vegetation pattern etc. solar insulations are responsible for surface heating which in turn affect the temperature. Latitude is an important factor and has direct relation with solar insulations. The general decrease in temperature from equator to poles is well known fact which clearly confirms the effect of change in latitude on surface temperatures.

Topography has certain role to play in temperature patterns of the world. Presence of water bodies, changing slope patterns and topographic relief exert an influence upon the surface temperature. Mountains act as barrier for moving cold air masses and affect the local temperature. Later it was stated that Himalayan ranges protect all regions located on its south from polar air masses.

Altitude is the most influencing factor in temperature change. It is reported that under normal conditions, reduction in temperature with increase in altitude in 6.5 degree centigrade per 1000 meters. In mountain regions, the altitude is responsible for lower surface temperatures during winters. Almora town is located at about 1640 meters above mean sea level due to which it experiences moderately cold winters. The climate of the town can be discussed under three main seasons i.e. winter that starts from December to February, summer from April to June and monsoon lies between July to September. Besides these three seasons, it has spring (March) and autumn (October and November)

seasons also but of shorter durations. The surface temperature patterns of the town are, therefore discussed only for the three main seasons of the year.

Rainfall patterns

The rainfall of liquid precipitation is defined as water in liquid form falling on the earth surface. Precipitation also occurs in solid form. The common forms of precipitation are rainfall, drizzle, snow and hail. Precipitation is primarily associated with rising air masses and is always preceded by sublimation or condensation in clouds or combination of both. A cloud is the source of precipitation. Cloud is an aerosol which has impression of minute water droplets or ice crystals along with other solid particles present in the air. In` Almora town (altitude 1646m above m.s.l), the average rainfall pattern is greatly influenced by south west monsoon. The annual; average rainfall in the town, for the past 14 years, is 1042.14 mm. The seasonal variation of rainfall on month to month basis, throughout the year, over an area is quite important and determines the total accumulated rainfall over a year. This variation is termed as" regime of precipitation "by Critchfield (1987) and is very important from water availability point of view. In India, monsoonal variations are quite significant and mountain barriers have certain impact on the amount of rainfall in the rainy season. In Almora town, the months of July and August fall within the peak of rainy season and are more than 40 percent of total annual rainfall occurs during these two months. Dependability of rainfall refers to the derivation from normal average rainfall during the same period. In Almora town, the variations are recorded for annual average. This indicates that the degree of dependability of rainfall at Almora town is not very high.

Frequency of rainfall at any place is the measure of number of days of actual rainfall. This has a great economic significance. The rainfall patterns of Almora town for the years 1991 and 1992 were studied. The number of days of rainfall in each month is plotted.

Total rainy days 1991 and 1992 are 69 and 66 respectively. October is the only dry month in 1991 whereas in1992 in April and December there was no rainfall in the town whereas in 2018- 2019 the total rainfall days were 82 and 80 and no rainfall had any rain in month of November in 2018 and May 2019. Intensity of rainfall is defined as ratio of precipitation and time which it fell. In Almora town, the records of the past 14 years indicate that maximum rainfall intensity of 1036.2 mm was recorded in 2019, in the months of July and August. Minimum rainfall intensity for 2 months was observed in October and November 2019 as 52.7 mm. As per the general trend, mid latitude mountains should have maximum

relative humidity in summer but at Almora the maximum values are observed in the month of August. This is due to amount of excess water present in air masses during the monsoon period. The variation in the average monthly values of relative humidity is quite high at Almora town. January and May are found as period of low humidity. Only for four months in a year, relative humidity exceeds 50 percent mark. In January, though the temperature is quite low, minimum relative humidity values are recorded. This is due to dryness of winter season in this area. In May, high temperature and low rainfall are responsible for lower values of relative humidity. Humidity has direct relation with the water content of the air. Evaporation controls the atmospheric moisture and it has direct relation with humidity. Lower rate of evaporation will be observed if humidity is high. Rate of evaporation is also dependent on vapor pressure, temperature and air movements. Relative humidity has an important role in fixing the rate of evaporation. Evaporation in high altitude is responsible for large amount of water loss from the water resources. Less humid climate of Almora is responsible for evaporation at greater rate from its water sources which in turn reduce total availability of fresh water for domestic needs.

3.3 Drainage pattern ofAlmora

The drainage patterns of entire town can be characterized by many small seasonal streams flowing in eastern and western slopes. The town is situated on a hill top which is origin of all the streams. The drainage system of the area is constituted by two major watersheds on both the hill, viz eastwards flowing streams and westward flowing streams. The western portion is drained by Jamtara gad, which is the main stream of this watershed and after flowing about 3km towards west it merges to river Kosi. The eastward flowing streams are Malgaon stream, Khamgara stream, Sarsyon stream, Chinkhan stream, Plri Gad stream which join the river Suyal at different locations. These streams play a significant role in the distribution of natural springs (locally known as naulas); most of the natural springs are located along these streams. The drainage pattern is generally dendrite type. Geological structure, human settlements, micro climatic conditions, different rock types and its erosional history are the major controlling factors of drainage patterns of the area.

Springs are frequently found in hilly areas where inclined ground and impermeable strata overlap the water table which is a fantasy line of such springs are unconfined aquifers. Flow of water in these springs is under gravity. Based on the flow, these springs are

classified as intermittent springs and regular springs. Intermittent springs remain dry for a period in a year whereas the regular springs provide water in all months of the year.

3.4 Geology and Hydrogeology of the Town

Several attempts have been made to characterize the geological environment of this part of central Himalaya. After revolutionary work of Strachery (1857) and more recently by Valdiya (1979) and Powar (1980) gave meticulous description for geology of this area. The specific geological texture of the area is existence of Muscovite as dominant clay mineral in the soil. Geologically the town is located on the laps of lesser Himalaya, which is enclosed by the north and south thrusts (Pande (1985) and Rawat(1990). The rocks are made up of crystalline rock group and granite rock group. Also the rocks of the area are mainly constitutes of quartzite, sandstone, mica- granite, weathered muscovite-schists, genesis and chlorite.etc.

The discussion on the quality of the rocks is essential to ensure the quality of water which might be due to the quality of rocks or the bed of the rocks which is holding water. Hence the nature of the rocks too imparts a significant impact on the quality as well as quality of springs in the region.

Hydrogeology / Hydrology of the town

Hydrology and water resource management cannot be represented separately in a study of urban ecosystem. In many countries as they are grouped together to form a combined unit (UNESCO 1979). Man has always manipulated the environment for his own purpose. Wildscapes have been cleared for other uses like agriculture, human settlements, etc and almost all the city of today are the small villages of yesterdays. The emphasis on hydrology has not been evolved very old and recently the concept of urban hydrology has been evolved Hengeveld and DeVotch (1982).By definition, urban hydrology is the study of hydrological cycle within the areas affected by urbanization. Natural water systems are altered and supplemented by sewage systems in the towns.

In Almora town, in initial stages of development, domestic wastes were collected manually for disposal in open pits. With the development of water supply schemes in the British period, concept of septic tanks came into existence for partial treatment and disposal of

sewage. So far, sewage collection system has not been developed for the town.

Presently, about fifty percent population is using septic tank as reported in the records of municipal board. Remaining fifty percent toilets are dry type in which the night soil is still collected manually. The collected sewage is then transported by road and it is disposed either as landfills in Badaldhouti reserve forests (in the north of the town) or in surface drains within the town.

All types of sewage disposal systems practiced in the town (Septic and manual disposal) have direct influence on the surface and groundwater sources of the catchment in the terms of quality and quantity which directly affects the hydrology of the area.

For the water supply of the town, springs (percolated water) were tapped and used in the past liken in most other hill towns in the country. With the increase in demand of water as the town developed additional supply was obtained through lift schemes from rivers located in the valley areas. In case of Almora the river Kosi was the only option for a lift scheme. Presently, the demand has further increased and it is becoming difficult to meet the daily demand (about 10 MLD) of the town through the existing schemes. There is gap of about 1-5 MLD in demand and supply levels in Almora. Available options for the town such as Pinder river scheme are cost intensive and involve several practical problems. Under these conditions, importance of high altitude fresh water springs needs to be highlighted as viable alternative which has almost been neglected at present.

Both water supply and sewerage systems, in one way or the other, are dependent on different components of hydrology of the area. The influence of urbanization is not only limited to the urban boundaries but also extends to the surrounding rural area.

3.5 Groundwater sources and Demography

Springs are only groundwater sources in the region and these springs are effected by various parameters in the region. Natural water always contains organic and mineral substances in dissolved or suspended form. These substances can enter the natural water from various sources. These sources can be classified in two broad categories i.e., natural and manmade. The important natural sources of these substances are atmospheric precipitation, soils, streams and surface water bodies etc. Man has always used water as medium or as a recipient body to take the load of waste generated by him. This practice is responsible for pollution of natural waters through addition of unwanted chemical and biological substances into it. Ground waters mostly contain dissolved substances whereas the surface waters are

rich in suspended matters Fried(1975). There are several classes of natural water based on its origin, characteristics and uses.

1) By its origin, water is classified as groundwater (springs and wells),surface water(rivers,lake and seas) and atmospheric water(clouds, precipitation)

2) Impurities present in water also used for classification of water as soft, hard, turbid, fresh and clean water.

3) Uses of water for different purpose also form several classes of water such as domestic water, industrial water, medicinal water etc.

All types of water are rich in bacteria, algae, worms and other organisms and the composition of natural water varies with time and season (Drever 1982). Settleable solids of mineral of mineral and organic origin generally settle gravity and their concentration in water changes with time. Some of the organics are destroyed by micro-organisms present in water which results in changes in its composition within the water body. The bulk of organic matters is due to humus (Metcalf and Eddy 1979). Other forms of organic matters such as proteins, fats, and organic acids are also found in water but in low concentration. The concentration of minerals varies quite substantially according to its origin. The sea water contains large quantity of dissolved salts whereas surface water has very low concentration of such salts in it. Groundwater falls in between these two classes as far as dissolved salt concentration is concerned Subterranean waters in the form of springs and wells are generally found as good source of fresh water and often used for local water supply. Ground water, in general is found clean but due to ecological and atmospheric factors (natural or manmade), certain variations in the groundwater quality have been noticed (Mahajan(1989).Groundwater passes through different geological formations and many chemical compounds present in the rocks may be dissolved in it. In hilly areas, the geological features and shallow depth of groundwater is responsible for the occurrence of number of springs at different locations. These springs are recharged by percolation of surface water through soil and joints present in the body of surrounding rock. In the plains, the surface water which reaches underground water bodies generally gets sufficient treatment by filtration within the soil layers (Gilbert 1990). But in hilly regions the depth of soil may not be enough to provide full treatment to surface water and the impurities present can be transported to subsoil water. This results in certain changes in chemistry and microbiology of spring waters .In densely populated townships, the municipal sewage

disposed through cesspools and unlined open drains passes through the topsoil to reach subsoil water which finally comes out with spring discharge. In large towns like Almora which is having a number of springs around it, the chances of such contamination cannot be ruled out. Study of chemistry and microbiology of spring water was therefore conducted to assess the seasonal changes in the quality of the spring water which is used in for drinking by major communities.

Demography

Study of human population is one of the most important aspects of Environmental Impact Assessment studies, because man is an active factor that influences all natural systems. Man is also the main user of natural resources. Therefore positive or negative impacts of human activities are dependent upon man environment adjustments. Any developmental planning is directly related to and dependent on its people. Hence it becomes important to understand demographic structure (growth, distribution, density, literacy levels, occupational structure etc) of the town.

In the study of spring water pollution within the town boundary, discussion on population details is important to understand its distribution and density. These population details are important in assessment of the impact of population growth on the quality of water of natural springs. According to Clark(1978), the population growth is a powerful force to bring about a change in traditional methods and to transform the economy into rather advanced and productive stages(quoted by Ghosh (1978). Therefore, the study of demographic structure of the town is essential in all developmental planning.

3.6 Population Growth:

Almora was one of the most populous towns of the region having 8596 persons in1901 AD. It was district headquarter even at that time. Now Almora town has population of 28,051 persons (census, 1991) which makes it as a class III town and as per area considerations (8.03 sq. km),it also falls class III category of cities in the country. The total population of the town (Almora MB and Almora cantt) as recorded in 1981 was 22,705 persons, which has increased by 23.55 percent during this decade (1981-91).The present census of Almora says the population has increased 35561 per sq km.(census 2011).The following graph (Fig: 3.3) shows the increasing trend in the population of Almora town in the years from 1901 to 2011. In general the growth of population is controlled by two main factors, i.e

natural population increase and net immigration from rural areas. In case of Almora town, net immigration from rural areas can be considered as important factor. Being a district headquarters maximum facilities as educational, administrative offices, medical and other services are available in the town which attracts immigrants from surrounding localities (Rawat1980)

The above chart shows that the population of Almora has increased in decades and it is believed that the coming census in 2021 will show the maximum growth in the population as the prominent increase in population in the consecutive years. Last 5 years the abrupt increase in the clustering of the buildings and other developmental works have indicated the drastic population growth in the headquarter. However the increase of population is very not considerable for Almora cant as it is restricted area.

The following chart(Fig 3.4) shows the population of the town Almora ward wise according to 2001 census. This is to specify that population of Almora town has increased in different wards in the current census. The early number of ward as in Almora town in 1994 was 15 in number. But as now a few of the wards are merged now to get 11 wards in the town.

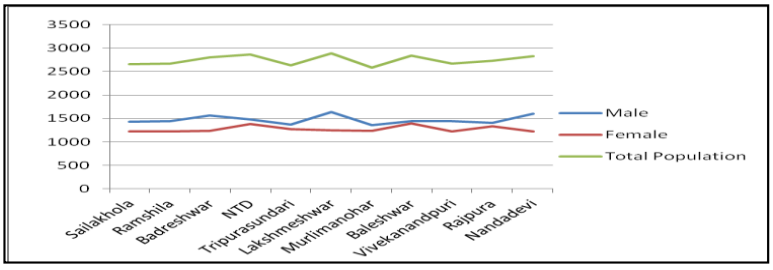


Fig 3.3 Population growth in Almora in decades

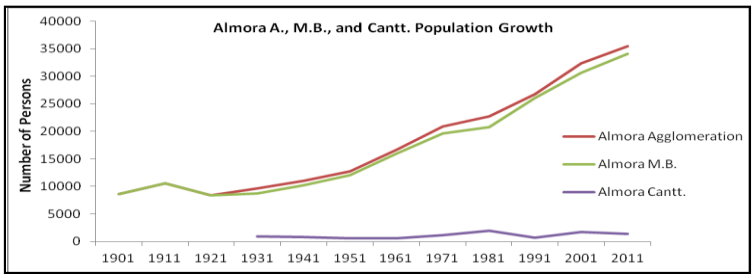


Fig 3.4 Ward wise population census 2001 of Almora

The increase in population ward wise according to 2011 census is shown in the graph below (fig 3.5) which clearly indicates that the challenging water quality status with rapidly increasing population ward wise. With the increase in population and urbanization has left Almora with detoriating water quality status to that level that most of the springs are no more fit for drinking and are used merely for domestic purpose or for the cattle use. The study area extends from Kantli to Ramanagar in order to fulfil the second objective and to also the study the impact of the discharge of the contaminated springs into the river Kosi. Hence the entire stretch of the watershed was selected for studying the major contamination points of the river. The basis of point selection was the clustering of the buildings on the banks of the river and population.

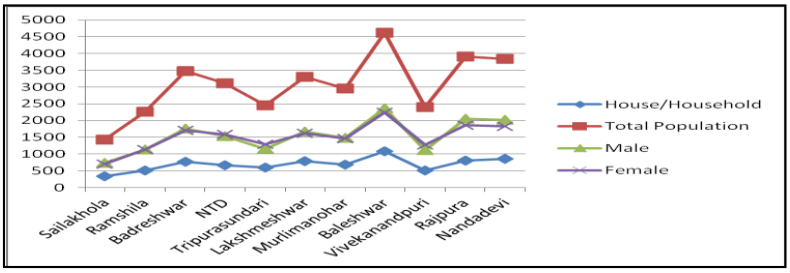


Fig 3.5 Chart for ward wise population census 2011 of Almora

Chapter 4

Experimental Methods

4.1 Experimental methods and description

Specialized sampling and sample handling procedures are essential for the assessment of water quality and hence to demonstrate whether the water is suitable for drinking as well as for other domestic purposes. The site for sampling was selected based on the population density, location as well as source of water. The analysis for the water samples collected were carried out for various parameters in the laboratory of Center of land and water resources management, GB Pant National Institute of Himalayan Environment Kosi Katarmal Almora.

1) The parameters that were monitored were temperature, turbidity, total dissolved solids, hardness, Biochemical oxygen demand, dissolved oxygen, electronegativity, sulphate, alkalinity, nitrate-nitrogen and sulphate. The biological parameters as fecal coliform and MPN for tracing the number of microbiological colonies were monitored in the springs of Almora.
2) Whereas for Kosi river which is the second and third major objective of the analysis three major parameters as Nitrate nitrogen, BOD, DO and pH was monitored.

For collecting the samples polythene bottles of 1 liter capacity that were sanitized and perfectly flow dried were used for physicochemical parameters and the glass bottles of 10 ml were used for biological parametric study after perfectly sanitizing and blow drying in the oven. In order to sanitize each bottle was washed with 2% HNO3 and then rinsed three times with distilled water. The bottles were then placed in dry place for use. Grab sampling was conducted for the samples for both springs as well as for river Kosi.

4.2 Water Sampling Procedure and analysis

Methods for analysis of the various parameters are suggested by various organizations as APHA, AWWA, WPCF 1985), Trivedi and Goel (1984) and NEERI (1986). The methods for my assembled sample analysis were opted as prescribed by APHA.

A brief description for the various pre-requisites is mentioned for the analysis.
The physicochemical parameters that were analysed were temperature, turbidity, pH, electrical conductivity, dissolved oxygen, BOD, hardness, nitrate and sulphate. Most of the parameters were analysed by the titration process and also was cross verified randomly with the kit model 191E. Except temperature all were analysed by titration and then verified by the kit randomly.

Electrical Conductivity: The electroconductometer was the instrument helped to measure the conductivity. It was first calibrated by solutions of 0.005,0 .05 and 0.5M standard KCl solution and then after calibrating the instrument the samples that were collected were analysed accordingly.

1) pH: The pH of the solution was measured by pH meter which was also calibrated by standard buffer solutions of pH-4, pH-9.2 and after the calibration the samples collected were analysed periodically.
2) Dissolved Oxygen was calibrated against Zero solution (Sodium Sulphate) and an air saturated beaker of water checked with a Winkler's titration. The titration is done with the Iodometric method in which into the 50 ml sample divalent manganese solution is added to the solution, followed by addition of strong alkali in a glass-stopper bottle. DO rapidly oxidize an equivalent amount of the dispersed divalent manganese hydroxide precipitates to hydroxides of higher valence states. In the presence of iodide ions in an acidic solution, the oxidized manganese reverts to the divalent state, with the liberation of iodine equivalent of the original DO content. The iodine is then titrated with a stranded solution of thiosulphate. The titration end point can be detected visually with a starch indicator
3) BOD is method that in which sample is incubated in the incubator for five days at 20 degree centigrade to see the microbial action of sample and then 50 ml of sample is taken and the procedure is followed same as DO titration.
4) Temperature is measured by the laboratory use thermometer and is a factory set instrument.
5) Turbidity is measured by turbidometer in which it is calibrated by turbidometer with 400 NTU solution using Hydrazine Sulphate and Hexamethylenetetramin.

6) For the analysis of Total Suspended Solids (TSS) the initial step followed is the whatmann paper is measured first for the dry weight and then 50 ml of the sample is filtered into through the paper. The whatmann paper is measured again with wet weight as well as after oven drying it for 24 hrs. The weight of the residue gives the amount of solids dissolved solids dissolved in the 50 ml sample.

7) For analysis of hardness the sample taken is 50 ml and is buffered at pH 8 with NH4Cl and NH4OH and is then titrated against Ethylene diaamine tetraacetate using indicator Erichrome black T whereas for Ca muroxide is used as indicator.

8) Magnesium can be calculated by using the formula Mg (mg/l) = (Total Hardness – Calcium Hardness) X 0.243. 33

9) Then the total alkalinity can be determined by titrating the 50 ml sample against N/50 solution of sulfuric acid by adding a few drops of methyl orange as an indicator.

10) Chloride content was measured by titrating against N/50 solution of silver nitrate using potassium chromate as indicator.

For biological parameter: Multiple-tube fermentation technique was performed for members of the coliform group. The standard test for the coliform group can be carried out either by the multiple tube fermentation technique or the membrane filter technique. The multiple-tube fermentation technique is more in use due to its applicability to almost all kinds of waters.

The technique involved inoculating the sample and/or its several dilutions in a suitable liquid medium. After the expiry of the incubation period, the tubes were examined for gas production by the coliform organisms. This test is known as presumptive test.

Since the reaction leading to the gas production is also possible by the organisms other than the coliform, the positive tubes from the presumptive test were subjected to a confirmative test. Sometimes, for a very definite presence of coliform bacteria, the completed test is carried out. The present examination was limited to confirmatory test for Total and Feacal coliform density count. The presence of E.coli was not seen in the samples of springs of Almora. The high concentration of microorganisms was observed in the samples from various springs of Almora.

4.3 Sampling Points

Selection of the site for springs of Almora

The prior step of the research in the field related activities was to select the site and sampling points site selection . The springs of Almora can be broadly classified as conventional type open pit type (naula) with slate roofing and as closed tanks with pipe outlet (dhara). The dhara water is protected from external surface contamination, is mainly used for drinking purposes whereas the naula water is mostly used for other domestic uses such as washing and cleaning. Most of the springs of the town are located along the four curved spring lines covering the town with one semi circle each on both the east and west sides of the hill. There is considerable similarity in the locations of the springs on both the sides of hill which indicates possibility of common recharge areas along these drainage lines. Water quality data collected from the selected springs indicate the concentration of nitrates beyond permissible limits of 10 ppm. This renders the water unfit for human consumption. It suggests leaching of nitrogen (converted to nitrates by nitrates by nitrate bacterial action) from domestic wastewater. Similarly the presence of organic matters (reflected in the form of BOD) and coliform bacteria in protected spring waters further indicated groundwater pollution in Almora town.

These research results of a detailed study conducted to monitor changes in spring water chemistry. Cleaning of springs and maintenance of hygienic conditions around these water sources by local people are the most important aspects of any management plan. This research is expected to provide baseline information to planners and local authorities regarding the water and wastewater in urban catchments of the Himalayan regions. In addition to this the hope is also that the report would generate public awareness regarding the importance of spring water and its quality. Natural water always contains organic and mineral substances in dissolved or suspended form. These substances can enter the natural water from various sources. These sources can be classified in two broad categories i.e natural and manmade. The important natural sources of these substances are atmospheric precipitation, soils, streams and surface water bodies etc. Water is always used as a medium or a recipient body to take the load of waste generated by the population. This practice is responsible for pollution of natural waters through addition of unwanted chemical and biological substances into it.

4.3.1 Sampling of the springs ofAlmora

Groundwater samples are normally obtained from existing drilled wells dug (shallow) wells or springs. Occasionally, during the course of a hydro-geological survey, test wells may be drilled and these can be used for monitoring purposes.

The usual situation, however, is that a producing well or spring will be a groundwater quality monitoring station. If the groundwater source is a flowing spring or a well equipped with a pump, the sample can be obtained at the point of discharge. The water should flow for several minutes before sampling until it has reached constant conductivity or temperature in order to avoid any water resident in the system's piping being taken as a sample (the piping material may have contaminated the water).

Samples for dissolved oxygen analysis should be taken by inserting one end of a plastic tube into the discharge pipe and the other end into a sample bottle. The water should be allowed to flow into the bottle for sufficient time to displace the contents of the bottle at least three times. Care should be taken to ensure that no air bubbles are introduced to the sample while the bottle is being filled, since this could alter the dissolved oxygen concentration.

Special care must be taken when sampling from springs that do not have an overflow and from shallow wells without pumps. The sampling container must not be allowed to touch the bottom of the well or spring catchment since this would cause settled particles to become resuspended and to contaminate the sample.

Sometimes, a spring catchment is higher than the surrounding ground and this permits water to be siphoned into the sample bottle. If this is done, water should be allowed to run through the hose for 2 - 3 minutes to rinse it thoroughly before the sample is collected. Siphoned samples are suitable for dissolved oxygen determination provided that the sample bottle is allowed to overflow a volume of at least three times its capacity.

The depth within an aquifer from which a sample of water is collected from a well is determined by the location of the well screen and cannot be varied by the collector, because water enters a well at the level of the screen. Similarly, water enters a spring through fissures in the rock. Consequently, a groundwater sample can only be obtained as a grab sample. The greatest danger of getting a non-representative sample occurs when insufficient water has been pumped before the sample is collected and that the sample

obtained is representative of the well rather than of the aquifer.

The methodology followed during the study can broadly be divided into three sections i.e. preliminary surveys through field visits, monitoring of springs through sampling and testing for water quality and data analysis. The main aim of the field surveys was to prepare drainage maps and locate springs whereas monitoring of spring water was done for continuous assessment of seasonal variations in its quality.

Reasons for occurrence of springs in Almora town are the interbedded impervious rocks like Quartzite and Muscovite Schists within the soil layer. In general it was observed that springs located at lower altitudes (i.e lower boundary of the town) have different chemical characteristics in comparison to the springs located on the ridge of the hill. The water chemistry of springs mainly depends upon the recharge area characteristics, soil and rock composition along the spring lines.

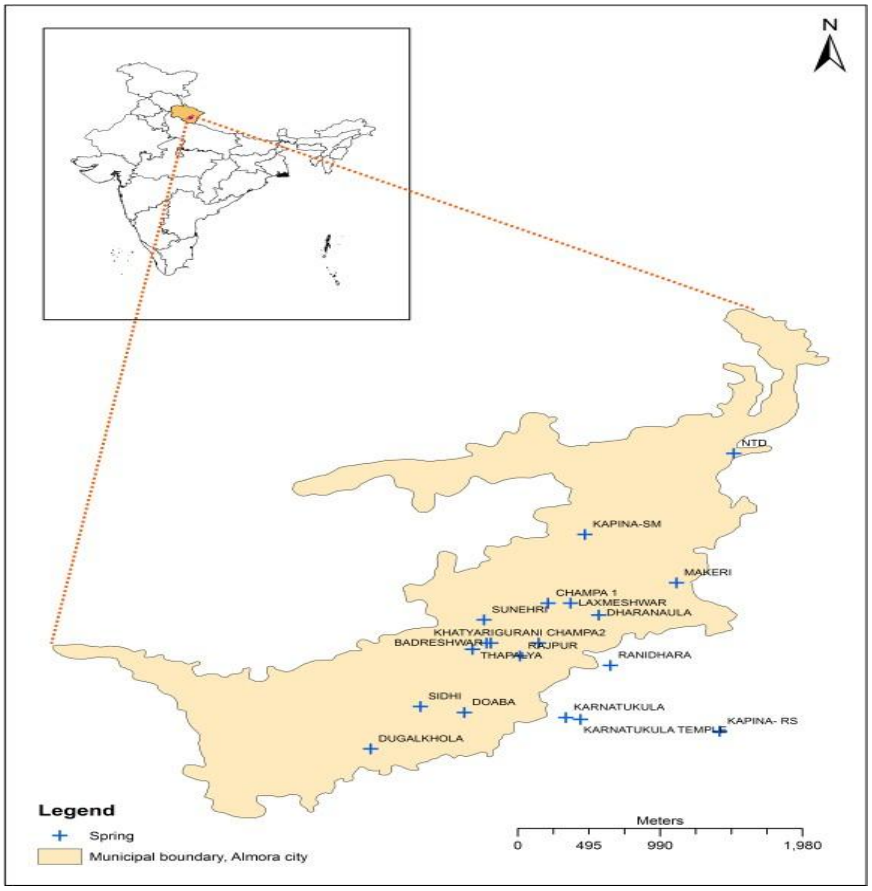


Fig 4.1 Map of Almora town specifying the sampled springs

SN	Names of springs	LAT/LONG	Elevation in mts
1.	THAPALYA	29°35´47.8´ 79°39´20.7"	1580
2.	BADRESHWAR	29°35´49.8´ 79°39´24.8"	1581
3.	GURANI	29°35´49.8´ 79°39´24.8"	1550
4.	CHAMPA 1	29°36´02.5´ 79°39´37.7"	1567
5.	CHAMPA2	29°35´49.8´ 79°39´35.6"	1555
6.	RAJPUR	29°35´45.7´ 79°39´31.4"	1542
7.	KHATYARI	29°35´49.8´ 79°39´24.8"	1450
8.	NTD	29°36´50.2´ 79°40´19.5"	1640
9.	SUNEHRI	29°35´57.2´ 79°39´23.3"	1531
10.	SIDHI	29°35´29.6´ 79°39´09.0"	1622
11.	DOABA	29°35´27.7´ 79°39´18.9"	1571
12.	DHARANAULA	29°35´58.7´ 79°39´49.1"	1535
13.	DUGALKHOLA	29°35´16.1´ 79°38´57.8"	1585
14.	MAKERI	29°36´09.0´ 79°40´06.6"	1479
15.	KAPINA- RS	29°35´21.7´ 79°40´06.6"	1471
16.	KAPINA-SM	29°36´24.4´ 79°39´46.0"	1504
17.	KARNATUKULA TEMPLE	29°35´25.5´ 79°39´46.0"	1477
18.	KARNATUKULA	29°36´26.1´ 79°39´41.7"	1445
19.	LAXMESHWAR	29°36´02.5´ 79°39´42.8"	1480
20.	RANIDHARA	29°35´42.7´ 79°39´51.7"	1593

Table 4.1 The latitudinal and longitudinal positioning of the springs of Almora

Spring 1 Thapalya Dhara

Thapalya dhara is located in the densely populated area (on western slope) of the town. Concentration of nitrates was found upto 61.8 ppm in premonsoon season. The main reason for high nitrate can be intrusion of contaminated surface water into this spring resulting from unplanned sewage disposal through open drains located above the springs as well as nearby vicinity. In monsoon season, rain water gets mixed up with the sewage and reaches the spring in the form of percolation from walls of the well which also contributes nitrogenous compounds.

These compounds are converted into nitrates by bacterial action. Presence of organic matter can be indicated by decreased BOD is 3.2 mg/l. Increase in BOD in monsoon again indicates enhanced percolation of surface water having high organic matter content. Total coliform as MPN was recorded as 320per 100 ml in summer. High chloride concentration of 121.4ppm with sulphates and calcium (22.2ppm and 93.7ppm respectively) makes the water of this spring comparable with the water of Rajpura dhara located on eastern slope at nearly the same altitude.

This indicates the possibility of the same spring line across the hill having similar bed rock composition. In general, the spring water chemistry has shown certain trends indicating the influence of percolation of surface waters and base flow through rocks. The concentration of nitrates was found high upto (60ppm) in the springs located in the midst of the thick population namely Thapalya and Rajpura. It is widely recognized that groundwater polluted with nitrates is spreading worldwide (Veda et al 1993).

Spring 2 Badreshwar dhara:

Badreshwar dhara is located just above the Thapalya dhara and is surrounded by dense population nearby with one side the passage of the mall road which is busiest road of the town. Hence more exposed to the pollution and contamination of the spring. Although VIPKAS has taken initiative to conserve the dhara by some plantation nearby and covering the source so that immediate contamination could be restricted and also cleaning the immediate vicinity of the spring. Although the effort is appreciable but the effort seems same as just wrapping the thing with good cover with the product within getting rotten and damaged. The effectiveness of conservation could be more if the aquifer could be restricted from contamination.

Spring 3 Gurani Naula

The name Gaurani naula comes from the community that has resided in the surrounding of the naula for decades. This Gaurani community people since are dominant in the area have named the naula as Gaurani naula. This naula is again surrounded by open drains which carry waste water from the various houses located above and nearby the naula, along with most of the houses having septic system of sanitation.

The open drains that carry waste water from the kitchens and bathing rooms also serve as good source of dumping the solid waste. Hence this Gaurani naula is no more considered fit for drinking.

Spring 4/5 Champa Naula 1/Champa Naulaa 2

Both the Champa naulas lie in the very same elevations with a little distance apart .Both the naualas are crowded with clustered buildings and population. On the conservation with the local people nearby the naula it was prominent that the water from the springs is used only when the population faces scarcity of water. The town receives water through pumping system al through the year but during summers as well as rainy season the supply water is restricted for days together. Hence the population in the vicinity depends on this spring for their water requirement. The naulas are not fit for drinking and are otherwise used for other domestic purpose.

Spring 6 Rajpura Dhara

Rajpura dhara is located on other side of the town and is surrounded with most densely populated community. The spring is named as "Rajpura dhara" due to its location in Rajpura.The open drains and dumping of the waste is common above as well as in the vicinity of the dhara. The sulphate and nitrate content of the dhara is 69 mg/l in summers which is at the alarming condition.

Spring 7 Khatayri Nauala

This naula is used only for domestic purpose and not used for drinking at all in any season. This is an unused naula and not used even when the local population is facing scarcity of water in rainy and summer season. The contamination level has reached to this level that it is not even used for domestic purpose. This naula is generally used for quenching the thirst of animals.

Spring 8 NTD dhara

The image is showing the vicinity of the dhara, which is located just next to the open drain full with solid waste dump as well as waste water. The flow of the dhara has also decreased which is confirmed with the conservation from the local people.

Spring 9 Sunehri dhara

This dhara is used for drinking and is located in the midst of the town. Some of the springs of the town are named after their location and some of the springs are responsible for the names of their respective locations.

However, this spring is named as "sunehri dhara" irrespective of its location. This is a protected spring and is used for drinking water source. The spring is located near Tilakpur drain which takes major share of untreated sewage from central part of the town. This drain is partly lined with cement concrete. Even then the possibility of seepage from the drain cannot be denied. There is sudden increase in sulfides during monsoon.

Conversion of sulfates into sulphides is possible which should be maximum in summer. In this case, these changes were observed in monsoon season and it indicates that conversion of sulfides is not responsible for increase in sulfides. Sewage may be responsible source of sulfides in water. Calcium and magnesium concentration, are however found very low in winter when sulfate concentration was maximum.

Spring 10 Sidhi naula

This naula is situated at highest altitude of the town and is of high religious value. Since the naula is situated at the highest altitude it is considered to be the spring of highest purity of the water. The spring is widely used for drinking and people from the vicinity depend on this spring for quenching their thirst. The spring has religious value and is worshipped and is situated within of the temple premises. This is a conserved naula and the naula is taken care and maintained by the Cantt personnel nearby. As the naula is situated in the cantonment area of Almora. The people are also made aware for keep the naula clean. The comparison of the water quality made by the analysis made by in 1991 and now in 2018-2019, it is evident that the water quality has detetoriated with most of the parameters but still within permissible limit and is within the permissible limit although.

Spring 11 Dharanaula/ Spring 12 Doaba naula

The locality gets the name from the naula dharanaula and is named dharanaula as the spring is actually a dhara which falls in a pit like structure as naula hence the name comes dhara and naula. People use this spring for drinking purpose .Even the water consumption is met by inserting a small pipe in the naula and pumping the water to the houses. Hence this naula supports huge consumption of water in the houses nearby**.**

Daoba nuala is an unused naula and lies within the temple premises. Hence is used only for religious purpose. However people in very scarcity of water mostly during summer season depend on this naula for water. The naula was seen by dumping of religious objects as flowers god goddess statue and many other worshipping rituals substances.

Spring 13 Dugalkhola

Dugalkhola is a conserved spring and is covered as well as locked well so that the foreseen foreign contamination could be restricted. This spring is located diagonally just below rajpura dhara and is a conserved spring.

The spring is completely covered and locked to protect it from immediate contamination whereas as the picture suggests a concrete drain flows just next to the spring. The water of the spring is used by the people nearby for cooking, drinking and other domestic purpose.

Spring 14 Makeri naula

This spring is located in the midst of the town and is clustered with drains flowing in the entire surrounding .The clusters of buildings around makes the quality of the water of the spring more vulnerable. The walls of the springs are painted with the fact that people are aware of the contamination of the water and have given as a caution that "**Paani ko ubaal kr piyen**".and also that a disclaimer that "Do not pollute the Naula". The cautions and disclaimer are invain when the conservancy system of sanitation is followed by all the houses in the dharanaula area and also the drains flowing all over the neck of the springs. This scenario brings the entire existence of springs under threat that if the situation prevails Almora will hardly be left with any water source fit for drinking.

Spring 15 Kapina dhara/ Spring 16: Kapina dhara SM

The kapina dhara is located just at the road side of the kosi almora route and is prominent source for drinking in the vicinity for the local people. The conservation with the people reveals that although water doesn't taste that well but people are forced to drink that water during water scarcity in summers. As the dhara has good flow of water the conception that the water would be of better quality prevails in the local people. The other dhara lying in the same region is Kapina sher mukh dhara which derives its name as the outlet of the dhara comes from a lion faced structure which gives it the name in the local language.

Spring 17 Karnatakula naula/ Spring 18 Karnatukla dhara

Both the springs are separated with the maid road of Kosi Almora .The spring 17 lies in the higher altitude whereas spring 18 lies in the lower altitude separated by the road. Both the springs are named after the locality it lies in. is used for drinking purpose although the upper and lower vicinity of the naula is heavily clustered with the concrete buildings and also the vicinity of the naula has the drain of concrete lining which carries the waste water of the upper locality near to the naula. The naula is highly contaminated and shows high values of MPN, nitrate and sulphate .DO of the naula shows considerable decrease in monsoon season.The karnatkula dhara which is situated at the lower ridge is used for drinking purpose.

Spring 19 Lamexwar

This is the spring which is no more used for drinking purpose. This is an ideally left spring which must be not even used for animals and folks. This spring is named on the locality it is situated in and has religious value as situated within the vicinity of Laxmeshwar temple The MPN values of the naula was 250-300 colonies and was found contaminated microbiologically**.**

Spring 20 Ranidhara

This is a protected spring and is locally known as Ranidhara and is located on the northern part of the town and locality owes its name to this spring. This spring was thought to be among the least affected by human activities due to its high location (1675m.s.l). But, this was not found to be true considering the presence of nitrates and sulphates. The MPN values in monsoon season are also above 110-130 colon

Plate: Springs of Almora and its vicinity

Dugalkhola

NTD

Rajpura vicinity

Dharanaula

Karnatakhola

Kapina vicinity

Ranidhara

Champa naula

4.3.2 Site selection for surface water analysis

The site selection is based on surveys and referring to the project IV which has proved to be torch bearer for isolation of the points in the entire stretch of the river Kosi. Hence all the 31 sampling points were selected for analysis in for the entire year to see the variations in the water quality of the stretch (Table 4.2). The water quality analysis of the current year to the previous year was compared for concluding the contamination levels of the points and selection of the points was made on the basis of the variation in the contamination levels in the entire stretch of the river Kosi. All the sampling points in the entire stretch was sampled and analysed for three seasons in the entire year

S.N.	Sampling station	Lat./Long
1	Katli pump	
2	Chanauda pul	29^0 48' 41.36" N
3	Sair river	29^0 46' 38.58" N
4	Kosi river at Someshwar (after confluence with Sair river)	29^0 46' 36.27" N
5	Kosi river near Harkhet water pump	29^0 45' 4.99" N
6	Saukhet gadhera, Patlibagar	29^0 40' 22.52" N
7	Kosi river, Patlibagar (after confluence with Saukhet gadhera)	29^0 40' 19.28" N
8	Nakot Gadhera (Devasthal)	
9	Kosi river, Devasthal (after confluence with Nakot gadhera)	
10	Nana-kosi river before confluence	29^0 38' 22.07" N
11	Kosi river (after confluence with Nana-kosi river))	29^0 38' 13.99" N
12	Sail-Jamthar gadhera near Shiv temple, Kosi	29^0 37' 48.24" N
13	Kosi river at Almora water pump	29^0 37' 38.00" N
14	Khoot Gadhera	
15	Almora Pandeykhola gadhera at Tungreshwar	29^0 36' 23.72" N
16	Kosi river near Pharka (after confluence with Almora gadhera)	29^0 36' 18.27" N
17	Suyal river, Quarab	29^0 33' 08.13" N
18	Kosi river (after confluence with Suyal river)Quarab	29^0 33' 07.48" N
19	Sarod River, Kakrighat	
20	Kosi river, Kakrighat (after confluence with Sarod river)	
21	Shipra river, Khairna	29^0 29' 44.67" N

22	Kosi river at Khairna (after confluence with Shipra river)	29^0 29' 52.42" N
23	Kujgar river, Bhujan	29^0 30' 41.45" N
24	Kujgar river, Bhujan (after confluence with Kujgar river)	29^0 30' 37.65" N
25	Kosi river Baderi pul/baderi water pump	29^0 30' 47.25" N
26	Kosi river, Ratauri pul	29^0 32' 39.48" N
27	Kosi river, Betalghar pul	29^0 33' 24.91" N
28	Kosi river at Seti pul, Betalghat	29^0 33' 42.41" N
29	Kosi river at Kumaria pul	29^0 32' 11.63" N
30	Kosi river, Garjia temple	29^0 29' 42.14" N
31	Kosi river near Ramnagar bairaj	29^0 24' 0.65" N

Table 4.2 Longitunal and latitudnal positioning of 31 sampled points in entire stretch of Kosi river

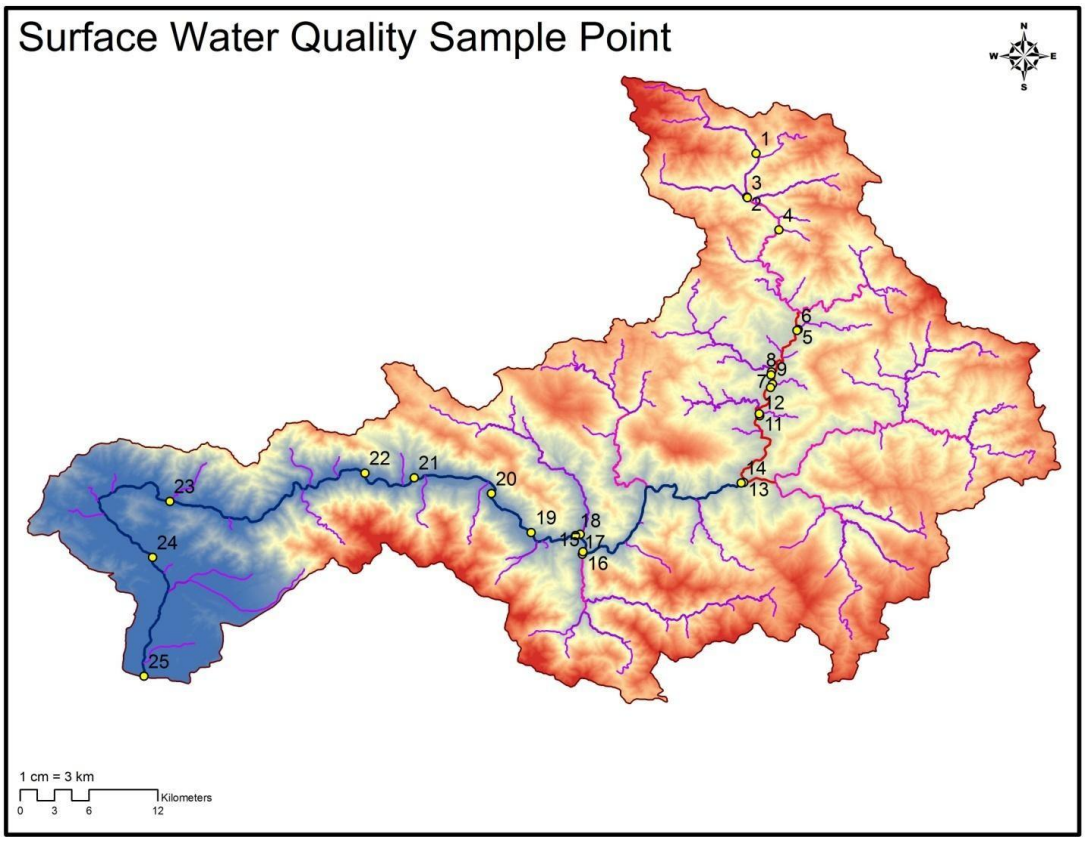


Fig 4.2 The depiction 31 sampled points in the Kosi river

4.3.3 Site selection for the points for the model execution

The site selection for the model execution was carried out with proper identification of the sampling sites.(Fig 4.3) The selection of the points was given proper dedication of entire one year.

The 31 sampling points was selected on the basis of previously selected points by project IV. These 31 sampling points helped to select the four sampling points on the basis of results of these 31 sampling points.

Hence the site selected for the entire stretch of Kosi river from its originating point in Kantli along with its a few merging springs into the main river at the various points of the entire stretch are as follows.

(1)Kantli

(2) Kosi barrage (before the river crosses Almora)

(3)Kwarab (After the river/ its merger springs crosses Almora)

(4) Ramnagar (Point where the river merges Ramganga).

Field studies and data collection

Hydrodynamic Data: Field studies include both hydrographic survey and water quality survey. The field characteristic decides the way of data collection .As the sampling points are of three types in the project. The naulas that are stagnant springs, dharas that are flowing springs and river Kosi which originates due to mergence of various springs into the river. The data collection for the flowing springs and stagnant well structured springs were done by grab sampling.

The data collection from the flowing river Kosi was done daily which was again grab sampling. The hydromet data was collected from the various sources as well as sensors present in the sampling points

4.4 Details of scientific data collected and equipments used

The whole process for the collection of the data comprises for the following process. The scientific data for the collection of the project includes various status for the fulfillment of the project. The sampling is the most important aspect of the project which requires precautions as sampling ultimately fetches to get the authentic values for the model input parameter. The major aim of selecting the water quality model is to show the prediction of the water quality of surface water as well as take preventive measures for the environmental management. Varied types of water quality are suggested both for surface as well as groundwater each model having its own benefits and limitation. Hence it is essential to select the model which goes well with the study area and fulfills all requisites.

The foremost important role of hydrological models are that these are applied for supervision, scheduling and pollution control. Each of the models has different characteristics and requires different state of assurance in the model output.

In the view of the fact that surface water quality since 1925 has undergone Since 1925, surface water quality models have undergone important three stages of development, of which in the first stage that lasted from 1925 to 1965 the prime focus was maintained in focusing various components of the river system such as hydrodynamic transmission, algal photosynthesis and respiration as well as the oxygen demand of the sediments. These models were not as precise as now since were one dimensional steady state models and the most

commonly used models were BOD-DO model for water quality prediction. Then came the second stage which ;lasted from 1965 to 1995 which proved to more precise and efficient than the first stage model in which researchers could include zooplanktons, phytoplankton and N,P cycling system along with DO and BOD. Hence this proved to be the stage of rapid development era for model.

Then came third stage of development after 1975 in which three stages of model was developed which stated sediments as important elements to be considered for the interaction in the environment. From 1995 onwards the scope of the third stage model was further broadened and it included fuzzy logy. Neural networks, artificial intelligence, genetic algorithms and support vector machines. These models hence proved efficient in with the rapid growing pollution, cities, towns and ultimately the economic growth. Hence these models assisted government in taking steps to manage the pollution.

Here model WASP is selected as for water quality analysis for reason being it does not have limitations with just point sources or is not a one-dimensional model. With rather more benefits and less constraints it is most widely used water quality analysis model that is suggested by EPA (Environmental Protection Agency).WASP is a 1,2, and 3 dimensional dynamic model. At present 8 versions of WASP is available and can be easily downloaded for free from EPA website.

The website reading http://www.epa.gov/athens/wwqtsc/html/wasp.html. In this research WASP 8 is used as descriptive version for the water quality analysis in the selected area. WASP systems are developed that comprises of ammonia, phosphate nitrate, phytoplankton, BOD, DO, organic nitrogen. It is used in analyzing various water quality analyses in various diverse water bodies as ponds, streams, lakes, rivers, estuaries, and coastal rivers.

WASP has a benefit to get linked with various other sediment and hydrodynamic transport models that which provides flows, depths, velocities, temperature, salinity and sediment fluxes. The most recent version of WASP 8 comes in general two kinetic modules as TOXI for toxicants for toxic substances in the water body whereas EUTRO for conventional water quality analysis to solve predictable conventional pollution as DO,BOD, nutrients, and eutrophication and toxic pollutants as organic chemicals metals and sediments. WASP utilizes the conservation of mass and momentum equation to determine the hydraulic characteristics employs the conservation of mass

and momentum equations to determine the river hydraulic distinctiveness as depth , velocity, width of the upstream and also the flow rate of the river or any surface water body) .The

complete procedure for the working of the model was given by (Di Toro et al., 1983; Connolly and Winfield, 1984; Ambrose, R.B. et al., 1988) and likewise continuously version enhancement and up gradation was continuously carried out with latest version 8 that would help people to interpret as well as predict the quality of water with the changing man made as well as pollution schedules in the environment. The model is helpful in various aspect as it is multidynamic model and allows to investigate in 1,2 and 3 dimensional systems.

The time dependent process as flows, depth, temperature, velocity can all be linked with the model and hence the user finds it convenient and easy to handle.

The entire WASP is classified into 3 major categories:

4.5 WASP model and its features

WASP 8 is a dynamic model that can fairly simulate water quality in various different water bodies as lakes, rivers, estuaries pond in 1,2 and 3 dimension[Ambrose et al., 1988]. Hence WASP 8 is considered to be a dynamic and compartment modeling program

WASP 8 constitutes two sub models for kinetic interaction of eutrophication, dissolved oxygen and sediment toxic chemicals interaction. EUTROWASP and TOXIWASP are the two sub model in which the model is divided.

The requirement of hydrodynamic characteristics is of the water body simulated in standalone program DYNHYD-8, while WASP8 simulates the movement and interaction of pollutants within the system.

The hydrodynamic model DYNHYD3 was employed in conjunction with WASP3 to simulate hydrodynamics of the estuary driven by variable tidal cycle.

The eutrophication model studies all the various eutrophication variables as P cycle, cycle, DO, phytoplankton kinetics. Hence it simulates all the eutrophication parameters. The linking of kinetic sub model for eutrophication constitute Eutrophication model and can be used in conventional state variables as Nitrate, BOD, DO , and Total Kjeldhal Nitrogen(TKN)

WASP MODEL Framework

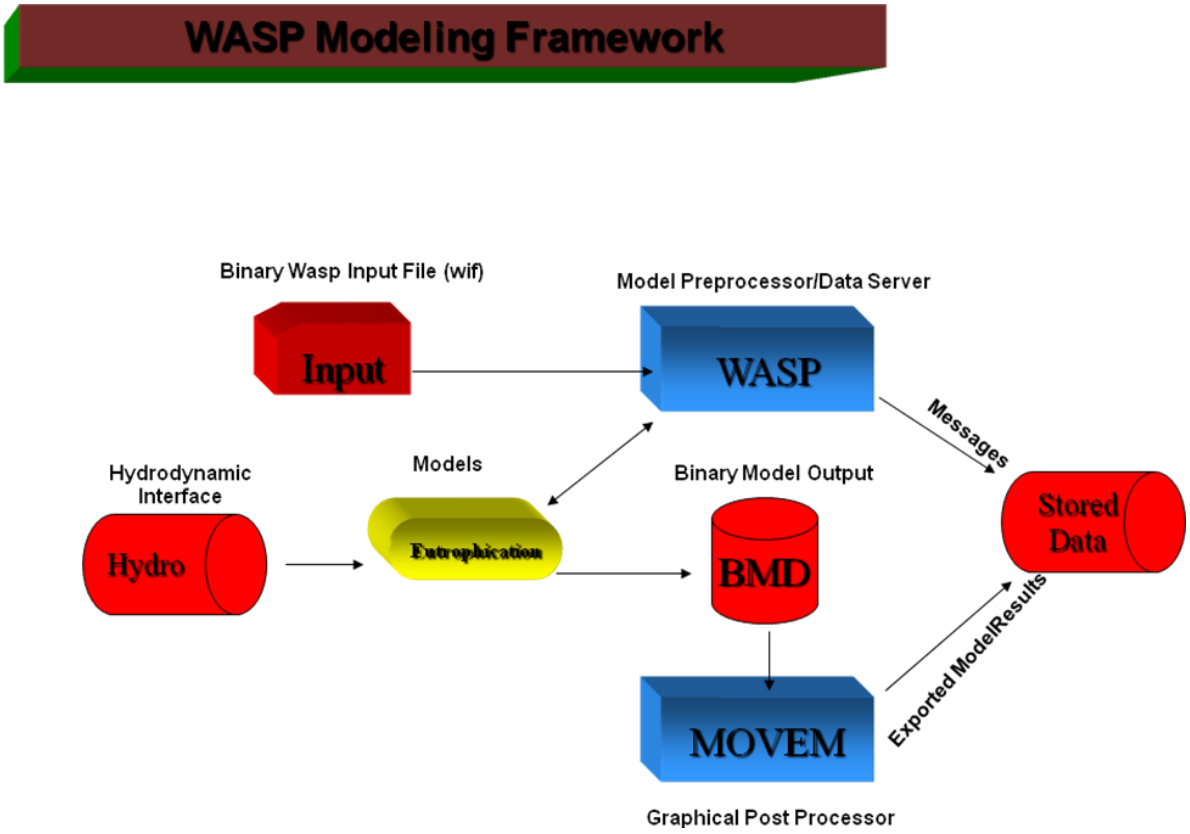


Fig 4.3 Flow chart of WASP model

TKN) For example Seng (1995) presented the application of WASP-EUTRO5 model to analyze the eutrophication and phosphorus control alternatives for Lake Pepin. Martin *et. al*(1992].

The WASP model operates in the above depicted diagram (Fig 4.3).

First comes the input data. The input data is all the constraints related to the model demanding objectives. This is fed into preprocessor. The parameters are interchangeable with the eutrophication model which ultimately helps in generation of BMD file and which along with post processor helps in generating the simulated data.

Hydrodynamic interface includes various parameter related to hydrological data as length, width, depth velocity of the water body

The flexibility afforded by the Water Quality Analysis Simulation Program is unique. WASP 8 permits the modeler to structure one, two, and three dimensional models; allows the

specification of time-variable exchange coefficients, advective flows, waste loads and water quality boundary conditions; and permits tailored structuring of the kinetic processes, all within the larger modeling framework without having to write or rewrite large sections of computer code.

The two operational WASP8 models, TOXI and EUTRO, are reasonably general. In addition, users may develop new kinetic or reactive structures. This however requires an additional measure of judgment, insight, and programming experience on the part of the modeler. The kinetic subroutine in WASP (denoted "WASPB"), is kept as a separate section of code, with its own subroutines if desired.

The WASP8 system consists of two stand-alone computer programs, DYNHYD5 and WASP6, which can be run in conjunction or separately. The hydrodynamics program, DYNHYD5, simulates the movement of water while the water quality program, WASP8, simulates the movement and interaction of pollutants within the water. While DYNHYD8 is delivered with WASP8, other hydrodynamic programs have also been linked with WASP. RIVMOD handles unsteady flow in one-dimensional rivers, while SED3D handles unsteady, three-dimensional flow in lakes and estuaries (contact CEAM for availability).

WASP 8 is supplied with two kinetic sub-models to simulate two of the major classes of water quality problems: conventional pollution (involving dissolved oxygen, biochemical oxygen demand, nutrients and eutrophication) and toxic pollution (involving organic chemicals, metals, and sediment). The linkage of either sub-model with the WASP 8 program gives the models EUTRO and TOXI, respectively. The tracer block can be a dummy sub-model for substances with no kinetic interactions.

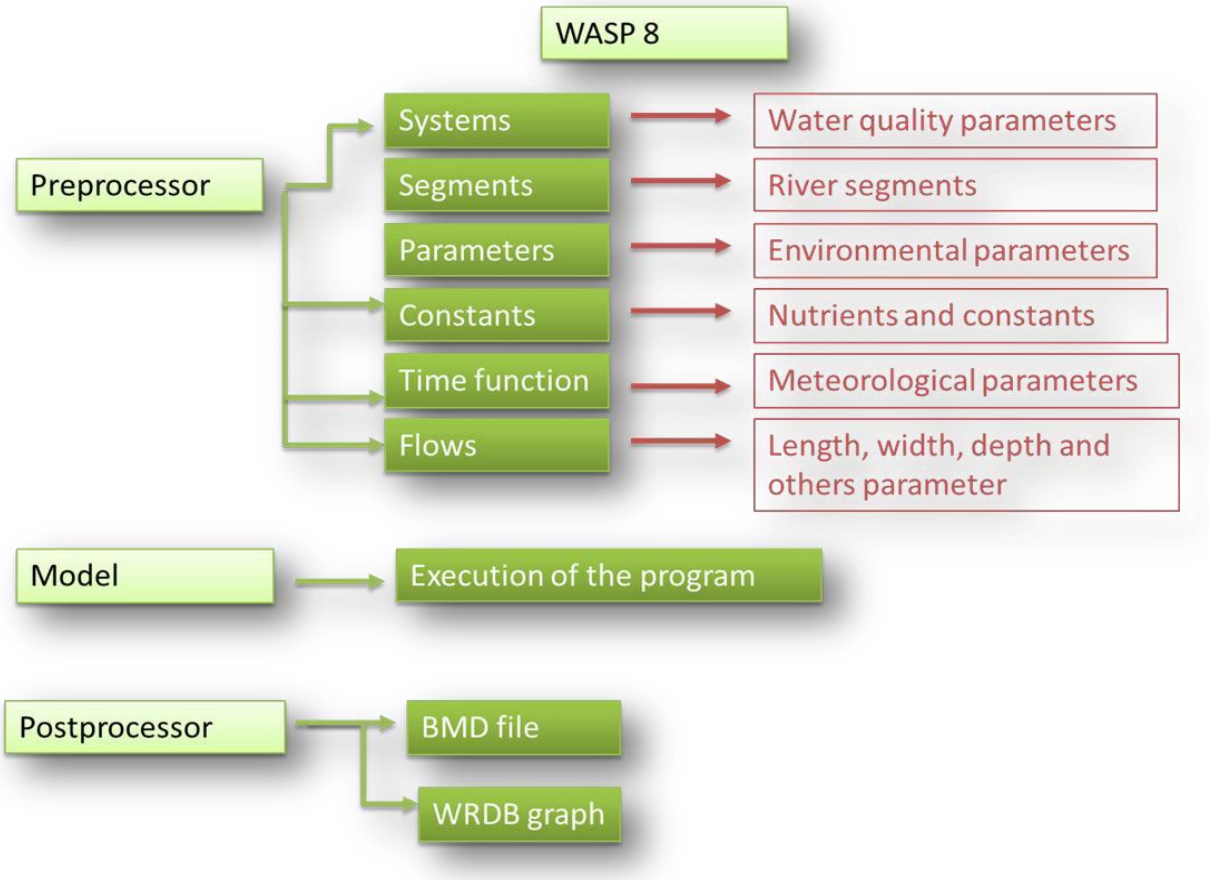


Fig 4.4 Flow chart for WASP 8

WASP Pre processor

The data preprocessor allows for the rapid development of input datasets. The ability to bring data into the model is as simple as cut and paste or queried from a database. The preprocessor provides detailed descriptions of all model parameters and kinetic constants. When linking WASP with hydrodynamic models it is as simple as pointing to the hydrodynamic linkage file. Import time series from WRDB.(Fig 4.4)

The preprocessor involves systems which is a complete set of water quality parameters that is collected from the field. The data set generated for my concerned interaction with the model is BOD, nitrate and DO. This data set was generated for months from May 2019 to December 2019. The selected stations were Kantli, Kosi barrage, Kwarab and Ramnagar. All the stations were hence selected that the entire Kosi watershed area would be covered and simulation of model would be for entire watershed.

1.	Spreadsheet
2.	Text files
3.	Automatically import hydrodynamic information
4.	Multi session capable
5.	Runtime diagnosis

Table 4.3 Process for pre processor details of the model

The data for water quality was done as for daily sample collection for the entire stretch, which proved a very tedious task. Hence the training of the local people that one who was allocated for collecting the sample from the station daily at one particular time for collection of samples meant for daily sample collection was done and executed.

River segments: Was another data set to be generated for the preprocessor which meant to describe the segments length, width, depth, in the selected stations. The river segments varied with little fluctuations with the change in the season**.**

Environmental parameters: The environmental parameters that were considered time duration for which the model was simulated, the environmental conditions suggested at that time

Nutrient constants: The nutrient constants are the parameters that are asked by the model. The nutrient nitrate is asked for many constants which was filled accordingly with major calculations.

As for nitrate denitrification constant. The major parameter focused was nitrate as the springs in Almora showed nitrate contamination. So in order to see whether the river Kosi is recharged well with nitrate this nutrient was focused in with for model output.

Meteorological parameters: Involves all the parameters as rainfall, solar radiation, dew point, humidity for the proposed period of time that was considered for model simulation.

Flow: the flow constraints included depth, width; length of the river for the selected station. This was a mechanical derived data, which was collected seasonally.

WASP Post Processor

The Post-Processor (MOVEM) provides an efficient method for reviewing model predictions and comparing them with field data for calibration. MOVEM has the ability to display results from all of the WASP models as well as others. MOVEM allows the modeler to displays the results in two graphical formats

Spatial Grid—a two dimensional rendition of the model network is displayed in a window where the model network is color shaded based upon the predicted concentration.

x/y Plots—generates an x/y line plot of predicted and/or observed model results in a window. There is no limit on the number of x/y plots, spatial grids or even model result files the user can utilize in a session. Separate windows are created for each spatial grid or x/y plot created by the user.

Uncertainty is an inevitable component of all predictions in EIA. The extent of uncertainty that invariably creeps into all predictions will depend upon the quality of data and type of models used. Two types of uncertainties play a significant role in EIA: the uncertainty at the level of prediction and at the level of elements of EIA approach.

Mathematical models are widely employed in the prediction of the quality of all major components of environment, viz., Air, Water, and Land in the EIA process. It is essential that all such models are required to calibrated in order to minimize the errors. Hence calibration and validation is important step to that all such models are needed to be calibrated in order to minimize the sources of error in EIA. Hence two process as calibration and validation of these predictive models is an effort in this path to minimize error

Calibration and Validation

Since the notion of "TRUE" model is "FICTION" for real life Applications, "USEFULNESS" rather than "TRUTH" should be the guiding principle of any modelling and calibration exercise, in order to place any credibility on the utility of the model. Unless otherwise such "degree of acceptability" or "degree of usefulness" is established any modelling effort will turn out to be a futile exercise .Errors in Modeling Generally errors creep into the model in three ways:

The errors are the major drawback that our models face while simulating and hence the results obtained would be altered. Hence in order to avoid various errors as model error

from input, parametric error, and model error calibration is essential.

Input error is error that results from inputs that are provided to the model and can evolve due to measurement, concurrence or due to harmonization of the data. The parameters for the model are generally highly interdependent and unique and this the probable reason why most of the models need calibration. The input error, model error and the parametric error together is termed to be as simulation error.Since the model involves a multiple process hence the multiple process simulation models is a process which further extends into the error between the model components.

Hence calibration process could be summarized as the process in which the model parameters or structures are determined on the basis of precedence knowledge. In order to calibrate a model in a given time for solute transport models, field concentrations can be fairly used until good enough simulation is achieved by hence adjusting the model parameters values frequently. After this calibration goes a robust then another simulation is executed and is hence compared with second measured data. After it is clear that the second simulation goes well with the first simulated data then the model is considered to be validated. Also that the model parameters are not adjusted based on the field observations and if the parameters are adjusted following the calibration, then the effort would be recalibration in contrary to validation.

Verification – Validation is ground truthing of the calibrated of the model in different environmental conditions to further examine whether it similarly shows fluctuations the changed environmental conditions. (Like, river flow or external load) to further examine the validity of the mode. Validation is to test that the designed calibrated model is applicable to limited range of conditions proposed by calibration and validation of the data sets. The collection and validation of the model needs to be done in wide range of conditions over which the prediction is required. The data collected should be such that it covers the range of conditions upon which are predictions are desired. Hence the calibration data should be impendent from validated data. The model hence verified could be fairly used for the prediction of water quality in agitated environmental conditions.

These input parameters helped generation of BMD file and with the help of post processor the simulation curve was obtained by the model for the prescribed time duration.

Input parameters for the model

The parameters required for the model simulation is classified into following generic groups. Model identification parameters: Which states the segments and state variables required for simulation.

Transport parameters: Detailed modeling network of segments with similar advective and dispersive fluxes. As cross section , length, depth

Transport Kinetic parameters: specific to state variables as deoxygenating rate, reareation rate being simulated which requires initial and final conditions. Initial condition refers to the values before simulation.

Simulation parameters: Include integration time step, advection factor, initial time, final time,and maximum and minimum concentrations.

The below pictures reveals the complete working of the model with description and period specific fluctuations in the parametric constraints asked by the model

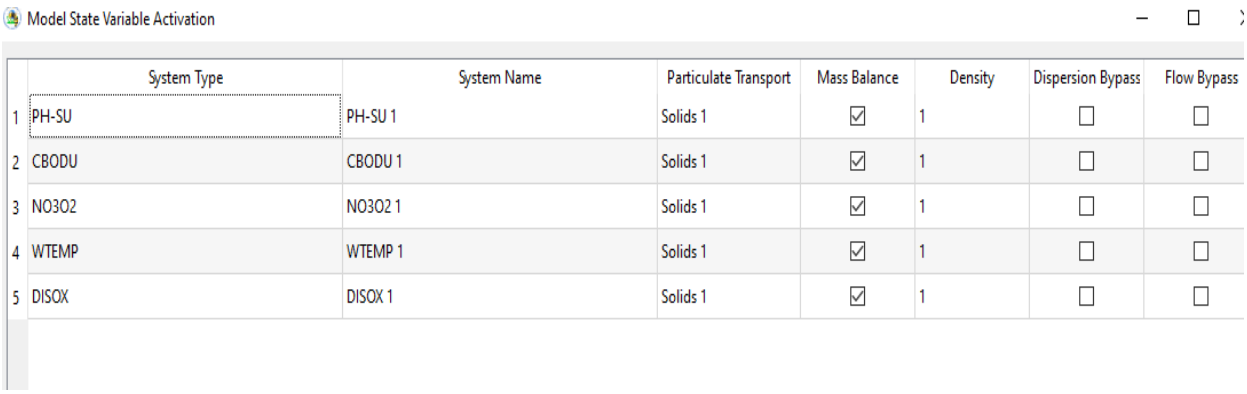
State variable Environmental parameters: The state variables includes the parameters that are selected for model execution

The picture selected (Fig 4.5) while the model simulation specifies the state variables required. These parameters vary for different users as it depends upon the parameters that user has selected for simulation. The direct interaction of segment parameter information with the scale factor screen is observed. Hence it is user specific segment in which user need to select the parameters.

The segment parameter information interacts directly with the Parameter Scale Factor screen. Few of the parameters are used to define specific information whereas others are used to point to environmental time functions as temperature.

The spatial and temporalvariations are defined well by environmental time functions as that are bacteria concentration, temperature water velocity: temperature, water velocity, pH, and bacteria concentration.

State Variable Activation



	System Type	System Name	Particulate Transport	Mass Balance	Density	Dispersion Bypass	Flow Bypass
1	PH-SU	PH-SU 1	Solids 1	☑	1	☐	☐
2	CBODU	CBODU 1	Solids 1	☑	1	☐	☐
3	NO3O2	NO3O2 1	Solids 1	☑	1	☐	☐
4	WTEMP	WTEMP 1	Solids 1	☑	1	☐	☐
5	DISOX	DISOX 1	Solids 1	☑	1	☐	☐

Fig 4.5 State variable activation inputs in model WASP

Since WASP 8 is a dynamic model hence it is essential to describe initial condition for each and every variable of every segment. The initial conditions include the values before the simulation has begun. The resultant of the pioneer concentrations as well as the initial volumes provides the part of the masses for each segment. For the selected study area if for the steady simulations where flow and loadings are kept constant and if steady state response is the necessity then it is required then the final concentration needs to same as initial concenteration.Whereas for dynamic simulations the transient concentration response is the requirement then the initial concentration is to be entered into the model before stating of the simulations.

Along with this the chemical concentration the other requirement is to specify the dissolved concentration at the beginning of the simulation for every segment. Tracers need to be set the value as 1 as default. For Dissolved oxygen for eutrophication and sediment transport the initial value for dissolved fractions remains constant for the complete simulation process. For rest of the contaminants the fraction dissolved is computed based upon user specific partitioning relationship

Segment Specification

The boundary concentrations is required for every segment that is receiving the input,outputs or any exchanges from outside the network of the model. As soon as the transport pattern is defined the model automatically determines its boundary segments

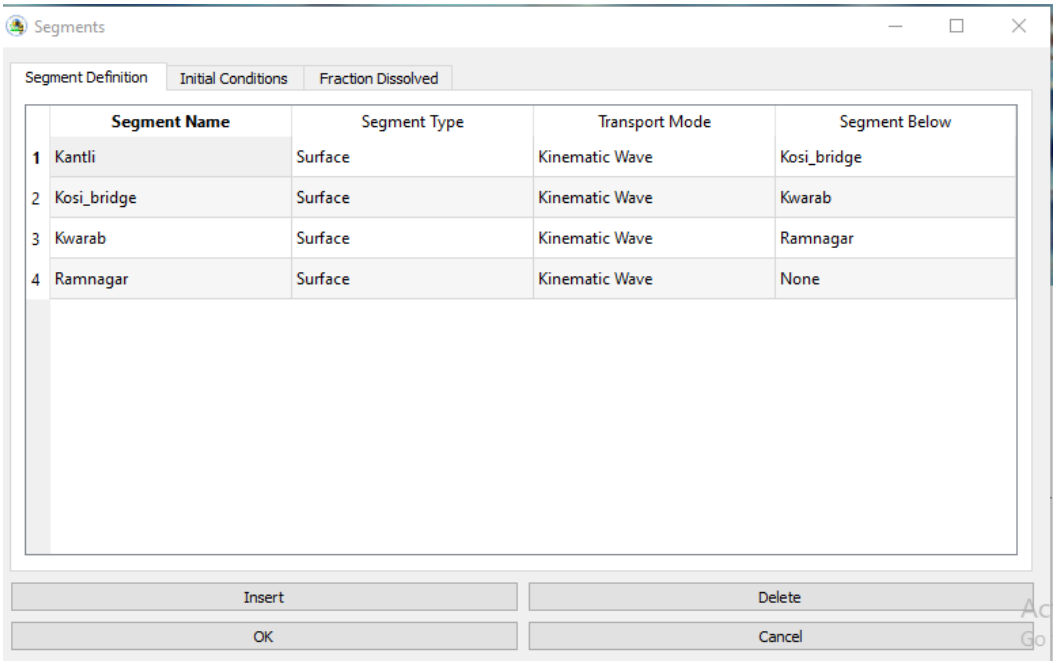


Fig 4.6 Segment specification input for model WASP

Hence it is mandatory to first enter the transport information and only then the boundary condition can be entered. WASP 8 is the model that operates only when the boundary information of every system of the segment that needs to be simulated is defined. Hence in order to state a boundary for a system, boundary is selected that a boundary needs to be specified and right click on the system.(Fig 4.6)

WASP8 by itself and default names the segments by number 1 along with permitting the user to name every segment. In order to facilitate the user the alphanumeric names are given to the segments so that it would be easy to isolate in post processor by the numbers alone. As soon as a segment is inserted WASP by itself names it as per previously given input. Later on simply highlighting cell the number could be changed into names.

Volumes: It is the section in which the volume of the segment is self calculated. The volume of the segment is classified into cubic meters unit. This column represents the volume of the segment that is being defined. The units for volume are cubic meters.

Water Velocity/Depth: The velocity and depth can also be held constant for steady state section by setting the exponent values to zero. As the selected section for the selected study area is dynamic hence I have entered the values of depth and velocity as varying function

with the flow. Hence have also provided the depth and velocity multiplier and exponent. The velocity (m/s) is computed from the formulation aQ^b while the depth (m) is computed from cQ^d , where a & d are coefficients and Q is the flow (m^3 /sec). Segment Type WASP 8 supports four different segment types.

There are four different segments of WASP 8. And hence it is essential to define the segment precisely.

1. Surface Water Segment – The segment that is exposed directly to the atmosphere and is immediate part of the river body to get reareation.

2. Sub-Surface Benthic Segment – The segment that is present just beneath the surface segment of the water body.

3. The bottom segment is that segment of the water body which does not any other segment after that. It is generally used in for transport calculations and hence is also known as for to define optical light path.
4. Sub-Surface Water Segment – This water segment of the water body that does not have an atmospheric surface.
5. Surface Benthic Segment – This segment is also known segment that is just above the benthic segment.

Environmental conditions

Environmental parameters can be defined as the sections which needs to be selected for the entry of meteorological parameters. In my model simulation the segments selected here involves(Fig4.7)

1. Temperature of segment
2. Solar radiation multiplier
3. Solar radiation time
4. temperature of segment

5. Pointer to air temperature
6. Wind speed multiplier
7. Pointer to wind speed time function
8. Dew point temperature multiplier
9. Pointer to dew point time function

These parameters are selected on the basis of the functions prescribed by the model , selection of the model whether dynamic or steady state and the concerned meteorological parameters affecting the water quality of the study area selected. The scale factor is selected 1 for all the selected segments of the model as per the requirement of the model

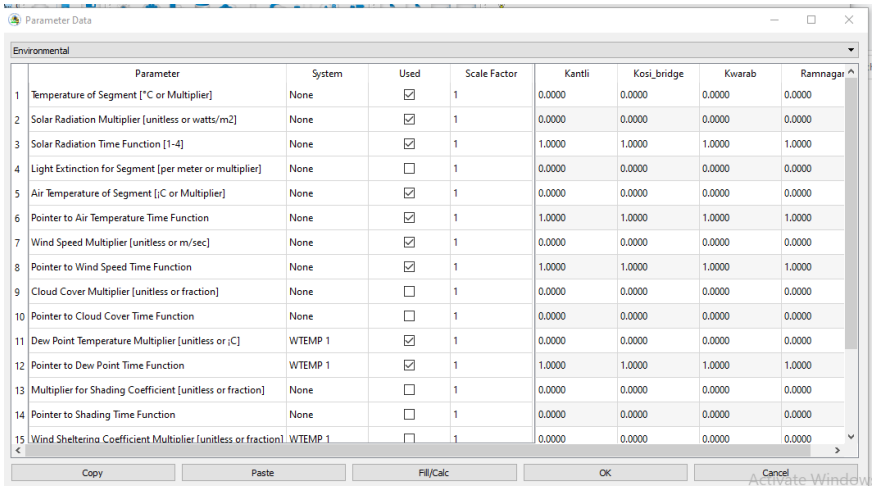


Fig 4.7 Environmental Time functions (Meteorological Parameters)

Meteorological parameters

The time function data entry forms allow the user to enter time variable environmental information. WASP 8 offers a selection of all the environmental time functions for a given model type. The information may be provided for all the time functions or toggle on/off any of the functions by simply clicking the “Use dialog box”. In order to enter the various information regarding the time function we simply need to select the desired function. The time series data form for the given time function is displayed in the lower table. The user should enter time/date and value for the time function.(Fig 4.8)

.The various meteorological parameters required were as Solar radiation: Solar radiation

plays important role as Dew Point ,Temperature, rainfall

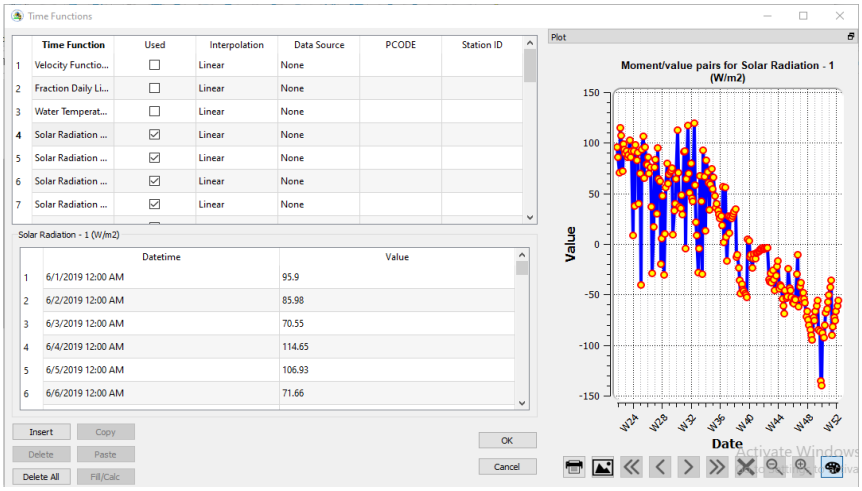


Fig 4.8 Meteorological parameters inputs in model showing radiation

Hydrological Parameters

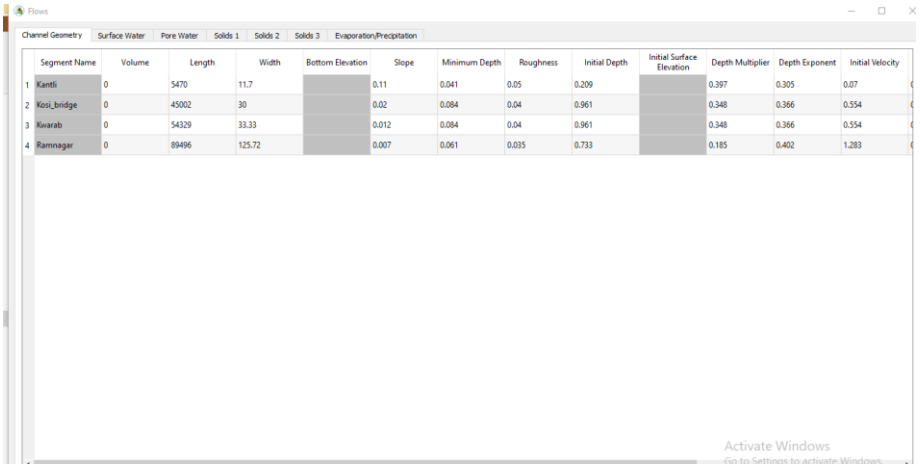


Fig 4.9 Four stations selected for daily analysis in the model

For hydrological parameters the four stations selected are analysed for detailed modeling network of segments with similar advective and dispersive fluxes. As cross section, length, depth.(Fig 4.9)

A good description of segment geometry as a function of flow conditions can be important in properly using WASP8 to simulate rivers. For flow option 3, velocity and depth are computed within the hydrodynamic model, and are read by WASP8. For flow options 1 and

2, a set of user- specified hydraulic discharge coefficients can be entered that which defines the relationship between velocity, depth, and stream flow in the various other segments. This method, described below, follows the implementation in QUAL2E .In WASP8, these segment velocities and depths are only used for calculations of reareation and volatilization rates; and are not used in the transport scheme. The discharge coefficients giving depth and properly using WASP8 to simulate rivers. For flow option 3, velocity and depth are computed within the hydrodynamic model, and are read by WASP8. For flow options 1 and 2, a set of user- specified hydraulic discharge coefficients can be entered that which defines the relationship between velocity, depth, and stream flow in the various other segments. This method, described below, follows the implementation in QUAL2E .In WASP8, these segment velocities and depths are only used for calculations of reareation and volatilization rates; and are not used in the transport scheme. The discharge coefficients giving depth and velocity from stream flow are based on empirical observations of the stream flow relationship with velocity and depth important to note that these coefficients are only important when calculating reareation or volatilization. The velocity calculations are not used in time of travel, and will not affect the simulation of tracers. The equations relate velocity, channel width, and depth to stream flow through power functions(WASP manual 8)

$$V = a\,Q^{b} \quad \text{Equation 1}$$

$$D = c\,Q^{b} \quad \text{Equation 2}$$

$$B = e\,Q^{f}$$

where D is average depth, m

B is average width, m a, b, c, d, e, and f are empirical coefficients or exponents Given that area is a function of average width (B) and average depth (D),

$$A = D\,B$$

From equation of continuity

$$b + d + f = 1$$

a c e=1

Following relationships hold

$$Q\text{-}U^{*}\ A\text{-}U^{*}\ D^{*}\ B\text{-}(a\ Q^{b})\ (c\ Q^{d})\ (e\ Q^{f})\text{-}(a\ ^{*}c^{*}\ e)\ Q^{\,b+\,d+\,f}\ \cdots\cdots\cdots\cdots$$

WASP8 only requires specification of the relationships for velocity, Equation 6-1, and depth, Equation 6-2; the coefficients for Equation 6-3 are implicitly specified by Equation 6-6 and Equation 6-7. These options can be put into perspective by noting that, for a given specific channel cross-section, the coefficients (a, c, e) and exponents (b, d, f) can be Manning's equation. For example, if a channel of rectangular cross-section is assumed, then width (B) is not a function of stream flow (Q), the exponent (f) is zero (0.00) and the coefficient (e) is the width of the rectangular channel (B). By noting that hydraulic radius (R) is approximately equal to depth (D) for wide streams
and that A = D B, the discharge coefficients for rectangular cross sections can be shown to be 0.4 for velocity and 0.6 for width. It was noted that stream channels in humid regions tend towards a rectangular cross-section because cohesive soils promote steep side slopes whereas no cohesive soils encourage shallow sloped, almost undefined banks

Boundary definition

This screen defines which parameters will be considered in the simulation as well as specifying a parameter scale factor. (Fig 4.9)By default the scale factor is 1.0. Before an environmental segment parameter will be considered by WASP8 the used box must be checked. Un-checking this box will remove the parameter from the simulation, but all entered information is not lost. An example of using this feature is looking at the influence of SOD on dissolved oxygen. Make the first simulation with the SOD parameter checked; make the next run with it un-checked. The differences between the two runs are the influence of SOD. The user can also change the scale factors for each parameter

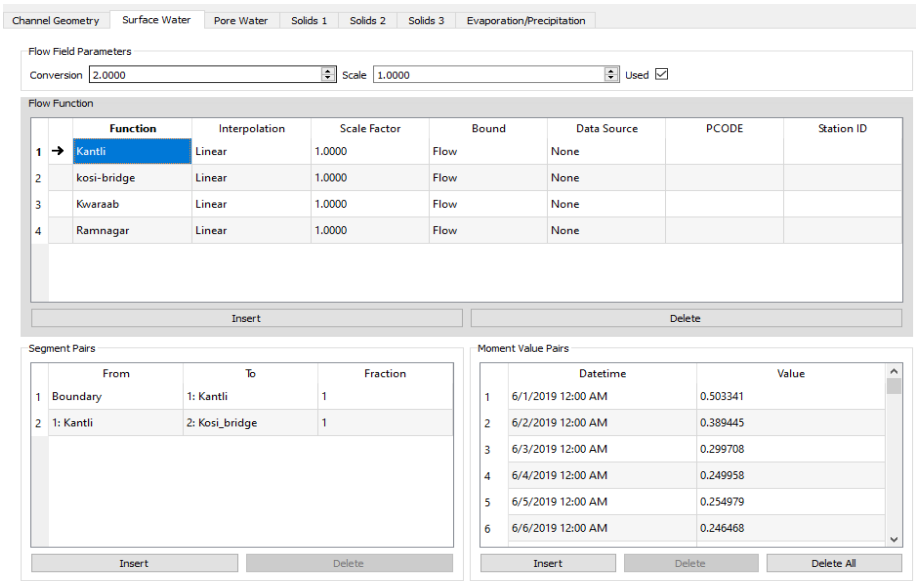


Fig 4.10 Boundary definition for the four station selected for the daily analysis

WASP Limitations

The WASP model is suitable for predicting daily water quality variations in different segments of the A–V Lake system. However, the model has some limitations.

- The biggest limitation with WASP model is that the daily sampling of the segments of the river system becomes difficult.
- It discreteness the lake system into a specific number of segments, depending on the location of the sampling sites, and then only predicts the variations in the parameters on a segment-wise basis.
- The water quality remains the same for a segment, and variations within the segment cannot be obtained with the model. Rather, it requires information on the water volume in different segments, inflow and boundary characteristics and environmental constants which fall under different categories of data and must be collected separately.
- WASP can be used for predicting only a limited number of water quality parameters.This model can be used to determine the temporal water quality variations in a lake system on daily basis, a task that cannot be achieved with statistical methods and remote sensing.

Chapter 5

Results and Discussion

5.1 Results and discussion

Groundwater is the major source of water supply for domestic purposes in urban as well as rural parts of India. There are various reasons for this, which include non-availability of potable surface water and a general belief that groundwater is purer and safer than surface water due to earth mantel covering. Presence of more than 200 chemical constituents in groundwater has been documented including approximately 175 organic and more than 50 inorganic and radio nucleotides.

The sources of these chemicals are both natural and anthropogenic. USEPA has detected volatile organic compounds (VOCs) in 466 randomly selected public groundwater supply systems. Those occurring most often were trichloroethylene and tetrachloroethylene. In the developing countries, contamination of water supplies by organic compounds is of minor concern or of no concern at all. In such places the major health problems are the result of inorganic chemicals contamination, poor sanitary conditions and illness brought about by pathogenic organisms. Once the groundwater at a site is degraded, it may remain in an unusual or even hazardous condition for decades or centuries.

The typically low velocity of groundwater prevents a great deal of mixing and dilution, consequently, a contaminant plume may maintain a high concentration as it slowly moves from points of recharge to zone of discharge (Pattyjohns, 1979). The physical, chemical and biological quality of water may vary within wide limits. It is very difficult to distinguish the origin (natural or anthropogenic) of many water quality problems. Natural quality reflects the type and amount of soluble and insoluble substances with which the water has come in contact. The quality of groundwater is most commonly affected by waste disposal and land use. Another major source of contamination in the storage of waste materials is in excavations, such as pits and mines. Water-soluble substances that are dumped, spilled, spread or stored on the land surface eventually may infiltrate. Groundwater can also became contaminated by the disposal of fluids through wells and, in lime stone terrains, through

sinkholes directly into aquifers. Likewise, infiltration of contaminated surface water has caused groundwater contamination in several places. Irrigation tends to increase the mineral content of both surface and groundwater.

The degree of severity in such cases is related to hydrologic properties of the aquifer, the type and amount of waste, disposal method and climate. Another cause of groundwater quality deterioration is pumping of groundwater, which may precipitate the migration of more mineralized water from the surrounding strata to the well. In coastal areas pumping has caused seawater intrusion to freshwater aquifers.

In parts of West Bengal, arsenic contamination problem has been attributed to excessive pumping of shallow groundwater.

Various sources of groundwater contamination have been encapsulated in (Table 5.1). Safe drinking water is essential to human health, so the physico-chemical properties of drinking water are of great concern. Various studies carried out in the past have reported the presence of excessive Fluoride, Arsenic, Nitrite, Sulphate, and Heavy metals, Salinity, Hardness and Pesticides etc. from different parts of the country. It has been reported that 77% of urban population and only 31% of rural population in India has access to portable water supply Kaul et al. (1999)

On land forms	1) Infiltration of contaminated surface water. 2) Land disposal of solid and liquid materials 3) Mining and Industrial tailings 4) Dumps 5) Disposal of sewage and sludge 6) Fertilizers 7) Accidental spills
Above water table problems	1) Septic tanks 2) Surface impoundment 3) Landfills 4) Waste disposal in excavations 5) Leakage from underground storage tanks and pipelines 6) Artificial recharge
Below water table problems	1) Waste disposal in wet excavation 2) Agricultural drainage wells and canals 3) Well disposal of wastes 4) Underground storage 5) Mines 6) Exploratory wells and test holes 7) Abandoned wells 8) Water supply wells 9) Groundwater development

Table 5.1 Sources of ground water pollution

5.2 Results w.r.t Groundwater (Springs) of Almora

The research findings relates into 3 major aspects for groundwater analysis of Almora: The groundwater analysis of Almora shows that the samples of the springs showed the limits above the permissible limit in most of the parameters. The 21 springs samples of the three seasons were analysed with the arithmetic mean values of the springs which is depicted in the table below (Table 5.2)

Parameters	Monsoon, 2017	Post Monsoon, 2017	Pre-monsoon, 2018
pH	7.1	6.56	7.26
EC (µS/cm)	913	870	877
Turbidity (NTU)	3.55	.10	.27
TH (mg/L)	200	210	400
Calcium (mg/L)	136	105	121.8
Magnesium (mg/L)	71	213	27.3
Chloride (mg/L)	7.1	7.25	8.52
Nitrate (mg/L)	25	30	42
Sulphate (mg/L)	6.01	11.61	10.25
Sodium (mg/L)	5.1	11	8
Potassium (mg/L)	2.1	5.5	5.4

Table 5.2 Parametric variation of springs of Almora showing the average values of the three seasons

The collaborative study and analytical result of the samples of springs of Almora for

all the three seasons of 2017-2018.The comparative study of all the three seasons of the samples were analyzed and compared with the data of 1991. The data of the springs compared showed the rapid deteoriation of water quality of the springs with rapid increase in population and urbanization in the years from 1991 to 2017.

5.2.1 Physicochemical characteristics of springs of Almora

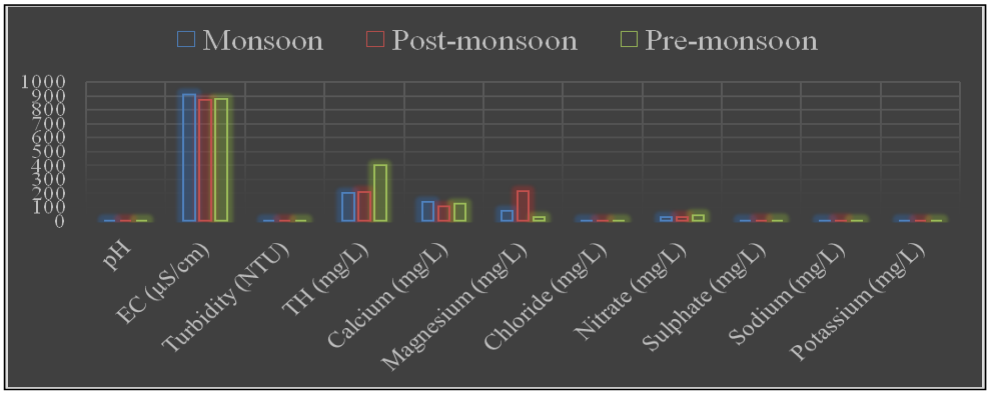


Fig 5.1 Graphical representation of the parametric variation of the springs

The monsoon premonsoon and post monsoon data of the springs samples states that pH did not fluctuate more in all the three seasons the more pH was compared for the three seasons it was found that premonsoon pH fluctuated to have more values in comparison to monsoon and pre monsoon season.

Conductivity however was more for monsoon season than post and premonsoon season which would probably be because of the dissolved solutes in the springs which ultimately increased the conductivity of the samples.

Total hardness varies from premonsoon to monsoon and post monsoon season which increases in premonsoon in comparison to post and monsoon season.(Fig 5.1)

5.2.2 Spring wise parametric study of the water quality

Nitrate

The nitrate vibration in the springs of Almora shows that the contamination of most of the springs that are in the midst of the dense population shows rather higher concentration of

nitrate. The nitrate that is present in urban water bodies that is due to putrefaction of proteins which enter the water bodies with waste water. Along with this the leaching as well as runoff from the agricultural fields is observed to be other reason for nitrate contamination in natural water. The trace of nitrogen of mineral origin in natural water is sporadic whereas if nitrates, nitrites sort of waste is found in the water clearly indicates that water is contaminated and intuited with domestic sewage as well as agricultural waste.

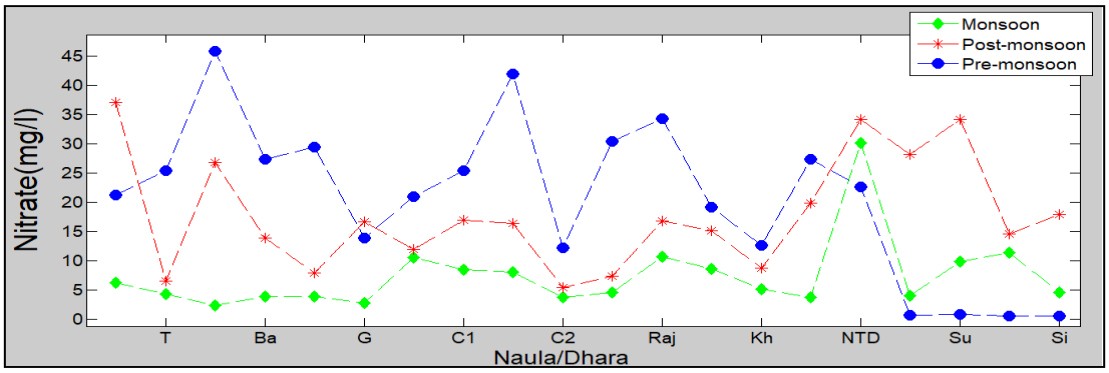


Fig 5.2 Nitrate contamination for springs of Almora for all the three seasons

But in urban areas like Almora possibilities of agricultural waste disposal are rare. Presence of ammonia in water indicate that sometime has already been passed and the water has purified itself to some extent. The highest oxidized form of nitrogen that would be present in water as well as waste water is nitrate nitrogen. Nitrate is treated as in important parameter in drinking water due to its featal effects on infants. An upper limit of 10ppm is fixed for drinking water by WHO considering the public health implication. The minimum value for the springs of Almora was found in Gurani naula of 3.9 mg/l for monsoon season whereas the highest value was detected for Gurani naula in post monsoon season for 45.85 mg/l

The dharas as Thapalya, Rajpura, NTD, Sunehri, Dugalkhola, and Ranidhara showed maximum concentration of nitrate as 60 mg/l in post monsoon season, 60.1ppm in post monsoon, 16. 7 mg/l, 25.35 mg/l in premonsoon, 42 mg/l in premonsoon, 19.15 mg/l in premonsoon, and 17.85 mg/l in post monsoon respectively.(Fig 5.2)

The naualas Badreshwar, Gurani, Champa1, Champa 2, Doaba, Dharanaula, Makeri, Kapina, Karnatukula, Lameshwar. The maximum concentration of nitrate is 25.35 mg/l in pre monsoon 45.85 mg/l for pre monsoon , 27.3 mg/l and 29.5 mg/l and 21 mg/l pre

monsoon 12.25 mg/l in pre monsoon,30.5 mg/l in pre monsoon, 34.5 mg/l in pre monsoon 112.65 mg/l, 34.2 mg/l in post monsoon , 28.25 mg/l in post monsoon, 14.5 mg/l in post monsoon season.

In spring water of Almora town, abnormally high concentration of nitrate nitrogen was found. Springs located within the lower boundary of townships e.g Rajpura and Thapalya dhara have nitrates as high as 60 mg/l nitrates values decreased in Ranidhara and Paltan bazaar springs located over the ridge.

The most likely source of nitrogen is the domestic sewage which leaches and infiltrates through the septic tanks, cesspools or open drains to the groundwater. Seasonal variations indicating changing nature of nitrogen inputs indifferent seasons of the year.

Sulphate

Sulphate occurs in water naturally and the main source of this in groundwater is dissolution of calcium sulfates from bedrocks. Sulfates are reduced to sulfides under anaerobic conditions in the presence of bacteria and there is scope for some correlations between concentrations between of calcium, sulfates and sulfides. In the spring water of Almora, sulfhates are found to be present in all samples and their concentration is ranging from 2.80ppm in Khatyari naula in summer season to 24.25 in chausar naula in winter.(Fig 5.3)

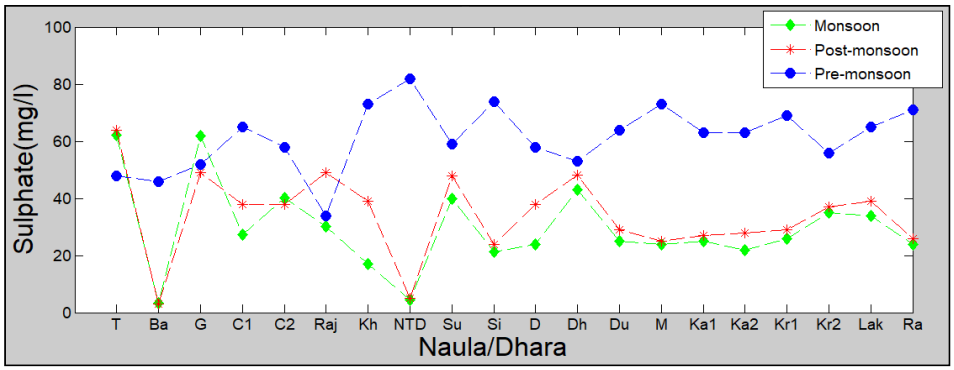


Fig 5.3 Sulphate Contamination of springs for all the three seasons of Almora

Significant seasonal variations in its level are observed and the values obtained in summer and monsoon is on the lower side in comparison to winter. One possible reason for decrease in summer season could be reduction in base flow through rocks. In monsoon season, the

decrease in sulphate is accompanied with raised level of sulfides in spring water.

The possibility of reduction of sulfates to sulfides cannot be ruled out. Sewage can also be the source of sulfur in water. In the town, disposal of sewage through septic tanks and open drains can enter the water bodies and bacteria present in water can create favorable condition to produce sulfides.

In monsoon season, the sulfur containing overflow from the waste wastewater drains can reach the springs. This will increase sulfur content in spring water which can give rise to higher sulfides concentration. This is signified by total sulphides concentration in monsoon season. Seasonal changes in sulfides were found significant as indicated by Cv value of 34.7 percent.

Of the dharas as Thapalya, Rajpur, Sunehri, Dugalkhola, Ranidhara, NTD the maximum concenteration was seen in as for 64 mg/l for post monsoon, 46 mg/l for pre monsoon, 49 mg/lfor pre monsoon ,49 mg/lfor post monsoon, 59 mg/l for premonsoon, 82 mg/l for pre monsoon, respectively.

Of the naulas of the Almora as Gurani, Champa 1 and 2, Khatyari, Sidhi,Doaba,Dharanaula, Makeri, Kapina ,Karnatula, Laxmeshwar and Badreshwar the maximum concentration was found as 62 mg/l ,65 mg/l, 73 mg/l,59 mg/l, 74 mg/l, 58 mg/l,53 mg/l, 64 mg/l, 73 mg/l,63 mg/l,69 mg/l,65 mg/l, 46 mg/l all for pre monsoon season respectively.

The trend of sulphate concentration showed a consistent variation for the naulas of Almora whereas dharas showed some fluctuations in pre and post monsoon season.

Dissolved Oxygen

For aquatic plants and other life forms the oxygen is offered in dissolved form. Oxygen is, to some extent, soluble in water and its solubility is reliant on many factors such as partial pressure of gas in the atmosphere, temperature and salinity of water, etc. The concentration of dissolved oxygen reduces with increase in temperature. This is explained by the amplification in biochemical reactions which consumes dissolved oxygen at a rapid rate and thus its concentration tends to be more grave in summer season. Presence of dissolved oxygen is required in waters to avoid undesirable odour. It plays an important role as pollution indicator. Low concentration of DO in water indicates presence of organic matter in water and measurement of DO is required for the assessment of biochemical oxygen demand (BOD) which is an indication for biodegradable organic matters

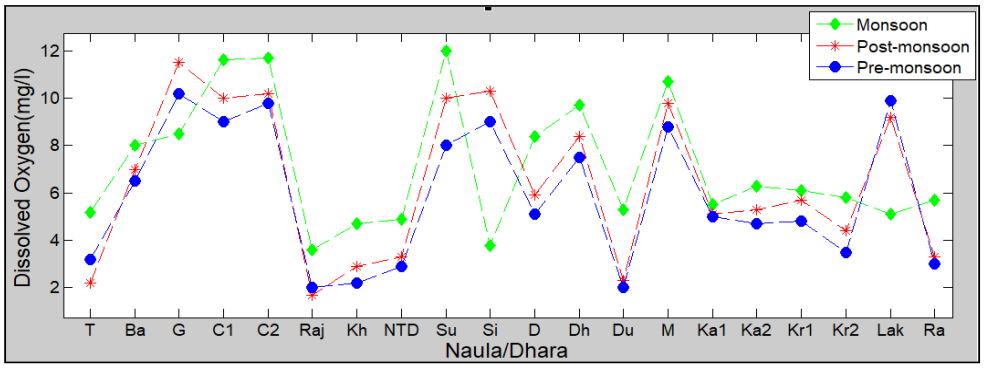


Fig 5.4 Dissolved oxygen for springs in Almora for all the three seasons

In spring water, dissolved oxygen was found above 5.80 ppm in all seasons and the DO levels ranged between 5.80 to 11 ppm.

Significant change was observed in its values during different seasons. Its concentration in summer is showing decreasing trend which is due to increase in water temperature. In Sunehri dhara, there is sudden increase in which may be due to local air mixing at the time of sampling. In monsoon season, the DO values are again increased slightly which is possible due to increase in flow and also due to slight decrease in temperature during that period. Water in general can be said to be fit for use by aquatic plants and other life forms considering the availability of dissolved oxygen in water.

Of the dharas in the springs of Almora as Thapalya, Rajpur, NTD, Sunehri, Dugalkhola and Ranidhara. The least value for DO was 2.2mg/l in post monsoon, 6.5mg/l in pre monsoon, 2.9 mg/l in premonsoon,8.2 mg/l in pre monsoon and 3.2 mg/l in pre monsoon respectively were observed through lab analysis. The desirable limit of DO as set down by WHO and EPA is 10 mg/l in potable water. The dharas show variations in amount of DO in premonsoon monsoon as well as post monsoon period that is probably because the dharas are flowing springs and the mixing of oxygen varies in as it come in contact with the air.(Fig 5.4) As the nauals as the springs of Almora Badreshwar, Gurani, Champa 1 and 2,Khatayari,Sunehri, Sidhi, Doaba,Dharanaula, Makeri, Kapina, Karnatkula, and Laxmeshwar. The minimum amount of DO was observed in as 6.5 mg/l in premonsoon,8.5 mg/l in monsoon,9mg/l in premonsoon, 2.2 mg/l in premonsoon, 8 mg/l in premonsoon, 3.8 mg/l in monsoon 7.5 mg/l in premonsoon 8.8 mg/l in pre monsoon 5mg/l premonsoon, 4.8 mg/l in pre monsoon ,5.1 mg/l in monsoon respectively.

BOD (Biochemoical Oxygen Demand)

The BOD of the samples of the springs specifies the amount of oxygen utilized by the microorganisms present in the samples in 5 days of incubation. The samples collected were incubated for 5 days from all the 21 springs and were found to have high amount of microorganisms present

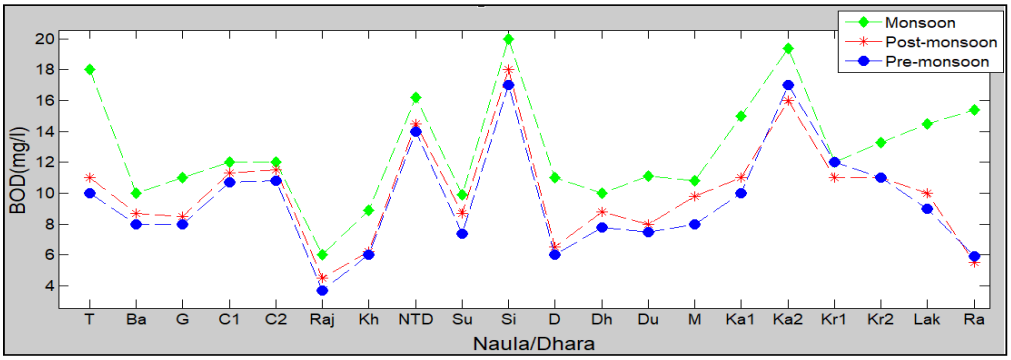


Fig 5.5 Biochemical Oxygen Demand for springs in Almora for all the three seasons

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As in dharas of springs of Almora as Thapalya, Rajpur,NTD, Sunehri, Dugalkhola and Ranidhara.the maximum limit of BOd was found in for as for 18 mg/l in monsoon, 6mg/l in monsoon, 16.2 mg/l in monsoon, 9.9 mg/l in monsoon , 11 mg/l in monsoon and 15.4 mg/l in monsoon respectively. (Fig 5.5) Whereas in naulas the Badreshwar, Gurani, champa 1 and 2, Khatyari, Sidhi, Makeri,Kapina,Karnatukula and Laxmeshwar the highest level of BOD was analysed as in 10mg/l in monsoon, 11mg/l,12mg/l 8.9 mg/l 20 mg/l, 19 mg/l 13.3 mg/l 14.5 mg/l respectively all in monsoon season.

Elecrtoconductivity

The elecrtoconductivity of the samples is defined as amount of electrolytes that are present in the sample. The samples analysed showed more conductivity of electrolytes in monsoon than in post or pre monsoon. The reason could be due to more dissolution of electrolytes in the monsoon season as the dilution of the water occurs due to more infiltration of the electrolytes into the aquifer.(Fig 5.6)

The electro conductivity variations of naulas and dharas showed similar trend of variation. Although dharas in most of the cases showed higher values of the electro conductivity in

monsoon season than the naulas.

The dhara Rajpur showed more elecrtoconductivity in monsoon and post monsoon and pre monsoon season. The Gurani naula showed more fluctuations in monsoon season in comparison to post and pre monsoon it being as high as 890 microsiemens. naulas. The dhara Rajpur showed more elecrtoconductivity in monsoon and post monsoon and pre monsoon season.

The Gurani naula showed more fluctuations in monsoon season in comparison to post and pre monsoon itbeing as high as 890 microsiemens

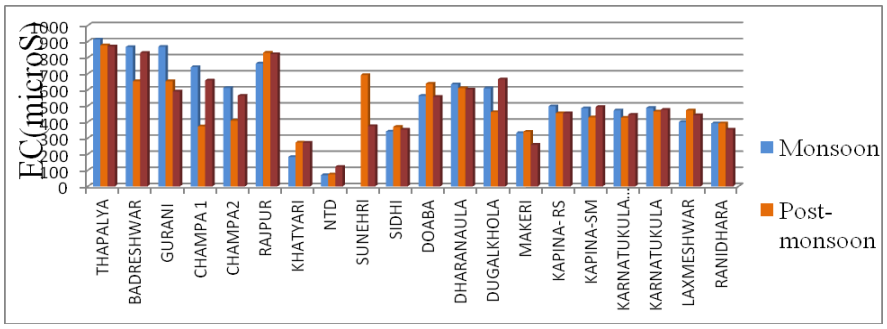
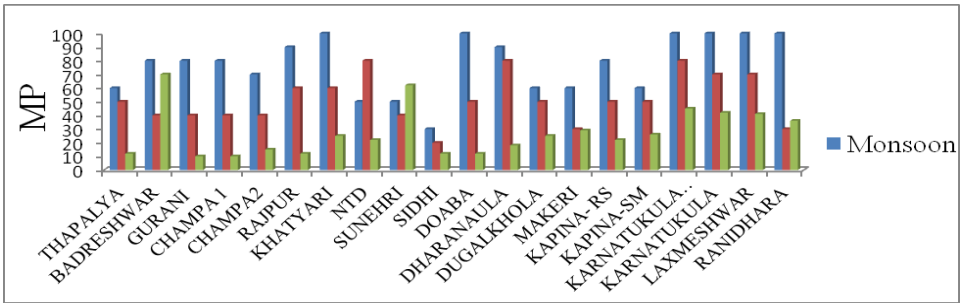


Fig 5.6 Electoconductivity variation for springs of Almora

MPN (Most Probable Number)



. Fig 5.7 Showing MPN for the sampled springs of Almora

The most probable number is a biological parameter to study the of colonies of

microorganisms present in 1 ml of the sample with the help of agar broth as culturing medium left for 48 hours. The samples of springs of Almora showed presence of huge amount of colonies of microorganisms colonies in the samples. The monsoon season showed highest amount of colonies in the samples. Although trace of E.coli was not observed in any of the samples which are generally present in human excrete. The monsoon season showed as high as 100 colonies in the 1 ml cultured sample of the springs.(Fig5.7)

5.2.3 Correlation matrix of the springs

The correlation matrix is process of expressing correlation coefficients in between variables. The correlation between the two variables is shown in each cell. The key role of correlation matrix is to show an input data into rather acute analysis and also to spot advanced analysis. The strength and direction of linear relationship between x and y is expressed by correlation coefficient "r". Though the observed data points in the sample expresses the consistency of the linear model. The sequence of the two variables indicates the relationship they share which is expressed in the following sequence

1. If the value of linear correlation between the two variables is 1 indicates perfectly negative correlation.

2. If the value of linear correlation between the two variables is 0 indicates no. correlation.

3. If the value of linear correlation between the two variables is 1 indicate perfectly positive correlation.

The two variables are parallel to each other and varies as the other vary is said to be in positive correlation between each other. Both variables are in perfect tandem with each other which decreases when one gets decreased and increases when other increases. The correlation between the variables was calculated for all the three seasons for the springs of Almora which showed the relationship between the variables. The correlation between most of the parameters was found significant, whereas depending upon the seasons the parameters were also not perfectly correlated or showed negative correlation. Some parameters also showed no correlation as their increase or decrease does not impact the effectiveness of each other.

Correlation Matrix For The Springs of Almora For Monsoon Season

Correlation Matrix Indicating Monsoon Season											
Parameters	**pH**	**EC**	**NO_3**	**Ca**	**Mg**	**TDS**	**Na**	**K**	**DO**	**BOD**	**SO_4**
pH	1										
EC	-0.04	1									
NO_3	0.043	-0.24	1								
Ca	-0.02	0.86	-0.34	1							
Mg	0.024	0.75	-0.13	0.73	1						
TDS	-0.06	0.99	-0.24	0.866	0.74	1					
Na	-0.10	-0.67	-	-0.39	-0.49	-0.66	1				
K	0.05	-0.27	-0.12	-0.11	-0.04	-0.29	0.62	1			
DO	-0.15	0.26	-0.12	0.433	0.22	0.30	-0.01	-0.19	1		
BOD	0.35	-0.25	0.37	-0.30	0.01	-0.27	-0.18	-0.05	-0.33	1	
SO_4	0.011	0.54	-0.11	0.50	0.42	0.55	-0.35	-0.24	0.23	-0.02	1

Table 5.3 Correlation matrix for monsoon season for springs of Almora

The statistical analysis of springs of Almora for monsoon season for 2018-2019 states that the relationship between various parameters with each other. The strong correlation exists between elecrtoconductivity and Ca ions as the conductivity increases with increase in ions in the water. The presence of more calcium ions indicates the possibility of hardness in the water. Correlation also exists between nitrate and pH, which indicates the possibility of more anions in the sample. Sulphate ions and TDS also show strong positive correlation in monsoon season probably due to flushing out more of the settled ions in the naulas and dharas. Very high correlation was seen between Ec and TDS, Mg and TDS, TDS and Ca.(Table 5.3)

Correlation Matrix For The Springs of Almora For Post Monsoon

Ec and TDS and Sulphate and Ec are strongly positively correlated. Ec and nitrate, calcium, magnesium are positively correlated. The presence of various ions establishes a strong relationship between Ec with the calcium, magnesium and nitrate. TDS correlated to Ca and Mg. DO and BOD is correlated with nitrate. Negative correlation is seen between sodium and magnesium. (Table 5.4

Correlation Matrix indicating Post-Monsoon Season											
Parameters	**pH**	**EC**	**NO_3**	**Ca**	**Mg**	**TDS**	**Na**	**K**	**DO**	**BOD**	**SO_4**
pH	1										
EC	-0.15	1									
NO_3	0.32	0.24	1								
Ca	0.05	0.32	-0.11	1							
Mg	0.1	0.44	0.41	0.22	1						
TDS	-0.15	0.99	0.24	0.34	0.45	1					
Na	0.02	-0.42	-0.24	-0.22	-0.36	-0.41	1				
K	-0.01	-0.29	-0.31	-0.08	-0.04	-0.28	0.11	1			
DO	-0.07	-0.04	-0.34	0.22	-0.47	-0.03	-0.07	-0.19	1		
BOD	0.45	-0.41	0.16	-0.16	-0.07	-0.41	-0.24	0.05	0.28	1	
SO_4	-0.12	0.63	0.38	0.06	0.40	0.63	-0.05	-0.24	0.05	-0.32	1

Table5.4 : Correlation matrix for springs of Almora for post monsoon season

Correlation Matrix For The Springs of Almora For Pre Monsoon

Correlation Matrix Indicating Pre-Monsoon Season											
Parameters	**pH**	**EC**	**NO_3**	**Ca**	**Mg**	**TDS**	**Na**	**K**	**DO**	**BOD**	**SO_4**
pH	1										
EC	0.12	1									
NO_3	0.28	0.18	1								
Ca	0.24	0.62	0.25	1							
Mg	0.26	0.63	0.35	0.97	1						
TDS	0.14	0.90	0.28	0.58	0.59	1					
Na	-0.34	-0.27	0.02	-0.22	-0.22	-0.33	1				
K	-0.27	-0.28	0.16	-0.33	-0.28	-0.22	0.21	1			
DO	0.27	-0.04	0.31	0.33	0.39	-0.01	-0.03	-0.24	1		
BOD	0.04	-0.28	-0.10	-0.28	-0.31	-0.33	-0.10	-0.02	0.19	1	
SO_4	-0.14	-0.86	-0.25	-0.59	-0.55	-0.87	0.15	0.34	0.03	0.44	1

Table 5.5 Correlation matrix for pre monsoon season

The pre monsoon season in Almora basically lies between April to June .June end or July stats with pre monsoon showers and hence has very short period of summer season. The summer season statistics witnesses strong correlation between Ec with both Ca and Mg ions

reason being the concentration of contamination of the contaminants. Very strong positive correlation of .99 is seen between TDS and Ec as the decrease dilution of water results in increase of contaminants in the spring and hence the dissolved solutes showed increase in contamination.(Table 5.5)

5.2.4 Piper Plot diagram for the springs of Almora

There are various methods to express the chemistry of the water as stiff diagram, piper plot, Wilcox diagram, Durov diagram, schoeller etc. They have being widely used in representing the chemistry of water and for expressing the ionic concentration of every sample.

The suggested Piper-Hill diagram (Piper, A. M) is used to infer hydro geochemical facies. These plots include two triangles in which one is used for plotting the cations and the other is used for plotting the anions. The cations and anion arena combined together to show a point in diamond shaped field, from which conclusion is deduced on the basis of hydro geochemical facies concept. (Back W. and Hanshaw). These tri-linear diagrams are basically meant to bring vital chemical reaction relationships among groundwater samples in more definite terms rather than with other possible methods.(Walton).The hydro chemical facies for post monsoon season says that the concentration of sulphates.

Here piper plot is used to express the classification scheme of water samples collected from the springs of Almora. The ions considered are Ca^{2+} -$HCO^{3\ -}$ and mixed Ca2+ -Mg^{2+} -Cl indicating that samples had influence of rock types as mixed Ca^{2+} -$HCO^{3\ -}$ and Ca^{2+} -Mg^{2+} Cl^{-} Ca^{2+} -HCO^{3} water types were referred to as base exchange water ions when compared with available alkali metal ions as sodium ion and potassium ions. In equivalent concenterations.These excess HCO3 ions then causes the release of earth alkaline ions into the solution Drever (1997). If no change in the hydro chemical faces occurs then it shows that the water is present in its natural form without any alteration.

Chemical data of the study are presented by plotting them on a Piper tri-linear diagram for each season. The concept of hydrochemical facies was extended to understand and isolate the water composition in different sets Back.W(1987) Facies are identical parts of different

characters that fit in to any genetically related system. Hydro-chemical facies are distinct zones that possess cations and anion concentration categories. The Piper diagram for the analysis cations of the properties of the springs for pre and post monsoon shows that they are more dominated by Ca ion followed by Mg ions.

Piper plot for the Post monsoon season of springs of Almora

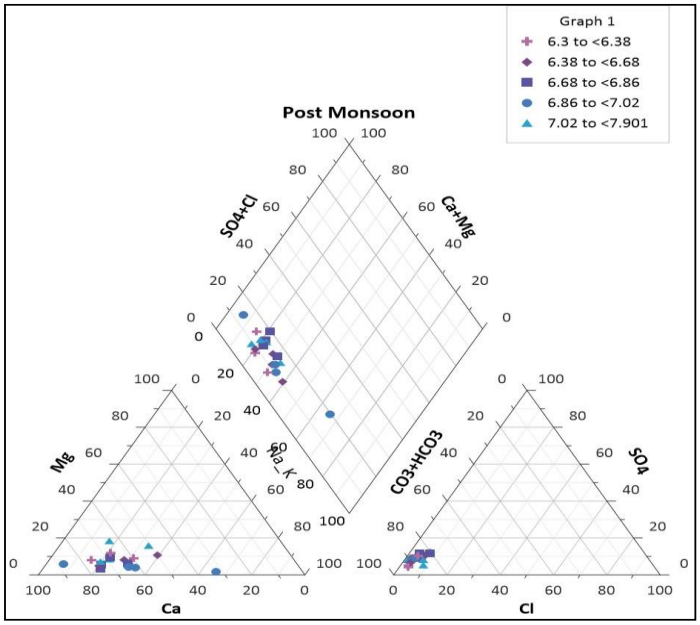


Fig 5.8 Piper plot of springs of Almora for post monsoon season

The piper plot diagram shows more dominance of Ca ions than in comparison to Mg ions in the springs whereas more dominance of carbonate and bicarbonate ions than chloride anions in springs. Sodium and Potassium ions however mark its presence but are however less than in comparison to Calcium and Magnesium ions. The presence of more calcium and magnesium carbonates and bicarbonates shows that the spring water is hard water with temporary hardness that could be removed by boiling the water and then filtering it. Sulphate and chloride concentration is however less in the values hence the water of the springs are not hard water as by the analysis of the sample in most of the cases. The chloride and sulphate contamination makes water permanent hard and it needs chemical purification for removal from the potable water.(Fig 5.8)

Piper Plot Diagram for Pre monsoon season

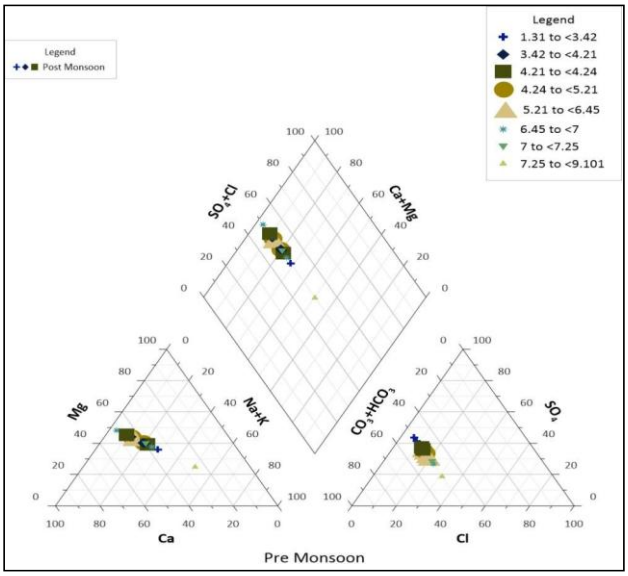


Fig 5.9 Piper plot of pre monsoon season of springs of Almora

The piper plot for pre monsoon season states that in pre monsoon season the sample of the springs were more dominated with calcium than magnesium .Also more concentration of sulphate ions were seen in the sample of pre monsoon in springs of Almora than carbonate and bicarbonate ions. Hence proving that pre monsoon samples were having more permanent hardness in comparison to temporary hardness. This could be due to more chloride ions dissolving in the springs due to more usage of detergents and septic tanks infiltration into the spring water. The carbonate and bicarbonate are also found to be present equally hence stating that the water is having both permanent and temporary hardness.(Fig 5.9)

5.2.5 Water Quality Index

The precise and apt timely information on the quality of water is essential to shape a sound public policy and to apply that for the water quality improvement programmes effectively and efficiently the water quality improvement programmes efficiently. Indices are considered to be one of the most important ways out to converse the information on water quality trends. The rating refection and the combined influence of different water quality parameters on the overall quality of water as well as for detection and evaluation of water are

the major purposes that Water quality index fulfills." Indices are further categorized into two parts as

a) Biological indices

b) Physicochemical indices

Physicochemical indices parameters on one hand where elaborates the characteristics due to physicochemical properties of water, on the other hand the biological indices related to the biological indies derived from the biological parametric calculation of the water sample. The biological indices are derived from biological information, diversity of species, the pattern of their distribution, behavior of indicator species or groups. (Trivedy and Goel, 1984). The attempt here is made on to calculate the water quality of springs of Almora on the basis of Harkins (1974), Lohani (1981) and subsequently modified by Tiwari et al., (1986) based on physico-chemical data. The method that was involved for the the investigation of the samples of springs of Almora were selected as 12 parameters. These 12 parameters were used as: pH, DO, Turbidity, Electrical conductivity, Hardness, Calcium, Magnesium, Chloride, BOD, Iron and Sulphate. In this present case I did not consider the water samples of the river as the concern was mainly on the springs of Almora.The generation of water quality index completely relies on the intended use of the water and this is the factor that decides the various water quality parameters to be included in the calculation of water quality. Here the intention to generate water quality index is to observe whether the water is suitable for human consumption. The standard which was hunt for the study of WOI is taken from Indian Council of Medical Research (ICMR) and hence the unit weight was calculated. In the formulation of water quality index, the importance of various parameters depends on the intended use of water; here water quality parameters are studied from the point of view of suitability for human consumption.

The 'standards' (permissible values of various pollutants) for the drinking water, recommended by the Indian Council of Medical Research (ICMR) and unit weights are given in (Table 5.6) Drinking water standards and unit weights Water Quality Parameters Standards Recommending

Agency Unit Weights (Wi) pH 7.0-8.5 ICMR 0.0354 Dissolved Oxygen 5.0 mg/l EEC 0.0496 Turbidity 10 NTU ISI 0.0248 Total Alkalinity 120 mg/l USPHS 0.0020 Total Dissolved Solids 500 mg/l ICMR 0.0004 Total Hardness 300 mg/l ICMR 0.0008 Calcium 75 mg/l ICMR 0.0033 Magnesium 50 mg/l ICMR 0.0049 Chloride 250 mg/l ISI 0.0009

Biochemical Oxygen Demand 5.0 mg/l WHO 0.0496 Iron 0.3 mg/l ISI 0.8276 Sulphate 200 mg/l ICMR 0.0012.

The quality rating "qi" for the water quality which is symbolized as "i". The water quality parameters shown as(i=1,2,3, 4….12) hence the relation obtained is

qi = 100 (vi/ Si).…….(1) -------

Here "v" is symbolized as value of i th parameter at a given sampling station and "Si" is symbolized as Standard permissible value for i th parameter. This is the equation confirms that qi is 0 when no pollutant is present in the sample, while the value of qi is taken as 100 if the parameter is equivalent to the permissible value for the potable water. Hence it is observed that greater is the value of qi the water is then considered as more polluted for the i th pollutant. It is to be noticed that the ratings for pH and DO needs special handling. The agreeable range for pH is 7 to 8. Therefore, the quality rating for pH may be

$= 100[(- 7.0) ( ) 8.5 - 7.0]$ pH

pH q v----------(2)

Where v pH symbolizes the value of pH ~ 7, it means the numerical difference between vpH and 7.0, ignoring algebraic sign. Equation (2) ensures the q pH = 0 for pH = 7.0.

The case of DO is different than other parameters since the quality of water enhances with the value of DO. Therefore, the quality rating q DO has been calculated from the relation.

qDO= 100[ ] ( ) 14.6 − /(14.6 − 5) DO DO q v----------(3)

The equation (3), 14.6 is the solubility of oxygen (mg/l) in distilled water at 0° C and

5.0 mg/l is the standard for drinking water. Equation (3) gives qDO = 0 when DO = 14.6 mg/l and qDO = 100 when vDO = 5.0 mg/l. Where v DO = value of DO. 102

The more harmful a given pollutant is, the smaller is its permissible value for drinking water. So the 'weights' for various water quality parameters are assumed to be inversely proportional to the recommended standards for the corresponding parameters i.e.

$$W_i = \frac{k}{S_i} \quad \text{---------- (4)}$$

Where Wi = unit weight for the i th parameter (i = 1, 2, 3 ----------12), k = constant of proportionality is calculated from the condition and k =1 for sake of simplicity.

$$\sum_{i=1}^{12} W_i = 1 \quad \text{---------- (5)}$$

The unit weights Wi calculated from equation (4) and (5) are listed in table

The water samples from the springs were collected for all the three seasons and were analysed in the laboratory by following the established procedures.

The parameters as pH, turbidity, elecrtoconductivity, sulphate, nitrate, BOD, DO were analysed as per standard procedures by (APHA1995).

In this study, for the calculation of water quality index, nine parameters were chosen. The WQI has been calculated by using the standards of drinking water quality recommended by the World Health Organization(WHO), Bureau of Indian Standards (BIS) and Indian Council for Medical Research (ICMR) Table5. 2.

The weighted arithmetic index method (Brown et. al.,) has been used for the calculation of WQI of the water body. The quality rating or sub index (qn) was calculated using the following expression.

$$\boldsymbol{q_n = 100[V_n - V_{io}] / [S_n - V_{io}]}$$

(Let there be ***n*** water quality parameters and quality rating or sub index (***qn***) corresponding to ***nth*** parameter is the number reflecting relative value of this parameter in the polluted water with respect to the standard permissible value.)

$\mathbf{q_n}$ =Quality rating for the **nth** Water quality parameter

$\mathbf{v_n}$ is the estimated value of the **nth** parameter at a given sampling station.

$\mathbf{S_n}$ is the standard permissible value of the **nth** parameter.

$\mathbf{V_{io}}$ is the Ideal value of **nth** parameter in pure water. (Is 0 for all other parameters except the parameter pH and Dissolved oxygen (7.0 and 14.6 mg/L respectively)

Unit weight was calculated by a value inversely proportional to the recommended standard value $\mathbf{S_n}$ of the corresponding parameter.

$$\mathbf{W_n = K / S_n}$$

$\mathbf{W_n}$ is the unit weight for the Standard value for **nth** parameters **K** is the Constant for proportionality.

The overall Water Quality Index was calculated by aggregating the quality rating with the unit weight linearly.

$$\mathbf{WQI = \Sigma\, qn\, W_n / \Sigma W_n}$$

The WQI of the region shows the quality of the water is not fit for drinking. The increase of water related disease in the area has drawn the attention for preserving the quality of water sources. Water quality Index of the springs of Almora is established from various important physicochemical parameters in the three different seasons of the year. The values of various physicochemical parameters required for the calculation of Water quality index are presented in Season wise Water Quality Index and its calculations are depicted in the (Table 5.7) The Water Quality Index obtained for the springs of Almora in different seasons of study period i.e., rainy season, winter season and summer season are 112.43, 108.8 and 98.6

respectively, which indicates the poor quality of water. The WQI is traced to be very poor in monsoon, which improved in post monsoon and was found to its best state in pre monsoon.

Drinking Water standards recommending Agencies and unit weights. (All values except pH and Electrical Conductivity are in mg/L)

Sr.No.	Parameters	Standards	Recommended agency	Unit Weight
1.	pH	6.5-8.5	ICMR/BIS	0.2190
2.	Electrical Conductivity	300	ICMR	0.371
3.	Total hardness	300	ICMR/BIS	0.0062
4.	Calcium	75	ICMR/BIS	0.025
5.	Magnesium	30	ICMR/BIS	0.061
6.	Nitrate	45	ICMR/BIS	0.0412
7.	Sulphate	150	ICMR/BIS	0.01236
8.	Dissolved oxygen	5.00	ICMR/BIS	0.3723
9.	Biological oxygen demand	5.00	ICMR	0.3723

Table 5.6 Drinking water standards ICMR/BIS

Water quality Index Level	Water quality status
0-25	Excellent water quality
26-50	Good water quality
51-75	Poor water quality
76-100	Very Poor water quality
>100	Unsuitable for drinking

Table 5.7 WQI and status water quality (Chatterjie and Raziuddin 2002)

5.3 Results w.r.t Surface water

5.3.1 Water quality analysis of Surface water (31sampling points analysed in the entire stretch of Kosi river)

The electro conductivity of the sampling points show that the conductivity of the samples have increased due to excessive load of sediments in the samples in monsoon season whereas comparatively less conductivity in post monsoon season.

The analysis of the samples for the 31 sampling points served as torchbearer for selection of the points for model WASP. The electronegativity shows an increased pattern as the sample collected moves from Kantli to Ramnagar.

This might be due to increase in dissolving of more solutes into the water as the water flows with high turbulence carrying away with it lots of soil and mud in monsoon season from the upstream of the river, which results in increase in electronegativity of the samples collected. The electronegativity is more in monsoon than in comparison to post monsoon.

Electonegativity

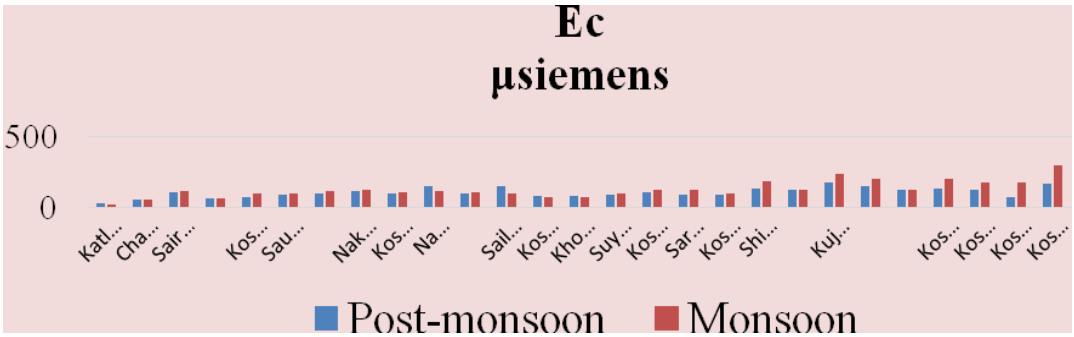


Fig 5.10 Electroconductivity of 31 sample points of Kosi river

An electrical current causes the movement of the electrically charged particles in response to forces that act on them from an applied electric field. In water or any fluids the net motion or charge of the ions may occur. The Ec visible in the chart shows is maximum in Ramnagar in monsoon season and is least in Kantli in both monsoon and post monsoon season.(Fig 5.10)

pH of31 sampling points

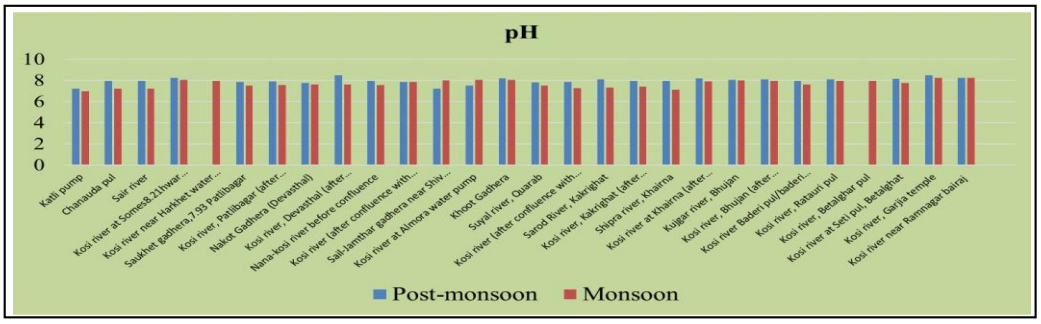


Fig 5.11 pH of 31 sampling points of Kosi river

The pH of the samples showed variation for post monsoon and monsoon period. The pH of t he samples showed slight variations in the sampling for 31 points. Although the pH of the samples did not serve as much help for the selecting the sampling points for model execution and daily sample collection. But because pH is an parameter for study of four

stations daily analysis.

This was considered as main parametric study for daily analysis of the samples. The pH of most of the samples remained in between 6.8-8.5 for both the analysed season. The slight fluctuation was seen in Devsthal before the Kosi barrage in between the two seasons, however the variations did not play any vital role in deciding the stations for analysis.(Fig 5.11)

Magnessium for 31 sampling points:

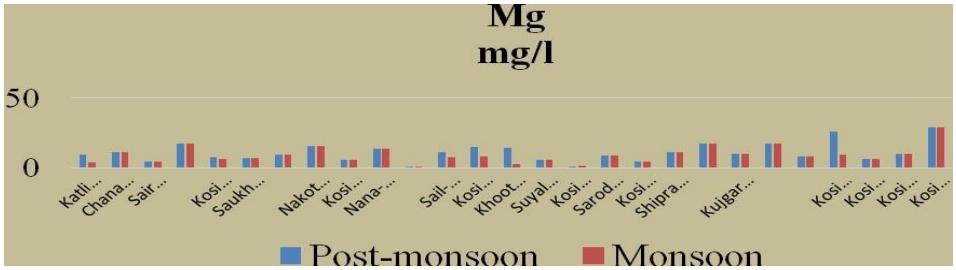


Fig 5.12 Mg concentration for 31 sampling points of river Kosi

Mg^{+} is an important criteria to study the hardness of water. The water is considered to be hard water when it has high content of mineral (in comparison of "soft water"). When the water infertilates through the deposits of minerals as gypsum, chalk or gypsum which are abundantly made up of magnesium and calcium compounds as its carbonates, sulphates, and bicarbonates.(Fig 5.12)

Temporary hardness is caused because of the presence of dissolve components of calcium carbonates and its bicarbonates as well as magnesium carbonates and bicarbonates. When dissolved, these type of minerals yield calcium and magnesium which are both cations (Ca^{2+}, Mg^{2+}) and the anions as bicarbonate and carbonates ($CO^{2-}$and $HCO^{-}3$).Also if the metal ions are present it will make water rather hard. However, unlike the hardness that are permanent are caused by compounds of sulphate and chloride, this "temporary" hardness can be removed or decreased by simply boiling the water, or by the adding of lime(Ca OH) through the procedure called lime softening. The boiling of the water promotes the formation of carbonate from the

bicarbonate and precipitates calcium carbonate out of solution, leaving water that is softer upon cooling. On the other hand permanent hardness (mineral content) are generally difficult to remove by boiling. If this is the case, it is would be caused by the presence of CaSO4 or Ca Cl or MgSO4 or MgSO4 in the water, which does not precipitate out even as the temperature increases.

These ions that cause the permanent hardness of water can be removed using a water softener, or through ion exchange column method. This damage which results from corrosive water cannot be reverted back, but can be repaired by only resurfacing the concrete and replacing piping and also by scrapping the surface scaling.

The highest variation in the Mg levels was seen in Betalghat between the two seasons, which would be due to the decreased flow of the river in post monsoon season, cremation at the banks of the river, or concentration of the contaminants coming with the flow of the river.

Calcium for 31sampling points

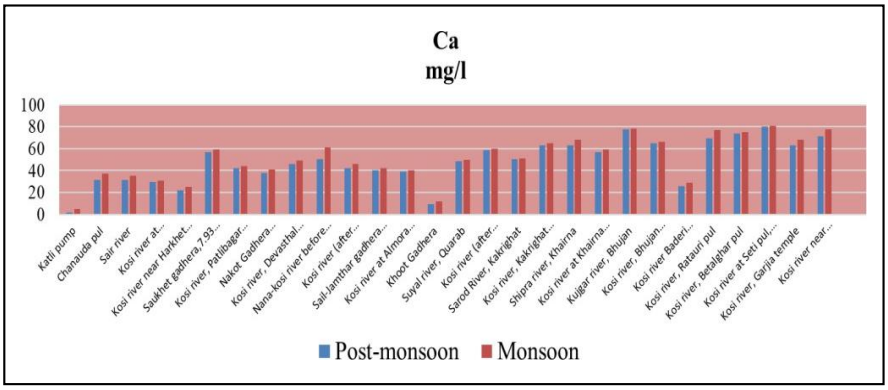


Fig 5.13 Ca concentration of 31 sampling points of river Kosi

The chemical balance of water can be actively managed by keeping calcium hardness pH and alkalinity in one alignment and proper chemical balance. The current scenario to maintain Ca hardness in water is said to be 200-400—mg/l in pools whereas in 150-25-mg/l in spas. Ca component is more relevant in comparison to Mg in water hence this is the only considered in water balance calculation for pools and spas. The four parameters that are considered to

understand the water balance, and the parameters are calcium hardness, pH, total alkalinity and this is known as Saturation index. (5.13)

If the saturation index value is zero then the water is said to be properly balanced.

When the SI value is zero, the water is properly balanced. Its calcium hardness, pH, and total alkalinity are acting in harmony with one another. When the SI is +0.5 or more, the unbalanced water is trending toward scaling, meaning conditions are right for calcium carbonate to come out of solution and deposit on surfaces as "scale." When the SI is -0.3 or less, the unbalanced water is trending toward corrosivity. Corrosive water attacks plaster, concrete, grout, and metal, resulting in etching, pitting, and surface stains and/or colored water caused by metal pulled out of piping, fittings, andequipment.

By reducing the SI to around -1.0 for a short time (usually by lowering pH), some calcium deposits in the filter and circulation piping can be dissolved, and the water's flow can even remove the soft chunks of the loosened scale. But this will come at a price. A thin layer of the concrete surface of the pool may dissolve as well, and copper can be lost from piping and/or heat exchangers.

The least concentration of Ca is seen at station Kantli whereas the values of Ca ion is showing increased values in most of the stations. Khairna, Baderipul, Ratauripul, Setipul, Girijia temple, Ramnagar all showed the values somewhere between 60-80mg/l in both the seasons.

DO for 31sampling points

Dissolved oxygen (DO) is a measure of how much oxygen is dissolved in the water the amount of oxygen available to living aquatic organisms. The amount of dissolved oxygen in a stream or lake can tell us a lot about its water quality.

Dissolved Oxygen is the amount of gaseous oxygen (O2) dissolved in the water. Water temperature and the volume of moving water can affect dissolved oxygen levels. Oxygen dissolves easier in cooler water than warmer water

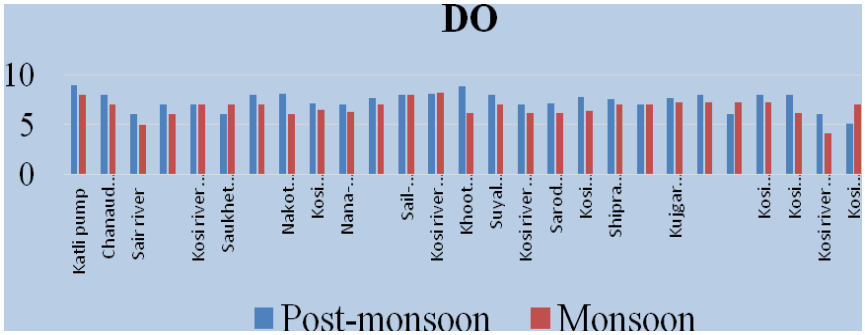


Fig 5.14 The DO of 31 sampling points of river Kosi

.Adequate dissolved oxygen is important for good water quality and necessary to all forms of life. Dissolved oxygen levels that drop below 5.0 mg/L cause stress to aquatic life. Lower concentrations cause greater stress. Oxygen levels that go below 1-2 mg/L for a few hours may result in large fish kills.

Dissolved oxygen for all the stations remained in the permissible limit probably because of the high turbulence of the river. The DO was found above 5mg/l and below 10mg/l in both the seasons. The highest fluctuation between the two seasons was seen in Ramnagar.(Fig 5.14)

BOD for 31 sampling points:

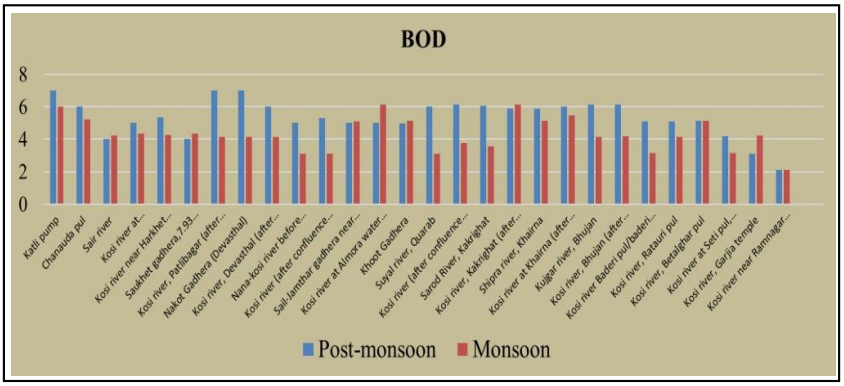


Fig 5.15 BOD of 31 sampling points of river Kosi

Biochemical oxygen demand (BOD) represents the amount of oxygen consumed by bacteria and other microorganisms while they decompose organic matter under aerobic (oxygen is

present) conditions at a specified temperature. Although the amount of dissolved oxygen that is present is small, up to about ten molecules of oxygen per million of water, yet it is subjected as key component of natural water bodies; the presence of a sufficient concentration of dissolved oxygen is vital in maintaining the aquatic life and aesthetic quality of any water body.(Fig 5.15)

It is an integral part of water quality management to determine how the organic matter affects the concentration. The decay of organic matter in water is measured as biochemical or chemical oxygen demand. The oxygen demand is considered as a measure of the amount of oxidizable substances in a water sample that can lower DO concentrations.
Many environmental stresses and constraints (hot summer temperatures) as well as other human induced factors (introduction of excess chemicals to a water body) can decrease the amount of dissolved oxygen in a water body, resulting in stresses on the local aquatic life. One water analysis that is utilized in order to better understand the effect of bacteria and other microorganisms on the amount of oxygen they consume as they decompose organic matter under aerobic (oxygen is present) is the measure of biochemical oxygen demand (BOD).
Determining how organic matter affects the concentration of dissolved oxygen in a stream or lake is integral to water-quality management. BOD is a measure of the amount of oxygen required to remove waste organic matter from water in the process of decomposition by aerobic bacteria (those bacteria that live only in an environment containing oxygen). The waste organic matter is stabilized or made unobjectionable through its decomposition by living bacterial organisms which need oxygen to do their work. BOD is used, often in wastewater-treatment plants, as an index of the degree of organic pollution in water.

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Nitrate for 31 sampling points:

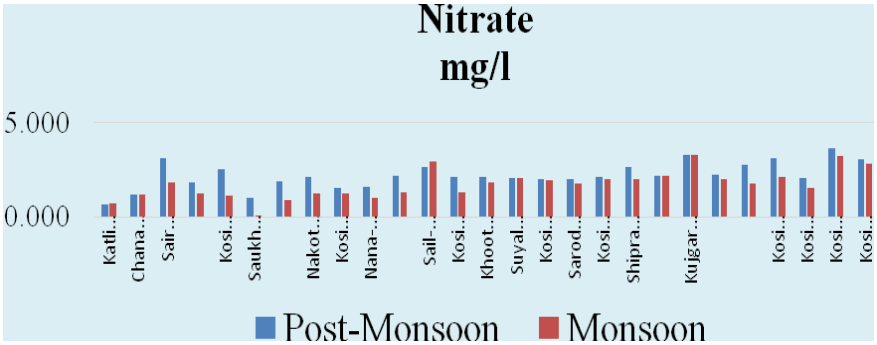


Fig 5.16 Nitrate concentration in 31 sampling points of river Kosi

Nitrate and nitrite are naturally occurring ions that are part of the nitrogen cycle. The nitrate ion (NO_3^-) is the stable form of combined nitrogen for oxygenated systems. Although chemically unreactive, it can be reduced by some microbial action. The nitrite ion (NO_2^-) contains nitrogen in a relatively unstable oxidation state. Chemical and biological processes can further reduce nitrite to various compounds or oxidize it to nitrate. The concentrations of nitrate in rainwater of up to 5 mg/l have been observed in industrial areas. In rural areas, concentrations can be somewhat lower.

The nitrate concentration in surface water is normally low (0–18 mg/l) but can reach high levels as a result of agricultural runoff, refuse dump runoff or contamination with human or animal wastes. The concentration often fluctuates with the season and may increase when the river is fed by nitrate-rich aquifers. Nitrate concentrations have gradually increased in many

European countries in the last few decades and have sometimes doubled over the past 20 years. In the United Kingdom, for example, an average annual increase of 0.7 mg/l ha s been observed in some rivers .The natural nitrate concentration in groundwater under aerobic conditions is a few milligrams per liter and depends strongly on soil type and on the geological situation. The nitrate can reach the aquifer through septic tanks and also by the increased use of artificial fertilizers, the disposal of wastes (particularly from animal farming) and changes in land use are the main factors responsible for the progressive increase in nitrate levels in groundwater supplies over the last 20 years.

Because of the delay in the response of groundwater to changes in soil, some endangered aquifers have not yet shown the increase expected from the increased use of nitrogen fertilizer or manure. Once the nitrate reaches these aquifers, the aquifers will remain contaminated for decades, even if there is a substantial reduction in the nitrate loading of the surface.

The current situation shows that the river Kosi has low concentration of nitrate in all the 31 station as less than 5mg/l. (Fig 5.16)

Sulphate for 31 sampling points:

Sulfates occur naturally in numerous minerals, including barite (BaSO4), epsomite (MgSO4· 7H2O) and gypsum (CaSO4·2H2O).These dissolved minerals contribute to the mineral content of many drinking- water. Reported taste threshold concentrations in drinking-water are 250–500 mg/litre (median 350 mg/liter) for sodium sulfate , 250–1000 mg/litre (median 525 mg/litre) for calcium sulfate and 400–600 mg/litre (median 525 mg/litre) for magnesium sulfate NAS (1977). Addition of calcium and magnesium sulfate (but not sodium sulfate) to distilled water was found to improve the taste; an optimal taste was found at 270 and 90 mg/liter for calcium and magnesium sulfate, respectively.

The 31 sampling points sampled in the entire stretch shows the level of sulphate somewhere between 10- 20mg/l which is quite a below the permissible limit. (Fig 5.17).

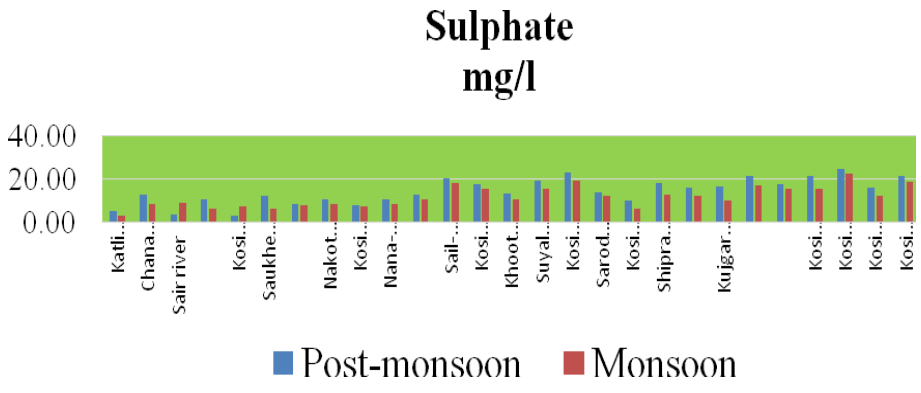


Fig 5.17 Sulphate concentration in 31 sampling points of river Kosi

Sampling Points for model execution

For 4 daily sampling points of river Kosi: The four sampling points selected for sampling and daily analysis were Kantli, Kosi, Kwarab, Ramnagar. The four stations were selected on the basis of the contamination levels of the the river Kosi that was isolated in 31 sampling points analysis.

The analysis for the two seasons done acted as a torch bearer to see the various contamination levels at all the 31 points and select the 4 major points in the stretch to isolate the contamination.

Hence Kantli was selected as an origin point of the river which was further extended to Kosi barrage before the Almora town and then Kwarab which is the station after river crosses the Almora town and then the final destination of the river which is Ramnagar. The stations considered for execution of the model (Table 5.8)

SN	Station	Name of the station
1	PS120	Kantli
2.	PS121	Kosi
3.	PS122	Kwarab
4.	PS123	Ramnagar

Table 5.8 Stations for daily sampling of the model

Results w.r.t model execution

The rapid increase in population, industrialization, urbanization and agricultural practices have ultimately resulted in pollution of the water bodies to an extent that most of the water bodies have become hazardous and poisonous for direct consumption. These practices has not only resulted to pollute the reservoirs with increase in pollutants but has also added new number of pollutants into the scenario. The major pollutants are the biodegradable waste, which are discharged as waste water in the water bodies. These discharged biodegradable waste decreases the water quality particularly by decreasing the dissolved oxygen

concentrations in water body. (Nakhaei, N. and Shahidi, A.E. (2010). This has affected the water quality at the level of serious concern. Hence for managing the future water quality of the water body a detailed survey, present and past trend analysis as well as strategic present time analysis is essential and vital. The past trend analysis is essential to understand the pollutant behavior, load and also transfer pathway so that the future effect with the pathway could be studied and analysed that would help taking the preventive measures, help manage the pollution and ultimately also help avoid the pollution.

The future prediction of the study area selected was done by WASP. The major reason for the water quality analysis for the river Kosi was..

1. To see the contamination levels inthe river

As the springs of Almora have either turned vulnerable because of excessive growth of population and urbanization and with the analysis of the spring of Almora town it has been prominent that the contamination levels are beyond the permissible limit in most of the springs and even most of the springs are no more in use for drinking purpose and this is proclaimed by the local people themselves with the disclaimer on the walls of the naulas and dharas. This proclamation by the local people is not because they have done some lab analysis with the spring water but rather with their own personal experience on consuming the water from the springs in years together, they have found the taste of the springs have changed and this has resulted in self proclamation of the local people to declare that the spring water is no more fit for drinking directly from the source.

2 To see whether the dilution of contaminants imparts any effect on river water quality.

As the stations selected for the water quality analysis is selected with great caution. The project IV of the institute GB PANT was a torchbearer to help in selection of the stations for the model execution. Initially for a year 31 sampling points that were considered for the water quality analysis in project IV was reanalysed. The samples from all the 31 sampling points were collected for two major seasons to see the contamination levels in present 2019. Then on the basis of the results generated,by the analysis of 31 sampling points 4 stations were selected for the analysis and also daily sampling.

3 As Almora is the most contaminated and densely populated town in the region, two points were selected in the stretch. One before the river Kosi crosses Almora and one after the river Kosi crosses Almora. The points were

Kosi barrage and Kawarb.

4 The model executes with daily samples collection, hence samples from May 2019 to December 2019 were analysed

5 The results generated by the analysis of the samples and model WASP execution is referred as below

6 Model WASP is a EPA prescribed water qua lity analysis simulation program which is designed to work for surface water and defines well the eutrophication as well as toxicants future in the water body. Lai Y C, Tu Y T, Yang. (2013).

Station Kantli: For Dissolved oxygen from 01-06-2019

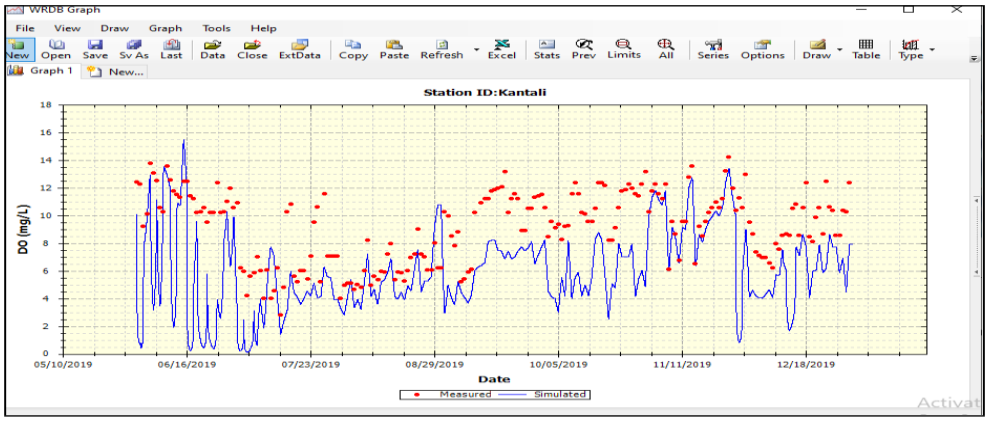


Fig 5.18 Simulation graph for station Kantli For DO as parameter

The red points show the simulated data given by the model, wheras the graph lines blue in color is the measured values for the station Kantli which is the starting point of the river Kosi and considered to be in its most serene state when originating from there.

The dissolved oxygen for the Kantli station described is that the simulation values lies nearby the values of the simulated values. The few measured values lies away from the simulated values between August and September. The probable reason being is the variation in the rainfall in the region for the current year. The excessive rainfall and scattered rainfall all through the month has resulted in the variation in the simulated and measured values in the region.

Hence for the month August to September the values of simulation shows increase in simulated values in comparison to measured. The values vary from 10mg/l -8mg/l for measured values whereas for simulated values varies from 2mg/l- 12mg/l which is in consideration with the values executed by the model WASP. Dissolved oxygen is an important parameter which is highly dependent on water temperature.

The temperature of water when is high or is too warm then there might be oxygen deficiency in the water body. If the presence of microorganisms or bacteria is more in the water body then it consumes more oxygen hence reducing the dissolve oxygen in the water body to a drastic amount. Oxygen is very much required for the functioning of the animals

and aquatic plants in the water body and when this oxygen decreases then it shows that the water is dead. As the aquatic plants don't then get enough oxygen for their survival. Since river Kosi has many hurdles as rocks in its pathway and hence in the course of its flow the turbulence due to this rocks increases hence dissolving the oxygen into the river. Also since the river from higher altitude flows towards plain region i.e Ramnagar, the height also adds more turbulence to the water(Fig 5.18). Hence dissolved oxygen of river Kosi in Kantli is within desirable limit and water at this station is considered to be healthy for potable as well as for aquatic life in terms of dissolve oxygen.

Kantli is the station point from where the river originates and hence the DO of the river is quite well at this point. The river is at its maximum serenity level and is pure. Since the terrain is mountainous hence the falling of the springs from heights helps the water to mix more with the atmospheric oxygen. This oxygen increases the dissolved oxygen content in water of the flowing springs. The dissolved oxygen is important criteria for the drinking water.

BOD of Kantli station 1-06-2019 to 31-12-2019

The BOD is again another parameter that was considered for the model execution. As this is the parameter which studies the amount of oxygen demanded due to consumption of oxygen from the water body by the microorganisms and bacteria in the water.

High BOD levels specify the more presence of biodegradable waste in the water. Hence higher the BOD less oxygen in water and lesser the BOD more is the oxygen in the water body. Hence high BOD levels signify that the levels of organic pollution generally caused by discharge of poorly treated wastewater resulting in high nitrate level.

When the nitrates and phosphates in a body increases results in more increase in algal growth in the water resulting in high BOD. The BOD levels of Kantli station shows that they go hand in hand with the simulated and measured values. However fluctuations are visible in between August and September where the simulated values are less and the measured values are more. The rainfall irregularity might be the cause. Also when the water from the spring takes river forms in many a cases due to the geography and geology the water sometimes gets collected in the pits or rocks in the river course.

Since the river that flows is a spring fed river hence when the spring merges the course and flow of the river is not defined. The collection of water in some of the pits might result in increase of the microbial activity in the pits and when such water along with the river flows, it might bring the microbial cultured water hence showing increase in BOD in that particular area.

Also river Kosi at the starting point does not that velocity and dilution that would nullify the presence of bacteria and microorganisms in the river.

The springs keep merging into the river Kosi in later part as flows from Kantli to the lower altitudes (Fig 5.19).

Hence this could be a probable reason that at measured value at Kantli for BOD is high than the simulated value. In the rest of the course of simulation the graph goes insimulation to the observed data.

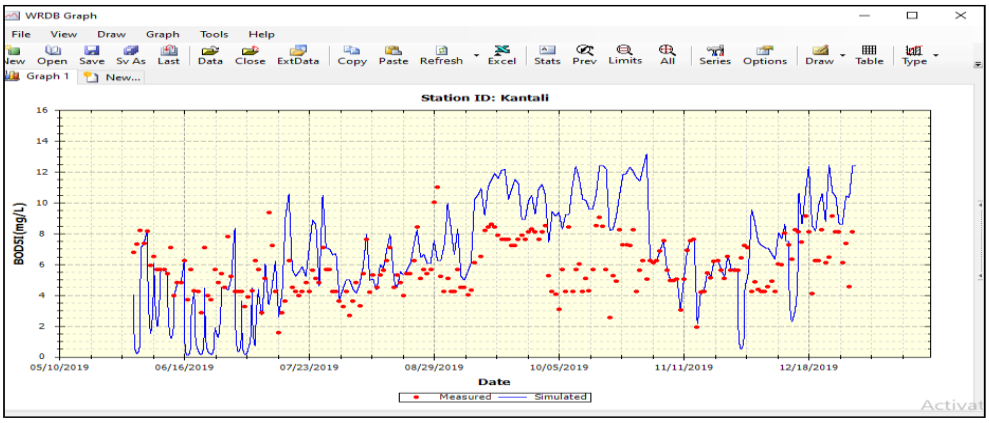


Fig 5.19 Simulation graph for station Kantli For BOD as parameter

Nitrate for Kantli station 1-06-2019-31-12-2019

The nitrate contamination in Kantli station is very less in comparison to Ramnagar where the river merges finally into Ramganga. The nitrate contamination has no source here in the origin of river Kosi however very minute concentration may be found which might be due to geology and geography in the region(Fig 5.20). The nitrate reads here as at maximum 5

mg/l. The permissible limit for nitrate according to EPA is 45 mg/l. The nitrate contamination simulation goes fairly well with the measured values.

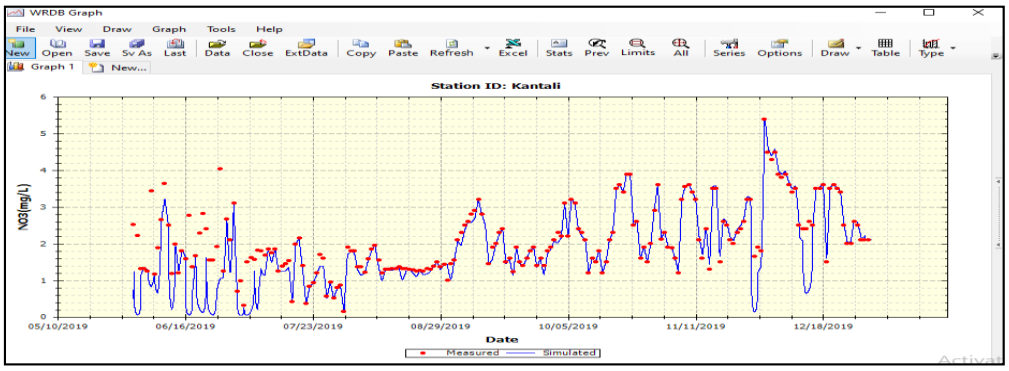


Figure 5.20 Simulation graph for station Kantli For Nitrate as parameter

Station Kosi 1-06-2019-31-12-2019:

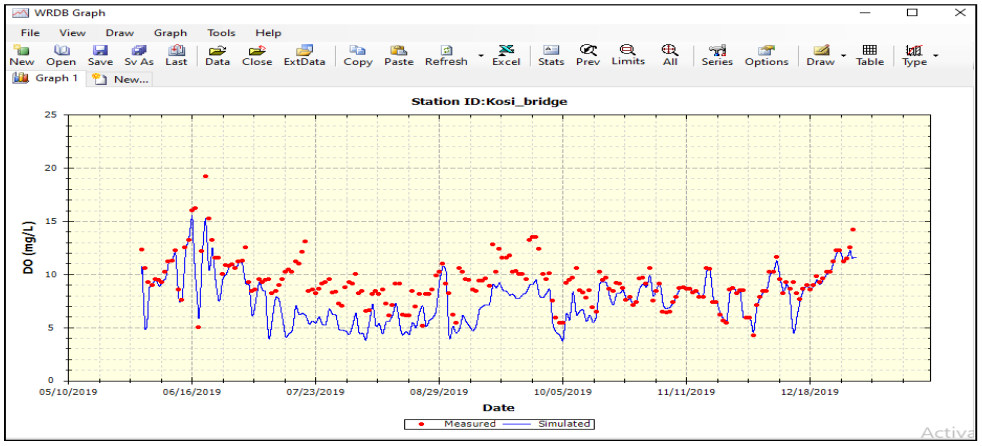


Fig 5.21 Simulation graph for station Kosi For DO as parameter

The concentration of nitrate in the river may be from the spring recharge. The springs of Almora are highly contaminated with nitrate, but since Kantli is the starting point of the river with very scarce population hence the concentration of nitrate is very less.The DO of Kosi barrage is going perfectly well with the simulated as well as measured data. In August and September however the values of Dissolved oxygen of simulated data is bit more in comparison to the measured values. These fluctuations are common with .5mg/l differences

between simulated and measured data. The Kosi barrage is built on river Kosi to provide water to Almora through uplift system (Fig 5.21). The barrage preserves the water and is sent to the town for potable as well as domestic purposes. However the sample was collected from the river Kosi rather than from the barrage. If the level of DO is high proves that water is fit for drinking as it makes the taste of the water better

However if the value of DO is very high it corrodes the pipe of the supply. This is the reason why industries use water that is less in dissolved oxygen. The water that is used in boilers have DO not more than 2 ppm but most of the boilers keep the DO as low as .007 ppm. The amount of oxygen dissolved in water depends upon various factors as for the river ,It depends upon the obstacles as rocks in the way of the flow of the river, plants in the river, temperature of the water,etc.The oxygen content in the water decreases as the temperature of the water increases. The temperature of the region is very less and because the water is fed from the springs the temperature of water remains normal hence the oxygen content in water is naturally more. The oxygen levels would be even more when in winters as they temperature decreases to 6 degree centigrade in day time. Oxygen levels also vary with the depth of the river. Oxygen level decreases with the depth of the river.

BOD Kosi 1-06-2019-31-12-2019:

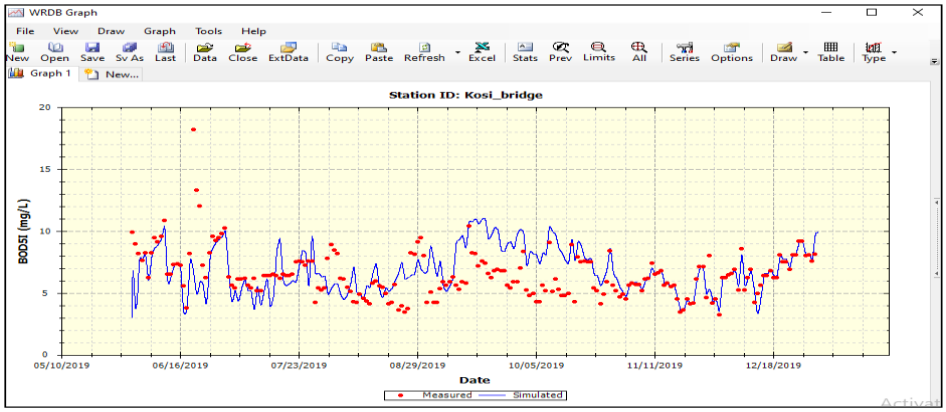


Fig 5.22 Simulation graph for station Kosi For BOD as parameter

The BOD of the river Kosi lies in between 4-10 mg/l for the measured values and might range from 4-18 mg/l as simulated values. The simulated value show a out layer in the

month of June. Whereas most of the values of simulated and measured lies in co existence with each other. The BOD of Kantli and Kosi shares the similarities with each other. The values as well as simulation goes hand in hand for the probable reason that till Kosi there is no intuition of the contamination into the river. The simulated values in BOD go less in comparison to the BOD of the measured values from August to September. The probable reason could be again the variation of rainfall in the region. The variations goes similar to that of Kantli.(Fig 5.22)

Hence as observed that the high levels of BOD means more microorganisms using more oxygen to survive which states competition for survival for the aquatic plants and animals. High value of DO shows that it is fairly good for drinking as well as aquatic plants and animals. BOD in Kosi remains same as Kantli and shows very less variation.

Nitrate in Kosi bridge 1-06-2019-31-12-2019:

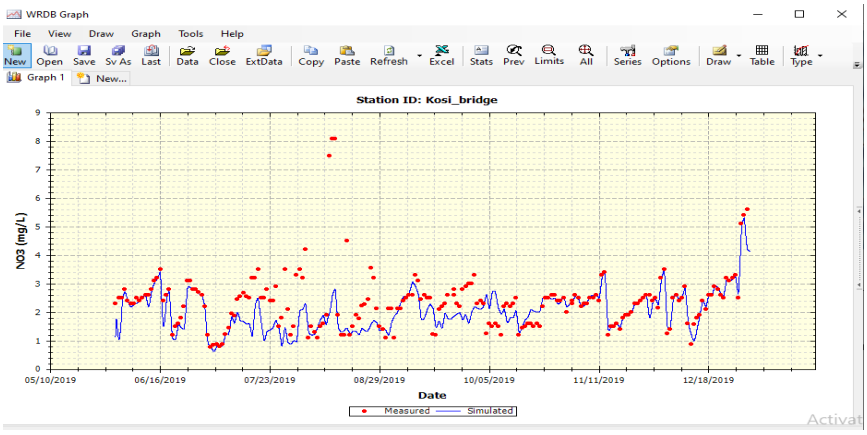


Fig 5.23 Simulation graph for station Kosi For Nitrate as parameter

Nitrate in Kosi shows variation from that of Kantli. The simulated values ranges from 0.5 mg/lto 9 mg/l wheras the measured values ranges from 1 mg/ l to 7mg/l. The reason being is the river Kosi after Kantli crosses a few towns as Someshwar which is fairly populated also because Someshwar is valley region fairly well amount of agricultural as well as population built up is seen in the region. However this could have impacted the quality of water hence we see little increase in the measured values of nitrate. The out layers in nitrate are seen in

simulated value for a day or two.

It is rarely possible to point out the exact sources of nitrate contamination as there are many possibilities for water to have nitrate. The various sources of nitrate may include runoff from the agricultural fields, municipal waste, garbage dumps, septic tanks, animal feed, decaying plant and debris. Nitrate although is not major concern in the river for the point Kosi since the values range within the permissible limit. However this might be a major concern with the increasing population in the stretch. Geologic formations and direction of ground water flow also may influence nitrate concentration (Fig 5.23). EU i.e Nitrate directives aim to quantify the human effects on nitrogen cycle and methods to promote as well as validate the various methods for sustainable nitrogen management this shows the seriousness of national as well as global effort for the management of nitrate into the region. In order to fulfill this EU has identified certain vulnerable areas for establishing the codes of good agricultural practices, national monitoring and reporting indicated by reducing trends in nitrate contamination in the ground water. Hence effective measures need to be taken in and near Kosi as well since increasing population and open dumps are contaminating the groundwater sources which are above permissible limit in Almora springs. The probable gift for the river Kosi is dilution. The dilution and flow of the river has unable the region to help spare from the devastating effect of nitrate contamination.

Kwarab dissolved oxygen 1-06-2019-31-12-2019:

The Kwarab is the point after the river Kosi crosses Almora. The river Kosi however merges with the river Suyal before Kwarab. The river Suyal is also a tributary river of Kosi which is spring fed. The dissolve oxygen of river Kosi for simulation as well as measured data showed variation.

The simulated data lied between 4mg/l to 18 mg/lwhereas measured data varied from 5 mg/l to 15 mg/l.In July month the simulated values showed variation of 5-7 mg/l from the measured values(Fig 5.24).

The Suyal river merger along with the intense rain inthe region would probably be the reason for more fluctuation in both the values in the region. It is observed that water at

comparatively minimal temperatures must have comparatively higher values of DO that the warmer water. It is observed that healthy water have dissolved oxygen concentrations above 6.5 mg/l to 8 mg/.Less oxygen level creates stress and can kill fishes if the value is 1-2mg/l for few hrs.

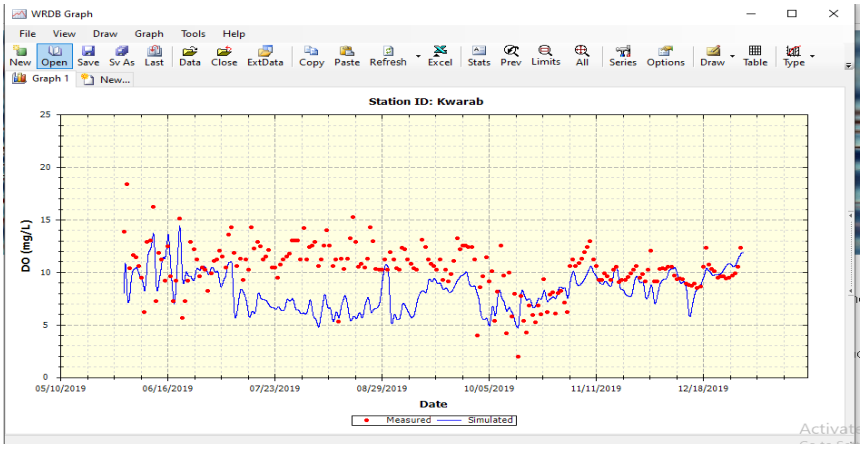


Fig 5.24 Simulation graph for station Kwarab For DO as parameter

BOD of Kwarab 1-06-2019-31-12-2019:

Kwarab is the station point which was selected to ensure the contamination levels and its variations from Kosi as selection point after the merger of river suyal river.

The suyal river is the river which merges down in the main river stream Kosi The suyal river is the river into which the sewage treatment plant from Almora merges into the river Kosi, hence the variation in the water quality before the emergence of suyal river into Kosi and after the emergence of the river to Kosi.

To study this variations the study was conducted to see BOD varying from 2-8 mg/l in from the duration from 10 th of may 2019 to December 2019. The simulated and observed value did not show much variation except a few days.(Fig 5.25)

The fluctuations in the observed values and simulated values were seen because of non uniform pattern and unprecedented rainfall in the region. Thus variations in the meteorological data showed variations in the water quality in the region. The unpredicted rain in winter season resulted in variations in the entire stretch.

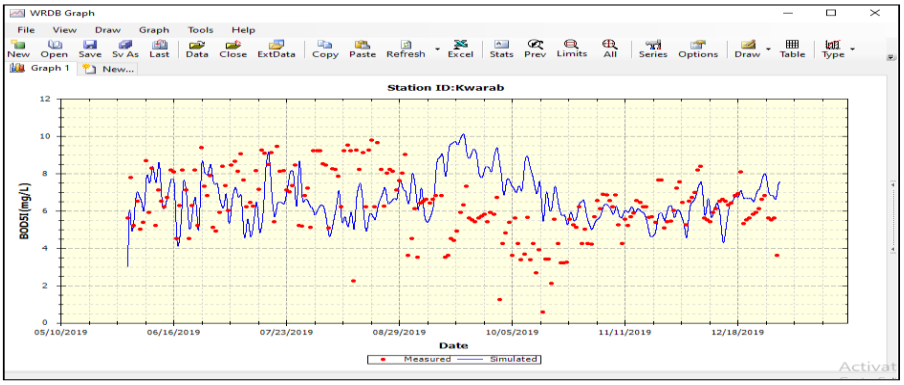


Fig 5.25 Simulation graph for station Kwarab For BOD as parameter

Nitrate in Kwarab 1-06-2019-31-12-2019:

The fluctuations in the observed values and simulated values were seen because of unpattern and unprecedented rainfall in the region.

Thus variations in the meteorological data showed variations in the water quality in the region. The unpredicted rain in winter season resulted in variations in the entire stretch.

The outlayers in the simulated and measured graph are depicted because of these variations in hydrometrological data.(Fig 5.26)

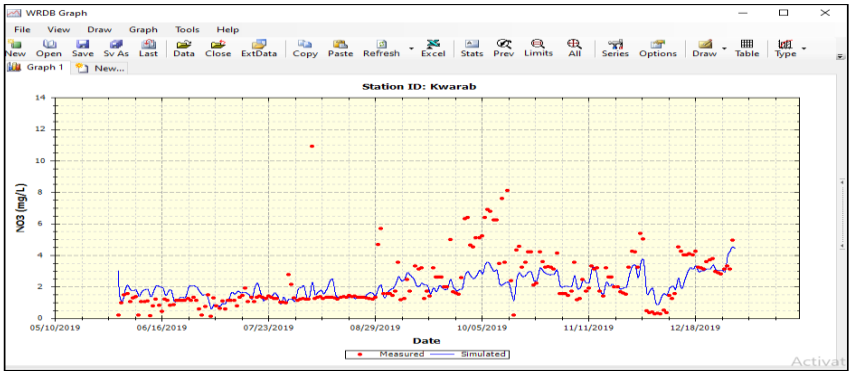


Fig 5.26 Simulation graph for station Kwarab For Nitrate as parameter

Ramnagar DO 1-06-2019-31-12-2019:

Ramnagar data for DO shows reduced amount of dissolved oxygen in the region probably because of the disposing of more treatment plant waste and construction of the barrage which restricts the natural flow of the river and also reduces the dissolved oxygen in the water.

The raining season poses more difficulty in the water quality of the river at the selected point for model execution (Fig 5.27). The collection of the city waste at the barrage also poses to hamper the quality of the river hence reducing the dissolved oxygen in the river. The dissolved oxygen varied from simulated and observed values from 5-10mg/l and observed from 3mg/l to 18mg/l.

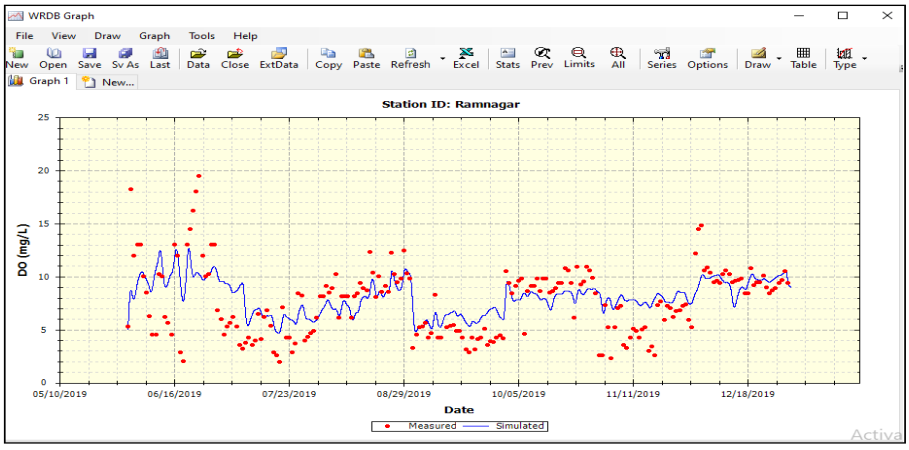


Fig 5.27 Simulation graph for station Ramnagar For DO as parameter

BOD in Ramnagar 1-06-2019-31-12-2019:

The BOD of the river Kosi at the Ramnagar selected point for model execution shows decreased value of dissolved oxygen hence BOD too. The disposing of the waste to the river has increased the microorganisms content in the sample hence increasing the BOD of the water. The presence of more microorganisms in the samples results in more oxygen consumption by the microorganisms in the sample hence decreasing the oxygen content.(Fig5.27)

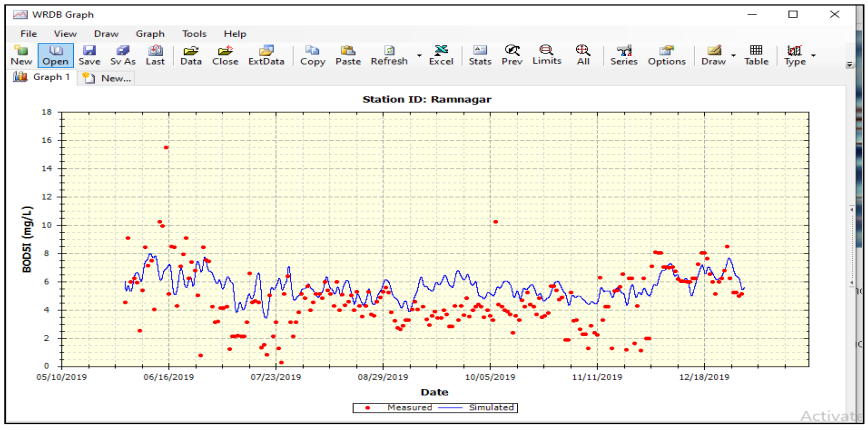


Fig 5.28 Simulation graph for station Ramnagar for BOD as parameter

Nitrate of Ramanagar1-06-2019-31-12-2019

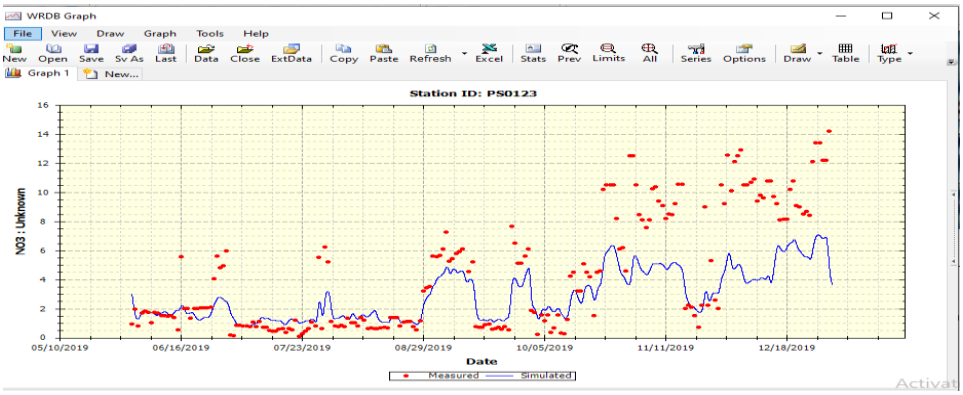
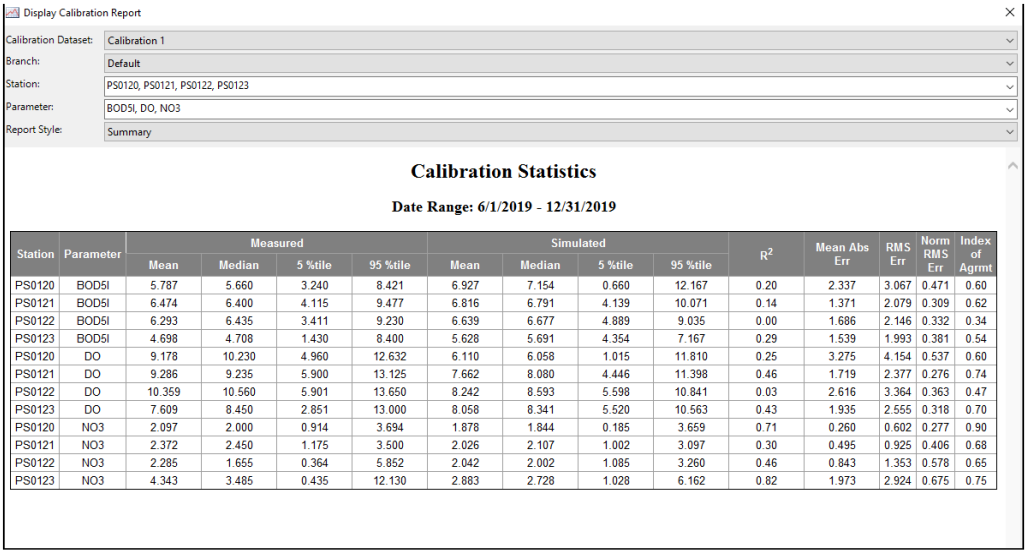


Fig 5.29 Simulation graph for station Ramnagar for nitrate as parameter

Nitrate is at maximum level at Ramnagar station. The measured values although shows till 15 mg/l the simulated values which is blue graph line shows variation from 3mg/l -6 mg/l. Here the variation is seen in between the simulated as well as observed value. The Ramnagar barrage where the dilution of water is at maximum, yet we see the level of nitrate to be at maximum range in comparison to any station value. The Ramnagar barrage collects all the water from the river and drains away all the solid waste coming in the region. The contamination level has increased due to carrying away of solid waste dumps that is abundant in the region The increased value signifies that nitrate (NO 3) is a compound of

nitrogen and oxygen found in nature and in many food items in our diet. As in the concentration of nitrate in the groundwater is generally less but it increases due to various reasons. The main intake of nitrate for individuals is generally from food rather fromwater. Vegetables such as spinach, lettuce, beets and carrots contain significant amounts of nitrate. Drinking water normally contributes only a small percentage of our total nitrate intake. Although low levels of nitrates may occur naturally in water, sometimes higher levels, which are potentially dangerous to infants, are found. Illinois has adopted a drinking water standard for nitrate of 10 milligrams per liter (10 mg/L) as N (nitrogen). This standard is mandatory for public water supplies and is used as a guide for private water supplies. The U.S. Environmental Protection Agency also uses 10 mg/L as N as a mandatory national standard for public supplies under the Safe Drinking Water Act. The 10 mg/L standard expressed as nitrogen (N) is equivalent to 45 mg/L expressed as nitrate.(Fig 5.29)

Statistics of the Simulated and Observed data data


Display Calibration Report

Calibration Dataset: Calibration 1
Branch: Default
Station: PS0120, PS0121, PS0122, PS0123
Parameter: BOD5I, DO, NO3
Report Style: Summary

Calibration Statistics

Date Range: 6/1/2019 - 12/31/2019

Station	Parameter	Measured				Simulated				R^2	Mean Abs Err	RMS Err	Norm RMS Err	Index of Agrmt
		Mean	Median	5 %tile	95 %tile	Mean	Median	5 %tile	95 %tile					
PS0120	BOD5I	5.787	5.660	3.240	8.421	6.927	7.154	0.660	12.167	0.20	2.337	3.067	0.471	0.60
PS0121	BOD5I	6.474	6.400	4.115	9.477	6.816	6.791	4.139	10.071	0.14	1.371	2.079	0.309	0.62
PS0122	BOD5I	6.293	6.435	3.411	9.230	6.639	6.677	4.889	9.035	0.00	1.686	2.146	0.332	0.34
PS0123	BOD5I	4.698	4.708	1.430	8.400	5.628	5.691	4.354	7.167	0.29	1.539	1.993	0.381	0.54
PS0120	DO	9.178	10.230	4.960	12.632	6.110	6.058	1.015	11.810	0.25	3.275	4.154	0.537	0.60
PS0121	DO	9.286	9.235	5.900	13.125	7.662	8.080	4.446	11.398	0.46	1.719	2.377	0.276	0.74
PS0122	DO	10.359	10.560	5.901	13.650	8.242	8.593	5.598	10.841	0.03	2.616	3.364	0.363	0.47
PS0123	DO	7.609	8.450	2.851	13.000	8.058	8.341	5.520	10.563	0.43	1.935	2.555	0.318	0.70
PS0120	NO3	2.097	2.000	0.914	3.694	1.878	1.844	0.185	3.659	0.71	0.260	0.602	0.277	0.90
PS0121	NO3	2.372	2.450	1.175	3.500	2.026	2.107	1.002	3.097	0.30	0.495	0.925	0.406	0.68
PS0122	NO3	2.285	1.655	0.364	5.852	2.042	2.002	1.085	3.260	0.46	0.843	1.353	0.578	0.65
PS0123	NO3	4.343	3.485	0.435	12.130	2.883	2.728	1.028	6.162	0.82	1.973	2.924	0.675	0.75

Table 5.9 Model generated statistics between observed and simulated data

The calibration statistics shows clearly states that the values attained by the sample analysis of the four stations have considerable effect. The overall consideration of **Index of Agreement** (d) developed as a standardized measure of the degree of model prediction error and varies between 0 and 1. The values here attained from the index of agreement vary from

0-1 which shows the model prediction and error of the model is within the prescribed statistics. The index of agreement for all the parameters for all the station showed the variation as above o and below 1(Table 5.9). The highest value as.90 was shown by nitrate in the Kantli station. And the lowest value was for BOD of the Kantli station as .34.

R^2 is the statistical value to measure how close the data are fitted to the regression line. 100 percent indicates that the model explains all the variability of the response data around its mean.

The value of R^2 for station Kantli Kosi Kwarab and Ramnagar for BOD was noticed to be 0.20, 0.14, .02 and 0.29 respectively. The maximum R2 was seen in Kantli for nitrate as .70. The RMS error was seen maximum for Kantli was 4.154 for DO and lowest value of RMS was for Kantli for nitrate. The Nor RMS error was maximum for DO for Kantli was .537 and lowest for Kosi as .236.

The calibration statistics in the table 7 is a self explained statistics of all the observed and simulated values. This shows that the Observed value shows in better correlation with its parameters than in simulated values .But on relating the two measured and simulated values for Index of agreement the both data shows in perfect correlation with each other.

5.4.1 Correlation between simulated and Measured values of the stations

Kantli Simulated and Measured values

The simulated and observed values of the parameters in Kantli show strong correlation between each other (Fig 5.30).

Kantli which is the starting point of the river Kosi was daily sampled and analysed and the values generated from the analysed data as well as simulated data from the model shows that the values are in correlation with each other. The water of Kosi upstream is at the highest level of serenity at Kantli.

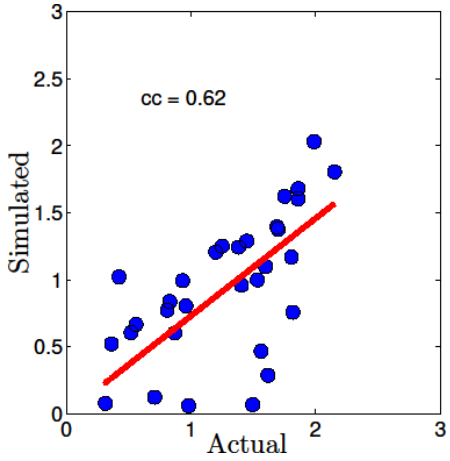


Fig 5.30 Correlation between observed and simulated data of Kantli

Simulated and Measured values for Kosi

The measured values of Kosi river at Kosi river and before Almora shows perfectly correlated. The values from the model generated and analysed data show perfect correlation between each other with 0.75. The major specialty of WASP depends on the accuracy of the data collected. The boundary inflow conditions the environmental constraints and hydrological data plays a vital role in determining the accuracy. conditions and environmental constants.(Fig 5.31)

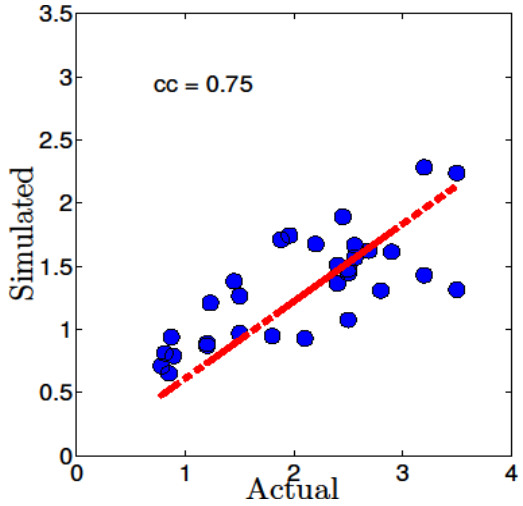


Fig 5.31 Correlation between observed and simulated data of Kosi

Kwarab Simulated and Measured

The simulated and observed data shows less correlation between the two. The correlation happens to be as 0.28 which is less.(Fig 5.32)

The data could be more precise if the sampling would be have done for a longer duration of time as this is the point where suyal river merges with the river Kosi and hence the bulk and precise data would help to know the variations more appropriately. The river suyal that carries the wastewater from the Almora treatment plant is supposed to be showing variations in the simulated and observed data.

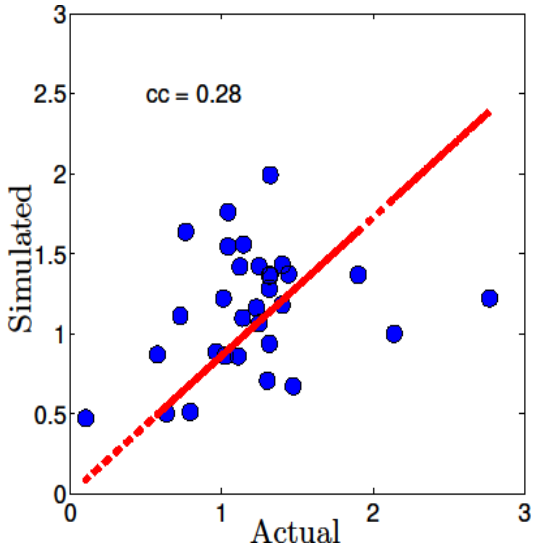


Fig 5.32 Correlation between observed and simulated data of Kwarab

Ramnagar measured and simulated value of Ramnagar

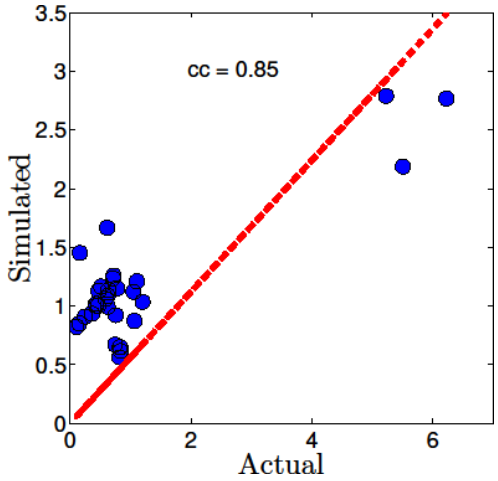


Fig 5.33 Correlation between observed and simulated data of Ramnagar

The data generated from Ramnagar shows the highest correlation between simulated and observed data (Fig 5.33**).**

Future of water quality in the watershed:

The coming five years the values of the the parameters studied remains the same with the minor fluctuations whereas when the time period of the simulation was increased the values ranged as following in the values referred in the (Table 5.10).

Depending the on the environmental and hydrometeorological constraints nature doesn't face any drastic changes as in 2013.The values of nitrate in Ramanagar is however supposed to increase in by 20-40 mg/l which is a matter of concern however the values at other stations remains within the permissible limit.

S.NO	Parameters	Kantli	Kosi	Kwarab	Ramanagar
1.	DO(mg/l)	10-14	5-10	5-15	5-12
2.	BOD(mg/l)	2-12	4-10	3-10	4-8
3.	Nitrate(mg/l)	2-4	2-5	3-10	20-40

Table 5.10 Future water quality of river Kosi at 4 daily sampled statio

Chapter:6

Nutrient Dynamics In Water

6.1 Nitrate as nutrient and its impacts:

The impact of nutrients is quite prominent in the springs of the region. The contamination of springs in Almora is majorly due to the leaching of nutrients from the septic tanks into the water sources. The water sources according to the samples collected from the most of the springs in midmist of the town specifies that the concentration of nitrate in the springs is 45mg/l-50mg/l. This shows the alarming condition of water quality in the region. The springs are the only source of water in the region and contamination of these springs with nutrients leave the region with quenching the thirst of the people with contaminated water. The contaminated water with nitrate poses so many health problems for the population. The water borne diseases are very common in the region. (Fan and Steinberg, 1996; WHO, 1999; WHO, 2004;and Chapman, 2004). The consumption of nitrate poses health issues and the consequences of ill impacts of nitrate that which includes increased risks of blue baby syndrome and other health related risks along with accumulation of nutrients in the environment hence causing eutrophication for surface water and contamination of ground water. (Vitousek et al., 1997; WHO, 1999; Mason, 2002). On one hand where most of the nitrate is believed to be coming from agricultural fields in most of the parts of the country as our country is agriculture based economy. But the study area selected is not having agriculture as their staple occupation as the people have many constraints related to agriculture(Foster, 2000).The people here are basically dependent upon tourism industry for their daily bread. It has been observed that 70-80% percent of nitrate contamination for surface as well as ground water is due to agricultural activities. (Defra, 2002). However in the current scenario for the selected study area the nitrogen based fertilizers do not contaminate the surface or groundwater as agriculture is not the prior occupation of the people of this area. The other reason for nitrate contamination in the groundwater could be discharge from the septic tanks and leaking sewers, atmospheric deposition and also spreading of waste water and sludge on the land. (Wakida and Lerner, 2005). The discharge from the septic tank is hence the major reason for the contamination of the springs from

nitrate in the region.

The standard permissible limit and desirable limit for nitrate in water as given by EPA is 45mg/ l and 10mg/ respectively whereas by European union and world health organization prescribed the limit as 11.3mg/l-50 mg/l (Drinking Water Directive 98/83/EC; WHO, 2004).

Many collective measures are into implementation worldwide to conserve the water resources and limit has been set to 45mg/ l for the natural waters. The Nitrates Directive (91/676/EEC) requires protection of all natural freshwaters and sets a limit of 45 mg-NO_3/l which applies to all the groundwater ir respective of its intended use, although it is identified that comparative very lower N concentrations, possibly about in the range of 4.4– 8.8 mg-NO_3/l (1– 2 mg-N/ l), might trigger the eutrophication in the nutrient-poor (oligotrophic) surface waters (James et al., 2005) in the region and in the Himalayan town in which springs are the only source of water becomes vulnerable with the quality due to leaching of even minute concentrations of N could cause a threat to the sustainability of the region with respect to the drinking water. The springs are the feeding source for river Kosi. The contamination of springs have been studied from long time since 1991(K.Kumar,Rawat) and the contamination levels of most of the springs were analysed to be more that 40 mg/l and a few as Gurani nauala had 60mg/l. The river Kosi is liable to get contaminated with nutrients if the situation continues and would question the sustainable existence of human beings with the current scenario. Many steps are taken to conserve the groundwater by various organizations.When nutrient rich water the concentration of phosphate which is also a nutrient is found to be limiting.

The mitigation of nutrient accumulation becomes difficult due to the long -term, diffuse and consistent nature of the problem (Hiscock et al., 2007; Mathias et al., 2007). The implementation of land use pattern is such a way that the reduced nitrate loading is seen in the subsurface level of the soil will help build to sustainable existence. The nitrate accumulation can be regulated from the soil so that it does not penetrate within the soil. If infiltrated could be regulated in some cases. This would be done only when the pathway of the nutrient

infiltration is known. The scientific and technical study of natural attenuation can be taken into play only when penetration of suggested nutrients into the soil is well understood. (Silgram et al., 2005; Hiscock et al., 2007; Johnson et al., 2007)

6.2 Septic systems and nitrate contamination:

The major reason for the contamination of the springs with nutrients is suggested as the septic tank in the proximity of the springs. The springs in the midst of the town were found highly contaminated with the nutrients hence the study for the distance of certain springs from the septic tank was studied to see if the distance between the septic tanks would make difference in the contamination of the springs.

On studying the population and septic system dominated areas the entire zone was classified on the basis of no water carriage system at all in the particular part of the town.

Also on the basis of cluster of population its elevation and distance between the springs and the nearest septic system the condition was studied by the collection of the field data to understand the immediate percolation of microorganisms in the springs as well as the distance of the septic systems.

Geological Survey (USGS) defined concentrations of nitrate in water beyond 2 mg L^{-1} as the level indicating human impact on water quality (Hanchar, 1991).Whereas the most of the springs of Almora showed the concentration above 45mg/l -60mg/l whereas the river Kosi showed the concentration of 10-12mg/l in few of the points in the entire stretch and also in Kwarab specifying that the contamination of the water sources is due to the septic system and also due to dumping of various waste in the vicinity of springs .

Out of 21 springs 15 springs were situated in the midst of the population with the nearest distance with the clustered population and septic system.

Out of the 21 spring water points sampled, none of the water sample consisted E.coli

bacteria. . However the cluster of colonies of bacteria was found very high in all the samples of the springs. The mean of MPN colonies found in per 1ml of the sample was 49.7.

On comparative analysis with limits of WHO it was found that bacteriological analysis of water especially MPN showed that the 27% of the springs were at high risk i.e had more than 100 colonies in monsoon season, 33 % of the springs were at medium risk with 50-70 colonies and low risk springs were from 20-60 colonies. These findings were supported by Opio et al. (2011) and in their studies they justified that spring water were more contaminated with bacteria than in comparison to the bore holes in the same locations and this was explained by them as a feature raised due to improper and unhygienic land use and poor sanitation. As clearly specified by WHO (2010) and USEPA (2009) standards, that water that is potable for use must not have any coliform bacteria and the MPN colonies are sign of fecal contamination (Haruna et al.,2005) and is reason for most of the water borne disease. All the springs in Almora had the pH range from 6.8-8.3.

This pH range supports the development of bacteria. The bacteria are more likely to grow happily in alkaline pH. The leachate formation occurs as the water infiltration into the ground and the soil is supposed to be acidic due to excessive dumpage of waste and septic tanks. The pH of the springs were analysed to be between 6.2-8.3 the probable reason for the samples to be more alkaline than being acidic is that the springs are of shallow aquifer .

The more the deeper the aquifer the more the filtration of the organic matter and hence the leachate turns acidic after various beds of filtration and hence more prominent concentration of E.coli could be also observed in the samples. It was also isolated that the 90 % of the spring had nitrate contamination ranging from 30-45 mg/l and 70% of the springs were contaminated with MPN. The contamination communicated due to density of the septic systems in the region. The contamination was seen more in the springs that were near to the septic tanks however most of the springs in Almora are clustered with the population and also population density is very high all around the springs. Ingestion of such water keeps the human health at high risk. The placement of pipes of the septic systems and drinking water sources

should be maintained in a proper distance according to the governing policies of the GOI and building codes needs to be followed.

Hence there is an urgent need of implication of friendly and sustainable tools that would help into rectify the septic tank contamination in the given geologic area.

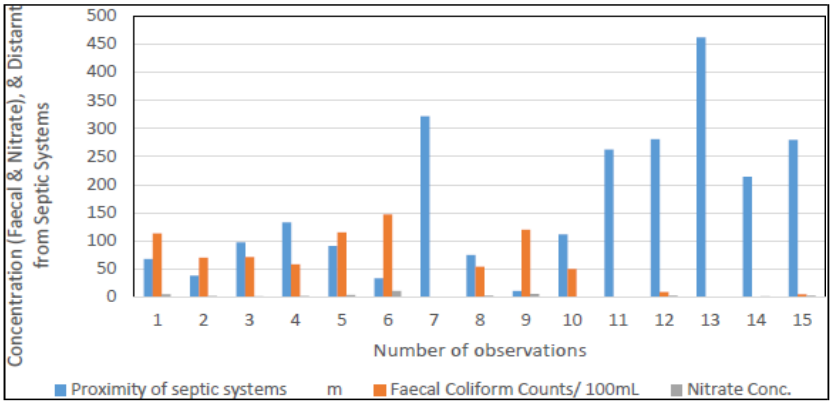


Fig 6.1 Graph showing the distance between the septic tank and MPN of the samples in comparison to the nitrate concentration

The field survey and lab analysis proves that the contaminant loads was found more in areas that were highly populated. The more the density of population more the contamination levels of the springs. The highest contamination was found in Sunehri, Thalapalya, Champa,Kapina , Karnatakula, all these nauala and dharas were surrounded by high density of population as well as open drains. The septic systems per 250,000 m^2 had MPN loads ranging from 100-120 colonies per 1 ml count in monsoon season (Fig 6.1).Whereas the septic systems for more than 250,000m^2 had colonies 40-50 colonies per 1 ml as in Laxmeshwar, Khatyari. Most of the sprigs since situated in most densely population of more that 30 per 250,000m^2 the contaminant loads were 100-120 per 1 ml sample.

Negative correlation is found between distance fro septic tanks and MPN colonies and was found to be -0.83(R^2 = 0.72) and similar variations were seen for nitrate contamination. The analysis confirmed exponential correlation between (R^2 = 0.68) between septic tanks and nitrate contamination. In addition to this it was also seen that the correlation was positive between nitrate contamination and MPN colonies. The distance and density of population if

reduced between the septic tank and the springs would reduce the contamination which is hence proved by the negative correlation obtained. The study is also confirmed by the previous researches by (Arnade, 1999; Taylor, 2003).They stated that if appropriate nitrate dilution was made in groundwater it would be made possible if the distance between the population and septic tanks was increased.

The positive correlations of 0.80 between nitrate concentration and faecal coliform counts in spring water implies that microbial colonies counts in water increases as nitrate concentration rises. Hence this is a signifies that the two contaminants are originating from the same source (Odetokun and Adetunji, 2011), the septic system in this case. The results showed that contaminations of water resources relied on the positioning of the spring. Springs located in region of high septic systems density had far more contaminant concentrations than those in areas with fewer septic systems. This result who also noted that groundwater contamination from septic systems can only be minimised by limiting the number of septic systems within a given area in order to protect the springs of the region from various contaminants.

Further, in Nigeria, contaminations of shallow wells were demonstrated to correlate with high human population density. However, in this study some springs had high nitrate concentrations even if the levels of coliform counts were low. It was reported that similar outcomes is possibly due to variations in soil type and depth to water table at different sites. The presence of both nitrate and faecal coliform in water showed wastewater contaminations. Increase in nitrate contamination on groundwater on one hand may lead to degradation of precious aquifer whereas may cause eutrophication for surface water .In order to decrease the nitrate naturally may lead in risk and hence its implementation of removal techniques is rather challenging.

Hence the better way is to avoid its flow into the natural resources. Inorder to understand the removal technique it is first important to understand the channel and process through which it enters into the water resources.

Denitrification is defined as microbial reduction of the nitrate or nitrite that is associated with the electron transport phosphorylation that results in gaseous N either in its molecular form as N2 or as an oxide of nitrogen. Hence it could be stated that denitrification is defined as the accessibility of Nitrogen oxides or nitrite or nitrate which are generally formed from autotrophic nitrification pathway substrate ammonia

that which is obtained from ammonium ion $NH4^{+}$. Inorder to understand denitrification in the surface groundwater environment the conditions needs to be favorable and the conditions required to be met are as follows (Fig 6.2)

- The nitrate, denitrifying bacteria, and electron donor for organic carbo, reduced iron and or reduced sulphur needs to be present.
- The conditions needs to be anaerobic and dissolved oxygen concentrations needs to be less than 1-2 mg/
- Since denitrifying bacteria generally are present in subsurface and hence the ketone factor for denitrification is the presence of ananerobic conditions and also the availability of convenient electron donor is the key component for rate of denitrification in aquifers
- The other major effects are comfortable environmental conditions as nitrate concentration, pH, presence of other toxins, nutrient availability. The effects of other ambient environmental conditions such as nitrate concentration, nutrient availability, pH, toxins and microbial acclimation does not impact to be as significant with the secondary influences likely to be apparent on denitrification rates in the generate d circumstances.
- A summarized view for controlling the nitrate balance is a continuous going on research and can be briefed in with the diagram as depicted. As shown in the diagram the conditions conducive to denitrification may not be encountered in many unconfined aquifers.
- Since the aquifer of mountainous region is unconfined aquifer hence the strategy of denitrification stays at hold in the region. Hence the only way out for removal of nitrates from the underground sources is to avoid its penetration in the groundwater." Treatment at the source is the key". (Rivett et a l. 2007.) The effectiveness of denitrification is for the river environment and for confined aquifers.

6.3 Nitrate Infiltration in the soil:

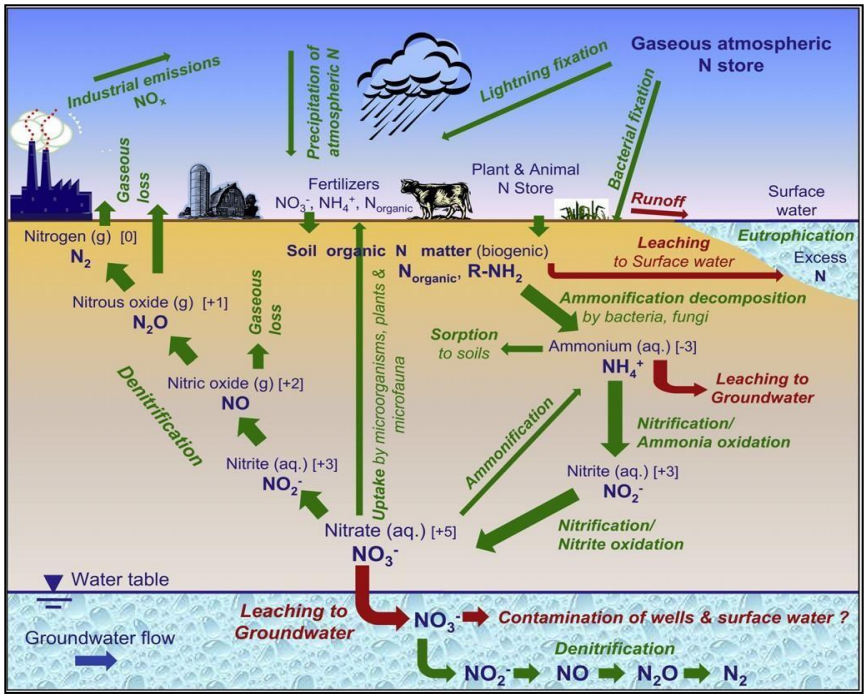


Fig 6.2 The mechanism of infilteration of nitrate into the aquifer and its reversal

However not relevant to our study area still the process of denitrification is discussed for the process defined.Organic carbon electron donors :composition and bioavailability to denitrifying bacteria, influence of pH, temperature, oxidants and occurrence as colloids or nano-particles all together play major role in movement nitrate in the soil. Sulphur and iron electron donors: biotic and abiotic autotrophic denitrification.

6.4 Sulphate as nutrient in springs

Although the major nutrient contamination caused in the springs are due to nitrate as nutrient but in some of the springs contamination of sulphate is also seen. The probable reason behind the sulphate contamination in the springs are that the use of these springs as sources of domestic use. As most of the springs because of the contamination are no more used for the drinking purpose hence these springs are used for other domestic purposes.

These springs are used for washing clothes and bathing by the local people. The bathing and washing of clothes takes place at the very source of the springs. The leaching and infiltration of these detergents could be the probable cause of contamination of the springs with sulphate/ phosphate. As the natural sources of phosphate and sulphate is not present in the region hence the contamination of the springs in the region are majorly due to anthropogenic factors.

The major cause for sulphate contamination is home laundry. In home laundry varieties of detergents are used and these detergents are simply allowed to flow in the drains without treatment. Markets are nowadays flooded with varieties of detergents that contains hazardous chemicals, surfactants, bleaches, fillers, optical brighteners, harmful colors, anti-redeposit ions, perfume which makes the color of clothes look bright by remitting blue light. There are also foam boosters that add lather to improve the chemical action, enzyme attack grim, soil and stains that cause allergies ((Hathi 2007).) Besides this lots of fillers used in the powder detergents are as it is poured into the drains that results in one hand wasting of the useful chemicals and on other hand clogging the drains/sewerage system. Of these innumerable amount of chemicals sodium sulphate present in the detergent causes devastating effect on the septic system. (Frydendall 2009). In Almora people carry their clothes to the springs where in they are washed at the very source. The water that are nothing but rich in chemical generated from the detergents infilterate into the ground effecting the groundwater sources. Hence these are contaminating the ground water sources (Weir 2007.)According to BIS standards the prescribed limit is 250-400 mg/l.

However the town doesn't have any industries as textile industries or leather and tanning industry yet the contamination can come from the garages or waste water flowing in drains. As the region is very fragile with limited source of water hence even a minute contribution of contaminants can cause the severe threat to the springs. The major effect of detergents is majorly seen post use effect after the wash water is discharged into sewage system. Ghai (2010) in his article, "Soap nut detergent-the best HE detergent" also stated that water pollution is caused by laundry used that used daily in domestic use. It is quite prominent that the non biodegradable wastes hence generated remain in the environment as for years together. With daily use of detergents and the amount of its disposal in the environment it is quite prominent that a huge and bulk amount of detergents go into the pipeline every year even if the city is quite small. The effect is seen in with the aquatic fishes plants and animals

widely as they keep on dying due to post effect of the detergents into the water body. These not only damage the water bodies but also the soil. Special effort needs to be taken to avoid the contamination of soil, surface water as well as underground water. The essential way out is to differentiate grey water from wastewater. This differentiation would help the lay less stress on the septic tanks. Also if the partial treatment of the grey water if done at the very source then it would be quite easy to handle the waste generated from the detergents. The filters are nowadays very much technically useful to handle this grey water and this water after the partial treatment could be used for flushing the toilets, washing cars etc. This would release the pressure on fresh and potable water.

Sulphate although is not very much toxic but can cause many diseases as catharsis, dehydration, and diarroheaa if ingested in higher amounts through diet then mathaemoglobin and sulphaemoglobin is changed in animal and human body. People have come out with various techniques to manage sulphate but due to lack of proper implementation the amounts of sulphate is rising continuously. Few of abiologic processes as thermochemical sulphate reduction (TSR) is said to reduce sulphur in water.

Sulphates are generally traced in oxides form in air water and soil. But because sulphur is highly soluble in water, it is found in very high concentration in many groundwater as well as surface water. MPCA (1999). A large number of combustion activities also effect the release of sulphur into the soil as well as water. As in the region forest fires are very common. In summers as well as dry winters the forest fires have been a major issue of concern in the region. After the fires the rains carry this ash to the ground and surface sources of water and hence contaminating the water as well as soil sources.

Sulphate with plus six oxidation state is considered to be stable whereas lower oxidation state a are stable as well as lower oxidation states are also stable but less in comparison to the higher oxidation state of sulphur. Since sulphate is major dissolved ion and has very high mobility in aquifer system it easily reaches ground water and also in anoxic condition or reducing conditions that mostly is present in geoenvironment, the sulphur can be changed into sulphate In the geosphere, sulphur as sulphate can be reduced to lower stable oxidation states under the anoxic, reducing conditions that exist in many geochemical environments (Goldstein and Aizenshtat, 1994).

Sulphate extensively comes in water from both natural and anthropogenic sources. Altough the region doesn't have any prominent The natural sources include sulphur mineral

dissolution, atmospheric deposition and sulphide oxidation from mineral (Krouse and Mayer, 1999). Human-induced sources are power plant, coal mines and metallurgical refinery (Seller and Canter, 1980). In many potential sources, gypsum is an important source in many aquifers having large amount of sulphate. In the last few decades, atmospheric deposition has become an important source of sulphate to soil and ultimately it goes to groundwater. Since sulphate is mobile in soil, addition into the soil will impact on shallow aquifer. According to EPA (1999, 2003,2009), sulphate concentration in potable water should be under 250 ppm level, which is based on aesthetic effects. According to an estimate average sulphate contamination of water in India has reached to 90-150 mg/l. The fate and transport of sulphate into aquifer system affects the dynamics of hydrogeochemistry of aquifers. And in such of this processes, sulphate is reduced and hence it becomes very important for most of the subsurface systems. In addition to this sulphate reduction is of prime significance for the system which possess metal-rich water acidic rich medium, as mining sites has acidic condition. Hence under these conditions, sulphate reduction significantly precipitates as a few heavy metals as metal sulphides (Langmuir, 1991)

$$CH4 þ SO4 -2 \rightarrow CO2 þ H2S þ 2OH- ð1Þ$$

Sulphate, derived from sea water, is a common constituent of many sediments. On burial, sulphate can undergo redox reactions with organic matter to ultimately form CO2 and H2O as in the equation above. Anaerobic microorganisms can utilize sulphate as an oxidant in metabolic processes, and organic matter in sediments can thus be oxidized by biological sulphate reduction (BSR) reactions. These reactions essentially cease as the sediment temperature rises above about 110 °C at which point the biological catalysts (enzymes) denature. At higher temperatures, it has been proposed that sedimentary organic matter can reduce sulphate by abiologic processes called ‘thermochemical sulphate reduction (TSR)’. Although such reactions are known at very high temperatures, there is only limited detailed information on TSR reactions at temperatures encountered in many oil field sediments (e.g. at temperatures of about 120–160 °C) (Goldstein and Aizenshtat, 1994). In many sedimentary environments, the oxidation of organic matter can occur by both bacterial and thermochemical sulphate reduction. There is abundant evidence to show that only the enzyme-catalyzed biochemical reaction is important at temperatures below about 100 °C and

that these reactions essentially cease at temperatures above 115 °C. The existence in sediments of a low-energy pathway for thermochemical sulphate reduction can account for TSR reactions under geologic reaction conditions that were difficult to account for by the energetically demanding direct reduction of sulphate. It was hence concluded that biochemical reduction of sulphate dominates insedimentary environments below 120 °C and supports the possibility that reactive sulphur species will oxidize certain organic molecules at meaningful rates in geochemically reasonable reaction periods at temperatures above 175 °C. It was concluded that under typical petroleum reservoir reaction conditions, both elemental sulphur and polysulphides are capable of oxidizing some organic molecules under basic conditions. But that sulphate alone will not react unless lower oxidation state sulphur is present.

Microorganisms are known to oxidize solid or dissolved organic sulphides, sulphonates and other organic forms of reduced S to SO_4^{2-} (aq) in a stepwise manner. Abiotic reactions may also produce SO_4^{2-} (aq) from these compounds. In some cases, reduced organic S may be released from its organic moiety prior to oxidation and thus can be considered to follow the same oxidation pathways as sulphide, S(s) and SO_3^{2-} (aq). (Van Stempvoort and Krouse) (1994) reported that dominant controls of the $\delta^{18}O$ of environmental SO_4^{2-} (aq) are S redox reactions and $\delta^{18}O$ of ambient H_2O.

Several other factors play a role in determining $\delta^{18}OSO_4$, including variable S oxidation rates, dissolution of mineral sulphate and transport and mixing of SO_4^{2-} (aq). In most environments, O exchange between SO_4^{2-} (aq) and H_2O, and isotope fractionation during sorption, precipitation, and diffusion processes apparently have negligible effects on $\delta^{18}OSO_4$. Sulphate proves to be a major anion in groundwater system and fluctuates between 1 to 2000 ppm majorly emphasizing upon the topography and geologic conditions of the concerned area.

The method of isolating the exact tract of sulfate contamination is an tedious task as it need to be done by isotopic method. As sulphate contamination of the ground water sources is not a point source contamination, hence in order to see the mechanism of contamination in an unconfined aquifer is a task to be fulfilled by isotopic method. The basis of applying the environmental isotopes for the studies in biodegradation of contaminants is based upon the

application of these environmental. For sulphate reduction the sulphate that remains gets enhanced in S34 as the concentration of sulphate decreases. In the case of sulfate, during sulfate reduction the remaining sulfate gets enriched in ^{34}S as the concentration of sulfate decreases (Strebel et al. 1990).

In Almora sulphate is not taken into concern although sulphate pollution is secondly most devastating contaminant erupting after nitrate. The approach towards contaminant reduction and treatment is far away the people are not even aware of the contamination and its future effect. This needs to be checked immediately. If not the contamination in Almora have already taken away 361 springs and left now with just 21 springs in the town. The days are not far that the contamination might reach to that level with solid waste dumpage and septic tank that merely dilution in river Kosi will not prove to be remedial measure further more in future.

Chapter 7

Summary and Conclusion

7.1 Summary and Conclusion

This research emphasized on the overall health and sustainability of the water sources in the region. The research work was a complete blend of tedious field work in order to collect the data lab analysis to continuously check and analyse the samples whereas the desk work to understand the model , its behavior towards the lab analysed results. The research could be summarized in below three categories.

The analysis of springs in the region:

The analysis of the spring of the region specifies that the springs are at greatest threat in the region. Because of the rapidly growing population , tourism, and since the town is a hub for the nearby villages for health and educational facilities, it is rapidly observing increase in population in every coming year. The springs are the only source of water in the region and unawareness of the general people and not being aware that what are they loosing have left the region with very a few springs. The seasonal springs have almost vanished from the town. Most of the springs are now covered with the concrete jungles now. The springs which were then found a decade before no more exist now as they are now covered with either buildings or have come under construction sites.e.g: Chausar naula which was then in way back analysed in 1991 is no more in the town and has now lost its identity form the midst of the town.

1) The quality of the springs has detetoriated to such an extent that, that most of the springs are now not fit for drinking. The Katyari naula, Laxmeshwar naula and Karnatula are not used for drinking anymore.
2) The rapidly increase in the construction of the region have blocked the recharge pits of the region .
3) The conservancy system of sanitation have brought the region to that stage that nitrate contamination has reached to as high as 60mg/l in some springs and most of the springs are having that above 45mg/l.
4) The presence of E.coli although is not found in the samples of the springs the reason probably could be the shallow aquifer recharge of the springs. The reason could also be the porosity of the soil which engulfs the bacteria

of the water and is leaching the chemical contaminant into the springs.

5) Also the precise recharge point of a particular spring is not known. The isotopic method would help in knowing the recharge points of the springs and hence would help in coming to the solution to check the contamination of the springs

II) The surface water river"Kosi":

1) The river Kosi is a spring fed river and flows with high velocity because of the topographical constraints.
2) The contamination of Kosi as showed by most of the parameters were within the permissible limit
3) The reason being the dilution of the contaminants
4) The condition now of the river Kosi is not a serious threat because the region is not an industrial belt hence the contamination is not industrial effluent based
5) The population is rare and scattered population and not clustered except one or two towns. This enables the contaminants to be scattered and hence does not cause point pollution.
6) The river does not have bank population. Most of cities have developed themselves along the banks of the river. Even nearly all culture and civilizations have developed along the banks of the river. But river Kosi in comparison to other cities of India does not have that sort of clustered population at its banks.
7) The banks are not agricultural based. Small and rare patches of agricultural fields are found which are insufficient for the contamination of inorganic nitrate.
8) The contamination at Kwarab in comparison to Kosi and Kantli was described at higher level. Stating the population and contamination after the river Kosi barrage crosses, increases. But since the dilution is high the river does not witness that after Kwarab
9) The contamination level increases significantly after the river was sampled at Ramnagar barrage.
10) This states that it is not that river Kosi which is under serious threat of

contamination, the velocity of the river and dilution proves to be a boon for the people of the region that contamination even though generated is carried to the lower part of the region i.e. to Ramnagar and also the population is simply cashing this property despite of the utmost pollution they can contribute to the river

The conservation of resources is although not in alarming state for Kosi but is for sure for Almora which is blindly growing in with the urbanization without taking proper measure to conserve the religiously auspicious springs.

The basic reasons for the conservation of the resources are given as below:

7.1.1 Socio-Economic Development

The project would help in the socioeconomic development of the region. Drinking water remains the major necessity for survival of life on earth. The springs are the only source of water in the region.

The local efforts are although taken by the residents for making people aware of the levels of contamination. Although the people are not aware of the parametric contamination and the boiling would not remove the contaminants from the drinking water. Only hardness that too temporary hardness could be removed to some extent by boiling the water and some microorganisms could be removed by boiling the water. The water purity consideration is important factor to make people aware of. The region would soon require a mini scale treatment plant for purifying water as during summer season as the flow from the springs decreases the contaminants concentration increases hence the portable water could only be attained by from proper treatment. And this could help in one way for the employment, on other hand would help in awareness in the people regarding the quality of the water.

7.1.2 Scientific Management of Natural Resources In IHR

Natural Resource Management is defined as the management of the resources such as soil, land animals water and plants, with an emphasis on how the resources are managed and used in such a way that it is left in a better health for the future generation. Hence the Natural Resource Management defines itself as the way in which people interact with the natural resources and also landscapes. Hence it is a collaborative existence of land use planning, water management, bio diversity conversation water management, along with the future sustainability of industries like forestery, fisheries, mining. It defines as that the people and their livelihoods rely completely on the productivity, fertility and also the

health of our landscapes, and the actions of people as stewards of the land play a key role in maintaining this health and productivity.

The main emphasis of the Natural Resource Management is to focus precisely on the scientific and technical understanding of resources and also the ecology as well as the life-supporting capacity of those resources. Environmental Management is same as the natural resource management. For the natural resource management, to combine with the establishment of a performance audit role in the governance of regional natural resource management.

Hence the audit framework which is build up from some other established audit methodologies, that which includes the internal audit, performance and environmental audit. The audits hence that are undertaken using this framework have provided confidence to stakeholders, identified areas for improvement and described policy expectations for the general public. Water conservation includes all the policies, strategies and activities to manage sustainability and the natural resources of fresh water to conserve the hydrosphere, in order to meet the required human demands. The important and driving factor is the population, household size as well as its growth decides the amount of water to be used. Many factors have increased pressures on natural water resources because such as because of manufacturing as well as agricultural irrigation. Many countries have taken steps to implement policies for conservation of water with much success. Ensuring the availability of water for future generations where the withdrawal of potable water from an developing ecosystem does not exceed its natural replacement rate. Many other activities as energy conversation, delivery and waste water treatment facilities as well as water pumping and all process requires a significant amount of energy. In some regions of the world over 15% of total consumption of electricity is devoted to water resource management. The minimization of the habitat conservation where the minimizing human water use helps to preserve the potable water for local animals and migrating birds , but also serenity of water with its quality. A concept that is closely related to water wasting is "water-use efficiency." Water use is considered not to be sufficient if the same purpose of its use can be accomplished with less water. Efficiency technically derives from engineering practice where it is typically used to describe the ratio of output to input and is useful in comparing various products and processes.

.7.1.3 Protection ofEnvironment

The Himalayan ecosystem is fragile and diverse. It includes over 51 million people who practice hill agriculture and remains vulnerable The Himalayan ecosystem is vital to the ecological security of the Indian landmass, through providing forest cover, feeding perennial rivers that are the source of drinking water, irrigation, and hydropower, conserving biodiversity, providing a rich base for high value agriculture, and spectacular landscapes for sustainable tourism. The Himalayan eco system is vulnerable and susceptible to the impacts and consequences of a) changes on account of natural causes, b) climate change resulting from anthropogenic emissions and c) developmental paradigms of the modern society. The Himalayas house one of the largest resources of snow and ice and its glaciers which form a source of fresh water for the perennial rivers such as the Indus, the Ganga, and the Brahmaputra. Glacial melt may impact their long- term lean-season flows, with adverse impacts on the economy in terms of water availability and hydropower generation. Recession of Himalayan glaciers will pose a major danger to the country. Currently available data gathered by multiples of institutions without a coordinated effort do not indicate systematic trends of recession of Himalayan glaciers.

Sustainability of an ecosystem demands a balance and equilibrium among various forms of life and their surroundings established over long periods of time. Therefore, the mission recognizes the need for creation and building of national capacities to observe and respond to changes in a sustainable manner. The mission proposes a coordinated effort in identification and strengthening of institutions engaged already in the conservation and management of the natural resources in the Indian Himalayan Region (IHR). Mission plans to effectively network such institutions with common and shared objectives, co-sharing of resources and co-generation of processes leading to ecologically sustainable development.

7.1.4 Developing Mountain Infrastructures

Mountains cover approximately one-quarter of the world's surface and are home to 12 percent of the human population. Mountains are complex and fragile ecosystems with marked topography, highly differentiated climatic conditions and vertical processes. They

are the water towers of the world – providing freshwater to at least half of the world's people for domestic use, irrigation, industry and hydropower – and storehouses of global biodiversity. However, mountains are also high-risk environments; avalanches,

landslides, volcanic eruptions, earthquakes and glacial lake outburst floods threaten life in mountain regions and surrounding areas, while fragile soils and vegetation cover make mountain areas vulnerable to environmental degradation.

Mountain people are among the world's poorest and most disadvantaged. Harsh climatic and environmental conditions, remoteness and often difficult access hamper development in mountain regions. Mountain people frequently face political, social and economic marginalization and lack access to such basic services as health and education.

The major ways to strengthen the mountain infrastructure is through education, providing better connectivity both technically as well as education wise. To provide opportunities to the local people.

7.1.5 Strengthening Networking in IHR

The network strengthening is an important aspect for the multidimensional development of the region.

a) For developing the networking in the region the prior thing is education and awareness.

b) Proper network conditions overcoming the topographical constraints in the region.

c) Proper connectivity is very important for overall development of the region

7.5 Scope of Future Work

The findings could be utilized for sustainable for sustainable development of IHR: The sustainability of the project intends for the survival of life on the mountainous region. Where most of the mountainous region are suffering the deficiency and scarcity of water, Almora is gifted with sufficient amount of springs.

a) The research intends to help sustain the serenity of water.

b) To understand the impact of urbanisation and increase in population on to the springs of the region.

c) To generate awareness among people to help them understand the water quality deteoriation due to dumping of waste in local boundaries of the springs.

d) To also understand the necessity of sewer treatment plant for the town so that nitrate contamination could be restricted in the town.

e) To extension of the research suggests to could develop more with designing the sewer

treatment plant with zone wise division of the town.

f) To ensure more and proper treatment of the sewer treatment discharge which at present carries just 10-12 percent of the waste water generated in the town. This would help to conserve the water quality of the river Kosi as well.

g) The remedies for water quality sustainance are major part of the project.

Efficient ways to replicate the outcomes of research in other parts of IHR

a) The research could be replicated for the forecoming years in order to see the contamination levels of springs of Almora.

b) The research could also help in understanding the contamination level of spring fed river Kosi as these springs are only source of water in the region.

c) The database could be generated for further research and precautionary measures to be taken in the forecoming years.

Identify other important areas not covered under this study but this needs further attention:

a) Almora is the major town which is most populated as well as continuously expanding with its concrete buildings which are unplanned hence Almora springs remains important point for regular monitoring.

b) Continuous monitoring of the springs to study the water quality could be done to keep a check on the variations in the quality every month.

c) Heavy metal contamination of the springs is still a left aspect of studying the springs water quality.

d) The surface water quality of the four stations was done for May 2019 to December 2019.This daily sample could be increased. The increase in frequency of the sampling will help in generating more efficient database which would help to estimate the quality of the water in the region.

e) The sampling points selected in the project needs to be sampled continuously so that database generation could be done for carrying out research work in future as well.

Major recommendations for sustaining the outcomes of the research in future

a) The major recommendations for sustaining the outcomes of the fellowship is to

design a sewerage treatment for Almora town zone wise considering the topography so that water carriage system of sanitation could be opted by the rapidly increasing clustering of the buildings.

b) The springs need to be conserved on community basis and also should be strictly undertaken by government as most of springs don't exist anymore as they have being collapsed under the construction work undertaken by the people of the region.

c) Frequency of sampling and analysis needs to be done frequently so that a check is maintained in the quality of springs.

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Groundwater hydrochemistry of Naulas and Dharas (Springs) of Almora Kumaon Himalayas in Uttrakhand their evaluation using graphical tools

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ABSTRACT

This paper focuses on the water quality status of the springs which are the only source of water of the region. Almora is an important region of Indian Himalayan region (IHR) which is rapidly growing in the population and urbanization that has compromised the ground water quality and even their existence. The onsite disposal of waste and infiltration of contaminants have posed miserable condition of the springs. A total of 21 samples from the springs of the region were collected to study the physicochemical parameters and most of the parameters were seen to be above the guidelines of USEPA and WHO. The quality of water in this paper is evaluated by Durov diagram method and Stiff diagram method. The results of most of the samples revealed that they were not found fit for drinking.

Key words : *Groundwater quality, Springs, Infiltration of the waste, Durov diagram, Stiff diagram.*

Introduction

Springs are underground water sources of the region and these springs are only source of water in the region. The springs in the form of naulas and dharas are the major form of springs in the region. Majority of naulas were thought to be constructed during Katyuri and Chand dynasties between 7th and 8th centuries. The constructions were complicated and involved a number of religious rituals for construction.

Number of steps in naula(conventional pit type springs locally called naulas) is invariably an odd number 5,7,9,11 and so on. The difference between the odd numbers and even numbers is quite intriguing in Uttrakhand. The masons when constructing step ladders anywhere as a general rule, always make odd numbers of steps and would accordingly adjust the height of each step. But perhaps a philosophical explanation account for this is that everything in nature is a flux. While constructing the step ladders of naula opening inlets would be provided at suitable places, usually at top and appropriate cuts were provided at times of need the water source could be cleaned.

The dharas (closed tanks with pipe outlet) are the flowing springs in which the water of the rivers, streams, waterfalls or lakes in mountains cannot be carried over the site of habitation unless it is drawn into some kind of vessel and then carried home. But water flowing in mountains as surface run off or water from springs rundown on the incline of the mountain slope skirting habitations. Such water however cannot be directly used for drinking or

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other purposes due to inconvenience involved. So mountain people across the world, since antiquity have deplayed a device that conveys water through it, and clearing the earth, the earth so conveyed is given a clear fall of some height then pours to ground some distance away from its original natural flow. Though the seasons in winter and summer monsoon in uttrakhand, the steep terrain and terrain and the ubiquitous sheet of pine needles accelerates the run off. Despite such adverse conditions the ancient people founds ways to harvest rain water for recharging their aquifers, their naulas. Communities realized that water seeps through pores, fissures and fractures into the underlying aquifers to recharge springs at lower elevations. In between the mountains peaks there are natural formations and depressions of the land. They were used in past for rainwater harvesting. They are known as chalas.

Most of the springs of the town are located along four curved spring lines covering the town with one semicircle each on both the east and west sides of the hill. There is considerable similarity in the locations of the springs on both sides of the hill which indicates possibility of common recharge areas along these drainage lines.

Study Area

The study area is situated in the midst of Himalayas at latitude of 29R 37′3″ and longitude 79R 40′20″ and at 1000 to 2000 meters above the sea level in the Central Himalayan region. This elevation zone is populated and people face the scarcity of water of various magnitudes during summer. The average rainfall recorded varies from 1800-1900 mm of which two thirds is in rainy season (mid June to mid September).winter rains are also common. The average mean temperature varied from 3R Cin winter to 24.9R Cin summers.

Materials and Methods

As per the standard methods all sampling bottles were washed with the filtered sample before filling it and labeled accordingly. The pH and conductivity of the water samples were determined with a digital pH meter and digital conductivity meter respectively. Sodium and potassium were determined using flame photometer. The samples are analyzed to determine the concentration of sodium (Na+), calcium (Ca2+), total dissolved solids (TDS), Alkanility, sulphate (SO42+), Chloride (Cl-), magnesium (Mg2+) and total hardness (Balachandar *et al.,* 2010). The results obtained were compared with the BIS standards (BIS, IS 10500 2009). The concentration of the major cations like Ca, Mg, Na, K and anions like CO_3, SO_4, Cl2 and HCO_3 are determined.

Durov Diagram

Durov diagrams represent the major ion composition, pH and TDS content of any number of samples (Somashekar, 2015). The cations specify the parameters of the left triangle. Default settings are the major cations Na, Ca, and Mg, however any other parameter can be selected (e.g. gas composition, trace elements etc.). The Anions generally specify the parameters for the upper triangle. Default settings are the major anions Cl, SO4, and HCO3, however any other parameters can be selected.

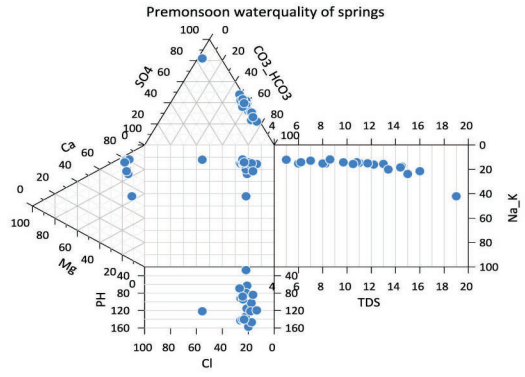
Note that measured Alkalinity is a valid anion parameter, provided the respective parameter is known by the system as being the Alkalinity. This may be done on the File>Database>Alias tab by assigning the respective parameter to the Measured Alkalinity (Manjusree *et al.,* 2009). If using the alkalinity in the anion triangle, change the respective displayed label field to $HCO_3 + CO_3$. In the durov diagram the pH and TDS values are given separate which is easy to identify. Durov diagram is different from piper diagram in the sense that it has additional properties to display as pH and TDS. The visual difference between piper and durov also helps to explain the characteristic of water. The durov diagram indicates that presence of anions are more in post monsoon than in premonsoon water samples. (Shyamala and Jeyanthi, 2016).

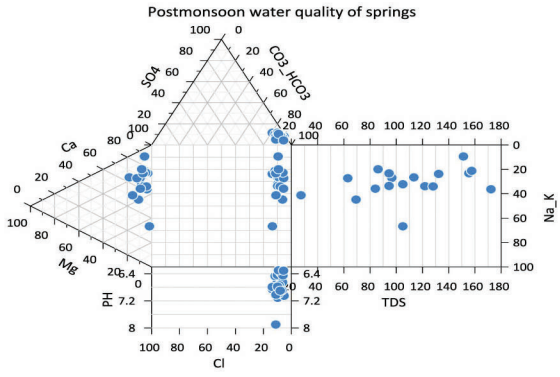
Stiff Diagram

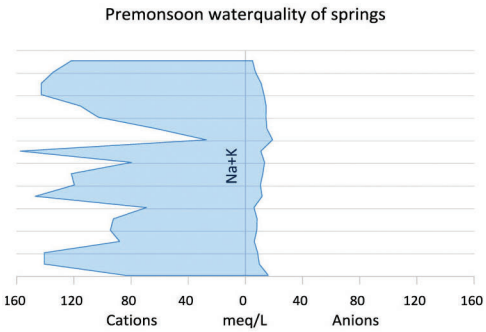
It is used to display the major ion composition of water sample. Stiff patterns are useful in making a rapid visual comparison between water from different sources. The domination of anion is higher in the stiff diagram. Premonsoon water quality shows the dominating characteristics towards Na+ and K+ i.e cations, wheras the postmonsoon waterquality sho slightly more inclination towards cations than ions in the water samples. The anions that are present is more for Cl and HCO_3/CO_3.

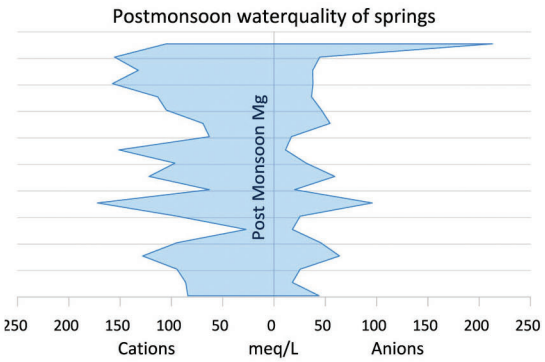
Results and Discussion

The pH, TDS cations, anions have increased in decades. The pH value varied from 6.85 to 7.82 which









is within the permissible limits of WHO. The permissible limit of pH value for drinking water as specified is 6.5 to 8.5 as per IS: 10500 std. The analysis of 21 samples of Almora town specified pH to be over 7.3 in Thapalya dhara. As the case we know that the pure water is not a good conductor of electricity and presence of ions facilitates conductivity. TDS imparts taste to the water and is important parameter to describe the salinity of water.TDS ranged from 587-600 in Thapalya dhara in the present study. The chloride content ranged from 8-10 mg/l which is quite within the permissible limit as the region of fragile mountains is not an industrial belt and also the geological sources of chloride content is rare found in the region. As per IS 10500 standards but in Almora is only over the range of rate value 1103 mg/l. Total hardness of water is characterized by presence of calcium and magnesium salts The presence of Ca ions shows making water hard in both premonsoon and monsoon water. Sulphate ion concenteration is highest in thapalya dhara and Champa naula of about 74 mg/l to 65 mg/l which has increased three times in last few decades (Kumar and Rawat) probably because of infilteration of sulphates as for years this dhara is used for washing clothes and other domestic purposes.

Conclusion

The ground water of the springs of Almora which are the only source of water in the region have deteoriated to this level that most of the sources no more remain fit for drinking. Most of the springs have disclosed themselves from the local sources that people nearby are supposed to boil water before drinking, irrespective to the fact that boiling just is primarily treatment for the water which kills certain microorganisms as well as reduces hardness to some extent. Then water samples of the springs of Almora are continuously deteoriating with the water quality due to unplanned and conventional way of sanitation. The town does not have water carriage system of sanitation and is carrying with conventional way of sanitation. The majority of the buildings still yet under construction are carrying the septic tanks for sanitation. The contamination of springs (naulas and dharas) has increased in the years and most of the springs are not fit for drinking Kumar and Rawat (1996).

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PERFORMANCE OF GEOCOMPOSITE CONCRETE

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ABSTRACT

This paper focuses on geosynthetics product, their applications and elegance methodologies needed for reinforcing soil and environmental protection work. From decades Geosynthetics area unit wide used construction materials for geotechnical and environmental applications in most elements of the world, as a result of they represent factory-made materials, new product and applications area unit developed on a routine basis to provide solutions to routine and necessary issues alike. Results from recent analysis and from watching of instrumented structures throughout the years have semiconductor diode to new style strategies for varied applications of geosynthetics.

Keywords: Geocomposite , concrete , strategies

INTRODUCTION TO GEOSYNTHETICS OR GEOCOMPOSITES

Geosynthetics area unit usually designed for a specific application by considering the first operate that may be provided. As seen within the incidental to table their area unit 5 primary functions given, however some teams recommend even additional. the foremost functions of Geocomposites area unit reinforcement, filtration, evacuation containment and separation. It has been recognized that the addition of tiny, closely spaced and uniformly distributed geo-fibre to concrete would act as crack restraint and would considerably improve its and dynamic properties. This kind of concrete is thought as fibre concrete. Plastic fiber's do an equivalent impact and perform higher than the other fiber's. plastic concrete will be outline as a stuff consisting of mixtures of cement, mortar or concrete and discontinuous, discrete, uniformly distributed geo-fibres. Fiber concrete is concrete containing fibrous material that will increase its structural integrity. It contains short separate fibers that are uniformly distributed and arbitrarily orienting. Fibres embrace steel fibres, glass fibres, artificial fibres and natural fibres. inside these completely different fibres that character of fibre concrete changes with varied concretes fiber materials, geometries, distribution, orientation and densities. It's true that plain cement concrete possesses a awfully low durability.

ADVANTAGES OF GEOSYNTHETICS:

1. Less sensitive to environment.
2. Improved performance and more sustainable.
3. More compatible with field conditions.
4. Cheaper in product cost, transportation and installation.

LITERATURE REVIEW

1. Uma Shankar. K, Arun Prakash. K & Pradeep Kumar. S14 in their paper titled as "Rehabilitation and Retrofitting of Building Structures" stated that fiber-reinforced polymer (frp) composite materials provide an outstanding means for rehabilitating and strengthening existing reinforced and prestressed concrete bridges, buildings and other structures. These advanced composites may be designed to act as flexural, shear, and confinement reinforcement. Use of these composites requires less disturbance to building occupancy, bridge traffic, and other functions than rehabilitation that uses additional steel reinforcement.

2. Yetimoglu and Salbas, 2003, studied Experimental Study on Effect of Geosynthetic Fibres on Compressive and Tensile Strength of Cement Concrete and teach us that, in comparison with conventional geosynthetics (strips, geotextile, geogrid, etc.), the advantages of using discrete fibre are as follows, (i) The discrete fibres are simply added and mixed randomly in mixing with cement, lime, or other additives. (ii) Randomly distributed fibres limit potential planes of weakness that can develop in the direction parallel to the conventionally oriented reinforcement. (iii) The inclusion of fibre only changes the physical properties of soil and has no impact on the environment. For these reasons, researchers have shown an increasing interest in mechanical behaviors of fibre. Yetimoglu et al., 2005, Consoli et al., 2007, Ibrahim et al., 2012 and EL, 2012. The results indicate that the discrete fibre reinforcement can significantly improve the mechanical performances. They concluded that the fibre reinforcement benefit on the mechanical properties is governed by the interfacial friction and cohesion. Perkins S.W. (2000) During past decades, application of geosynthetics for stabilization has become wider and wider. Various types of synthetics are used right now in different cases of soil improvement like geotextiles, geogrids, geonets, geofibers and etc. There have been wide efforts on reconnaissance of geosynthetic application effects on geotechnical properties of reinforced soil such as Constitutive modeling of geosynthetics.

3. Khalid Bashir, Rayees Ahmad Bala, Arif Ahad and Riya Gungnia4, 2012 in their paper titled "Experimental Study on Shallow Funicular Five Layered GFRP Shells over Square Ground Plan", studied that the deflection of shallow funicular composite shell decreases with the increase in rise within the elastic range. The ultimate load carrying capacity increases with the increase in rise.

4. Ciprian Cozmanciuc, Ruxandra Oltean and Vlad Muntean1, 2001 in their paper titled "Strengthening Techniques of RC Columns using Fibre Reinforced Polymeric Materials", stated that the most utilized techniques of performing composite confining systems for reinforced concrete columns are wet lay-up method, automated method and the method based on using prefabricated elements. For developing efficient composite confining systems, it is required to respect the technological steps that lead to a corresponding transfer of stresses from concrete to the composite membrane. These steps include priming of the concrete substrate, of the application surface, execution of the resin mixture, application of the composite system and of the protection layers.

MATERIAL AND METHODOLOGY

In easy terms, concrete is that the mixture of rock and soil. Through a series of chemical reactions known as association, the paste hardens and gains strength to make the rock-like mass referred to as concrete. at intervals this method lies the key to a motivating attribute of concrete: it's plastic and malleable once new mixed, sturdy and sturdy once hardened. These qualities make a case for why one material, concrete, will build skyscrapers, bridges, sidewalks and superhighways, homes and dams. The compressive strength of the concrete cubes test provides an idea about all the characteristics of concrete. By doing this single test, one can judge that whether concreting has been done properly or not. Concrete Compressive strength for general construction varies from 15 Mpa to 30 Mpa depend on the needs. As we all know concrete compressive strength depends on various factor like water cement ratio, workability and admixtures.This test is carried out either on a cube or a cylinder**.** Various Codes recommend a concrete cube as the standard specimen for the test.**Compressive Strength Formula-:** It is the load applied at a point of failure to the cross section area of the face on which load was applied.

Compressive strength =Load/Cross sectional area.

APPARATUS USED FOR THE DETERMINATIONS/TESTS :-

1) Vibration machine,
2) Cube moulds of 150mm,
3) Test sieves conforming IS : 460-1920,
4) Gauging towel,
5) Containers for mixing concrete and materials,
6) Stop Watch
7) Water Bath,
8) Weighing device

9) Rulers etc.

Compressive Strength may be defined as the ability of material or structure to carry the load on its surfaces without any crack or deflection.

This mixed can be done in two ways:

i. Hand Mixing
ii. Mechanical Mixing

But for casting our cubes we use hand mixing.

Hand Mixing

1. Mix the cement and aggregates on a watertight none absorbent platform until the mixture is thoroughly mixed and is of uniform color.

2. Add the coarse aggregate and mix with cement and fine aggregates until the coarse aggregates is uniformly distributed throughout the batch.
3. Add water and mix it until the concrete appear to be homogeneous and of desired consistency.

a) **Workability:** Slump check is that the most ordinarily used technique of activity consistency of concrete which might be used either in laboratory or at web site of labor. it's not an acceptable technique for terribly wet or terribly dry concrete. It doesn't live all factors causative to workability, neither is it perpetually representative of the placability of the concrete. The pattern of slump is shown in Fig. It indicates the characteristic of concrete additionally to the slump worth. If the concrete slumps equally it's known as true slump. If one 1/2 the cone slides down, it's known as shear slump. just in case of a shear slump, the slump worth is measured because the distinction tall between the peak of the mould and therefore the average worth of the subsidence.

b) **Workability of Fresh Concrete by Compaction Factor Test:**

Methodology

Compacting Factor Test: The compacting issue check is meant primarily to be used within the laboratory however it may also be utilized in the sector. it's additional precise and sensitive than the slump check and is especially helpful for concrete mixes of terribly low workability as area unit commonly used once concrete is to be compacted by vibration. The strategy applies to plain and air-entrained concrete, created with light-weight, traditional weight or significant aggregates having a nominal most size of forty millimeter or less however to not aerated concrete or no-fines concrete.

c) **Compressive Strength of Concrete Cubes:**

The compressive strength of hardened cement is that the most vital of all the properties. Therefore, it's not shocking that the cement is often tested for its strength at the laboratory before the cement is employed in necessary works. Strength tests aren't created on neat cement paste thanks to difficulties of excessive shrinkage and resulting cracking of neat cement.

Calculations and Data Analysis:

Sieve Size	Weight Retained (In kg)	Cumulative Weight retained (In kg)	Cumulative % Retained	Cumulative % passing
80mm	0	0	0	100.000
40mm	0	0	0	100.000
20mm	1.517	1.517	30.245	69.210

10mm	3.412	4.970	99.210	0.714
4.75mm	0.333	5.000	100.000	0.000
2.36mm	0.000	5.000	100.000	0.000
1.18mm	0.000	5.000	100.000	0.000
600 micron	0.000	5.000	100.000	0.000
300 micron	0.000	5.000	100.000	0.000
150 micron	0.000	5.000	100.000	0.000
TOTAL	**5.262**		**729.455**	

Sl. No.	**Description**	**Trail 1(Kg)**	**Trail 2(Kg)**
1	Wt. of empty container W1	2.5	2.5
2	Wt. of container with material W2	4.79	7.08
3	Wt. of container + material + water W3	5.46	8.375
4	Wt. of container + water W4	3.98	5.710

Sl No.	**Wt. of cement taken (In gm)**	**Wt. Of water Taken (In gm)**	**Plunger Preparation**	**Time Taken**	**Consistency**
1	300 gm	90	27	4 min	30%
2	300 gm	102	11	4 min	34%
3	300 gm	105	5.5	4 min	35%

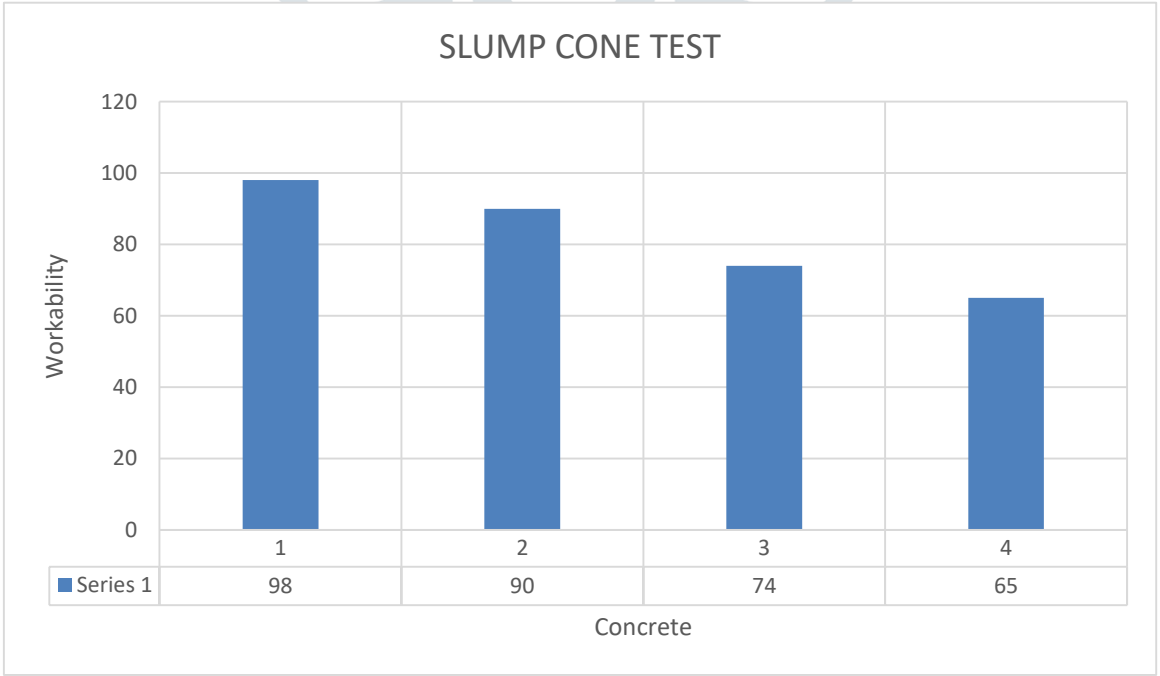
•Results and Analysis:

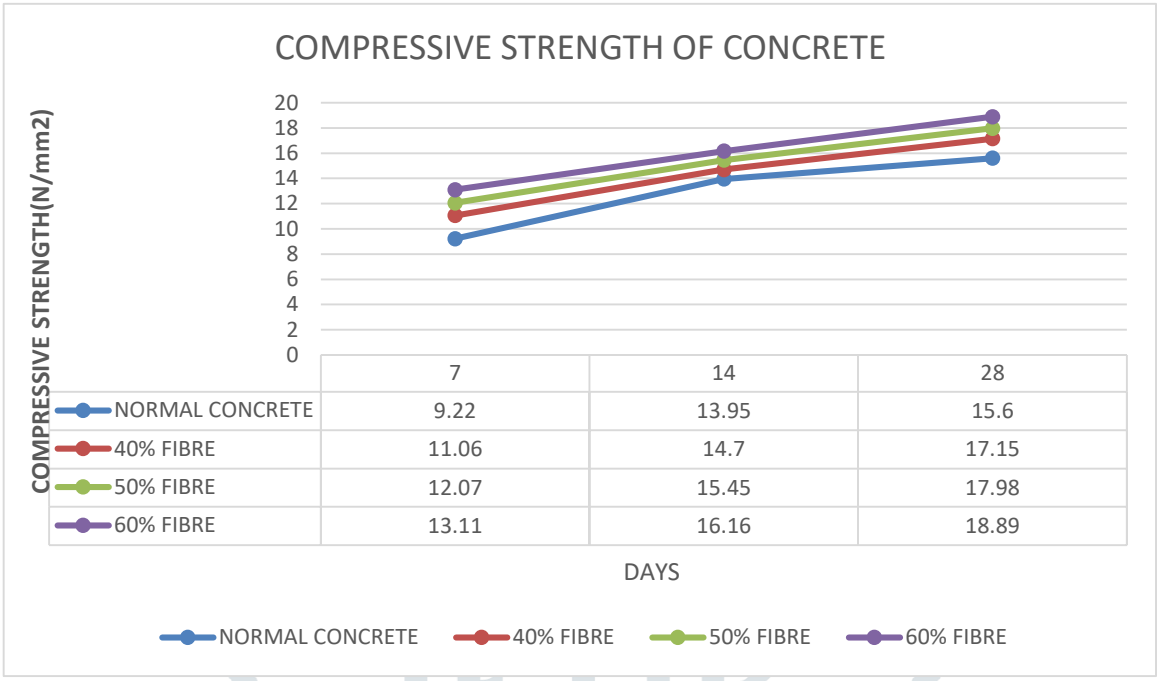
The compressive strength of the concrete cubes test provides an idea about all the characteristics of concrete. By doing this single test, one can judge that whether concreting has been done properly or not. Concrete Compressive strength for general construction varies from 15 Mpa to 30 Mpa depend on the needs. As we all know concrete compressive strength depends on various factor like water cement ratio, workability and admixtures. This test is carried out either on a cube or a cylinder. Various Codes recommend a concrete cube as the standard specimen for the test.

Compressive Strength Formula-: It is the load applied at a point of failure to the cross-section area of the face on which load was applied.

Compressive strength = Load/Cross sectional area

- Machine used for compressive testing is Compression Testing Machine.
- Load should be applied gradually at the rate of 140kg/cm2 per minute till the specimen fails.
- Firstly, the Geocomposite concrete performed quite well. The materials required were Cement, Sand, Aggregate and fiber mesh. To begin with the casting process, we had to cast 7 normal concrete cubes of Grade M15 with a nominal mix ration of 1:2:4, so to compare the strength of normal cubes with the Geocomposite Cubes.
- The compressive strength of normal concrete cubes after 7th and 14th day came out to be 9.22/mm2 and 13.95N/mm2.
- Now, with the addition of fiber mesh, we casted 21 concrete cubes with increase in addition of fiber mesh w.r.t total mix ration.
- For next 7 cubes, we added 40% of glass fiber to M15 concrete, which resulted in reduction of sand and aggregates volume by 20% each. After casting ad compaction by hand, it became quite difficult to mix.
- After 7th, 14th and 28th day, the compressive strength of fiber reinforced concrete came out to be more as compared to normal concrete cubes.
- Subsequently, with increase in addition of fiber mesh in concrete mixture, the required volume of sand and aggregate decreased.
- With addition of 50% of glass fiber to normal M15 concrete, we casted 7 cubes and after compaction, curing ad resting them for 7, 14, 28 days the compressive strength increased.
- Lastly, with addition of 60% of fiber mesh with normal M15 concrete, the compressive strength increased.





Conclusion and Future Scope:

- This research presents a new cost-effective method to develop a low-cost concrete having high tensile strength. This helps in detection of increasing strength require for different purposes.
- This project paper also presents a detailed view on geocomposite concrete based on its mix proportions.
- With increase in percentage of fibre, the wet density of fiber reinforced concrete increases.
- The main purpose of adding fibre to concrete is not add strength but to prevent it from cracking from plastic shrinkage or drying shrinkage.
- The slump test and dry matrix compaction factor of fibre reinforced concrete provides a better result of workability.
- The temperature of fresh concrete is reduced with addition of fibre i.e., hydration reaction slows down. Also, the fresh mix becomes dry with increase in percentage of fibre.
- With the selection of good quality fibre, the right FRC can reduce voids and increase tensile strength.
- Also, fibre reinforced concrete is heavier than non-fibre concrete as fibre absorbs more water.
- This project also discusses the advancement of concrete mixing technique ad its effective way to absorb the fibre easily and stabilizing the structure quite effectively.
- The paper further analyses the performance of concrete and fibre with increase in strength over time.

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GBPI/CLWRM/2020-21/ Dated 10.12.2020

CERTIFICATE

This is to certify that the thesis entitled, ***"Prediction of water quality emphasizing on nutrient dynamics in Kosi watershed Uttrakhand"*** being submitted by Ms. Pooja Rani Sinha for the award of Ph.D. degree is a research carried out by her under my supervision. In my opinion, the work fulfills the requirements for which it is being submitted.

The work incorporated in this thesis has not been submitted elsewhere earlier, in part or in full, for the award of any other degree or diploma of this or any other Institution or University to the best of my knowledge.

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भारतीय वन्यजीव संस्थान
Wildlife Institute of India

Dr. V.P. Uniyal
Scientist - G
Faculty of Wildlife Science

CERTIFICATE

This is to certify that the thesis entitled "**Prediction of water quality emphasizing on nutrient dynamics in Kosi watershed Uttarakhand**" submitted by **Ms. Pooja Rani Sinha** (Enrolment no. **16PhD422**) to Forest Research Institute Deemed to be University, Dehradun, for the award of the degree of **Doctor of Philosophy in Forestry (Wildlife Science)**, embodies research work carried out by her under my supervision. The thesis has been duly checked through URKUND a plagiarism detection tool approved by F.R.I. Deemed to be University and the thesis has plagiarism to the acceptable limits. No part of this thesis has been submitted for any other degree/diploma of the same Institution where the work was carried out, or to any other Institution and it fulfils the requirements of the ordinance governing award of Ph.D. Degree of F.R.I. Deemed to be University.

Place: Dehradun
Date: 27/1/2021

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This is to certify that

Pooja Rani Sinha

has actively participated in **12th Uttarakhand State Science and Technology Congress 2017-18**, 07th – 09th March, 2018 and presented a research paper (Oral/Poster) entitled

Water quality analysis Emphasising on nitrate dynamic using WASP model in ALMORA of KOSI watershed

under the discipline

Engineering Science and Technology

at Uttarakhand State Council for Science and Technology, Vigyan Dham, Dehradun.

Dr Ashutosh Mishra
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Chairman - 12th USSTC
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Uttarakhand

CERTIFICATE OF PARTICIPATION

National Mission on Himalayan Studies (NMHS)

Himalayan Researchers Consortium (HRC)-2018

November 26–27, 2018

Certificate of Paper Presentation

This is to certify that **Ms Pooja Rani** from **G. B. Pant National Institute of Himalayan Environment and Sustainable Development, Uttarakhand, HQs, Almora** has participated and made Presentation on the theme "**Natural Resource Management (Physical Sciences)**" in the "**2nd Himalayan Researchers Consortium (HRC)-2018**" held during November 26–27, 2018 in Gangtok, Sikkim, India.

(Er Kireet Kumar)
Scientist 'G', GBPNIHESD
Nodal Officer, NMHS-PMU

(Dr. Ranbeer S. Rawal)
Director, GBPNIHESD
Kosi-Katarmal, Almora

APPENDIX-7

FOREST RESEARCH INSTITUTE DEEMED to be UNIVERSITY

DEHRA DUN

This is to certify that **Ms Pooja Rani Sinha** enrolment no **2016PhD422** carried out research work under **Dr. V.P. Uniyal, Scientist G** of **Wildlife Institute of India**. The topic of the research registered with FRI Deemed to be University was **"Water quality prediction emphasizing on nutrient dynamics in Kosi watershed, Uttrakhand".** The scholar presented his work in the pre-thesis submission seminar held on **01-07-2020** and the RAC found the work to be satisfactory and approves the work to be presented in the form of thesis for evaluation by examiners for "Award of Ph.D. Degree" by FRI Deemed to be University.

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Dr. Gopi G. V.
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Dr. Samrat Mondol
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Dr. S.K. Gupta
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Dr. Y. V. Jhala
Dean, Faculty of Wildlife Science
Chairman RAC

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Signatures of the Members of the RAC including Supervisor and Member Secretary

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Dr. V. P. UNIYAL
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APPENDIX-6

Minutes of Meeting of RAC for Pre thesis submission seminar

(i)	**Name of the PhD Scholar:**	Pooja Rani Sinha
(ii)	**Registration Number & date:**	16PhD422 01-09-2017
(iii)	**Date of meeting:**	01-7-2020
(iv)	**Topic:**	Water Quality prediction emphasizing on nutrient dynamics in Kosi watershed Uttarakhand.
(v)	**Institute's name:**	Wildlife Institute of India, Dehradun
(vi)	**Discipline:** **(as per clause 3.3 of the Ph.D. ordinance)**	Climate Change and Forest Influence
(vii)	**Chairman's Name:**	Dr. Y. V. Jhala Dean, Faculty of Wildlife Science
(viii)	**Expert Member's Name:**	(1) Dr. B. S. Adhikari, Scientist - G (2) Dr. Gopi G. V., Scientist - E (3) Dr. Samrat Mondol, Scientist - E (4) Dr. S.K. Gupta, Scientist - E
(ix)	**Supervisor's Name:**	Dr. V.P Uniyal Scientist - G Wildlife Institute of India
(x)	**Co-Supervisor's Name:**	Er. Kireet Kumar Scientist - G G.B Pant National Institute of Himalayan Environment, Kosi Katarmal, Almora, Uttrakhand.
(xi)	**Head of Division (Member Secretary):**	Dr.V.P Uniyal, Scientist - G

(xii) Suggestions (in detail must be given)/ Recommendation of RAC

1. **The Correlation matrix needs to be explained in more detailed manner.**
2. **The simulated value and measured value of the model needs to be explained well for the statistics.**
3. **Index of Agreement for simulated and observed values needs to be explained.**
4. **Nutrients than nitrate needs to be explained and their probable sources with remedy.**
5. **Suggest remedial measures in detail for the control of nitrate in springs of Almora.**

All the queries, comments, and suggestions made by the experts and audience will be incorporated by the researcher in the thesis

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This is to certify that

Pooja Rani Sinha

has been awarded Young Scientist Award for best Oral / Poster Presentation under the discipline

Engineering Science and Technology

during 12th Uttarakhand State Science and Technology Congress 2017-18
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Dr Ashutosh Mishra
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