DISSERTATION REPORT

ON

"AN APPROACH FOR THE MANAGEMENT OF GROUNDWATER IN THE COASTAL REGIONS OF WEST BENGAL"

SUBMITTED

BY

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SUBMITTED IN : MAY, 2017

CANDIDATE'S DECLARATION

I hereby declare that the work which is being presented in this dissertation entitled " **An approach for management of groundwater in the coastal region of West Bengal"** in partial fulfillment of the requirements for the award of degree of **MASTER OF SCIENCE** in **ENVIRONMENTAL SCIENCES** submitted in the **CENTRE FOR ENVIRONMENTAL SCIENCES, CENTRAL UNIVERSITY OF JHARKHAND**, is an authentic record of my own work carried out during the period from 10th January, 2017 to 10th May,2017 under the supervision of Dr. Pragya Sourabh, Centre for Environmental Sciences andDr. M.S. Rao., National Institute of Hydrology.

The matter embodied in this dissertation has not been submitted by me for the award of my other degree.

Date:Shivani Kumari Shivani Kumari

Place: Roorkee

This is to certify that the above statement made by the candidate is correct to the best of my knowledge.

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(जल संसाधन मंत्रालय के अधीन, भारत सरकार की समिति)

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CERTIFICATE FROM SUPERVISOR (EXTERNAL)

This dissertation entitled "An approach for the management of groundwater in the coastal region of West Bengal" submitted by Miss Shivani Kumari, Centre for Environmental Sciences, Central University of Jharkhand, Ranchi as a part of the Master programme, is an original work and has not been submitted so far in part or in full, for any other degree or diploma of any University or Institution.

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ABSTRACT

The tittle of the dissertation work and report is "An Approach for the Management of Groundwater in the Coastal Region of West Bengal.''Groundwater is most important natural resources and it serves as large subsurface water reservoir.The availability and quality of groundwater is degrading very rapidly in coastal areas. The depletion of groundwater happens due to the involvement of different factors like over pumping and over exploitation, sea level fluctuation, landuse changes, climatic variations etc. So to maintain the availability of groundwater the management is needed to be done. The proper management is required to maintain the sustainability of groundwater resources. The management should be economically sound and environmentally beneficial.

West Bengal has coastline of 210km and coastal region covers three districts of the state i.e. East Medinipore, South24 Paragnas, North24 Paragnas. The state has a wide range of mangrove forest in the south portion. Mangrove forest covers the coastal district South24Paragnas. The groundwater quality is different in these three districts. These districts have shallow aquifer system. The quality of groundwater in these districts varies according to their aquifer system. The state has high groundwater reserve, although, the depletion of groundwater is being recognized from 80's in some areas of the state. The significant fall was noticed in both pre and post monsoon period.

Coastal zone groundwater faces many hydrogeological problems due to over exploitation, over-pumping of water. The seawater intrusion, land subsidence, up coning of water, salinity, sea-level rise etc leads the depletion and retardation of the quality and quantity of groundwater in the coastal regions. The detection of size and extent of problem is important for the any management program. This detection can be done by knowing the quality and composition of the groundwater.

Different analytical techniques are used during analysis of sample and they are ion chromatography and isotopes techniques. Ion chromatography is a process that separates ions and molecules based on their affinity to the ion exchanger. It is often used in water analysis and quality control. In hydrology isotopes provides information on the movement and distribution of water in the hydrological system.Water contains environmental isotopes and conclusion may be drawn from their variation. The study of hydrochemical data and information of isotopic ratios provides a figure of the contaminated aquifer that helps in order to evaluate remedial alternatives. The studied data are integrated with GIS techniques and used for the successful

implementation of program. GIS helps in the prediction of the future condition of groundwater scenario.

Some measures like rainwater harvesting, artificial recharge and many other techniques are used to control the problems of the groundwater in the coastal region. The quantitative understanding of the pattern of movement of seawater into the groundwater and factor that influence these processes are required to manage and maintain the availability and quality of groundwater in the coastal region.

The report is divided in the different chapters and they consist of basic information about the groundwater, some literature reviews are included for guidelines and some related work information are also included. In the chapter on methodologies analytical techniques are detailed and the in the result section isotopic and chemical concentration of various analytes and their variations are detailed. In the management section various mitigation measures to address the coastal hydrological problems to reduce the impacts marine effect in reduction of groundwater resource is addressed. The work presented is useful in general to researchers working in coastal groundwater resources and to field researchers in groundwater problems of West Bengal in particular.

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Chapter 1: INTRODUCTION

In this chapter, along with some basic information about groundwater, the literature on the subject is reviewed and the objective of work is discussed. The objective is to providesuitable approach for management of improvement in groundwater quality and quantity in the coastal region of West Bengal. The first chapter details basicsof groundwater, it'soccurrence, movement, recharge process etc. Literature is reviewedto get an idea of work accomplished and gaps in the field of work and advanced methodology of the investigations to execute the work. After getting all the information from these materials the study area and experimental work are described in the Chapters 2 & 3. The improvement of groundwater potential and its quality requires various field implementable techniques. These are discussed in the Chapter 4.

Groundwater is the water that percolates through porous terrain, and is held underground in the soil, or in fractures and crevices in rocks. Groundwater is the renewable source of water and it is the main source of supply of water throughout the world. The origin of groundwater is rainfall and infiltration.

1.1 Importance of groundwater

Water resources of the earth contain 96.5% of its water in oceans as saline water, 2.5%isin inland freshwater, 0.93% is there as saline groundwater and 0.07% as saline lake waters. Of the fresh inland water, 68.6% is locked up in glaciers & ice caps, 30.1% is there as groundwater and 1.3% is there as surface water (ice, snow, lakes, rivers, soil moisture, biological water etc). Groundwater makes up to 35 times the amount of water in lakes and streams.

Globally, groundwater is extensively used in irrigation, industrial needs, and for domestic purposes. Groundwater constitutes a small fraction of the earth's water resources but, it is very important for the existence of the human life. Groundwater constitutes one portion of the earth's water circulatory system known as the hydrological cycle.

In India, groundwater plays an important role in agriculture productivity. Over 50% of total irrigated area of Indian agriculture is dependent upon groundwater (CWC Report,2000) and about 60% of irrigated food production depends on irrigation from wells (Shah et al,2000).

1.2 Groundwater and Hydrological Cycle

The hydrological cycle is the most fundamental principle of groundwater hydrology. Hydrological cycle is the conceptual model or process that describes the storage and movement of water from the atmosphere, hydrosphere, biosphere and lithosphere. Hydrological cycle play important role, it maintains the water balance on the earth and also it is important for biological condition. The water cycle is continuous process that occurs from different reservoirs. There are different processes that are involved in water cycle and they are considered as the major component of hydrological cycle and they are evaporation, condensation, precipitation, infiltration, runoff, transpiration , groundwater flow shown in fig(1).

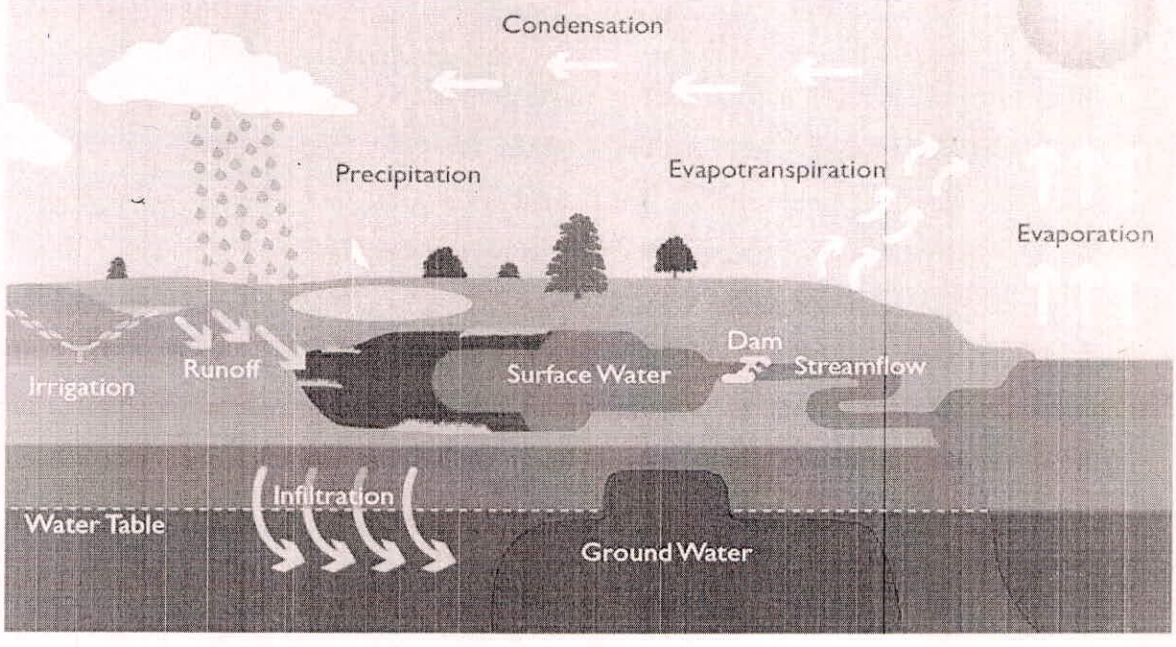


Figure 1): The hydrologic cycle is the cyclic movement of water in its various phases through the atmosphere, to the Earth, over and through the land, to the ocean, and back to the atmosphere (Rossi, F and J Grant. 2009. Long term evaluation of reduced chemical pesticide management of golf course putting turf. Intl Turfgrass Society Research. nysgolfbmp.cals.cornell.edu)

The whole process of hydrological cycle shown in fig(1) and it illustrates that water evaporates from the reservoirs (rivers, lakes, streams, oceans) and travels to the atmosphere and water also evaporates from soil and vegetation and moved to air. In the atmosphere these evaporated water become the part of cloud by process of the condensation. It falls down to the earth's surface as precipitation. Precipitation creates runoff over the surface and these runoff enters the rivers, lakes and streams and other reservoirs. Some precipitated water percolates in the pores of soil and rocks this process is known as infiltration. The downward movement of water leads to recharge of aquifer. Water always used to move from reservoirs while changing their form (solid, liquid, gas) and involve in this process. That's why it is a continue process.

1.3 Vertical distribution of groundwater

The subsurface occurrence of groundwater may be divided into two zone: zone of aeration and zone of saturation. Zone of aeration consist of voids which are partially filled of water and partially by air. In the zone of saturation the voids are completely filled of water. These difference and categorization are represented in fig(2).

Zone of aeration is further divided into three zones: soil water zone, intermediate zone, capillary zone. The fig(2) represents the three division of zone with their characteristics; soil water zone is nearest zone to the ground surface, plants and trees gets moisture from this zone. The middle zone is intermediate zone is also known as sub soil zone. Below these zones there is third zone exist i.e. capillary zone. In capillary zone some capillary actions are occurred due to the surface tension of water that leads to the increase of groundwater level to the certain height.

The infiltrated water filled the voids by gravity at the certain depth that zone is known as zone of saturation. The water in the saturated zone settles with a smooth horizontal upper face known as water table. This zone starts from the water table to the underlying impermeable rocks.

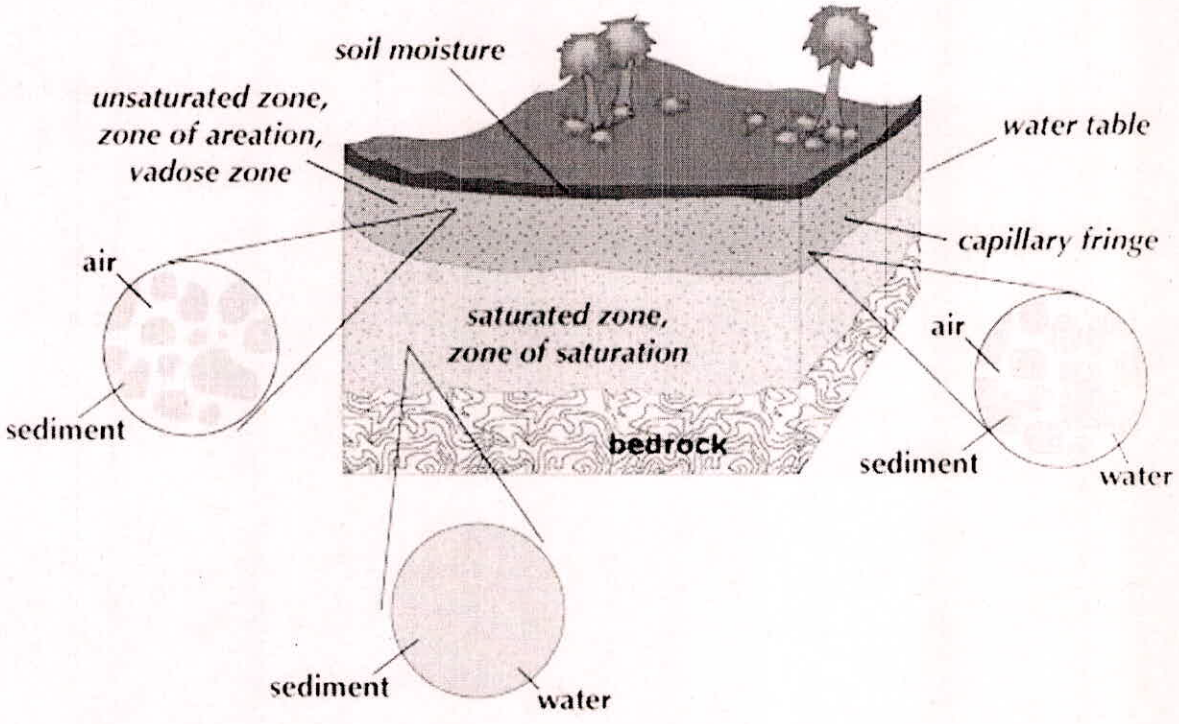


Figure 2:Representing the vertical distribution groundwater in the zones with their characteristics.

1.4 Water bearing formation

Water bearing formation defined as the formation of structure beneath the ground surface that leads to the storing and movement of groundwater by their interconnected pores. There are various types of water bearing formation and they are: aquifer, aquiclude, aquitard, aquifuge.

Aquifer:

Rock beds at the saturated zone that allow the flowing of groundwater. Aquifer rock contains pores and fissures, shown in fig.3.The size and number of pores and their interconnection shows the qualities of the aquifer. From aquifer sufficient amount of water can be withdrawn by drilling wells. Aquifers are recharged from precipitation and the recharge rates are not same for all aquifer, it varies from the pore interconnection and properties (porosity, permeability).

Aquifer are classed into two category based on the presence or absence of the confining layer of aquifer and they are confined and unconfined aquifer(fig3).

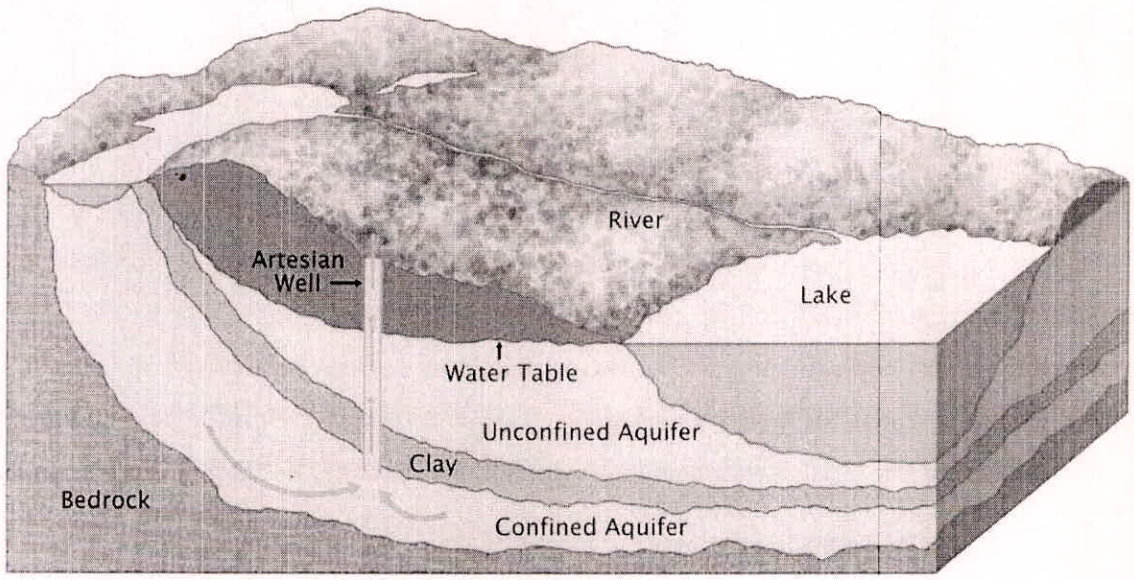


Figure 3 Representation of flow of groundwater in aquifer and the occurrence of water in the types (confined and unconfined) of aquifer.(Illutration by Tim Gunther, National Geographical Society)

Confined aquifer:

Confined aquifer is poorly permeable body of rock or sediment that restricts groundwater flow. The yielding of water from the confined aquifer is very difficult so it is incapable of providing the water for sustaining the life.

Unconfined aquifer:

Unconfined aquifers are also known as "water table aquifers" because they usually have a significant vadose zone between the land surface and the water table; the depth of the water table, and thus the thickness of the unsaturated zone, fluctuates seasonally in response to precipitation patterns, groundwater recharge, and water levels in adjacent streams.

Aquiclude:

Rock strata that prevent the flow of groundwater are called aquiclude. Aquiclude are important components of groundwater system because it prevents the infiltrating to greater depth(fig4). Aquiclude rocks have low water conductivity due to their lack of interconnection between voids.

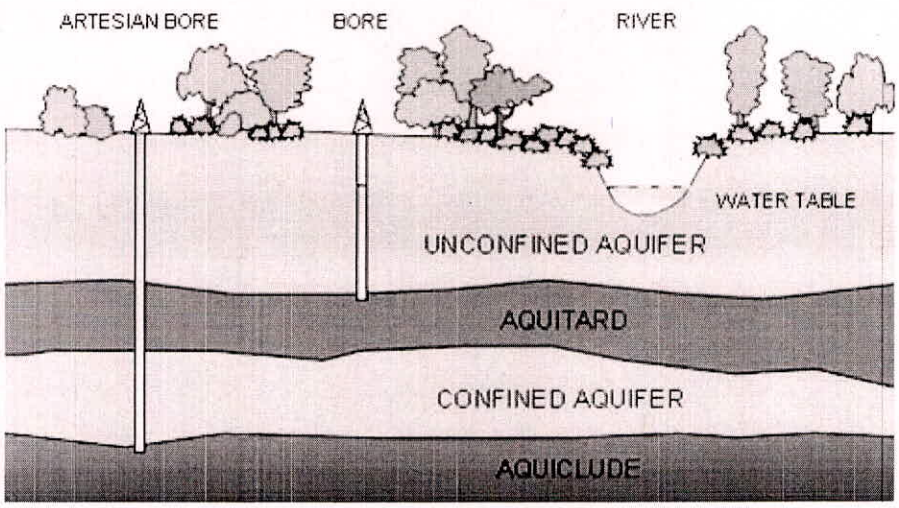


Figure 4the strata and nature of aquitard and aquiclude for the flow of groundwater. (relationship between component of groundwater system,AS hydrology,Sydney)

Aquitard :

Aquitard is the strata that resist the flow of groundwater but some movement of groundwater occurs in this strata(fig 4). The flow rate is very slow so the yielding cannot be possible in this.

Aquifuge :

Rock strata that neither store nor transmit the groundwater. Rocks are not having interconnected pores.

1.5 Movement of groundwater

The movement of groundwater is governed by established hydraulic principle. The flow of groundwater through aquifers can be expressed by Darcy's Law. The application of Darcy's law enables the rate of groundwater flow and direction of movements in an aquifer.

1.6 Recharge of groundwater

Recharge is the replenishment of groundwater by adding water into the aquifer. Natural recharge occurs naturally as precipitation or infiltration of stored water from the surface. Natural recharge occurs without any influence of humans. Artificial recharge occurs as the result of human activity as irrigation or injection of water.

Method for aquifer recharge

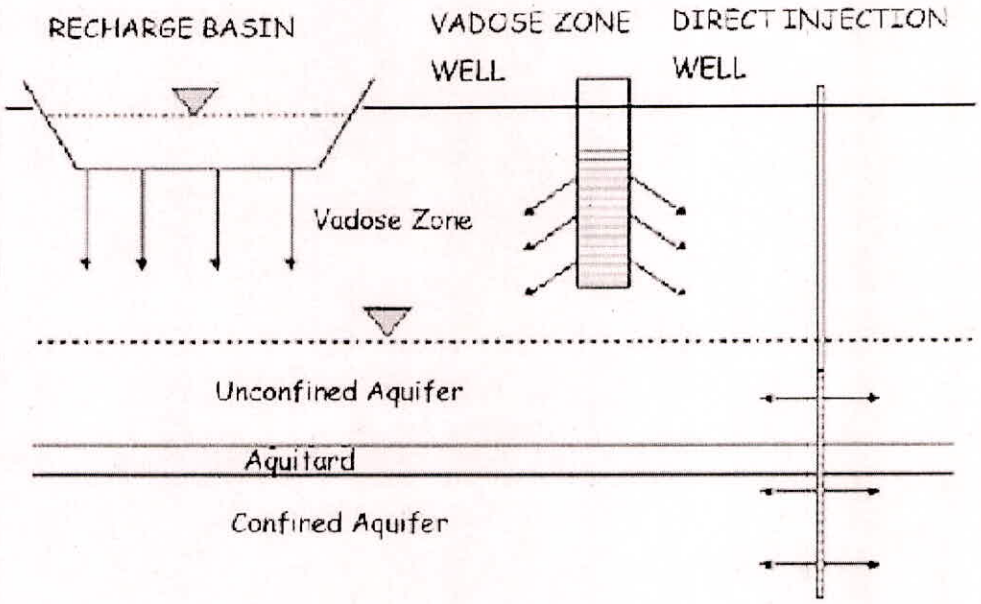


Figure 5:Representation of method of aquifer recharge by both natural and artificial manner. (strategy of recharge of groundwater, by S.K.Sharma)

1.7 Interaction and exchange of surface water and groundwater

The interaction and exchange of water between surface water and groundwater is arises due to infiltration, thermal flow, connection between rivers and geological strata.

Interaction of surface water and groundwater not only exchange the water masses between the water and soil but also fluctuates the physical, chemical, biological characteristics of both water. The interaction and exchange depends on the characteristics of water bodies involved in that and environmental condition of that area where the interaction occurred.

1.8 Seawater intrusion

Seawater intrusion is defined as the migration of saline water from the sea into groundwater aquifer. Thus, seawater intrusion leads to the salinization of fresh water aquifers

along the coastlines. The density of seawater is marginally higher than that of freshwater. Hence the intruded saline water settles at the bottom of the aquifer and fresh water floats on the top of it.

The most important causes of seawater intrusion is the reversal of groundwater gradients in coastal aquifers, where over pumping of wells disturbs the hydrodynamic balance. Over pumping of fresh water aquifers results in the development of a cone of depression and the reversal of groundwater gradient. This causes the entry of seawater to the original fresh water zones.

The depletion of groundwater are observed by the fluctuation in the level, degradation in quality and their components. The groundwater aquifer face lots of problems if there is nearby any coast. The depletion rate of groundwater is high in coastal areas. So the management is required to maintain the availability and quality of groundwater.

There are many work and research are going on or some are completed to maintain the groundwater quality and maintain their sustainability. So next section some reviews are discussed that are related to the management of groundwater in coastal regions.

1.9 Literature Review

The Government of West Bengal conducted impact studies due to climate change for the climate projections for 2050s and 2100. These projections have been derived from PRECIS (Providing Regional Climate for Impact Studies) simulated dataset of Indian Institute of Tropical Meteorology, Pune.Projections of rainfall in West Bengal for mid-century i.e 2050s indicated that there is no change in monsoon rainfall in the entire WB region in the mid-century, except, an increase in the southern Sundarbans region of the South 24 Parganas and in Eastern part of coast area. In the winters, the scenario changes, the rainfall decreases in most parts of southern Bengal, no change is seen in eastern parts, except and in the Sundarban region. In summers, the rain fall is likely to be increase in the south 24 parganas. As projection of temperature, in 2050s, the average daily maximum and minimum temperatures are both rise by 2.2□C in 2050s and by 2100, the temperatures are likely to rise by 3.6 to greater than 5□C with respect to the base line i.e 1960-1990. There are number of climate scenarios indicate that the sea level may rise from a minimum of 0.21m to a maximum of 0.48 m by the end of the century at the rate of 0.4mm/yr .The cyclonic storm

tracks seem to shift more southwards over the Indian Subcontinent, with very few hits along the WB coast. Overall, floods are caused by storm surges resulting from cyclones and sea level rise. The southern part of South 24 Pargana district, is extremely vulnerable to storm surges and cyclones. The soil in this region has become saline due to this event. In view of the above mention issues the main strategies are involve to ensure the water security of these regions : Enhance the activities of the Sundarban Development Board by creating more number of "Rain Water Harvesting Scheme with land Shaping". Reconstruct the Sundarbans embankment in vulnerable areas through public and private partnership. Construct sluices to prevent the intrusion of saline water in channels where it does not exist.

The Andhra Pradesh Ground Water Department (APGWD), on the basis of the water quality data obtained from public water supply wells, had reported that the salinity front in the groundwater is moving landwards. The study was based on limited data pertaining mainly to the shallow dug wells in the southern part of the study area, which has led to a concern regarding the sustainability of the valuable groundwater resources.

This was the first study being carried out in the Krishna Delta using a combined approach with hydrogeological, hydrochemical and isotopic techniques. .(Kumar et al., Bhishm Kumar et al,2011).The objectives of this study were to identify the cause of groundwater salinity, and to identify active hydrological processes including the present day seawater intrusion, if any.The groundwater condition in the multi-aquifer system of the Krishna River Delta using an integrated approach reveals that, there is no present day seawater intrusion in any of the aquifer systems in the study area. The existing salinity that ranges from slight to moderate brackish quality in shallower and intermediate depths and highly brackish to saline quality in deeper depths in certain locations, is due to palaeo-geographic conditions, when the sea coast was more inland than at present.

As per the investigation conducted by CGWB (Govt. West Bengal, CGWB report, 2001)it is clarified that, ground water in the coastal region are neutral to mildly alkaline in nature. The coastal districts have shallow aquifer system and at the shallow depth, water is found to be fresh but at the deeper aquifer there is intrusion.The general gradient of surface water is towards sea but there is minor movement of saline and fresh water. Because of

salinity problem the agriculture rate is very low in east medinipore and south 24 paragnas. Because of sea level rise and high tides in the sea, many villages of these districts are vanished and there are some areas of the districts which are at the rate of vulnerable. To resolve the problems of the coastal districts some strategies are prepared by the government of the state, some awareness and training activities have been provided in those areas

The Nakajami Island in Japan has a small watershed and the possibilities to use surface water are limited. On the island a subsurface dam was constructed initially as a test dam for numerous purposes. One of the purposes of the dam was to study methods for protecting and monitoring groundwater quality. After the pumping tests, it was also established that the dam retained groundwater, making it possible to pump, whilst at the same time preventing salt water intrusion.(Japan, Nakajima Island,1992)

In an attempt to overcome the spring drought period, the county of Nanpi decided to pump brackish/saline groundwater and divert river water in order to balance the quality of water. As upstream users extracted more and more water from the river, less was available for the downstream users in Nanpi County. Groundwater became a last resort. The Hebei Institute of Hydrotechnics developed the technology of using brackish and semi-saline water for watering crops during drought periods The Institute also promoted the development of drainage so as to create a buffer in the shallow aquifer that could be replenished by freshwater rainfall infiltration as well as from river and canal seepage. A sustainable equilibrium was found to sustain agriculture in NanpiCounty. (HebeiProvince,China,October 2011)

Australia is experiencing a growing problem of dry land salinity, which is of particular concern to its rural industries. Land affected by salt typically has shallow saline groundwater tables with varying degrees of salinity. In 2002 the Centre for Natural Resource Management (CNRM) proposed a method which enables the exploitation of saline groundwater, thereby dropping the level of aquifers, and remediating affected land through

an aquaculture based salt interception system. Saline groundwater was shown to be suitable for the culture of snapper, black bream and King George whiting. (Australia,2002)

Department of Geology, Anna University, Chennai has conducted a research work on seawater intrusion and its mitigation by managed aquifer recharge. Managed aquifer recharge is one of the best suited methods for mitigating seawater intrusion. Seawater intrusion has been identified along the coastal aquifers of Chennai, India by geoelectrical, geochemical, isotope and groundwater modeling studies.

In order to improve the groundwater potential and to mitigate the seawater intrusion in the Chennai's coastal aquifer, certain longterm water management measures such as construction of checkdams across Arani- Korattalaiyarrivers have been proposed by the Government of Tamil Nadu to augment the groundwater resources. This study shows that the check dam has considerable effect on increasing the quality of groundwater.

LubingaHandia et al (2003) investigated the potential of rainwater harvesting. Chemical analysis of the water collected by rainwater harvesting system were carried out and the result showed that water sample can be used after boiling for the drinking purpose.

Saleemet al (April,2013)analysed the groundwater samples from JamiaMillliaIslmia Campus, NewDelhi. Samples were collected from the campus before and after the implementation of RWH in the campus in the year 2011-12. The result showed that there was an improvement in groundwater quality after the implementing RWH technique in the campus.

1.10 Objective

The management of groundwater is needed to be done for future availability of the groundwater. The wider aspect of groundwater and its integration with seawater needs legal, socio-economic aspects of management. Management measures can be applied as to minimize the problems of the area. Management measures should be economically sound and environmentally benefits.

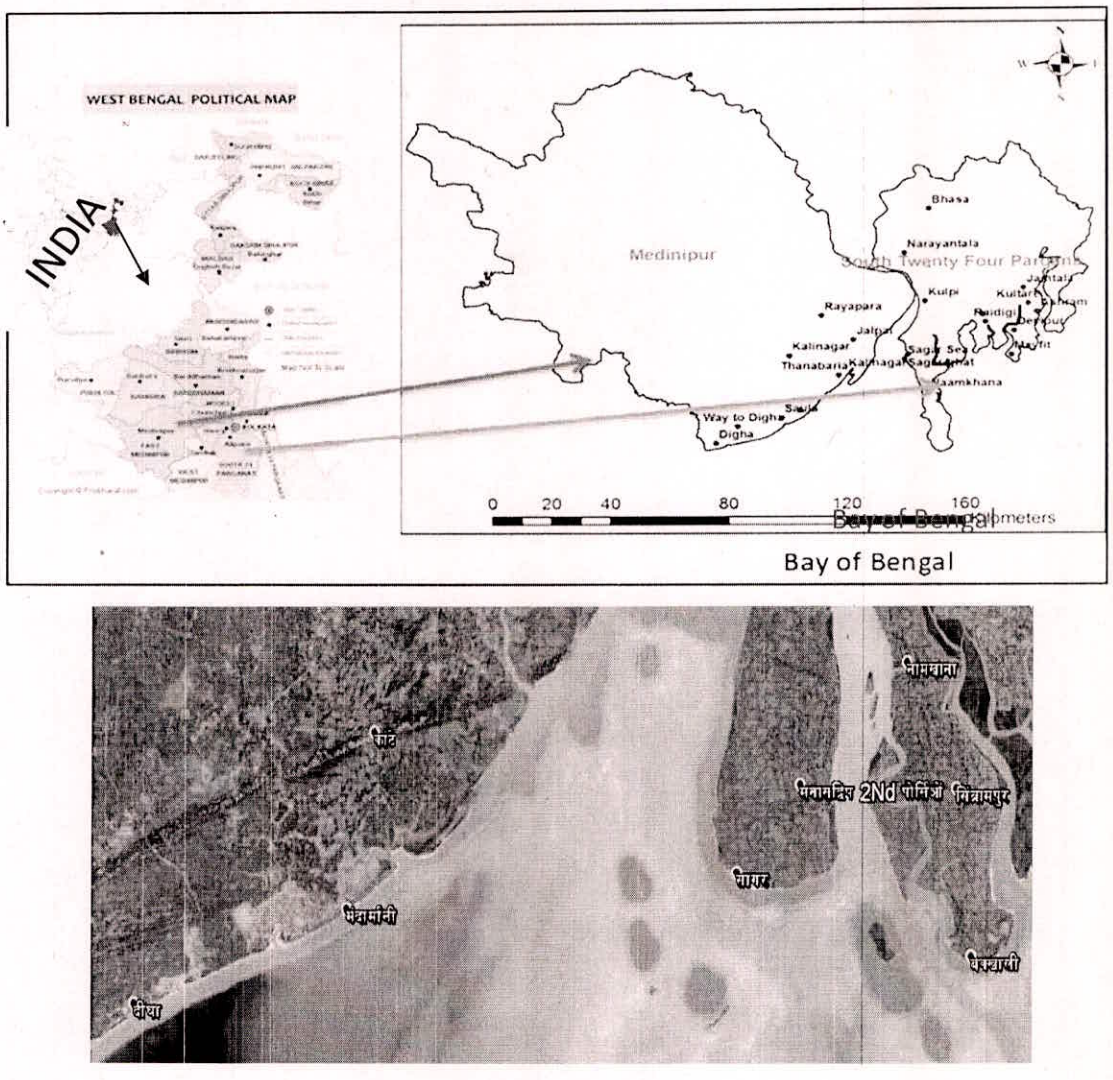


Figure 6Study area: (a) Location of West Bengal in India, (b) the studied districts – Medinipur and South 24 Pargana (c) Google Earth image of the study area

Chapter 2: Study area

2.1 State profile:

2.2.1 Location:

West Bengal is in the Eastern region of India. The State is situated between N 21°30' & 27° 30' and E 85° 30' & 89°45'. The total area of the state is 88,752 sq Km having a dense population of more than 80 million people.

2.2.2 Rainfall and Climate:

The rainfall range is different in the parts of state. North Bengal receives highest as 200-400cm and coastal region receives 200cm. in the Ganga plain and the central part of the state receives about 150-200cm and the western plateau receives 100-125cm.

There are 4 season faced: a) cold dry weather from December to February , the temperature ranges between 9-16□C ; (b) hot dry weather from march to May, temperature ranges up to 38□-45□ C ;(c) monsoon period from June to September ; (d) post monsoon period from October to November.

2.2.3 Landuse:

The Himalayan hills and Shiwalik hills covered the northern portion of the state and from the base of the Himalayas the Terai region begins that consists the huge amount of grassland, forest and wetland. The Ganga deltaic regions cover the large portion of state. Many tributaries and streams are originated from the river Ganga. Coastal region is on the extreme south of the state. The Sundarban delta is the largest mangrove forest is situated in the south 24 paragnas district of the state. The western plateau consists of chottanagar plateau and the slope stretched from the west to the east part of the state.

2.2.4 Geological Condition:

The geography of the state is unique its northern part is in the Himalayan Range, whereas the extreme southern part touches the Bay of Bengal and is covered by the Active Delta of the Sundarbans Mangrove forest.

The west Bengal represents the three major parts:

1. The extra peninsular region covering northern part

2. The peninsular mass in the south west
3. The eastern and southern region of alluvium and deltaic plain

- Geology of the extra peninsular region:

The Extra-Peninsular region covering the northern part *i.e.* the terrain of the Darjeeling Himalayas.The major lithological units of the extra peninsular region belong to the central Crystalline Gneissic Complex and comprise of the Daling Group, the Gondwana Super group, the Siwalik Group and the Quaternary formation.

The hard rock terrain broadly observed in two distinct regions covering the extra peninsular mountain ranges of the Darjeeling Himalayas in the north and the peninsular tract comprising of a rolling topography in the southwestern region.

The Darjeeling gneiss consists of migmatitic-banded gneiss containing enclaves of high grade schist. The Gondwana group of rocks occurring in the Darjeeling and the Jalpaiguri districts consists of pebble/boulder, quartzite, sandstone, slates, carbonaceous slates and coal seams. In the northern part of the Jalpaiguri, the Cooch Behar and the Darjeeling districts, the alluvial belt of tertiary age is underlain by soft Quaternary formation comprising sand, silt and clay with fine texture sediments.

- Geology of the peninsular mass in the south west:

The western margin of the Bengal Basin comprises of the oldest rock complex.
The unclassified metamorphic from Chhotanagpur Gneissic Complex (CGC) represents oldest litho-unit of Archean Era occupied by the southern part of Purulia district and the western part of the Bankura, Bardhman, Birbhum and Midnapore districts.

Gondwana sequences occur between Damodar, Ajay and Trans-Damodar areas of Birbhum coalfield.Rajmahal hills in the central part of the State have dark to very dark hard and fine grained Basalt in large amount.

- Geology of the eastern and southern region of alluvium and deltaic plain

This region is known for the basinal region of the state. Basinal region is made up of smaller units is known for its thick alluvium deposits over the Precambrian basement. Gondwanasupergroup rocks are the oldest rocks in the eastern part of the Basin.

Quaternary geology of the Bengal Basin is driven by many factors such as Global climatic changes, uplift of the Himalayas and subsidence in the Bengal Basin by the rise in the sea level, changes in the sediments.

2.2.5 Drainage:

The drainage of the state West Bengal can be divided into three divisions: the Himalayan river ; the rivers of the chottanagpur plateau & the tidal rivers.

- The Himalayan rivers :

The main Himalayan rivers are the Ganga river, Bhagirathi- Hooghly, the Mahananda, Jaldhaka and there are many tributaries of these rivers.

The Ganga river flows through maldah, murshidabad and dinajpur district. The main stream of the river ganga is channelized to Bhagirathi – Hooghly river at Jangipur.

The River Bhagirathi-Hooghly is known as the heart and soul of West Bengal. It flows through Murshidabad, Malda, Nadia, Hooghly, Howrah and south and north 24 Paragnas. It flows south and falls into the Bay of Bengal after forming a large delta at its mouth. Jalangi, Churni, Ajoy, Damodar, Rupnarayan, Haldi, Mayurakshi are the main river of Hooghly.

The Mahananda river rises from the Mahaldhiram of Ghum Range of the Darjeeling district. It flows through North-Bengal and joins the river Bhagirathi-Hooghly. It is the longest river of North Bengal. Its left bank tributaries are Nagar, the Tangan and the Punarbhaba and its right bank tributaries are Kalindi, Balsan and Mechi.

- The River of Chottanagpur Plateau:

The rivers of the Chottanagpur plateau are Darakeswar, the Mayurakshi, the Ajay, the Damodar, the Rupnarayan, the Haldi, the Dwaraka, the Kansai, etc. These rivers are following the western part of West Bengal.

The Mayurakshiriver flows through chottanagpur plateau and enters in the birbhum district of west Bengal. The Haldiriver also flows from plateau through Purulia and Medinapore district. In medinipore region the river Subarnarekha flows and enters the state Odessa.

- The Tidal River:

The Rivers of the Delta Region are tidal rivers. They are Bartala, Saptamukhi, Jamir, Matla, Gosaba, Haribhanga etc. Water of these rivers is saline as they are influenced by high tides and low tides. During low tide, they get more or less dry but during high tides, they overflow their banks.

2.2 Sampling Site

Samples are collected to proceed the chemical and isotopic analysis of groundwater so that the concentration or abundance of any element is found that leads to create problems in the quality and quantity of groundwater.

The samples are collected from the coastal district of the state and collection is done from the seven different areas. The samples collected from the sites are Bakkhali,Amrabati (Fraserganj),Admail, Sibrampur (Namkhana),Sibnagar Abad,Digha (near old Digha bus stop) Digha-Contai road, Fatehpur and Contai. The source of collection of sample is through the hand pumps in that area. The collection sites are come in the coastal district of West Bengal. The coastal districts of the state are East Medinipore, South 24 Paragnas.

2.2.1 East Medinipore

East Medinipore district covers Contai and Digha from where the collection is done. Both the sites are comes under the seashore area. The location of east medinipore is between north latitudes 21□36'35'' to 22□57'10''north and east longitudes 86□33'50''to 88□12'40'' east and covers an areas of 4,736 sq km and the district have population density of 5,094,238 (as per 2001census). The rainfall experience inthis region is 1640mm and

climate is humid-subtropical type. The temperatures of these areas are 9□C in winter and 38□C in summer. The landuse pattern in this region are different in this region, the total geographical area is 3,96,600 ha out of this 10,7,230 ha land are non- agricultural and barren land , so the high area is unculturable. Some area comes under the forest (900ha). East medinipore consists the two lithosystem: alluvial plain and coastal area.

The groundwater quality in this region is somehow different. In upper litho system the groundwater quality is same but in lower litho system the variation is occurred in the quality of groundwater. Groundwater is mildly to distinctly alkaline in coastal area. Groundwater used as in irrigation purpose in general areas of district except southeastern part because in southeastern parts the sodium hazard is anticipated.

In Contai, there are some aquifers at the depth of 25mbgl in sub basin and this horizon contains some saline water. But here the interfaces do not show any depletion of quality of water at mean time. In Digha the sand dunes are formed by sea contain fresh groundwater. The near surface aquifer emerges the sea on the continental shelf thus seawater having easy access into this aquifer. The general gradient of the near surface water is towards sea, but minor movements of saline and fresh water occur at mean time.

But the situation is very much alarming inthis area because there is very much probability of depletion of quality of groundwater because of mixing of saline water and groundwater. The piezometric head is also lowering in these areas due to overpumping so some measures are needed to be done to minimize the problems.

2.2.2 South 24 Paragnas

South 24 Paragnas district is bounded by the latitudes 22°33′45N and 21°29′00″ N and longitudes 89°4′50″ E and 88°3′45″E. The total geographical area of the district in 9960 sq.km. The rainfall experience in this region is 1800mm and climate is hot and humid climate type. The temperatures of these areas are 10□C in winter and 40□C in summer. The district covers a large area of forest around 4263 sq km and agriculture plot around 3782 sq km area.

The district is divided into 4 geographical units: deltaic plains, levees, marshes, islands of Sundarban. Mangroves forest covers the large portion of this district.

The samples are collected from Bakkhali, Amrabati (Fraserganj), Admail, Sibrampur (Namkhana),Sibnagar Abad area of the district. The site (bakkhali, amrabati, admail, sibrampur, sibnagarabad) comes under the unconfined aquifer system. Groundwater from the unconfined aquifer are neutral to mildly alkaline with pH ranges from 7.2 to 8.1 andelectro-conductivity ranges from714 to 2692 µS/cm (at 25°C) and the chloride value ranges from 14 to 596 ppm., hence suitable for human consumption, but this water is not safe for long term use. The fresh groundwater is found under the confined aquifer group. The southern and south-eastern part of the district contain fresh water and favorable for exploitation. In the coastal belt of this district the aquifers under semi confined to confined condition contain ground water with very high dissolved salts.

The main problem is salinity in the site area; because of saline condition the swallow tube wells are not feasible for either drinking or irrigation purposes. The areas near to the islands is highly prone to flood and cyclone.

The brief information about the sample site and samples.

Table 1The information of collected samples from the coastal districts

Sampling Date:	18/11/2015
Source	Handpump
No of Samples collected	07
Sampled water ID	SGD 1, SGD 2, SGD 3, SGD 4, SGD 5, SGD 6 and SGD 7

2.3 Description of Coastal West Bengal

Total coast length: 210.0km

Table 2:The brief description of coastal districts

Coastal Districts	Coastal Blocks/Mandalam	District Population (2011)
East Medinipur	Kolaghat , SahidMatangini , Tamluk , Nanda Kumar ,Mehisdal , Sulahata , Haldia ,Nandigram I , Nandigram II , Khajuri II , Deshopran , Contai I , Ramnagar II, Ramnagar I	5095875
South 24 Parganas	Gosaba, Kultali , Patharpratima , Namkhana , Sagar ,Kakdwip , Kulpi , Magrahat I, Diamond Harbour I , Diamond Harbour II	8161961

Coastal Districts	**Coastal Hydrogeology**
East Medinipur	Quaternary alluvium and tertiary sediments Rivers: Kasai , Kaliaghai, Rupnarayan , Hugli
South 24 Parganas	Quaternary and tertiary alluvium Rivers: Hugli , Matla, Bidyadhari, Raimangal, Saptamukhi

The above table 2 is the summarision of information of the coastal districts including their blocks/mandals,population, the main drainage of that regions and hydrogeology of the districts. These information are needed for the implementing the any maeasures of management of groundwater in the sampling districts.

Chapter 3 : Methodology & Results

To know the exact current condition of groundwater quality, the analysis of the samples arerequired and the analysis is isotopic studies and hydrochemistry. Isotopic study is done by mass spectrometry with the help of instrument dual inlet mass spectrometer. Hydrochemistry is done with the help of ion chromatography. From the both analysis the concentration of ions are separated and detected.

3.1 Measurement & Analysis

3.1.1 Isotopic Study: Mass Spectrometry

Mass spectrometry is an analytical technique that used to generate ions from organic, in-organic compounds in by any suitable methods. This is done by mass spectrometer.

In mass spectrometer, the ions are generated by ionization, separation by their mass to charged ration (m/z) and detection of ion in the gas phase and measured the isotopes of the sample. The major component of mass spectrometer is ion source, mass analyzer and detector and these are operated under high vacuum condition.

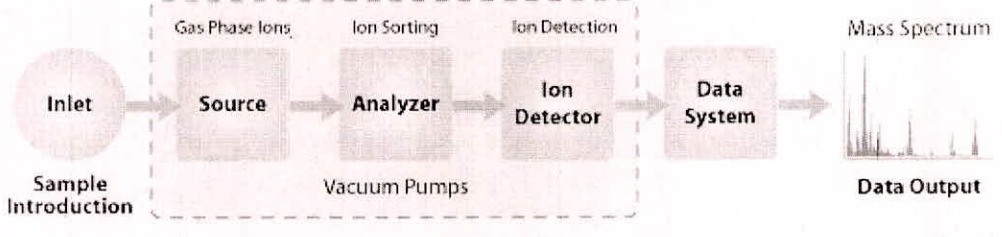


Figure 7: Components of mass spectrometer along with sampling and outcome processes. (Premier biosoft article on the research for glycan and lipid detection.)

Principle :

During analysis of compound the first step is the production of gas phase of compound through ionization source by inducing either gain or loss of a charge. These molecular ions are gone under fragmentation and the product ion are derived from molecular ion and it so on. The ions are separated according to their mass-charge ratio and are detected in proportion to their abundance, these are shown in fig6. The atmospheric pressure is around 760torr (mm of mercury) and the pressure under which ions may be detected at approximately 10^(-5) to 10^(-8).

Working:

Mass spectrometer converts individual molecules to ions so that they can be moved and manipulated by electric and magnetic fields. Because ions are very reactive and short-lived, their formation and manipulation occurs in the highly vacuum conditions.

Each of three processes maybe done in different ways. Ionization is effected by a high energy beam of electrons; ion separations occur by accelerating and deflecting the ions in beam; ions are detected electronically; and the results are stored in computer.

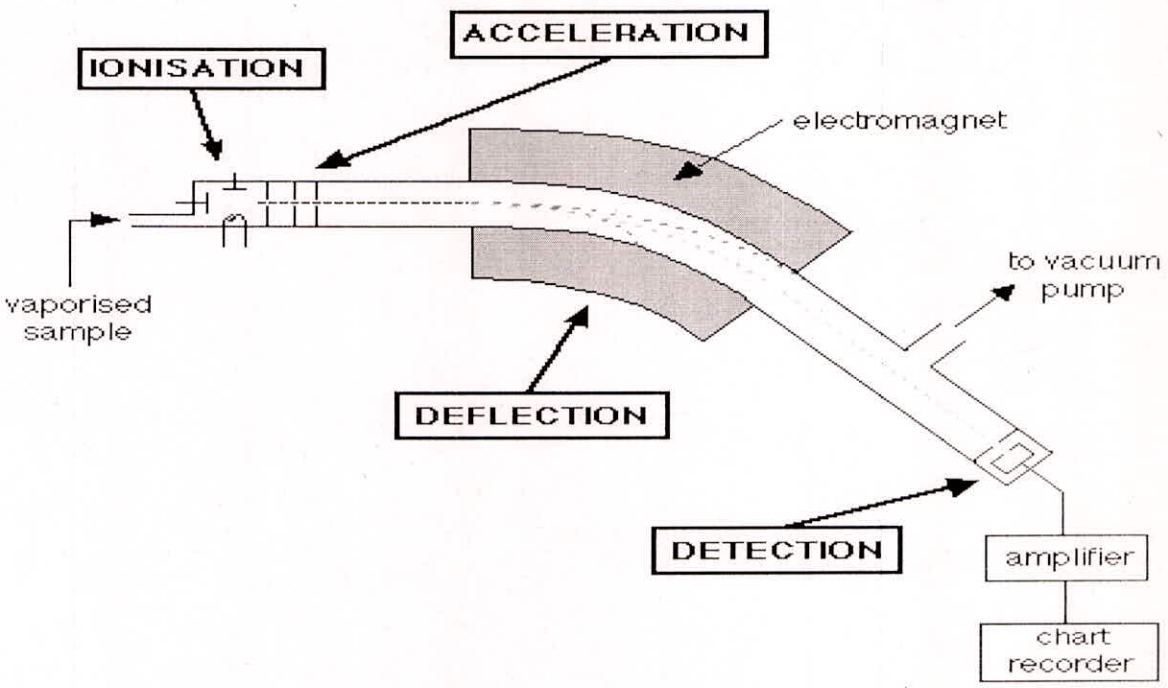


Figure 8The representation of working of mass spectrometer (working aspect of mass spectrometer by Jim Clark,2000)

Ionization:

The vaporized sample passes into the ionization chamber. The electrically heated metal coil gives off electrons which are attracted to the electron trap which is a positively charged plate.

The particles in the sample (atoms or molecules) are therefore bombarded with a stream of electrons, and some of the collisions are energetic enough to knock one or more electrons out of the sample particles to make positive ions. These positive ions are persuaded out into the rest of the machine by the ion repeller which is another metal plate carrying a slight positive charge.

Separation:

Acceleration: The positive ions are repelled away from the very positive ionization chamber and pass through three slits, the final one of which is at 0volts. The middle slit carries some intermediate voltage. All the ions are accelerated into a finally focused beam.

Deflection: Different ions are deflected by the magnetic field by different amounts. The amount of deflection depends on: The mass of the ion, lighter ions are defected more as compare to heavier ions. The charge on the ion, ions with two or more positive charge deflects more than single positive charge. These two factors are combined into the mass-charge ratio (m/z).

Detection: The beam of ions passing through the machine is detected electrically. When an ion hits the metal box, its charge is neutralized by an electron jumping from the metal on to the ion. That leaves a space amongst the electrons in the metal, and the electrons in the wire

shuffle along to fill it. A flow of electron in the wire is detected as an electric current which can be amplified and recorded.

Outcome of mass spectrometer:

The result of analysis by ionization, separation and detection are displayed by mass spectrum. The results are displays by peaks, bar graph, histogram, stick diagrams.

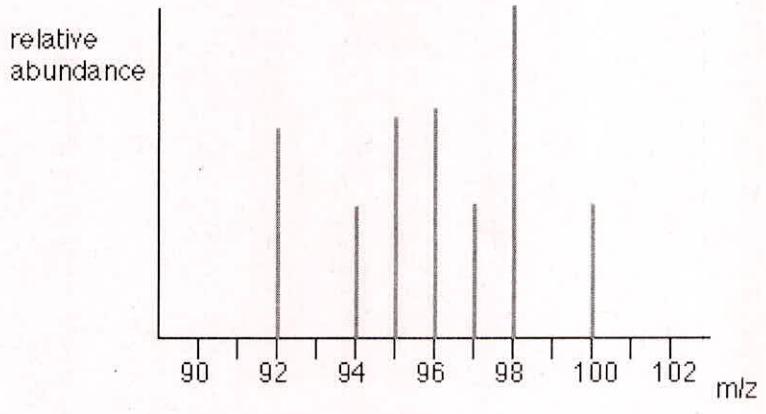


Figure 9The representation of working of mass spectrometer

The outcome of analyte is shown in the inform of stick diagrams by the mass spectrum. The sticks in spectrum show the peaks of the abundance of ions.

Mass Spectrum: Mass spectrum is the two dimensional representation of signal intensity versus mass charge ratio (m/z). The intensity of peak as signal reflects the abundance of ions of that respective m/z ratio which has been created from analyte within the ion source.

3.1.2 Dual Inlet Mass Spectrometer

Dual inlet mass spectrometer allows ratio measurement on both a sample and a standard by alternating between inlets. It has the measurement techniques of preference for isotope ratios of most of the light elements (H,C,N,O,S). Reference gases are used in analytical method for the conversion of different sample compound. The reference gases are carbon dioxide, nitrogen, helium etc.

Samples are placed in highly pumped vacuum condition and sample gases are injected and at the same time reference gas are passed into the ion source. In ion source, a heated tungsten coated iridium filament inside the source block cavity ionizes a laminar steam of gas entering the ultrahigh vacuum source.

The gas molecules are stripped of one electron, producing positive ions which are then accelerated through a voltage gradient and focused into the flight tube upon existing the source. The ion beam bends as it passes through the field of a magnet installed over the flight tube.

Here, the beam separates into spectrum of masses where faraday cup collectors measure each ion current. By collecting two or three ion beams simultaneously the ion currents can be expressed as mass ratio.

3.1.3 Hydrochemistry: Ion Chromatography

Ion chromatography is used for water analysis. The measurement of concentration of major anions such as fluoride, chloride, nitrate, nitrite and sulfate as well as major cations such as lithium, sodium , ammonium , potassium, calcium and magnesium in the parts-per-billion.

The analyzer, suppressor, column, detector are the component of ion chromatography, shown in fig10. In ion chromatography,. As an ion extraction liquid runs through the column, the absorbed ions begin separating from the column. The retention time of different species determines the ionic concentration in the sample.

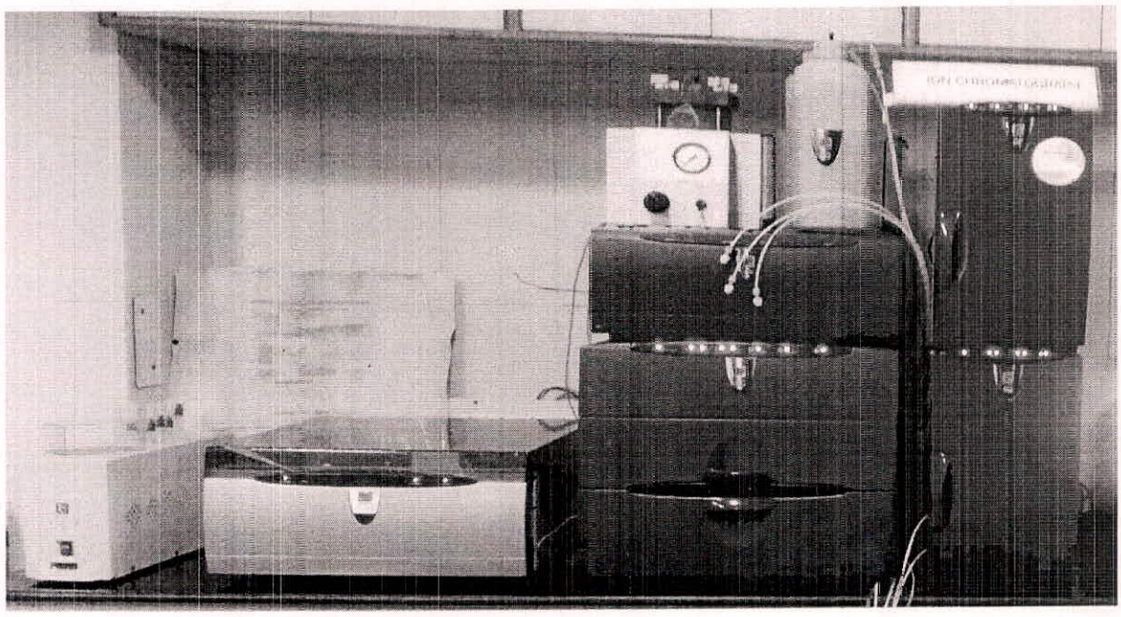


Figure 10Ion Chromatograph with their components suppressor, column and analyzer.(Image from the nuclear laboratory of NIH)

Working:

In ion chromatography, the samples are passed through analyzer where the mixtures of sample are injected into a carrier fluid (eluent) shown in fig11. Then the solutions are passed to suppressor where the conductance of eluent is reduced and at the same time it enhances the conductance of the sample. Then the sample solutions passed through a pressurized chromatographic column where ions are absorbed by column constitutes i.e. adsorbent. Different materials are adhere to adsorbent with different forces. As the eluent are flows through column the components of analyte are moved down the column at different speed and therefore they separate from one another. As the analyte are emerge from the column, the detector gives the output at the end of column (fig11).

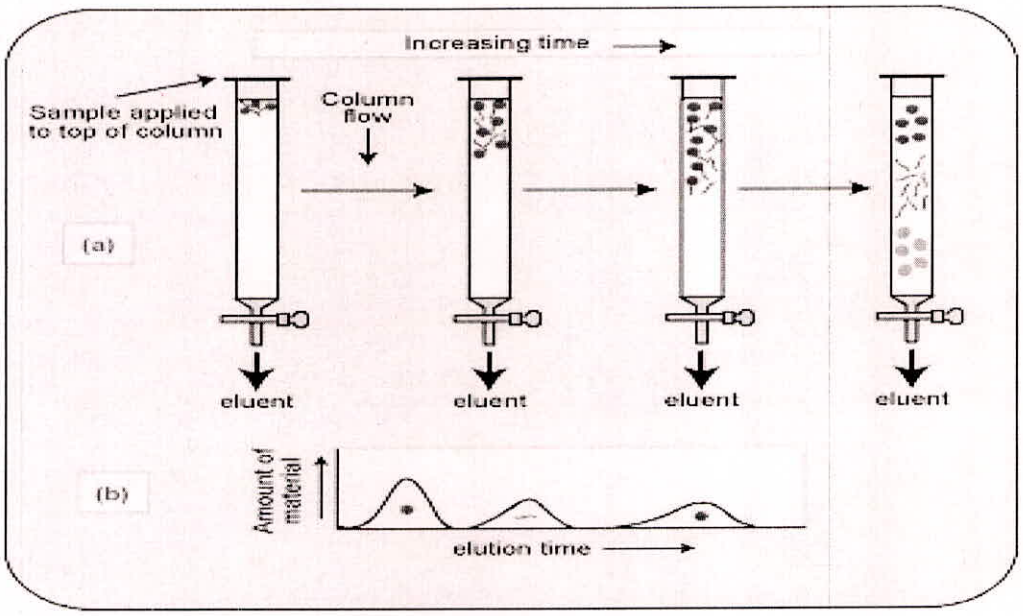


Figure 11Working of component of ion chromatograph (Image from the Microbial Life Educational Resource)

Outcome of ion chromatography:

The outcome of ion chromatography is given by detector. Detector generates a measurable signal when the analyte are emerges from the column. These signals are represented as the peaks on the chromatogram (fig12).

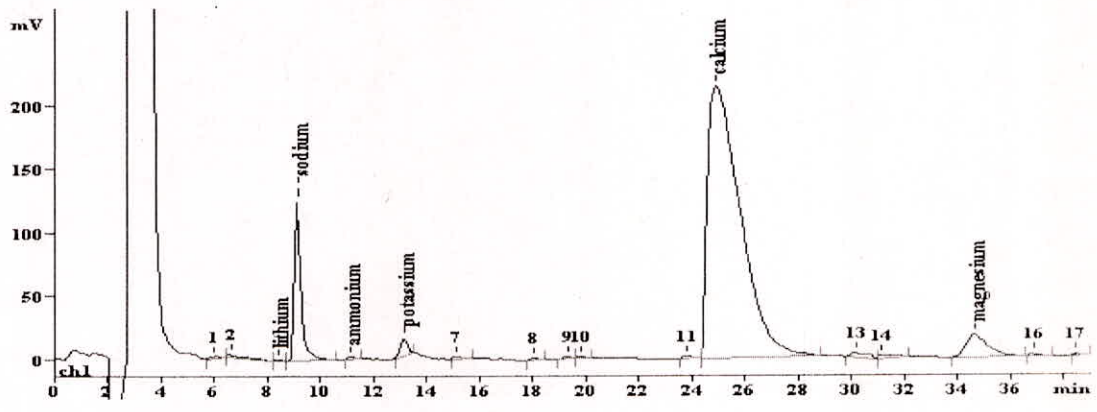


Figure 12 Representation of outcome of analysis in the form of peaks in chromatogram (Source: Image from the Microbial Life Educational Resource)

Chromatogram is the record of the outcome of detector as in the form of electrical conductivity versus time of the analyte passes through the chromatographic system.

3.1.4 GIS Study:

Geographical Information System (GIS) is a piece of software that captures the geographical data purpose for manipulation, viewing and analysis in whichever context and parameters user desire or needs. GIS gives the coastline of the West Bengal, from that data the coastal district are identified.

The captured data provided in the form of shape file and they are plots in the surfer software. From the surfer image we get the information of the sample site and their exact location of the sampling site. the information provided from the surfer image helps in study the condition of that sampling site and their ranges near to coast. For the study in surfer and GIS, the correct latitude and longitude is needed, otherwise the chance of error in data and result will be increases.

The use of GIS application helps in the getting the complete scenario of any area. The past and present scenario of any area can be obtained from this application. So for the management or monitoring purpose this application is being in use.

GIS is providing integrating technology, bringing together geospatial data and knowledge, providing methods for analysis and collaboration and making them widely accessible. GIS applies the geographic approach, providing tools, methods and works flows that support collaboration and action. This leads to better decisions, greater efficiency, more effective communications, thus improving the way of work

3.1.5: Field Parameters

Some parameters are measured in the field at the time of sample collection and parameters like electric conductivity, pH and radon. The measurement of radon at the spot is necessary at the field. Parameters like electric conductivity and pH can be analysed at some interval of time but measurement of radon happen at the time of collection.

Electrical Conductivity is the measurement of amount of total dissolved solids in the water, it measured in the unit of microSimen/centimeter. The flow of water is calculated by the electric conductivity.

pH measures the concentration of hydrogen, the property of acidic and basic nature of water is measured by pH analysis.

Radon measure the concentration of .the measurement unit of radon is picocurier per litre.

3.2: Result

The samples were measured for stable isotope and hydrochemical details. The result of the analysis is presented in the table below:.

Table 3 : Isotopic composition of samples from West Bengal

Site ID	$\delta^{18}O$(‰)	δD (‰)
SGD 1	-3.68	-22.86
SGD 2	-3.97	-24.49
SGD 3	-3.63	-23.16
SGD 4	-3.65	-23.07
SGD 5	-3.81	-25.43
SGD 6	-4.56	-27.50
SGD 7	-6.90	-45.46

Table 4(a): The result of analysis of cations ions

Site ID	**F^- (mg/l)**	**Cl^- (mg/l)**	**NO_2^- (mg/l)**	**SO_4^- (mg/l)**	**NO_3^- (mg/l)**
SGD - 1	3.5	79.1	35.1	n. d.	n. d.
SGD – 2	1.5	86.1	29.6	1.8	1.0
SGD – 3	1.3	112.1	32.3	0.1	1.2
SGD – 4	1.9	71.9	32.0	2.0	3.0
SGD – 5	3.6	24.8	28.1	17.9	2.0
SGD – 6	0.9	8.0	n.d.	3.7	0.2
SGD – 7	1.6	107.5	n. d.	197.6	2.6

nd..: below detection limit of the instrument

Table 4(b): The result of analysis of anion ions

Site ID	Na^{+} (mg/l)	NH_4^{+} (mg/l)	K^{+} (mg/l)	Mg^{+2} (mg/l)	Ca^{+2} (mg/l)
SGD – 1	243.8	5.6	2.6	4.4	14.0
SGD – 2	214.7	7.0	3.8	4.3	11.2
SGD – 3	186.1	4.7	6.6	13.5	47.0
SGD – 4	158.9	5.3	5.8	7.7	17.9
SGD – 5	57.5	4.5	3.4	16.9	47.8
SGD – 6	38.4	1.9	2.9	13.1	42.0
SGD – 7	52.8	1.8	2.3	13.5	72.5

The measurements of EC, Temperature, pH and radon analysis conducted in-situ at the time of sample collection is tabulated below:

Table 5: The result of field parameters of the sample

Site ID	EC (µS/cm)	Temp (□C)	pH	Rn(pCi/L)
SGD - 1	1070	30.5	8.1	1054
SGD-2	1090	28.5	8.1	1914
SGD-3	1050	27.9	8	4736
SGD-4	870	28.1	7.7	6917
SGD-5	650	30.5	6.8	3929
SGD-6	570	29	6.6	6439
SGD-7	840	27.9	7.9	5299

The statistical range of the measured parameters is given in the table 6.

Table 6: Measured parameters, value range and location name:

Parameters	Permesible limit	Minimum & Maximum concentration & the Observed place		
		Minimum	Maximum	Average
EC (μS/cm)	-	570 (Fatehpur)	1090 (Amrabati)	877.14
Temp(^{0}C)		27.9^{0}C (Admail,Sibrampur)(Namkhana)	30.5 ^{0}C (Digha near seabeach)	28.91
pH	6.5-8.5	6.6 (Fatehpur)	8.1 (Bakhali) (Amrabati)	7.6
Radon	-	1053.83 (Bakhali)	6916.87(Sibnagar abad)	4326.766
$\delta^{18}O$	-	-6.90 (Contai)	-3.63 (Bakhali)	-4.31
δD	-	-45.46 (Contai)	-22.86 (Bakhali)	-27.43
F (mg/l)	4	0.9 (Fatehpur)	3.6 (Digha near seabeach)	2.0
Cl (mg/l)	250	8.0 (Fatehpur)	112.1 (Admail , sibrampur; Namkhana)	69.9
Nitrate (mg/l)	10 (nitrate plus nitrite)	0.2(Fatehpur)	3.0(Sibnagar abad)	1.7
Nitrite (mg/l)	-	28.1 (Fatehpur)	35.1 (Bakhali)	31.4
Sulphate (mg/l)	250	0.1 (Admail,Sibrampur, Namkhana)	197.6 (Contai)	37.2
Na (mg/l)	-	38.4 (Fatehpur)	243.8 (Bakhali)	136.0
K (mg/l)	-	2.3(Contai)	6.6 (Admail,Sibrampur; Namkhana)	3.9
Mg (mg/l)	-	4.3(Amrabati)	16.9 (Digha near seabeach)	10.5
Ca (mg/l)	-	11.2(Amrabati)	72.5 (Contai)	36.2
Ammonium (mg/l)	-	1.8 (Contai)	7.0 (Amrabati)	4.4

Table 6 is the summarized form of table 3,4a and 4b,5. Table6 shows the maximum and minimum value of parameters and the location of area. The higher value at any site shows that site containing the maximum range of that parameter and lower value ranges the minimum range of that parameter. In Bakkhali, the maximum parameter (pH, $\delta^{18}O$, δD, nitrate, nitrite , sodium) is higher than their permissible limit. In Fatehpur maximum parameters (electrical conductivity , pH, fluoride, chloride, nitrate ,nitrite, sodium) are in lower range.However, pH 6.6 at Fatehpur indicates water quality is acidic and not suitable for drinking use.

Table 7: Sample density falling within and outside the permissible range:

Chloride value (mg/l)	**Category**	**No. of points**
0-250	Perm for dri as per who	07
250-1000	Unsuitable	00
>1000	Unsuitable	00

The table 7 represents the chloride ranges of the sample and the ranges classified on the basis of the standards. All the chloride value of the samples are comes in range <250 that means the samples are freshwater, there is no salinity in the sample site.

Table 8: Samples having EC values

EC value (µS/cm)	**Category**	**No. of samples**
<250	Fresh	00
250-750		02
750-2250		04
2250-4000		00
>4000		00

Table8 shows the sample distribution as per standards for the conductivity. The maximum samples have the conductivity value in the range of 750-2250microS/cm and some samples value comes in the range of 250-750microS/cm, that means sites from where sample are collected have water that can be consumed by humans and suitable for all livestock. But when used for irrigation, requires special management including suitable soils, good drainage and consideration of salt tolerance of plants

Table 9: samples having O^{18} value

O18 Value	**No. of samples**	**Types of water**
>[-0.8]	00	Seawater
[-2.5 to -0.8]	00	Mixed
[-2.5 to -4]	05	Freshwater (<100m alt.)
<[-4]	02	Freshwater(>100m akt.)

If the O18 range of any sample is positively enriched by -2 in that case the water type is considered as seawater. From the isotopic analysis it is elaborated that the all seven samples are of freshwater type there is no seawater or mixed water type five samples are of freshwater type and the recharge is at lower altitude(<100m).

* Exact altitude of recharge can be provided using isotope altitude gradient relation popularly known as altitude extract.

From the analysis of the samples of coastal district it is clarified that the groundwater quality is not having saline problem. But the isotopic analysis gives only the concentration of ions in the water not of the soil. So it is known to be necessary the soil salinity condition because from the saline soil the groundwater may get affected. The saline soil is measured by the concentration of ions with the electric conductivity of the sample and their ratio of observed electric conductivity. The outcome of this measurement indicates that the samples of

bakkhali is in saline soil condition, ambravati,Sibnagar Abad, digha and contai are at the freshening stage and the samples of fatehpur are fresh.

3.3 Conclusion:

The result of hydrochemical study and the isotopic study of the collected samples indicate the quality of groundwater of these coastal districts. The resulted values of samples are under permissible limits. There is no occurrence of mixing of groundwater and seawater in the coastal districts. The samples have the qualities of freshwater.

These results can be representative with the help of surfer digitized image. With the help of digitization of the image, the allocation of sample site became easy for detecting the quality of groundwater and the effects of intrusion or any factors that may affect the quality and availability of groundwater.

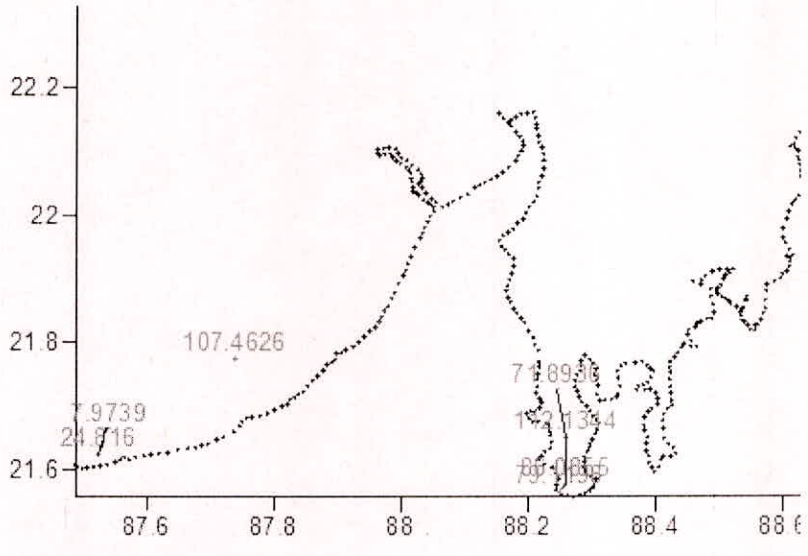


Figure 13Representing the sample location with respect to their chloride value(mg/l)

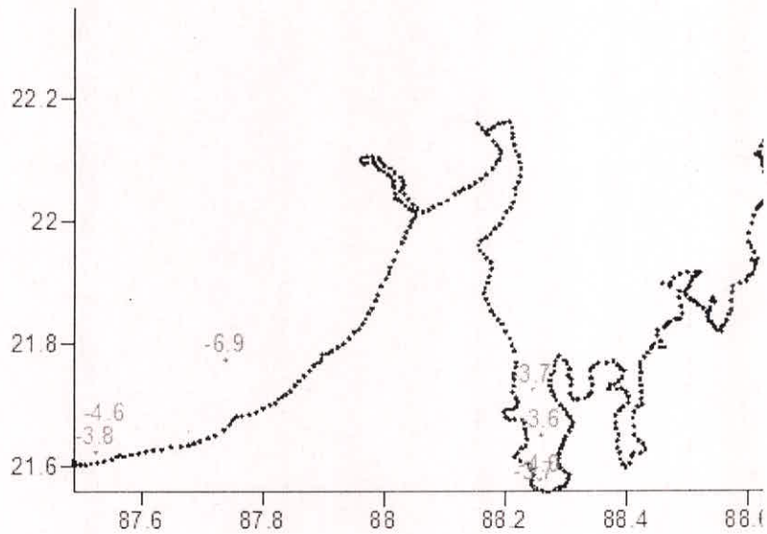


Figure 14Representing the sample location with respect to their $\delta^{18}O$ value

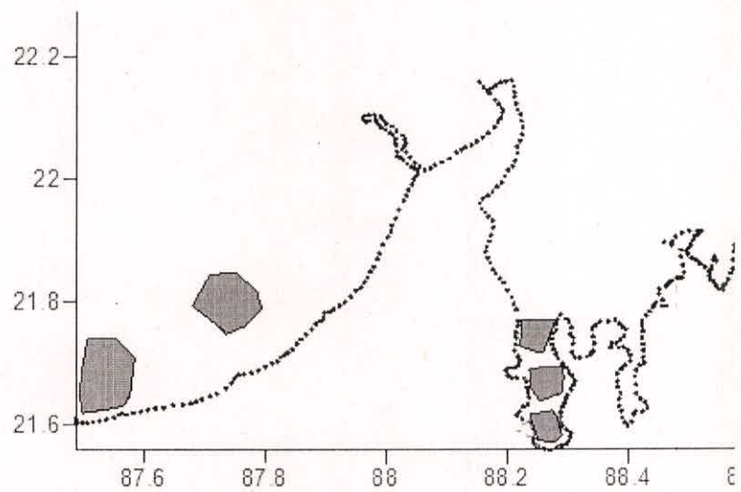


Figure 15:Representing the quality of samples in the coastal region

Fig 15 and 16 represents the plotting of chloride and $\delta^{18}O$ in the surfer digitized image and from this represents the quality of groundwater collected as the sample. From the fig 17, it is concluded that there is no occurrence of intrusion or any other factor that fluctuates the groundwater quality.

On the basis of the outcomes of the analysis it can be concluded groundwater at the examined locations are fresh with no or negligible signature of seawater intrusion. Groundwater at these sites is suitable for drinking and irrigation needs except for the mild acidic condition (pH =6.6) of water at Fatehpur.However, a large difference existsin the measured parameters between the investigated sites. For example; Cl conc. at Fatehpur is 8.0 mg/L whereas, at Admail, Sibrampur it is 112.1 mg/L. similarly, sulphate at Admail,Sibrampur is 0.1 mg/L whereas at Contai it is 197.6 mg/L. Such large difference in the water quality parameter occur mainly due to difference in the soil type of the recharge area through which the infiltrating water at the time of its infiltration dissolves and gets enriched with the particular chemical parameter. Such situation is very common in the coastal soils as they get frequently flooded by seawater and also by rain water (due to congestion in outflow of run-off). The flooding and evaporation cycle leads to enrichment of salt content in the coastal soil. Leaching of salts with the infiltrating water causes enrichment of salinity of the groundwater.

These sites vulnerable to salinity increase under the conditions from coastal flooding requires suitable management measures which otherwise may cause slow rate of deterioration of groundwater quality. Therefore, it is essential to take up management measures to control the deterioration of groundwater quality and for groundwater sustainability. The following chapter provides management steps to control the groundwater quality at the vulnerable sites.

Chapter 4:Management of groundwater

4.1 Need of management

The management of groundwater is needed to be done for future availability of the groundwater. The wider aspect of groundwater and its integration with seawater needs legal, socio-economic aspects of management. Management measures can be applied as to minimize the problems of the area. Management measures should be economically sound and environmentally benefits.

For the applying any management measures the appropriate information like the climatic condition, groundwater quality, availability and pattern of utilization etc are required. Theseinformationssupports the implementation of management measures and also linked a perfect relation between environment and management. The information about the economic condition of the area is also needed for implementation of management measures. The implementation will depend upon the income rate, if the income rate will be high then the implantation rate will be also high and the methodology use will be advanced or far better outcome quality. If the area having low income rate at that time the implementation should be done with the mindset that the perfect management will done at low cost. So that the relation between management and socioeconomic condition will be maintained.

4.2 Purpose of management

Before implementing any management program some strategy and policies are prepared and in that part we must have the detailed knowledge about that area and their related issues and problem, sample quality, monitoring schedule etc. After getting the brief description of the area the management program can be implemented.

In case study of West Bengal, all the information is mentioned already. The information of location and their groundwater system details like quality, aquifer system, problems in that area are provided. The hydrochemical and isotopic results are also available. From all these data, it is shown that there is no fluctuation or retardation in the quality of groundwater but the soil are having saline condition that may leads to degradation of groundwater.

As per the CGWB report, the aquifer system is shallow in the east medinipore and south 24 paragnas. the water in the swallow aquifer are freshwater but at the deeper aquifer there is occurrence of seawater intrusion and the minor movement between groundwater and seawater occurs. There is very much probability of seawater intrusion.

So the management approaches are necessary to implement for the prevention of the quality of groundwater. The measures of management are based on the regions and their associated problems.

4.3 Strategies for management

The measures were explained for mitigate and minimize the problems. To mitigate these problems some strategies and policy are prepared and they are as:

• Constant monitoring of the pumping, movement of the fresh water saline water interface are to be carried out.

• Tidal influence into the aquifer has to be studied in detail and is to be monitored periodically.

• Safe yield of the aquifer has to be evaluated and accordingly the extraction has to be restricted.

• Remedial measures have to be done wherever sea water intrusion has taken place.

4.4 Policy and regulation:

Some of the policy matters are discussed below in brief.

• Finding alternate source of water or other suitable remedial measure wherever serious ground water problem exists.

• Impose restriction for ground water withdrawal along over exploited, critical and other problem areas.

• Mass awareness/ mass interaction programs shall be conducted to educate the masses and also to understand their problems.

4.5 Measures for management:

Management measures are different for regions. The region where the recharge of freshwater occurs at higher altitude (Contai and Fatehpur) and the other region where the recharge of freshwater occurs at the lower altitude (Bakkhali, Amrabati,AdmailNamkhana, Sibnagar Abad, Digha).

The region where the recharge occurs at higher altitude in that region the management measures are done in such a way that groundwater can be stored at suitable zone or it can be used to flush out salinity of saline soils at the time where groundwater levels are low in the low lying area.

The region where the recharge occurs at lower altitude in that region management measure are done by constructing barriers at saline zone to protect groundwater and to protect soils from getting salinized due to coastal flooding.

4.5.1 Management measure for higher altitude region

4.5.1.1 Artificial recharge techniques

Artificial recharge technique is the highly site-specific. Modification of natural movement of surface water into the aquifers through various structures like check dams, percolation ponds, recharge pits, shafts or wells are considered suitable methods for artificial recharge.

Benefits of Artificial Recharge Schemes

- To maximize storage(long-term & seasonal)
- Water quality improvement through dilution
- Preventing saline-water intrusion & land subsidence
- Reducing reduction volumes from river f low
- Controlling effects of climate change
- Maintaining declining ground water levels

Percolation Pond: Percolation pond is an artificially created surface water body that submerge a highly permeable land area so that the surface runoff percolates and recharge the groundwater. The ponds are not provided by sluices or outlets for discharging the water for any purpose. The pond must have the arrangement for spilling away the surplus water that may enter the tank so as to avoid overtopping of the tank bund.

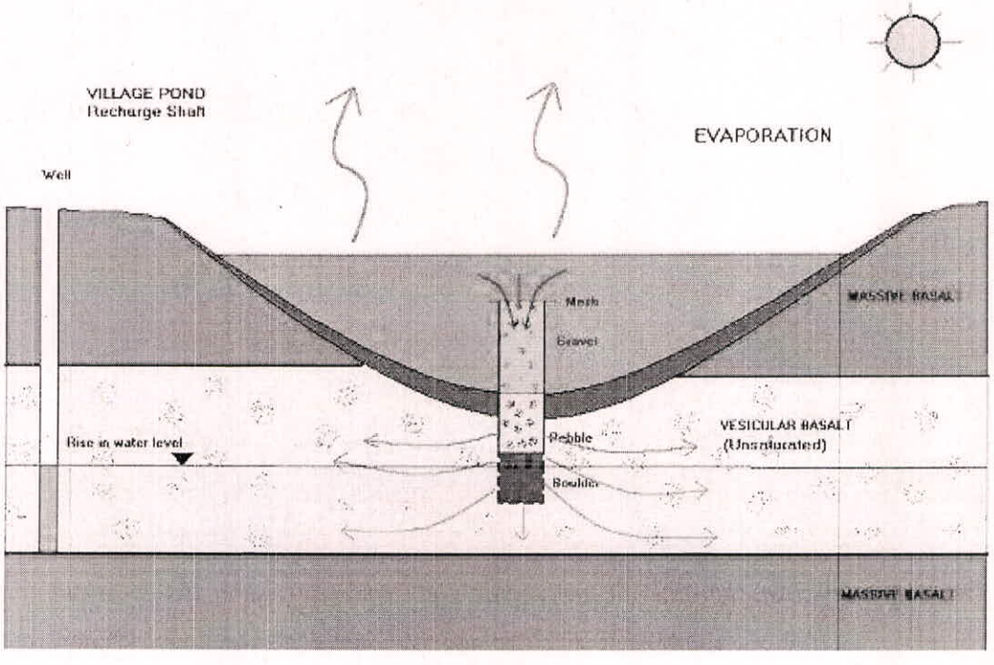


Figure 16: Representation of artificial recharge of water through percolation pond.

Check dams: Check dams are not only useful to direct storage of water, but also to reduce the erosional action of water. Check dams increase the contact time of water with land surface, thus increasing the soil moisture and recharge to groundwater.

Injection well: The adding of water in the aquifer system with the help of injection pipe leads to the recharge of groundwater. The pipes are drilled upto the higher depth so that the recharge of aquifer can be possible.

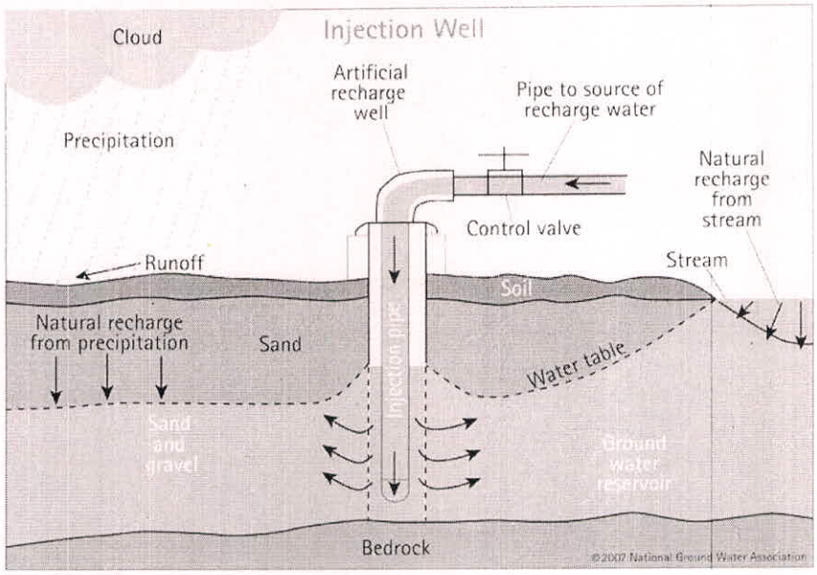


Figure 17:Recharging of groundwater by naturally and artificially through injection well(Source: National Groundwater Association)

The groundwater aquifers are recharge by both processes naturally and by human influence. The above fig19 illustrates that the water gets percolates after precipitation by the process of infiltration, runoff or by flow of river or streams. In this way the water is gets recharged naturally. The water is added to the aquifer through injection well, percolation pond or by any human influenced techniques by these methods groundwater aquifers are recharged.

4.5.1.2 **Rainwater Harvesting**

Rainwater harvesting refers to the collecting of rainwater, mostly on a roof, from where it flows through gutters into a collection tank. In other words, it refers to a storage system-could be either above or below the ground that collects, stores and distributes runoff of rain from roof.

Rainwater harvesting have now been accepted worldwide as cost-effective methods for augmenting ground water resources and for arresting/reversing the declining trends of ground water levels. RWH have many advantages like it is easy accessible and sustainability is

higher, it is cost effective the setup cost is low and its maintenance cost is also low. Rainwater harvesting methods reduces the demand on wells or pumps by that groundwater can be sustained. The water that can harvested by this techniques can be used for different purposes.

In coastal region the overpumping or overexploitation of water from wells leads to the degrading the quality of groundwater by the mixing of freshwater and seawater. So to prevent the mixing of these two aquifers the rainwater harvesting is the best methods in the coastal region.

Rainwater harvesting can be established in various form of water harvesting system depending upon the source of water supply and places as classified below.

a) In situ Rainwater harvesting: Bonding and terracing, vegetative / stone contour barriers, contour trenching, contour stone walls, contour farming, micro catchments.
b) Direct surface runoff harvesting : Roof water collection , dug out ponds / storage tanks, tankas ,diversion bunds , water spreading
c) Stream flow / runoff harvesting : Nallabunding, gully control structures, check dams– temporary permanent, silt detension tanks ,percolation ponds
d) Runoff inducement by surface treatment: Roadedcatchments , use of cover materials – Aluminum foils, plastic sheet, bentonite, rubber, etc, using chemicals for water proofing, water repellent etc. to get more run off water.

4.5.2 Management measures for lower altitude region

4.5.2.1 Salt Tolerance Plant

Salt related problems can be minimizes by the growing these crops in the affected regions. These crops have capability of reduce and tolerate the salinity conditions.

Barley is the most drought- and salt-tolerant of the domesticated cereal grains, and is often substituted for wheat when conditions became too salty. Coconut palm is considered one of the most useful plants in the world; endemic to the coastal tropics and generally tolerant of extreme salt spray and seawater flooding. Eel grass is a submerged aquatic herb that grows in shallow tidal regions and coastal marine habitats. Eel grass beds tend to stabilize bottom sediment, and provide shelter and food for a variety of marine species. Sea

oats is an attractive dune grass to the coastal regions. It is tolerant of saline soils and sea spray, and the spreading rhizomes are highly effective in stabilizing sand dunes and controlling coastal erosion. Jelly palm is an attractive feather-leaved palm that is moderately tolerant of salt and sea spray.

The cultivation of these crops not only reduces the salinity problem in the area near to coast but also enhance the economic condition of that area. These crops can also help in the trade of that area.

4.5.2.2 Construction of barriers

Reduction in pumping of existing wells and changing the locations of pumping wells to inland areas can reestablish a stronger seaward hydraulic gradient and can slowdown the inflow of saline water towards the fresh water aquifer. Another way of mitigationof movement of groundwater and seawater is the construction of an impermeable subsurface barrier parallel to the coast and the prevention of inflow of seawater into the basin. The construction of physical structures including sheet piling will sufficiently prevent the inflow of seawater in the freshwater strata. The injection of emulsified asphalt, plastics and other materials can also reduce the permeability which can retard the movement between the both aquifer.

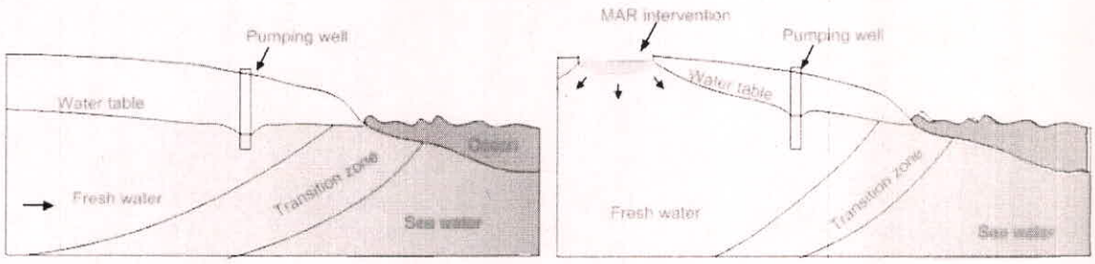
4.5.2.3 Strip planting technique

Strip cropping is sometimes practiced with strips of land where every other strip is irrigated while the strips in between are left permanently fallow. Owing to the water application in the irrigated strips they have a higher water table which induces flow of groundwater to the irrigated strips. This flow functions as subsurface drainage for the irrigated strips, whereby the water table is maintained at a not-too-shallow depth, leaching of the soil is possible, and the soil salinity can be controlled at an acceptably low level.

In the unirrigated (sacrificial) strips the soil is dry and the groundwater comes up by capillary rise and evaporates leaving the salts behind, so that here the soil salinizes. Nevertheless, they can have some use for livestock sowing salinity resistant grasses or weeds. Moreover, useful salt resistant trees can be planted.

4.5.2.4 Managed Aquifer Recharge (MAR)

Managed Aquifer Recharge (MAR) is the most environment friendly and cost effective method for mitigation of seawater intrusion. MAR is the process of adding water to aquifers under controlled conditions for withdrawal at a later date, or used as a barrier to prevent seawater or other contaminants from entering the aquifer. The sources of groundwater recharge may be natural run-off or specifically captured water



Source:Managed Aquifer Recharge: Methods, Hydrogeological Requirements

Figure 18Conceptual cross section showing (a) seawater intrusion due to over pumping and (b) MAR intervention for mitigation

4.5.2.5 Gabion:

Gabion is a cage or cylindrical in shape, or box filled with rocks, concrete. Gabion wall is a retaining wall made of stacked stone-filled gabions tied together with wire.Gabion stepped weirs are commonly used for flood control; the stepped design enhances the rate of energy dissipation in the channel. It have advantages over more rigid structures, their strength and effectiveness may increase with time in some cases, as silt and vegetation fill the interstitial voids and reinforce the structure.

4.5.2.6 Revetments:

Revetments are sloping structures placed on banks or cliffs in such a way as to absorb the energy of incoming water. Coastal revetments are usually built to preserve the existing uses of the shoreline and to protect the slope, as defense against erosion.

Many revetments are used to line the banks of freshwater especially to prevent damage during periods of flood or heavy seasonal rains. Many materials may be used: wooden piles, loose-piled bouldersor concrete shapes,or more solid banks.

Wooden revetments are made of planks laid against wooden frames so that they disrupt the force of the water. Although once popular, the use of wooden revetments has largely been replaced by modern concrete-based defense structures such as tetrapod.

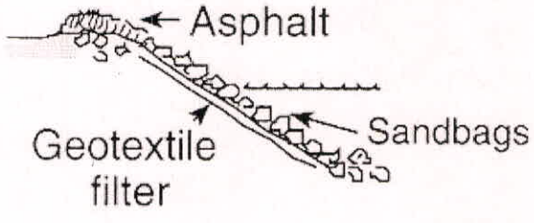


Figure 19the diagram of asphalt and sandbag revetment with geotextile filter

.Fig19, illustrates the formation of revetments. The slope is made up of wooden piles in between piles the sandbag are placed. So that the compactions are maintained in the slopes.

4.5.2.7 Riprap:

Riprap is rock or other material used to armor shorelines, streambeds, bridge abutments, pilings and other shoreline structures against scour and water or ice erosion. It is made from a variety of rock types, commonly granite or limestone, and occasionally concrete rubble from building.

4.5.2.8 Seawall:

Seawall is a form of coastal defense constructed where the sea, and associated coastal processes, impact directly upon the landforms of the coast. The purpose of a sea wall is to protect areas of human habitation, conservation and leisure activities from the action of tides,

waves, or tsunami. As a seawall is a static feature it will conflict with the dynamic nature of the coast and impede the exchange of sediment between land and sea. Sea walls may be constructed from various materials, most commonly reinforced concrete, boulders, steel, or gabions. Other possible construction materials are: vinyl, wood, aluminum, fiberglass composite, and large biodegrable sandbags made of jute and coir.

Figure 20:seawall made up of rocks in the Paravur in Kollam(kerala in India)

Above explained measure are highly cost effective measures and they are advanced techniques. Their implementation may cost very high.

4.6 Cooperative Management:

Management measure that integrate the government, non-government, blocks heads, panchayat and other administrative measures to enroll in the program for the motivation and involvement of peoples of any area that integrated management is said to be cooperative management.

Apart from these techniques of management, some other measures are also necessary for managing groundwater system in coastal regions. These measures are providing awareness and training program can be implemented.

These awareness and training activity can be implemented by government of area or some NGOs to provide the knowledge about the conserving and managing the groundwater resource by own. Public involvement is necessary in program. There must be some program

for providing education and training to the local peoples of that area for the successful management.

Government should make a link between the blocks or district head or village panchayat to make some strategy so that the local peoples were get interested for the involvement in those programs. There should be some cooperative management in the area like some prizes or certificate like paani purasar or something else that incentive the local communities of that area. Because of these the people may involve the program.

NGOs work in the management program, they involve lots of programs like skit play, campaigns in the villages, some posters distribution and many more activities they involves in the areas to provide knowledge to the local peoples and motivate them for participate in the management program to conserve the groundwater resource and to maintain their quality and availability for future.

Chapter 5 : Conclusion & Summary

Groundwater is most important natural resources and it serves as a large subsurface water reservoir. The availability and quality of groundwater is degrading very rapidly in coastal areas. The depletion of groundwater happens due to the involvement of different factors like over pumping and over exploitation, sea level fluctuation, landuse changes, climatic variations etc.

The seawater intrusion, salinity, sea-level rise etc., leads to the depletion and retardation of the quality and quantity of groundwater in the coastal regions.The impact of these factors on groundwater can be detected by some analysis techniques i.e. hydrochemical study and isotopic study. The result of analysis shows the extent of factors that effects groundwater. After the result and detection of extent of problem, the management measures for groundwater can implemented. To maintain the availability of groundwater the management is needed to be done. The proper management is required to maintain the sustainability of groundwater resources.

The coastal districts of West Bengal have freshwater quality in theshallow aquifer. But the salinity is observed in the soil of some areas so that may leads to the retarding of quality of water As per the report of CGWB, there is sign of intrusion occurs in the deeper aquifer in minor way. There is very much probability of mixing of groundwater and seawater. So management is done for the prevention phase in the coastal region. Management of groundwater can be done by different methods as per the accommodated problems of the region.Management is done to protect the groundwater aquifer and soil from getting salinized. The management should be economically sound and environmentally beneficial. Management program can be implemented by government or NGOs in different manner by motivating the local peoples, by providing education and awareness training activity.

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