GROUND WATER QUALITY STATUS AND ANALYSIS OF KANCHIPURAM COAST BY REMOTE SENSING AND GIS

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Abstract
Water is one of the main natural's resources in the world and it's very essential for all human livings not only for human, animals, and agricultural purpose and other activities. Kanchipuram district lies adjacent to Chennai in the state of Tamil Nadu in India. It is bounded in the west by Vellore District and Thiruvannamalai District, in the north by Thiruvallur District and Chennai District, in the south by Viluppuram District and in the east by the Bay of Bengal. Study area was generated all along the coast with a width 15 km. A total of 171 villages were within the total area of 1678 sq.km. A detailed investigation on ground water quality status for ground water sample (71 locations) along Kanchipuram Coast was taken up for pre monsoon data for the years 2011 – 2015 in ArcGIS software. Ground water variables such as pH, EC, TDS, Total Hardness, NO_3, SO_4, Cl, F, CO_3, HCO_3, Na, Ca and Mg were analyzed for statistics in MS Excel for pre monsoon season. Graphs were plotted for each parameter across all years separately for pre monsoon to understand parameter variability between seasons and years. Spatially interpolation tool followed by kriging techniques exhibited spatial spared values based on environmental conditions of pre monsoon were analyzed graphically. Results of the analysis enumerated that pre monsoon value for the all the 13 variables. Critical variable such as chloride, fluoride, nitrate, sulphate, responses was higher for pre monsoon season. Spatial map of these variables responded for higher concentration of the northern coast of the study area and lower concentration on the middle and southern part study area.

Key words *- pH, EC, TDS, Total Hardness, Remote sensing and GIS .*

Introduction

Water is an important to life sustaining substance. It is the most common and yet the most precious resource on earth without which there would be no life on earth. Groundwater is the water that exists below the surface of the ground in the spaces between particles of rock or soil, or in the crevices and cracks in rocks. Most groundwater is within 100 meters of the surface of the Earth. Groundwater can contain many constituents including microorganisms, gases, inorganic and organic materials. Industrial and agricultural activities are major sources of contamination. These activities can lead to contamination of well water, municipal drinking water sources and the environment. Polluted groundwater is less visible, but more difficult to clean up, than pollution in rivers and lakes. Groundwater pollution most often results from improper disposal of wastes on land. Major sources include industrial and household chemicals and garbage landfills, excessive fertilizers and pesticides used in agriculture, industrial waste lagoons, tailings and process waste water from mines, industrial frocking, oil field brine pits, leaking underground oil storage tanks and pipelines, sewage sludge and septic systems. Water derives its unique properties of being universal solvent. Today quantity of water on our planet is nearly constant and it keeps circulating through what is called the water or hydrologic cycle. Water is thus strictly a fixed resource and we cannot really destroy it on any significant scale we can only spoil it; yet it will keep purify itself. The earths water resource is referred to as a hydrosphere consisting of oceans, ice and snow in the polar and other regions, mountain glaciers, lakes streams, rivers, swamps,

water in surface soils and in underground strata of the total quantity of water on our planet almost 97% is in the oceans. Of the balance that is fresh water, only 0.7% water is in liquid form. 0.6% as Groundwater and 0.1% is in lakes, rivers and vapor in the air.
Groundwater is often cheaper, more convenient and less vulnerable to pollution than surface water. Therefore, it is commonly used for public water supplies. For example, groundwater provides the largest source of usable water storage in the United States, and California annually withdraws the largest amount of groundwater of all the states. Underground reservoirs contain far more water than the capacity of all surface reservoirs and lakes in the US, including the Great Lakes. Many municipal water supplies are derived solely from groundwater. Water in its pure form, is a tasteless, odorless substance that is essential to all known forms of life and is known also as the most universal solvent. Water is formed by the union of two hydrogen atoms with one oxygen atom. The oxygen atom is bonded to the hydrogen atoms asymmetrically, with a bond angle of 105. This unsymmetrical arrangement gives rise to an unbalanced electrical charge that imparts a polar characteristic to the molecule. Water in the liquid state, although given the formula H_2O or HOH, is composed of molecular groups with the HOH molecules in each group held together by hydrogen bonding. Water is unusual in that the density of the solid phase, ice, is substantially lower than the density of the liquid phase, water. In the liquid phase the maximum density is achieved at 4 0C. With further cooling below this temperature there is a significant density decrease. (A. Ponniah Raju, et al., 2013), (I. Ameeth Basha, et al., 2016), (S. Packialakshmi, et al., 2015), (Ramesh Pandian R. et al., 2013). The main aim of the study is to utilize the remote sensing and GIS technologies for the sustainable development of ground water quality analysis in the coastal zone of Kanchipuram district in Tamil Nadu.

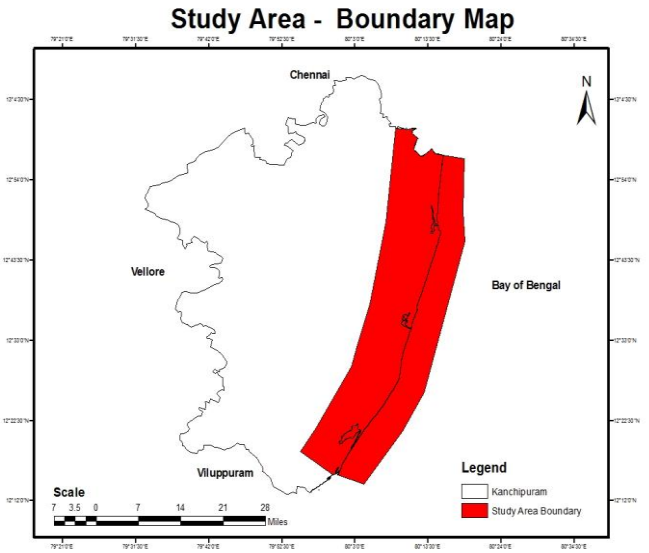

Figure: 1. Study Area map.

Study area description

Kanchipuram district is the northeast district in the state of Tamil Nadu in India. It is bounded in the west by Vellore District and Thiruvannamalai District, in the north by Thiruvallur District

and Chennai District, in the south by Viluppuram District and in the east by the Bay of Bengal. It lies between 11° 00' to 12° 00' latitudes and 77° 28' to 78° 50' longitudes. The district has a total geographical area of 4,432 sq.km (1,711 sq mi) and coastline of 87.2 sq.km as per (Centre for Coastal Zone Management and Coastal Shelter Belt, Institute for Ocean Management, Anna University Chennai). The town of Kanchipuram is the district headquarters. It is the third most populous district of Tamil Nadu (out of 32), after Chennai and Coimbatore. The Chennai International Airport is located in Tirusulam in Kanchipuram district. The district produces over 15,000 engineering graduates every year, same as Gujarat state.

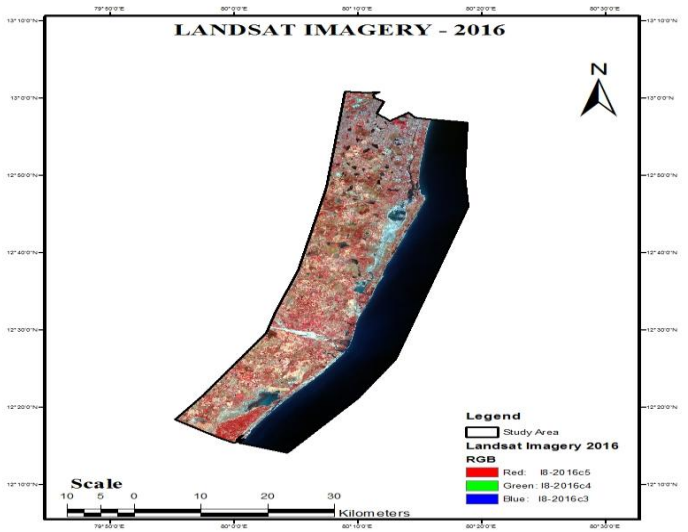

Figure: 2. Landsat Satellite imagery of Study area corresponding to 2016

Kanchipuram district is situated on the North East coast of Tamil Nadu. It is bound by the Bay of Bengal in the East, Vellore and Thiruvannamalai districts in the west, Thiruvallur and Chennai districts in the north, and Viluppuram district in the south. The district has a total geographical area of 4, 432 hectares and a coastline of 87.2 km. The table below shows the maximum and minimum temperatures experienced in the district during different seasons.
The pre monsoon rainfall is almost uniform throughout the district. The coastal regions receive more rainfall than the interior ones. The district is mainly dependent on the monsoon rains. Failure of monsoon leads to distress condition. Northeast and Southwest monsoons are the major seasons, with 54% and 36% contribution each to the total annual rainfall. During normal monsoon, the district receives a rainfall of 1200 mm. The Palar River is the most important river running through the district. There are only a few hills of considerable elevation in the district on the southern part of Maduranthakam taluk contains small hills. The total forest area in the district is 23,586 hectares.

Methodology

Groundwater data description

A total of thirteen water quality parameters were selected because of its quality issues on

drinking water of Kanchipuram district, Tamil Nadu. All water quality data were collected from Institute for Water Studies (IWS), Public Works Department (PWD), Taramani Chennai. Water quality data consists of pre monsoon coinciding in the month of June and post monsoon data in the month of December/ January for the corresponding or the preceding year. Data pertaining to pre monsoon Ground water collection is well distributed widely spread among seventy one villages extending all the four corners of the district. Data are collected periodically for pre monsoon season. Such collected data are analysed in laboratories for water quality parameters. Water Quality parameters like pH, Electrical Conductivity (E.C.), Total Dissolved Solids (TDS), Total Hardness, Calcium, Magnesium, Bi carbonate, Sodium, Chloride. Water Quality data pertaining for a period of 5 years (2011-2015) was used for this study.

Collection of water quality data

Water quality data are preliminary screened for contiguity in data collection, cross check for abnormal error due to typing, manipulation of data in case of inconsistency at short interval in MS Excel software. These data were filtered according to year, season are made as a separate spread sheet. Such data are manipulated to get the consistency of data flow. It could be observed that during the year 2011 they maintained 71 permanent observation wells and the same were maintained for the year 2015. The specific characteristics and properties of drinking water quality are verified for established WHO 2011: BIS 10500 standards. Later, to process the information statistical techniques was applied to determine the maximum, minimum, mean and standard deviation of each parameter for each season and each year. Water quality parameters such as pH, Electrical Conductivity (EC), Total Hardness (TOT HARD), Total Dissolved Solids (TDS), Calcium (Ca), Magnesium (Mg), Bicarbonate (HCO_3), Chloride (Cl),Na, SO_4,CO_3,NO_2,NO_3,F, and are used throughout our study period. Statistical analysis on each variable as minimum value, maximum value, mean and standard deviation are arrived in MS excel format for each year for a period of five years was considered for pre monsoon analysis respectively.

Pre monsoon data description

Filtering techniques is supplied for the data of sample collection to understand the pre monsoon values are corresponds to June and July month of every year. Thus of initial filtering techniques is applied to extract the pre monsoon values of 2011-2015 all the extracted values are made as a separate input file in another excel file. Ground water data of Kanchipuram district comprising the year 2011-2015 is collected from state ground and surface water resources data centre, Taramani, Chennai in Tamil Nadu. All the data are given in ms excel format. The data in Ms Excel format has nearly 4 worksheets considering for each year. Each year had detailed information on wells, block names, village names, co ordinates (latitude and longitude) and water quality parameters such as Tds,No_2+No_3,ca,Mg,Na,cl,so_4,co_3,hco_3,F,ph general, Ec general Hat total, These data are checked further for gaps if available during the analysis. Each parameter or each variable is filtered to identify the lower and upper values. In case of discrepancy among the values the proper verification id taken up with standards. All the parameters are manipulated according to the standard levels.

Statistical analysis

Ms excel software has the capability of determining the statistical values of the parameters that can be derived through a functional tool available within the software. Statistics such as

minimum, maximum, average, Standard Deviation (SD) are calculated for all the observation wells and for the parameters. The same table is created for the year 2011-2015 for the pre monsoon data. A preliminary analysis has been taken up to plot each variable of the year 2011 in a linear graph exclusively for pre monsoon values. This study enables us to understand the abnormal values corresponding to the village. The same exercise has been taken up for all the parameters for all the years (pre monsoon). The data corresponding to a single parameter ex. TDS is selected for pre monsoon for the year and plotted in Line graph.

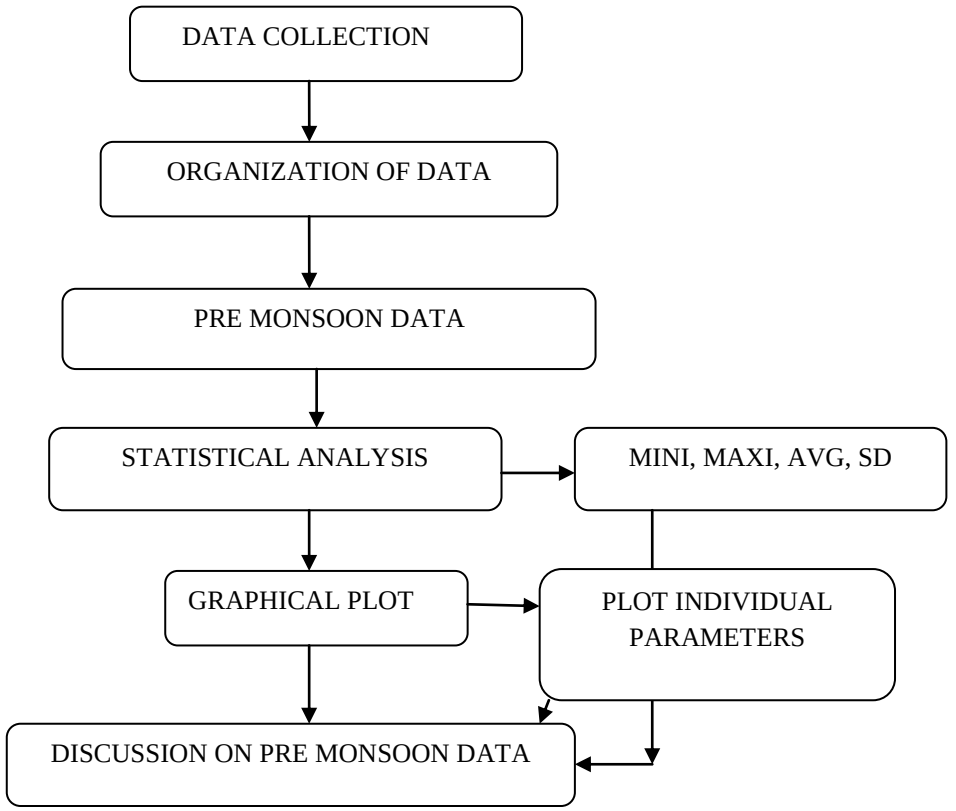

Figure 3. Methodology work Flow

GIS and Data Base Creation And Spatial Interpolation

The GIS database may include computer images, hardcopy maps, statistical data or any other data that is needed in study. Successful GIS implementation typically includes two major steps. 1. Data input 2. Analysis. Data input involves collecting the necessary data layers with the image database. In the analysis phase, these data layers will be combined and manipulated in order to create new layers and to extract meaningful information from them.

In the present study, the data set of spatial & non spatial were prepared by using Arc GIS & Arc View, GIS Software. The data sets obtained from various GIS software, brought under Arc GIS core software and GIS data base was created for all the thematic maps. Arc GIS is

a modular vector based software and is versatile for creation, organization, storage, retrieval, analysis, display and Query. It is also good tool for making cartographic quality outputs in the form of maps and generation of statistical tabular reports. The spatial data is organized using topographical data model. While the non-spatial data attribute is stored using database management software. The database is organised collections of attribute data file containing information on the feature attribute codes of several features which includes river, road, village boundary, settlement, lineament, control wells etc. The database consists of description on the attribute code for each spatial data elements. Topology was built up for each theme for automatic creator of database such as length, area and perimeter.

Spatial interpolation

Toposheet corresponding to the district of Kanchipuram of 1:50000 scales are scanned and imported into open source ERDAS IMAGINE software. All the toposheets are geo referenced using 1st polynomial order equation. Referenced toposheets are checked for the Root, Mean, Square, and Error (RMSE) considering the fact, if the RMSE is less than 20% then final georeferenced file as geo was created in GIS environment. Thus all the toposheets are geo referenced moasicked in GIS software. Area of Kanchipuram district is approximately 1637.82 sq km. which lies above the Chennai district. This district is very near to Chennai and also to the influence of urban development, industrial development within Kanchipuram. The detailed methodology is as follows. All the toposheets numbers 66C/4, 66C/8, 66D/1, 66D/2, 66D/3, 66D/4, 66D/5, 66D/6, 66D/7, 66D/8 corresponding to Kanchipuram Coast are made as input layers in GIS considering the values of latitude and longitude with positional accuracy and mosaic king and made as a single layer. A shape file is created in GIS environment having input of projection parameters using Mount Everest 1984 projection (UTM projection). Universal Transverse Mercator, WGS 84 datum for all the toposheets as well as the digitization of Kanchipuram district a polygon layer is created and digitization is being carried out for the boundary of Kanchipuram and Kanchipuram Coast. Considering the over shoots and undershoots rectification within the polygon. Water quality levels for all the parameters are judged based on the national international standards. National standards refer to BIS (bureau of Indian standards). International standards refer to W.H.O (World Health Organization) for drinking water quality. All the data within min and max values comparing 2011-2015 are compared with standards to understand the quality of water that are very poor that cannot be taken for drinking.

Result and discussion

Kanchipuram coast is approximately 1637.82 sqkm comprising 8 taluks in namely Sholinganallur, Tambaram, Chnagalpet, Maduranthagam, Cheiyur, Thirukalukundram, Thiruporur, Uthiramerur in (2001 censes) and 71 villages. Ground water quality data for the study area is obtained from Ground and Surface Water Resource Data Centre, Taramani, Chennai. They usually collect data from reference wells regularly for pre monsoon seasons. These observation wells are well distributed throughout the study area.

Pre monsoon water quality parameter 2010 – 2015

The detailed note on water quality parameter (all parameters) of pre and post monsoon data between the years 2010 to 2015 or detailed below relevant tables corresponding to the study period.

pH

pH is influenced by a number of factors including rock and soil composition and the presence of organic materials or other chemicals. Higher pH results in higher alkalinity by the presence of two common minerals, calcium and magnesium, affecting the hardness of the water. pH is principally controlled by the balance between the carbon dioxide, carbonate and bicarbonate ions (alkaline nature) as well as compounds such as humic and fulvic acids (acidic nature) in the ground water. Lower values are pronounced in dilute waters high in organic content especially 7.3 for pre monsoon. Average pH of pre was of 8.25. Standard Deviation of (pre 0.32) for 71 obseravations. High pH levels are undesirable since they may impart a bitter taste to the water. High pH levels depress the effectiveness of disinfection by chlorination, thereby requiring the use of additional chlorine or longer contact times.

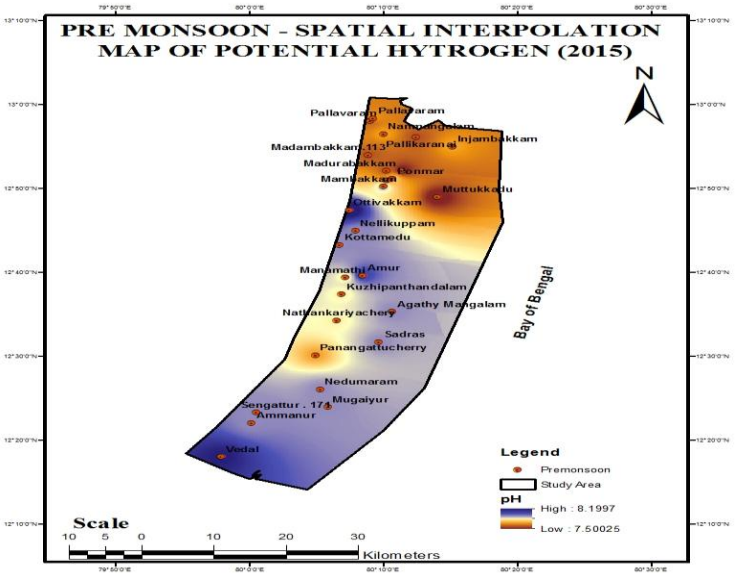

Figure: 4. Pre monsoon spatial interpolation map of Ph (2015)

Pre monsoon pH of the study area showed that lower concentration of pH was observed on the northern part of the study area. Southern part of the study region exhibited higher concentration and middle region showed moderate pH. Higher concentration at the lower part might be sea water intrusion.

Total dissolved solids (tds)

Ground Water Quality data obtained from Surface and Ground Water resources data center Chennai (Tharamani), were used for the water quality parameters analysis for the pre monsoon. The study period include 2011 to 2015 including pre monsoon data. The observation of data include district name, taluk name, block name, village name, Ground Control Points (GCP) comprising latitude, longitude, well number and the water quality parameters. There were seventy one (71) observations for pre monsoon period. These data were organized in a systematic manner and made an input in MS excel and plotted as line graphs. Most of the pre monsoon values are greater than 1000. Maximum values were in the range of 2562 and minimum of 192 and average value of 618.6 and SD 386.3 was observed.

Bicarbonate

The presence of carbonates (CO_3) and bicarbonates (HCO_3^-) influences the hardness and alkalinity of water. Most of the pre monsoon values CO_3 are greater than 20. Maximum values were of 120 and minimum of 0 and average value of 11.33 and SD 22.05 was observed. The weathering of rocks contributes carbonate and bicarbonate salts. In areas of noncarbonated rocks, the HCO_3^- and CO_3^{2-} originate entirely from the atmosphere and soil CO_2, whereas in areas of carbonate rocks, the rock itself contributes approximately 50 per cent of the carbonate and bicarbonate present. Most of the pre monsoon values HCO_3 are greater than 250. Maximum values were of 561.2 and minimum of 67 and average value of 204.40 and SD 100.50 was observed. Pre monsoon HCO_3 of the study area showed that lower concentration of HCO_3 was observed on the southern part of the study area. Northern part and middle region of the study region exhibited medium concentration.

Calcium

Calcium is present in all waters as Ca^{2+} and is readily dissolved from rocks rich in calcium minerals, particularly as carbonates and sulphates, especially limestone and gypsum. The cation is abundant in surface and groundwater. The salts of calcium, together with those of magnesium, are responsible for the hardness of water. The major source of Ca_2+ in the groundwater is due to ion exchange of minerals from rocks of this area. Further, this may also be due to the presence of $CaCO_3$, $CaSO_4$, Ca Mg $(CO_3)_2$ minerals and soils by water. Most of the pre monsoon values Ca are greater than 50. Maximum values were of 328 and minimum of 10 and average value of 64.09 and SD 49.33 was observed. Pre monsoon Ca of the study area showed that lower concentration of Ca was observed on the northern part and southern part of the study area. Middle region of the study area exhibited higher concentration which might be attributed to calcium contain rocks such as gypsum.

Sodium

All natural waters contain sodium since sodium salts are highly water soluble and it is one of the most abundant elements on earth. It is found in the ionic form (Na^+), increased concentrations in surface waters for pre may arise from sewage and industrial effluents or coastal influence may result in sea water intrusion result in higher concentrations. The WHO guideline limit for sodium in drinking water is 200 mg/l However, ground-water concentrations frequently exceed 50 mg/l. Sodium is commonly measured where the water is to be used for drinking or agricultural purposes, particularly irrigation. Most of the pre monsoon values Na are greater than 100 for the years 2011-2014 and for the year 2015 values were found to be less than 100. Pre monsoon Maximum values were of 449 and minimum of 9 and average value of 99, 24 and SD 74.80 was observed. Pre monsoon Na of the study area showed that lower concentration of Na was observed on the northern part, Southern part and middle region of the study region exhibited medium to low concentration of Na. Isolated patches exhibited higher concentration.

Nitrate-n

Pre monsoon NO_3 of the study area showed that lower concentration of NO_3 was observed on the Southern part and middle region of the study area whereas northern isolated patches exhibited a relatively high to very high NO_3 concentration, Higher NO_3. Concentration at northern part might be influenced by the disposal of waste all along the buckhingham canal of the study area. Nitrate-N concentrations of pre monsoon ranged from 0.1 to 37 mg/l. Average value of 7.07 and SD 6.70 was observed for pre monsoon.

Magnesium

Magnesium arises principally from the weathering of rocks containing ferromagnesium minerals and from some carbonate rocks. Most of the pre monsoon values Mg are greater than 25 for the years 2011-2015. Pre monsoon Maximum values were of 204 and minimum of 4.86 and average value of 40.96 and SD 29.63 was observed.

Pre monsoon Mg of the study area showed that higher to very high concentration of Mg was observed on the northern part of the study area. Middle and southern region of the study area exhibited low to very low concentration which might be attributed to calcium contain rocks such as gypsum or dolomite.

Chloride

Pre monsoon Cl of the study area showed that higher to very high concentration of Cl was observed on a single location of northern part of the study area. Middle and southern region of the study area exhibited low to very low concentration. High concentrations of chloride can make waters unpalatable and, therefore, unfit for drinking seems to be prominent 1375 for pre period for Coastal villages of Kanchipuram district, large contents of chloride in freshwater is an indicator of pollution. In addition to the adverse taste effects, high chloride concentration levels in the water contribute to the deterioration of domestic plumbing, water heaters and municipal water works equipment is due to domestic wastages and/or leaching from upper soil layers in dry climates. High chloride concentrations in the water may also be associated with the presence of sodium in drinking water.

Sulphate

Pre monsoon SO_4 of the study area showed that higher concentration of SO_4 was observed on the northern part of the study area. Middle and southern region of the study area exhibited medium to lower concentration. Higher concentration in the northern part might be attributed to calcium contain rocks such as gypsum associated with sulpahate salts as rock bearing minerals and its dissolution in the Ground Water. The concentration of sulphate in the study area ranged for pre monsoon ranged from 2 to 265mg/l average 44,66 and SD 37.46. The sulphate concentration of recommended limit is from 200-400 mg/l. The concentrations of sulphate in all the sites are under the desirable limit. It is concluded that water are highly alkaline, pH above 8.5 were recorded and natural alkaline water may be due to the lime deposits at the source of water.

Fluoride

Pre monsoon F of the study area showed that higher concentration of F was observed on the southern and middle region of the study area. Northern region of the study area exhibited medium to lower concentration. Higher concentration in the southern part might be attributed to F bearing minerals. One of the main trace elements in groundwater is fluoride which generally occurs as a natural constituent. Bedrock containing fluoride minerals is generally responsible for high concentration of this ion in groundwater. Fluoride normally accumulates in the bones, teeth and other calcified tissues of the human body. Excess of fluoride in water causes serious damage to the teeth and bones of the human body, which shows the symptoms of disintegration and decay, diseases called dental fluorosis, muscular fluorosis and skeletal fluorosis. Higher intake of fluoride may change the metabolic activities of soft tissues (brain, liver, kidney, thyroid and reproductive organs). The permissible limit of fluoride in drinking water is 1.5 mg/l as per BIS standards. The fluoride concentration in the study area varies from 0.05-1.13 mg/l in pre monsoon season. Ground water containing

more than 1.5 mg/l of fluoride cause mottled tooth enamel in children and are not suitable for drinking purpose.

Electrical conductivity ec

Electrical Conductivity is a measure of the ability of water to conduct an electric current. It is sensitive to variations in dissolved solids mostly mineral salts, related to the concentrations of total dissolved solids and major ions. High Conductivity, 4510 and among the villages for pre monsoon may arise through natural weathering and anthropogenic sources. The conductivity of most freshwaters ranges from 10 to 1,000 µS cm^{-1} but may exceed 1,000 µS cm^{-1}, especially in polluted waters. This ability depends upon the presence of ions, their total concentration, mobility, valence and temperature. Although the large variation in EC is mainly attributed to geochemical process like ion exchange, reverse exchange, evaporation, silicate weathering, rock water interaction, sulphate reduction and oxidation processes.

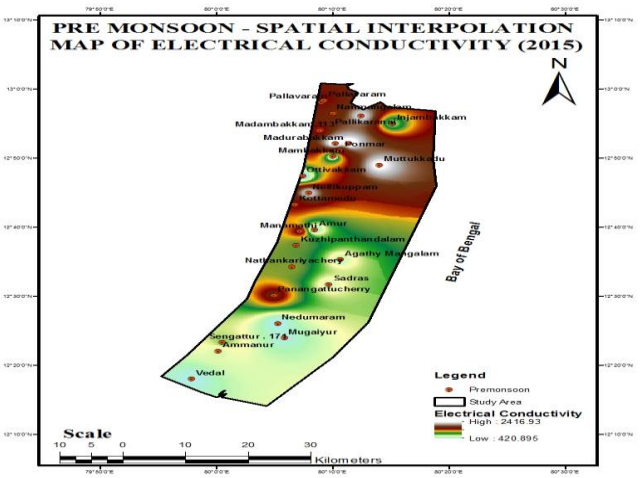

Figure: 5.pre monsoon spatial interpolation map of EC (2015)

Pre monsoon Maximum values were of 4510 and minimum of 280 and average value of 1002 and SD 696.6 was observed. Pre monsoon EC of the study area showed that higher concentration of EC was observed on the northern region of the study area. Southern region of the study area exhibited medium to lower concentration. Higher concentration in the northern part might be attributed to higher soluble salts particularly anions availability was higher in the ground water.

Total hardness: HAR_total

The hardness of natural waters depends mainly on the presence of dissolved calcium and magnesium salts. The total content of these salts is known as general hardness, which can be further divided into carbonate hardness (determined by concentrations of calcium and magnesium hydro carbonates), and non carbonate hardness (determined by calcium and magnesium salts of strong acids).

Low values of hardness 110 for pre monsoon were observed and higher values 1360 pre monsoon was observed. Hardness is a measure of the ability of water to cause precipitation

of insoluble calcium and magnesium salts of higher fatty acids from soap solutions. The principal hardness causing ions are Calcium, Magnesium Bicarbonate, Carbonate, Chloride and Sulphate. Pre monsoon Total Hardness of the study area showed that higher concentration of Total Hardness was observed on the northern region of the study area. Southern region of the study area exhibited medium to lower concentration. Higher concentration in the northern part might be attributed to higher availability of Cations and anions in the northern part.

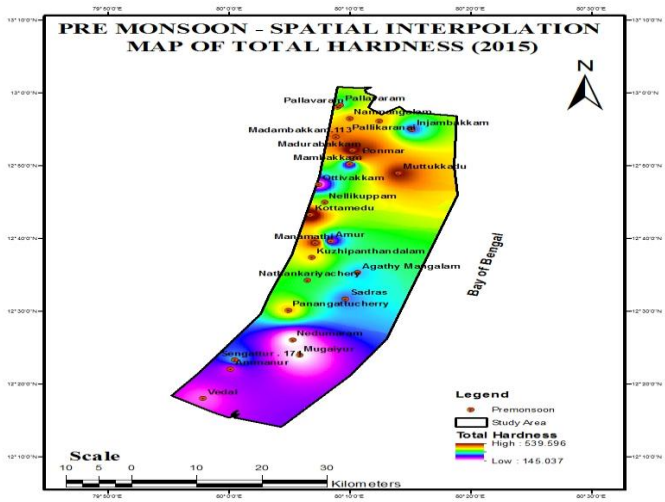

Figure: 6. Pre monsoon spatial interpolation map of Total Hards (2015)

Conclusion

Ground water quality data of pre monsoon pertaining to the year 2011 to 2015 was used for this analsysis. All the data were analysed for the pre monsoon values across all the years. The parameters such as pH, EC, TDS, Total Hardness, Ca, Mg, SO_4, NO_3, Cl, F, CO3, HCO3, Water Quality Values which are considered significant for drinking and irrigation such as No_3, SO_4, Cl, F are at higher levels during the pre monsoons season. Spatial interpolation was carried out to understand the distribution of each variable all along the Kanchipuram Coast. This study signifies that Northern part seems to posses the higher contribution all variables compared to the middle and the southern region. Such higher level will pose a deleterious effect on the human health for consumption.

Reference

Atikeh Afzali, Kaka Shahedi, Mahmoud Habib Nezhad Roshan, Karim Solaimani, Ghorban Vahabzadeh., 2014., Groundwater Quality Assessment in Haraz Alluvial Fan, Iran. International Journal of Scientific Research in Environmental Sciences, 2(10), pp. 346 - 360,

A. Ponniah Raju, Dr. N. Chandrasekar, S.Saravanan., 2013., Spatial Analysis of Groundwater Quality Investigation in North Chennai, Tamilnadu, India, International Journal of Water Research 2013; 1(1)pp: 1- 6.

I. Ameeth Basha, T. Shanthi and R. Nagalakshmi., 2016., Water Quality Analysis Of Chinna Kanchipuram, Tamil Nadu, India, Int. J. Chem. Sci.: 14(S2), 2016,pp:431- 438.

S. Packialakshmi, Meheli Deb and Hrituparna Chakraborty., 2015., Assessment of Groundwater Quality Index in and Around Sholinganallur Area, Tamil Nadu, Indian Journal of Science and Technology, Vol 8(36), December 2015.