Geohydrological and Hydrogeochemical Studies: A Case study of Visakhapatnam City, Andhra Pradesh, India using Geospatial Techniques

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Abstract: In today's world of rapidly advancing remote sensing scenario, there are a number of possible wide applications. Remote sensing and Geographical Information System could generate data required for micro and macro-level planning of mineral exploration in their identification and quantitative estimation. Remote sensing, as a direct adjunct to field, litho logic and structural mapping, and more recently GIS have played an important role in the study of mineralized area. A review on the application of remote sensing in identification of rock types like (Charnockites, Mafic Granulites, megacrystic Granites) is attempted here. It involves understanding the application of remote sensing in identification of mineral deposits and rock types, in its own right, when the primary and secondary processes of mineralization of rocks result in the formation of spectrum anomalies. Reconnaissance lithologic mapping is usually the first step of present task. This is complimented with structural mapping. In addition to these, understanding the use of hyper spectral remote sensing is crucial as hyper spectral data can help identify and thematically map regions of exploration interest by using the distinct absorption features of most rocks. Finally coming to the quantitative estimation stage, GIS forms the perfect tool in integrating and analyzing various geo referenced geosciences data in find out the area and volumes of desired hills with detailed 3d views.

Groundwater is an important source of water supply throughout the world. Its use in irrigation, industries, municipalities, and rural homes continues to increase. Shortage of groundwater in areas where excessive withdrawals have occurred emphasize the need of exploring the groundwater and the proper planning to ensure the continued availability of water supplies. To know the occurrences of groundwater it is necessary to take a review of where and how groundwater exists. The geologic zones important to groundwater must be identified as well as their structure in terms of water holding and water-yielding capabilities. Assuming hydro geologic conditions furnish groundwater to the underground zone, the subsurface strata govern its distribution and movement; hence the important role of geology in groundwater can be understood. Springs, hydrothermal phenomena, and water in permanently frozen ground constitute special groundwater occurrences. It is now generally recognized that the quality of groundwater is just as important as its quantity. All groundwater contains salts in solution that are derived from the location and past movement of the water. The quality required of groundwater supply depends on its purpose; thus needs for drinking water, industrial water, and irrigation water vary widely. To establish quality criteria, measures of chemical, physical, biological, and radiological constituents must be specified, as well as standard methods for reporting and comparing results of water analysis. Dissolved gases in groundwater can pose hazards if their presence goes unrecognized. The uniformity of groundwater temperature is advantageous for water supply and industrial purposes, and underlying saline ground waters are important because they offer potential benefits (Gowd, S. S. (2005).

This study included collection of analyzed water sample data for the years 2019 and 2020 and the study of spatial distribution for the interested areas along the coastal part Chukkavanipalem, Madhurawada, Sivajipalem, Gajuwaka, Gollalapalem, Pedagantyada. The satellite image IRS 1D 2005, LISS-III was used in this study.

Keywords: Ground water, Landsat, Hyper spectral, Remote Sensing, GIS,

1. Introduction

The remote sensing techniques are the most efficient tools for geological, structural, geomorphologic studies and their mapping because of its synoptic view, multispectral, multi temporal capabilities (Krishnamurthy and Srinivas 1996). The geomorphic units have specified set of characteristics that determine its image signature. High-resolution satellite data provides reliable source of information to delineate and generate comprehensive and detailed inventory of geomorphic units in an area (Mukerjee 1982).

Satellite remote sensing (RS) technique has proved its utility in all fields of earth science studies, including the study of prospects identification, mining, mine planning, and surface deposits exploitation, because of the rapid, repetitive, synoptic and multispectral coverage of the satellites. Geographic Information System (GIS) is designed to work with data referenced by spatial / geographical coordinates. The major advantage of GIS is that it allows identifying the spatial relationships between features and temporal changes within an area over time.

2. Study area

The study area lies between Latitudes of 17^0 38’ to 17^0 50’ and longitudes of 83^0 11’ to 83^0 20’ and the total extent of the study area is approximately 160 sq kms. The area under studied is the ten minute (10’) interval of both longitude and latitude. The study area falls in the main city of Visakhapatnam, and mainly the study area is on the coast line of the Visakhapatnam between the areas of Bheemili and Duvvada (Fig.1&2).

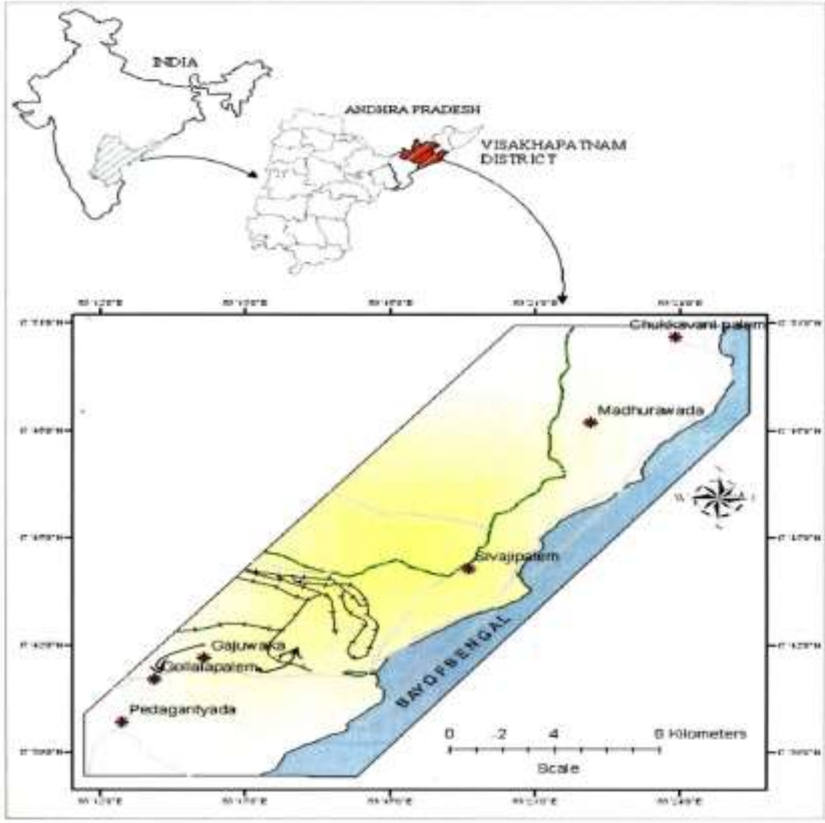

Fig 1: Location map

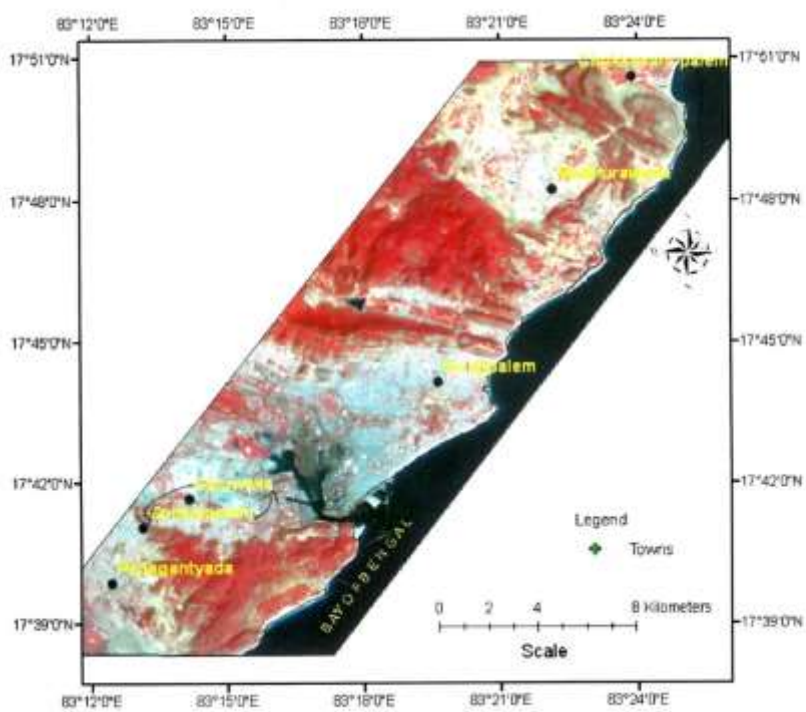

Fig 2: Satellite imagery of the study area.

3. Geology and Geomorphological studies

3.1.Geological Set-Up

The study area is part of Eastern Ghats region, and geologically it comes under the principal metamorphic units of peninsular India. Major geological formations belong to the Archaean and Quaternaries. The former include Khondalite suite of rocks, in which Charnockite occur as isolated zones, traversed by pegmatite and quartz veins; and the latter comprise Laterite / Lateritic gravel and surficial deposits. A generalized geological succession of the region is given below

System	Formation	Lithological Units
Quaternary	Recent	Surficial Deposits (Alluvium : Red sediments; piedmont Fans, Colluvium and coastal Sands)
	Sub-Recent	Laterite –lateritic Gravel
Archaean	Eastern Ghats	Pegmatite and quartz veins Charnockite, Khondalite suite of rocks

3.2.Archaean Formations

3.2.1. Khondalite

About ninety-five percent of the region is underlain by the Khondalite suite of rocks. These rocks occur in two varieties: (a) Khondalite and (b) Leptynites. The former verity of rocks are medium to coarse grained with gneissose texture and consists of quartz feldspar, garnet and sillmanite as essential minerals, and apatite, biotite and opaques as accessory minerals. The rocks exhibit different colors, the dirty –brown is due to the ferromagnesium minerals present in the rocks and the brownish – white color is due to high properties of quartz and feldspar minerals. They are hard when fresh, and friable when weathered. Generally, these rocks are exposed in the hill ranges.

The Leptynites are formed due to recrystallization of the khondalite (Rao et al., 1986). They are medium grained with pink and cream colors and show both gneissic and granulitic texture. These rocks are made up of quartz, potash and plagioclase feldspar, and garnet as essential minerals. They are easily susceptible to weathering. The weathered rocks are more porous, but clayey in nature, and the non-weathered varieties present at a depth are more compact. They usually occur in the plain areas and exist between Charnockite, Khondalite rocks. Generally, Leptynites are soften then Charnockites, but harder than Khondalites.

3.2.2. Charnockite

Charnockites are massive, hard and compact, dark colored with greasy luster, fine to medium grained or occasionally coarse grained and granulitic in texture. The essential mineral constituents are quartz, potash and plagioclase feldspars, ortho-and clino-pyroxenses with garnet. Biotite, apatite, zircon and opaque’s are present as accessories. These rocks occur as alternate layers in the Khondalite suite of rocks, especially in the Waltair area. They are several small occurrences as lenses and layers within the Leptynite rocks. Pegmatite and Quartz veins: Pegmatite and Quartz Occur as intrusive bodies, which cut across the Khondalite suite of rocks and Charnockites.

3.2.3. Structure

Regional trend of the Eastern Ghats is NE-SW; dipping towards SE. The foliation of the Khondalite suite of rocks in the hill ranges is parallel to the general disposition of the hill / hill ranges. The formations are usually folded and refolded, giving rise to isoclinal folds (Sriramadas and Rao, 1979).

3.3.Quaternary formations

3.3.1. Laterite / Lateritic Gravel

Laterite / Lateritic gravel occur as capping with a maximum thickness of 3m on elevated ground. It is reddish -pink with pisolitic texture. Two types of laterites occur in this region: (i) in -situ laterite and (ii) colluvial laterite. They occur at lower levels on piedmont fans in gully sections and on low-detached mounds close by hills, showing inversion of relief. The occurrence of colluvial laterite and lateritic gravel on colluvial plains and piedmont fans indicates long - period of tectonic stability, leading to weathering and lateralization of the surficial materials (Raghavaswamy, 1981). Laterites are well-developed on congenial landforms with gentle favorable slopes, aided by effective permeability under tropical-climate conditions in the Indian Sub-Continent during the Mio-Pliocene (Srivastava 1968), informed a warm- tropical -climate during the Pleistocene and Sub-Recent. The in-situ laterites occurring at about 10-45m AMSL close to the coastal line are thought to be remnants of the Quaternary (Pleistocene to Holocene) planar surfaces.

3.3.2. Surficial deposits

Piedmont Fans and Colluvium: Foot-slope of the hill ranges is blanked by a series of piedmont fans in the region. The fans are not uniform in size, shape and in thickness. They consist of silt, sand and gravel in various proportions, cobbles, pebbles and boulders forming a veneer. They are accumulated as debris materials at the base of the steep-slopes of hill ranges and essentially are through by the disintegration of the Khondalite suite of rocks and water action. The formation of piedmont fans explain humid to sub-humid climate in the past or change in the base level, leading to increased erosion and deposition. In the interfan area and along the rest of the foot slope devoid of fan, it is all colluviums with the similar material composition as the fans. The slope of the colluvial plain is with 3-5^{o}. Thickness of Colluvium is not uniform (<1-6m), because of irregular bedrock and slope, followed by weathered and fractured Khondalite rocks of 6-20 m and 20-40 m respectively.

3.4.Coastal sands and other marine features:

The coastal sands are of two types: (i) sand dunes and (ii) dune sands. The sand dunes show, generally oval to parabolic shape and their size is not more than 3-5 m from the seashore, they consists of loose sand heaped up by the wind and show NE-SW direction, formed due to wind action.

A narrow transitional zone of dune sands is present behind the sand dune belt.

They contain fine to medium grained sands derived from the sand dunes and are carried by winds and deposited inland, which are blown to more than 1 km with a height up to 90m.

3.4.1. Geomorphology

Geomorphologically the area under study is covered by the structural hills. These hills are trending towards northeast and east -west direction. The Colluvium / bajada are associated with structural hills and extended upto the lower portions of the hills; the second largest portion is optical by this Colluvium / bajada. The Pedi plains are also taken place over the areas near to Singavaram and Modivada. The remaining areas of low lying, surrounded by the all structural hills are consists the material of loose sediments and the Vaddadi and Madugula occupied by piedmont fans, among these prominent geomorphic features recognized from the satellite imagery.

3.4.2. Topography

The present study region lies at the foot - hills of eastern Ghats, extending up to the Bay of Bengal. The area is a plain land with gentle undulations and regional sloping towards south -east. The altitude in the region ranges from 159 to 570 m AMSL. The highest peak (507m) of kailasa hills range is located in the southern part. A number of hillocks/residual hills, less than 30 m in height are located in the different parts of the region (Fig.3). The physical characters of summits and crests, generally integrate humid to sub-humid climate in the past. The hills steeply descend and give way to rolling plains and intermediate fluvial plains / lowlands. This plain is covered by red sediments (red sandy soils). The nature of rolling plain is due to irregular bedrock profile, differential rates of erosion and deposition of material attributable to gravity and water or wind.

3.4.3. Drainage network

The extensive drainage is present in the study area; all the third and second order streams are moving towards the northeastern side with slope direction. Some of the major streams flow towards southeast direction due to the structural control (Fig.4).

The water tanks also showing their bunds towards the north east-to-east west direction. Especially in the Madhurawada area the drainage flow direction is in north east direction and the remain areas are in south east direction. It is also an indication to the structural control of the valley fill area. The drainage figure is following with the trend with respect to the structural trends of surface exposures. The study area has a number of tanks, which are interconnected with river/stream courses in many places.

All streams are ephemeral in nature. Drainage pattern of the area is sub-dendritic type, which appears to be mainly controlled by structural and topographic features.

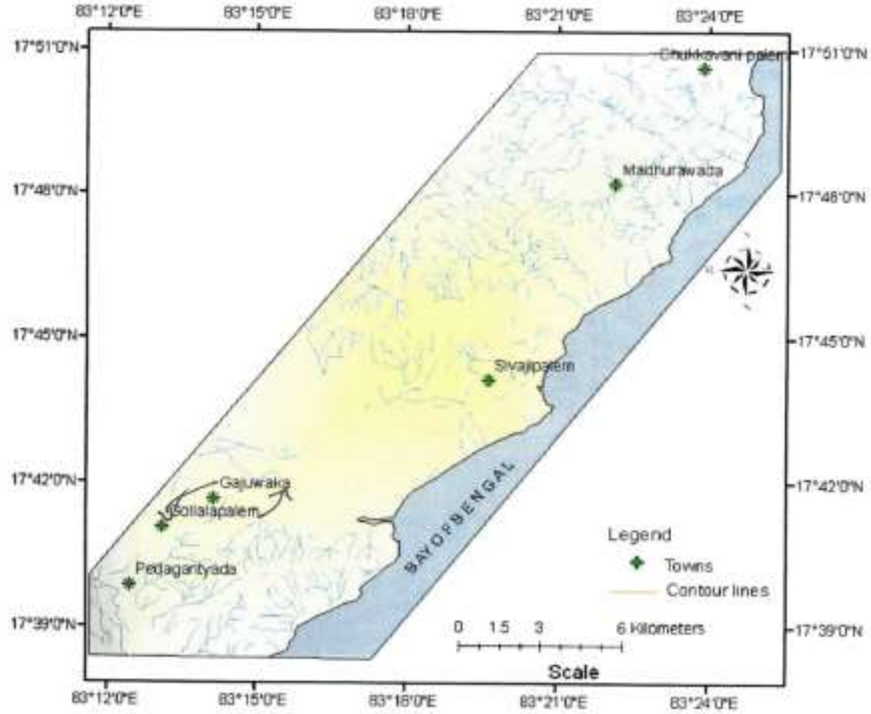

Fig 3: Drainage map of the study area.

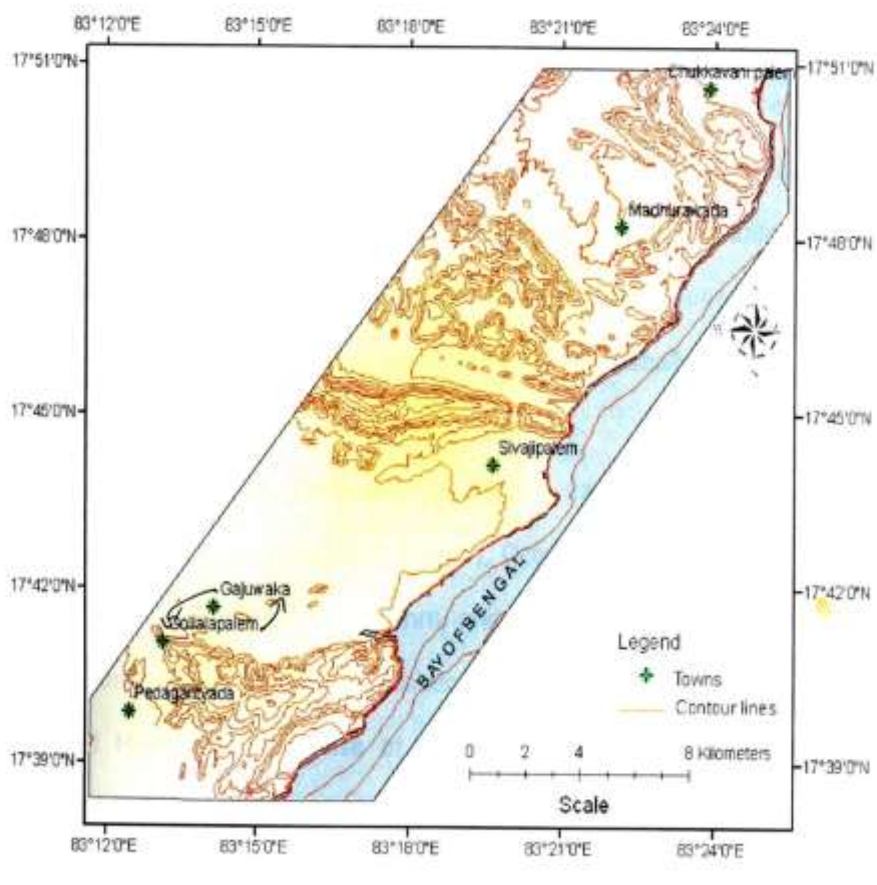

Fig 4: Contour map of the study area.

3.5.Climate and rainfall

The climate components, rainfall, evaporation, humidity and wind, will play a vital role in evapotranspirative regime of an area. Monthly mean minimum and maximum temperatures are 17.8^0 C in January coldest month and 33.8^0C in May (hottest month). The mean annual variation of temperature is about 8^0C, which is a characteristic feature of the coastal region. Relative humidity ranges from 70-83% (mean: 76.6%) in the mornings to 72-83% (mean: 78.6%) in the evenings which is relatively high (80-83%) from April to September owing to the monsoonal rains. The region has a semi-arid type of climate having a moisture index of-42%.

Mean annual rainfall (900mm) is highly variable (monsoon: 888mm; winter: 34mm; and summer: 68mm), October being the wettest month with a maximum rainfall of 261 mm, and January the driest month with a minimum rainfall 08mm. October records the highest rainfall (261 mm) and May 54 mm because of thunder storms and cyclones originating in the Bay of Bengal, as reported by earlier researchers. The climatic intensity is observed to be maximum (28.4 mm/day) in October and minimum (11.6mm/ day) in January, which is a useful indicator in certain aspects of water management. Winds place a significant role in evaporation and evapotranspirative stress on vegetations. The wind speed is 16 km/hour in summer and 7.5 km/hour in winter and hence movement of sand has a distinct summer and winter patterns.

Soils

Soils consist of weathered of rocks. Topography (relief), climate conditions (temperature and rainfall), groundwater regimes and organic activity (primary vegetal) govern the genesis of soils.

The thickness of soils is primarily controlled by relief and, of course, the length of time of soil formation. In a hot - humid climate, red and yellow soils are characterized by sesquioxides of Al $_20_3$ and Fe203 compounds.

In general, for classification of soil, soil texture, portion of occurrence (landform) and lithology are considered. The main soil types in the region are:

1. Red sandy soils,
2. Alluvial sediments,
3. Coastal sandy soils, and
4. Skeletal soils (colluviums and lateritic gravel)

3.5.1. Red sandy soils

The red sandy soils are medium to coarse grained with high percentage of sand (76-92%) with low clay content (1-7%). They are non-saline in nature (TDS<1000 mg/l) with P^H ranging from 7.0-7.6 and can be considered as neutral to slightly alkaline.

3.5.2. Alluvial sediments

All alluvial sediments formed with fine to medium grains have P^H ranging from 7.2 to 7.8 and are in general non - saline type (TDS<1000 mg/l). They have higher percentage of sand (56-62%) and clay (11-15%).

3.5.6. Coastal sandy soils

Coastal sandy soils are fine to coarse grained with more percentage of sand (36-

64%) than silt (11-30%). They show saline character with TDS more than 1000mg/l and p^H varying from 6.6 to 7.8.

3.5.7. Skeletal soils

Skeletal soils, including colluviums and lateritic gravel, are poorly sorted type with grain size varying from silt to gravel. They are of non-saline (TDS, 1000 mg/l) type with p^H ranging from 6.8 to 7.0.

3.5.8. Vegetation

Vegetation is one of the major components of man's environment and its relation with climate and soil is extremely complex and is usually changing. Since the potential -evaportranspiration exceeds the actual evaportranspiration in the present region; it favors the presently occurring forest type of vegetation. The existing forest type vegetation region can be classified into three categories: (I) dense deciduous forest, (ii) degraded forest. A dense deciduous forest contains thick vegetation cover, whereas the scrubs are thorny bushes of less than 2m height. Dense scrubs contain thicker bushes than sparse scrubs, which are located on denudational hills. A degraded forest is one, which has scattered tree cover with bush and grass. Grasses, shrubs and Climbers occur widely on the plains.

Maritime bushes cover the coastal sand dunes. Coconut, cashew and casuarina equistifolia are being grown in the beach and on dune sands. Vegetation is abundant, where the calcretes are present in the red sediments.

On the basis of water requirements, it is possible to distinguish two extreme types of vegetation: (a) heath- scrubs and (b) forest -woodlands. The former are mainly shallow rooted species, and the roots spread obliquely and laterally downwards, and there is no descending root to the water table. They can survive in dry conditions and effectively use soil moisture in the vadose zone. However, the latter have roots, which descend up to the water table to utilize the water in phreatic zone. They cannot survive in dry conditions, and hence, if they grow above the water table, their roots will descend to grater depths to tap the groundwater.

The area is under a semi- arid and receives and average rainfall of about 1042mm per annum. Usually isolated low pressure centers are formed in the Bay of Bengal during the months of October and November, which intensify into cyclonic storms. High temperatures (48^0C) occur during May while low temperature (22^0C) is recorded in January.

3.6.Transport and communications

The study area is well- connected road-line from Visakhapatnam to Bheemili and it is connecting the towns of all surroundings. The remaining smaller villages are connecting with the unmetalled, cart-track roads. The rail transportation is not available in this area but the nearest station is Anakapalli, which is nearly 14 kms. The communications and transportations are well established by the main roads interlining with the smaller towns and the cart roads for all villages. Road map of the study area shows the transporting facilities (Fig.5).

4. Data used

The survey of India topomap of 65 O/1, 2, 5 & 6 on 1:50,000 scales are used in the preparation of base map for present study area. The satellite data in digital form is acquired i.e., IRS-1S LISS -III of 2005 was used for interpretation and delineation of general and lithological studies. The ancillary data of analyzed water samples from the bore wells of selected areas along the coastal track of Visakhapatnam. The methodology flow chart described in detailed about on procedures of work. The following data of analyzed water samples are collected from the A.P. state groundwater board, Visakhapatnam.

	P^H	EC	TDS	CO_3^2	HCO_3^-	Cl^-	F	NO_3^-	Na^+	Ca^+
Chukkavanipalem	8.46	2812	1800	37	451	396	2.5	13	600	16
Madhurawada	8.29	1217	779	0	167	218	0.5	53	180	16
Sivajipalem	8.26	1154	739	0	186	208	0.4	4	170	24
Gollalapalem	8.35	914	585	9	196	129	0.2	8	130	16
Gajuwaka	8.7	1006	644	74	314	40	2.5	24	185	16
Pedagantyada	8.5	922	590	37	167	109	0.6	4	165	24

Table 1: Water sample analysis for the year 2015.

	P^H	EC	TDS	CO_3^{2-}	HCO_3^-	Cl^-	F	NO_3^-	Na^+	Ca^+
Chukkavanipalem	8.9	2648	1694	115	620	308	0.07	62	398	144
Madhurawada	9.2	1250	800	100	130	198	0.11	12.4	163	54
Sivajipalem	8.6	1052	673	20	280	100	0.17	23	153	50
Gollalapalem	7.6	1212	775	0	135	244	0.1	1.86	217	28
Gajuwaka	8.3	1160	742	15	395	117	0.12	4.9	179	18
Pedagantyada	8.7	657	420	40	240	99	0.04	0.6	53	56

Table 2 : Water sample analysis for the year 2020.

5. Methodology

The Survey of India (SOI) Topomap No's. 65 O/1, 25 & 6 on 1:50,000 scales were scanned and Geocoded using the geographic lat /long projection, spheroid - Everest and datum - undefined. The SOI topomap is used as base map. This satellite data product also Geocoded through the digital image processing using the method image- to - image rectification. Then a subset is created to all the data sets for the study area .i.e., Topomap, IRS1D LISS-III OF 2015 data.

The study involved the visual interpretation of satellite image with limited ground checks. Geocoded data sets with the help of Toposheet and other ancillary data to derive spatial information related to topographic and general features of the area. Image was interpreted based on the recognition elements tone (relative darkness or whiteness), texture (frequency of tone or color changed), shape, pattern (distinctive arrangement on the ground by different features), scale of all these factors were used for the image interpretation of the satellite imagery in conjunction with the collateral information are used to delineate geomorphic units. The image enhancement techniques are also used to improve the image contrast and to avoid the haze, noise etc.

Adequate field checks were conducted for deriving information on geomorphic units and to establish the relationship between the image elements and geomorphic unit characteristics. The vector layers (Arc, point coverage) are created for the delineated features (i.e. geomorphic and land use /land cover) on satellite image. Field checks have been carried out in selected sites to verify the boundaries and properties of the delineated geomorphic units. And all these layers are over laid in ARC GIS environment for preparation of delineated the spatial distribution of maps.

6. Results and discussion

6.1.pH

The pH value is measure of the acidity or alkalinity of water pure water consists not only of H_2O but also relatively small number of negative hydrogen ions. In general and approximately solution were acid characteristics when the concentration of hydrogen ions exceeds the concentration of hydrogen acid ions in which was the pH is less than 7. Excess hydroxyl ions indicate pH more than 7.

In the present study area in 2005 Gajuwaka is showing high pH value as 8.7, and most of the areas remaining Gajuwaka area found below 8.5 which safe and permissible for drinking water purpose. Madhurawada and Sivajipalem areas are showing least pH values in the study area. In 2020 analysis the pH values of Gajuwaka decreased to 7.7 where as it was 8.7 in 2015. Most areas in 2020 analysis show pH values between 8.4 to nearly 9.2 and surrounding areas of Madhurawada showing pH values more than 9. It is observed that the pH values increased during the five year period.

Generally the pH of a drinking water should be in the range of 6.5 to 8.5. In the present study area it is observed that some areas in 2020 analysis show pH values more than 8.5 which not suitable for drinking water purpose , but in 2015 the highest pH value was 8.7 which can be permissible for drinking purpose.

6.2.EC

In the present study area the EC values are ranging from 900-2900 mg/l in 2005 where it is ranging from 600-2450 mg/l in 2020. In both the years analysis most places of the study area are showing EC values between 1000 to 1300 mg/l. Chukkavanipalem area is showing high EC values in both the years.

6.3.**Total dissolved solids**

The source or cause for TDS is chiefly mineral constituents derived from rocks and soils for many purposes. The dissolved solids contained are major limitations in the use of water. A general classification of water based on TDS. TDS values can be measured by evaporation method.

- Fresh- less than 1,000 mg/L
- Slightly saline – 1,000 to 3,000 mg/L

- Moderately saline - 3,000 to 10,000 mg/L
- Very saline – 10,000 to 30,000 mg/L
- Brine - more than 30,000 mg/L

In the present study area in both the years 2015 and 2020 the TDS values varies approximately 500 to 1800 mg/L. The sample stations Pedagantyada, Gollalapalem and Gajuwaka of present study area show the least TDS values in 2015 and as well as 2020. The Chukkavanipalem sample station show high TDS values approximately between 1500 to 1800.

The GIS analysis reveals that nearly 75 % of the study area contains total dissolved solids less than 1500 mg /L which is safe for drinking purposes. As the maximum limitation of TDS for drinking purpose is 1500 mg/L the areas around Chukkavanipalem sample station are found unsuitable for drinking purpose.

6.4.Carbonates

In the present study area Gollalapalem station show least carbonates values and the adjoining areas (Gajuwaka and Pedagantyada) show carbonate values (up to 45 mg/l) slightly more than Gollalapalem station but in 2020, Madhurawada and Sivajipalem stations show least carbonate values. In 2015, Chukkavanipalem station showing high amount of carbonates (103 -115 mg/L) where as in 2020, in Gajuwaka station shows high carbonates values between 65-75 mg/L. During the five years period the carbonates content in Gajuwaka area increased from 45mg/L to 75 mg/L where as in Chukkavanipalem station the carbonates content decreased from 100 mg/L 45 mg/L.

6.5.Bicarbonate

Ground waters located in the crystalline rocks show HCO_3 ranging from 120 to 1464 mg/L while it varies from 60-1078 mg/L in unconsolidated rocks.

In the present study area only two stations Chukkavanipalem and Gajuwaka show more than 235 mg/L, remaining all the stations show bicarbonate values between 167 to 235 mg/L respectively. In 2020, Gollalapalem and Madhurawada stations show least bicarbonate values between 130 to 190 mg/L. same as in 2015 Gajuwaka and Chukkavanipalem areas show high bicarbonate values. Maximum area between Madhurawada and Gollalapalem stations show bicarbonate values between 200 to 300mg/L.

6.6.Chloride

Chloride is natural waters may reach of leaching from natural rocks and in coastal areas with admixture of sea water however, greatest source in fresh waters is disposal of sewage of industrial waste. Water solutions also add considerable quantity chlorides. Chloride in some parts gave a salty taste to water. People who are not accustomed to high chloride in water will not taste salty but 100 mg/L is the maximum limit for drinking water. It is found to have chloride content ranging from 15 to 2910 mg/L in ground water of crystalline terrain. But it ranges from 35 to 6250 mg/L in coastal unconsolidated.

In the present study area the Gajuwaka station show chloride values between 350 to 400 mg/L which is highest in entire the study area, the adjoining areas Pedagantyada station show the chloride values as 300 to 350 mg/L . It may be due to Gajuwaka and adjoining areas are highly industrialization. In 2020, Chukkavanipalem station highest chloride values and they are decreasing gradually to words the Sivajipalem stations. Areas between Madhurawada and Gollalapalem are found to have nearly 100 mg/L where as it was 400 mg/Lin 2005. But the adjoining areas of Gajuwaka like Gollalapalem and Pedagantyada remain nearly same as in 2015.

6.7.Flouride

Fluoride have of late become a matter of great concern due to "flourosis" problem reported from various part of India as well as abroad it is however, ironical as fluorides are having concentration of fluoride in water is less than 0.5 mg/L. However, in higher concentration it causes a crippling this is flourosis. The natural fluoride content in drinking water depends on the source, climate and geological factors. The fluoride concentration of sea water is usually constant around 1-3 mg/L. The concentration below 1 mg/L is unpolluted surface waters. The industries may lead to higher content in fluoride in water. The safe limit of fluoride in drinking water supply is 1.5 mg/L.

In the present study area most of the stations remaining Gajuwaka and Chukkavanipalem are showing fluoride values less than 1 mg/L. In both the areas Gajuwaka and Chukkavanipalem it is more than 2- 2.5 mg/L. High industrialization might have caused the highest fluoride content. As BIS recommended 1 mg/L as the highest limit for drinking water purpose all the stations remaining Gajuwaka and Chukkavanipalem areas are suitable for drinking purpose. There is lot of variation in the fluoride values of the entire study area from 2015 to 2020, Gajuwaka area show fluoride content as 0.1 mg/L in 2020 where as it was more than 2 mg/L in 2015. As no station in 2020 show fluoride values more than 0.16 mg/Lit is good for drinking purpose.

6.8.Nitrates

Nitrates are highly oxidized from of nitrogen. Natural waters are usually deficient of nitrates. Nitrates are contributed to fresh water through discharge of sewage and industrial wastes and run-off from agricultural Fields. Some ground water naturally have high nitrate concentration above 45 mg /L can cause some diseases in children.

In the present study area most of the stations show nitrate values below 20 mg/L and the highest the nitrate values are from Madhurawada station as 45 -55 mg/L. The nitrate values consistently decreased from Madhurawada to Sivajipalem. In Gajuwaka area it is nearly 30 mg/L but in 2020 it decreased to 10 mg/L in 2020 Madhurawada areas show nitrate values are nearly same as in 2015 but in the Chukkavanipalem area nitrate values increased to 6 mg/L where it was nearly 10 mg/l in 2015 .

6.9.Sodium

Sodium is also commonly present in water and also its concentration in unpolluted waters less than that of calcium. Sewage and industrial waste greatly influences the sodium concentration in water. Sodium is highly soluble in water. Ground waters associated with unconsolidated formations of coastal parts of Andhra Pradesh, India contain sodium in ranges of 15 to 1500 mg/L and in crystalline rocks it is found to have sodium content varying from 6 to 1950 mg/L.

In the present study 50% of the areas show sodium content between 100 to 230 mg/L. Chukkavanipalem area shows highest sodium content as 550 to 600 mg/l. It is observed that the sodium content from Madhurawada to Pedagantyada decreasing largely. In 2010 also Chukkavanipalem area is showing highest sodium content but at a relatively less range as 350 to 400 mg/l when compared to the range in 2005. In both the years 2015 and 2020 the sodium content decreased from Chukkavanipalem to Pedagantyada. In the present study area the sodium content decreased from the year 2015 to 2020. As per the indications of WHO for drinking water most of the places of the study area are not having sodium content more than 200 mg/l, so that most of the areas are suitable for drinking purpose as per the 2010 analysis.

6.10. Calcium

Calcium is commonly present un all water bodies when it usually comes from leaching of rocks Natural waters usually have calcium content varying from traces to 100 mg/l. At high P^h values it precipitates as $CaCo_{3.}$ Most kinds of water pollution influence the concentration of calcium in water. Human body can tolerate a very high calcium concentration; however higher concentration of calcium is undesirable due to its contribution to hardness of water.

In unconsolidated formations of the coastal belt calcium content varies from 5 to 480 mg/l. where as in groundwater it is reported to be 10-600 mg/l (Sathi babu 1990, Subba Rao 1998).

STATIONS	PH		EC		TDS		CO_3^{-2}		HCO_3^-		CL^-		F		NO_3^-		NA^+		CA^+	
	05	10	05	10	05	10	05	10	05	10	05	10	05	10	05	10	05	10	05	10
CHUKKAV ANIPALEM	8.85	8.85	2700 High	2500 high	1700 High	1600 High	37	107 High	445 High	600 High	380 High	290 High	0.04 Low	0.04 Low	12	58 High	575 High	380 high	16.4 Low	135 High
MADHURA WADA	8.30 Low	9.20 High	1350	1200	900	750	7 Low	95	180 Low	150 Low	210	190	0.07	0.06	49 High	9	200	130	16.8	60
SHIVAJI PALEM	8.30 Low	8.70	1300	1000	800	600	10	30	180 Low	260	210	90	0.16 High	0.16 High	6	23	170	100	23.5 High	49
GOLLAPA LEM	8.40	7.65 Low	1050 Low	1200	700 Low	800	17	20 Low	200	180	170	220	0.07	0.08	7	7 Low	160 Low	210	16.8	30
GAJUWA KA	8.65 High	8.30	1050 Low	1250	700 Low	800	68 High	30	310	375	55 Low	130	0.1	0.12	22	7 Low	195	120	16.5	27 Low
PEDAGAN TYADA	8.50	8.5	1050 low	800 low	700 low	500 low	35	40	192	290	90	90 low	0.4 low	0.04	7	7 low	160	70 low	23	58

In unconsolidated formations of the coastal belt calcium content varies from 5 to 480 mg/l. where as in groundwater it is reported to be 10-600 mg/l (Sathi babu 1990, Subba Rao 1998). In the present study area stations Sivajipalem and Pedagantyada show high calcium content as 23 mg/l. the calcium values decreased from Sivajipalem to Gajuwaka and to Chukkavanipalem. In 2020 calcium content in study area increased largely to 150 mg/l where as it was 24 mg/l highest in 2015.

7. Conclusions

It is found from the results of spatial distribution of chemical parameters that all the values observed are within the permissible limits according to WHO except in Chukkavanipalem and Madhurawada. In Chukkavanipalem and Madhurawada the comparatively high values (Alkalinity, EC, TDS, Chlorides, Nitrates, Sodium and Calcium) may be due to the proximity of these villages near to the GVMC dumping yard from where the leachate pollutes the groundwater table and also due to chemical weathering of surrounding rocks from the hills. The high incidence of nitrates is may be due to the decay of organic debris and there by polluting the ground waters.

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