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Water Quality Mapping of Coastal Aquifers in Central Part of Penisular India Using Geographic Information System

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***Abstract**: The coastal tract of central Kerala, India comprises of Tertiary sediments and the phreatic aquifer here acts as an important source of drinking water. The most important climatic feature in the region is the monsoon, which has great influence on the quality of the groundwater. Water samples were collected during pre-monsoon and post-monsoon seasons from open wells and quality analyses including bacteriological studies were carried out. Groundwater quality maps were prepared based on GIS. The groundwater quality classification maps of the study area reflect the areal extent of each zone accurately and the variations in each parameter. Application of GIS further helped in delineating the potential potable groundwater zones of the area. The study revealed the inferior quality of groundwater in most of the coastal belt and also prevalence of E. coli in drinking water.*
***Keywords:** coastal aquifer, groundwater quality, GIS*

I. Introduction

Groundwater is one of the most important natural resources necessary for humanity. It is vital for the existence of mankind but faces acute shortage. Groundwater is that invisible supply of water that seeps beneath the surface of the ground, collects in natural underground reservoirs known as aquifers, and is the source of water in springs and wells. It provides almost a third of all freshwater on earth. It is threatened, however, by pollution, water mismanagement and exploding populations just as the world's remaining sources of freshwater are endangered. Groundwater resources are dynamic in nature as they grow with the expansion of irrigation activities, industrialization, urbanization etc. As it is the largest available source of fresh water lying beneath the ground it has become crucial not only for targeting of groundwater potential zones, but also monitoring and conserving this important resource. The expenditure and labour incurred in developing surface water is much more compared to groundwater, hence more emphasis is placed on the utilization of groundwater, which can be developed within a short time. Besides targeting groundwater potential zones it is also important to identify suitable sites for artificial recharge usage cycle. When the recharge rate cannot meet the demand for water, the balance is disturbed and hence calls for artificial recharge on a country wise basis (Sameena et. al. 2000). With the world's population explosion, increasing pollution and wide-scale mismanagement of freshwater supplies, a critical water shortage may occur within the next 50 years and hence counter-measures are essential. The slow penetration of pollutants has been called a "chemical time bomb." It threatens humankind. Another danger is that of saltwater intrusion: the displacement of fresh water in coastal aquifers by seawater. The problem is acute in some coastal regions and for small islands. India with its long coastline also faces this problem. Another important aspect is water quality. Improvements in existing strategies and the innovation of new techniques resting on a strong science and technology base will be needed to eliminate the pollution of surface and ground water resources, to improve water quality and to step up the recycling and re-use of water. Science and technology and training have also important roles to play in water resources development in general. Water is one of the most crucial elements in developmental planning. As the country prepares itself to enter the 21st century, efforts to develop, conserve, utilize and manage this important resource have to be guided by national perspectives.

The problems faced by the coastal zone of Kerala, where the present study area falls, are unique among all other states of India m mainly due to its high density of population and peculiar geological setting. The hydrogeological environment along this 560 km long coast with its backwater, lagoons, estuaries and barrier islands is complex in nature. The groundwater development along the coast has been increased many fold during the last four decades to meet the increase in requirements as a result of population growth, industrial development and change in lifestyle.

GIS is an effective tool for the integration of various data and hence has multifarious uses in geological studies. The GIS offers unique opportunities to integrate spatial data from different sources with the natural resources management models (Goodchild, 1993). GIS has been put to effective use in delineating groundwater potential zones in many earlier studies, Saraf and Choudhary,(1998); Sarkar et al., (2001); Khan and Moharana, (2002); Srinivasa et al., (2004). Application of GIS for groundwater resource assessment has also been reported by Sanjay K. Jain, Rathore, and Sharma, K.D. (2004). Edmund Merem and Yaw Twumasi, (2007) utilized GIS and Remote Sensing in the Conservation of Pearl River watershed in Mississippi. Asadi et al., (2007) evaluated the groundwater quality in the Municipal Corporation of Hyderabad, India using GIS. Ground-Water Quality Classification was done using GIS Contouring Methods for Cedar Valley, Iron County, Utah by Matt Butler, Janae Wallace, and Mike Lowe (2002). In the present study GIS has been utilized in deriving a comprehensive user friendly database of the area which can be used for the integrated water resources management of the area in future.

The city of Kochi falls in the study area (fig.1) and there are more than 20 major industries on the eastern outskirts and most of these industries depend on the river Periyar for their water requirements. Even then, there are a number of bore wells in the industrial areas. Effluents from these industries affect water quality and scope for further study in this field is vast. Another major problem of the area is the saline water intrusion through the river Periyar, especially when the daily flow rate through the river is less.

Groundwater is the main source of drinking water supply except in Kochi city and some major towns, and there is vast potential to develop groundwater in these areas for domestic and irrigation purposes. Proper development and management techniques are absolutely essential in the use of groundwater for agricultural purposes. The study area also offers a platform for a comparative analysis of the characteristics of the coastal area with the corresponding crystallines. The present study area has been selected as it provides immense scope to contribute to the existing knowledge and practices elsewhere in the coast.

The potential of Geographic Information Systems, although in use for some time, has not been fully exploited and this tool in conjunction with conventional techniques like geophysical prospecting offers tremendous scope for further contributing to the existing knowledge on groundwater.

II. Environmental Setting

The study area lies in the Ernakulam, Alleppey and Trichur districts of Kerala (India). Coastal tracts of Kerala are formed by several drainage systems. Thick pile of semi-consolidated and consolidated sediments from Tertiary to Recent age underlies it. These sediments comprise phreatic and confined aquifer systems. The corresponding hard rock terrain is encountered with laterites and underlain by the Precambrian metamorphic rocks. Supply of water from hard rock terrain is rather limited. This may be due to the small pore size, low degree of interconnectivity and low extent of weathering of the country rocks. The groundwater storage is mostly controlled by the thickness and hydrological properties of the weathered zone and the aquifer geometry.

III. Materials and methods

Sample collection was carried out following the well laid out procedures in Standard Methods for the Examination of Water and Waste Water (APHA 1985) Sampling was done covering both pre monsoon (April) and post monsoon (December) periods. Groundwater samples were collected from 41 dug wells from the study area. The well locations are shown in the location map, fig.1which also shows the coastal and crystalline belts separately. The well locations were selected in such a way that a comparative account of the coastal belt and the crystallines could be made. For bacteriological analysis the samples were collected aseptically in sterilized bottles and transported to the laboratory in icebox maintaining the temperature at 40 C. Coliform tests were done within 12 hours of sampling. The samples were analyzed following the standard procedure of water analysis (ISI, 1964), standard methods for the examination of water and waste water (Lenores et al., 1989) and standard analytical procedures for water analysis (Anon, 1998). GIS has been used to create spatial distribution of each element and also for its overlay analysis to generate zonation maps and spatial overlay maps. Zonation maps of each element, which are accurate and user friendly gives the areal extent of each element as also the variation between the two seasons (premonsoon and postmonsoon). We also calculated the land-surface-area percentage of each ground-water class category by building the polygon coverage in ArcInfo and calculating the corresponding areas. Spatial overlay maps were prepared to know the change in the zonation area of each element between the premonsoon and postmonsoon periods. Suitability maps of each element as per drinking water standards prescribed by WHO and the overlay showing variations between the two seasons were prepared. Range as per WHO standards were input in Arc Map and suitablity zones for each element delineated. Premonsoon and postmonsoon maps were overlain for suitability. An overlay operation of all the drinking water suitability maps resulted in the final water quality map. In the present study the water quality map has been prepared separately for the coastal alluvium and lateritic terrain which outcrops as the most important feature in the crystallines.

IV. Results and Discussion

The total concentration (TDS) of dissolved minerals in water is a general indication of its suitability for any particular purpose. Groundwater with a TDS value of less than 300 mg/l can be considered as excellent for drinking purpose according to WHO (1984). The TDS values for the crystallines fall well below 300mg/l. The value ranges from 26mg/l to 228mg/l. But in the case of the coastal belt, the values are pretty high in many wells and ranges from 80mg/l to 3425 mg/l. According to Venugopal (1998) and Aravindan (1999) the TDS values are higher during pre monsoon than the post monsoon season. In the present study also this feature is very evident. This can be attributed to the dilution resulting from the rainfall. Groundwater with TDS levels greater than 1500 mg/l is considered too saline to be a good source of drinking water. (Kelly and Wilson, 2003). Concentrations in 5 wells exceeded 500 mg/l. The well located at a place called Chellanam in the study area shows a high TDS value of 3424mg/l and here salt water intrusion has been reported earlier by many authors. This value is well above the I.S.I standard of 1500mg/l. Groundwater at 4 locations belongs to brackish water type as per the TDS classification (Twart et al. 1974). All these locations fall in the coastal belt. Rainwater is relatively pure distilled type water with very low TDS As rain water comes in contact with earth materials (soils, sediments and bedrock), soluble minerals are dissolved and carried in solution with the water during surface water flow or groundwater flow. Therefore TDS levels tend to increase in the downstream direction of surface flow and in the down gradient direction in the groundwater flow. From the analysis of EC and TDS values it can be safely inferred that wells in the crystalline terrain of the study area are much suitable for drinking purposes than those in the coastal belt. The drinking water suitability map for TDS is given in fig.2. From the overlay map it is evident that 70.47% remains in the suitability zone in both the seasons, 1.9 % changes from suitable to unsuitable and 9.04 % changes from unsuitable to suitable zone.

Bacteriological analysis carried out in the study area indicates the presence of e.coli in the groundwater in most of the locations. Coliforms are naturally present in the environment. E.coli comes only from human and animal faecal waste. During rainfall e.coli may be washed into rivers, streams or ground water. When this untreated water is used as a source of drinking water e.coli may end up in drinking water. The suitability map for e.coli in the study area is given in fig.3. The suitability range has been taken as low to medium e.coli and high e.coli has been taken as unsuitable. 24.88% of the area falls in the suitable range in both the seasons, 6.25% changes from suitable to unsuitable and 5.57% changes from unsuitable to suitable zone.

V. Conclusions

Although the present study aims to develop a comprehensive database of the coastal belt using GIS, taking into consideration prominent laterite outcrops in the study area, a drinking water quality map of the lateritic terrain was also prepared (shown in fig.5), along with the coastal area water quality map fig.4.These two drinking water suitablity maps were prepared by an overlay operation of all the quality parameters using GIS. The water quality maps act as clear pointers of the water quality in the study area and helps in a comparative analysis of the coastal belt with the crystallines. The present study reveals the inferior quality of groundwater in the coastal alluvium of the study area compared to the hard rock terrain. Analysis of the drinking water suitability map shows that 13.42% of the lateritic terrain falls in the good zone, 83.71% in the moderate and 2.88% in the poor water quality zone. From the drinking water suitability map of the coastal belt it is clear that 97.8% (888.9 Sq.Km) falls in the ‘poor’ zone. Only 2.2% (19.3 sq.km) of the alluvium falls in the ‘good’ zone. These zones are located away from the coast towards east and are also not influenced by tidal inlets. In the study area the flow is from east to west and thus increase in heavy precipitation events are likely to flush more contaminants and sediments into the coastal areas, degrading water quality. Where uptake of agricultural chemicals and other non-point sources could be aggravated, steps to limit water pollution are likely to be needed. In some regions, however, higher average flows may dilute pollutants and, thus, improve water quality. In the coastal regions where river flows are reduced, this could result in increased salinity. The quality of ground water in the coastal belt is being diminished by a variety of factors, including chemical contamination. Salt-water intrusion is another key ground-water quality concern in the coastal belt where changes in fresh-water flows and increases in sea level occur. Rampant sand mining in many river beds of the study area, especially Periyar leads to stagnation of tidal water which can lead to increased salinity in many parts of the study area.

VI. Future Outlook

The potential of Geographic Information Systems, although in use for some time, has not been fully exploited and this tool in conjunction with conventional techniques like geophysical prospecting offers tremendous scope for further contributing to the existing knowledge on groundwater. The integrated study using GIS is proved to be an efficient and scientific method for groundwater management. Hence it is recommended that integrated study using GIS may be taken up in the Cadastral scale so as to generate an accurate database.

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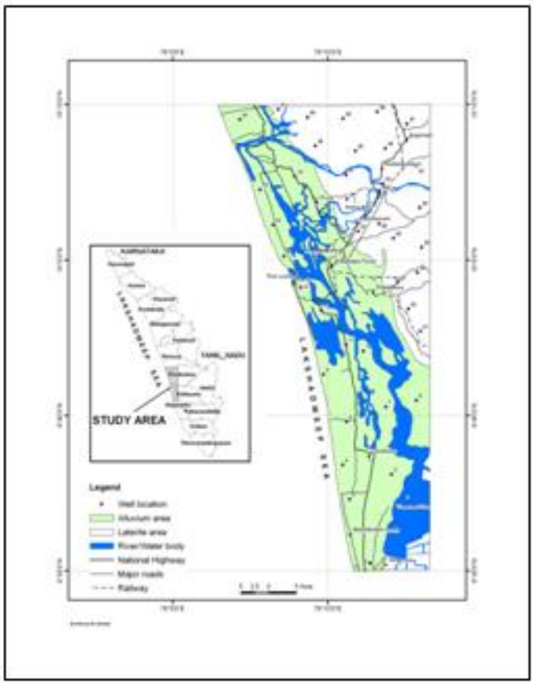

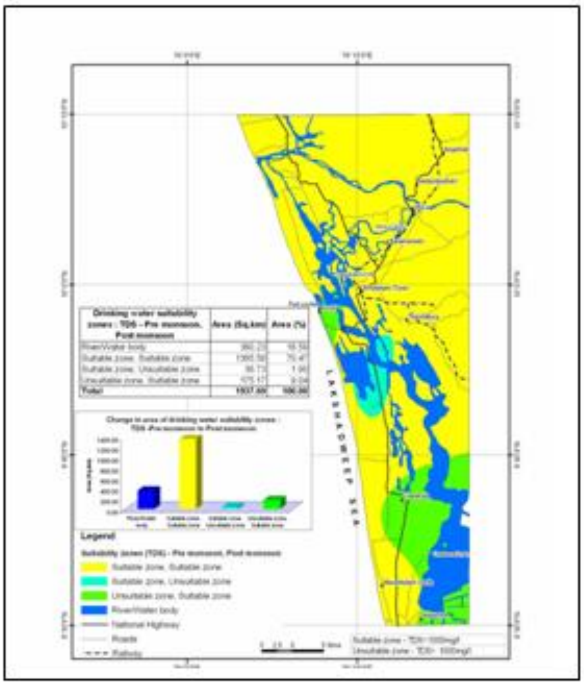

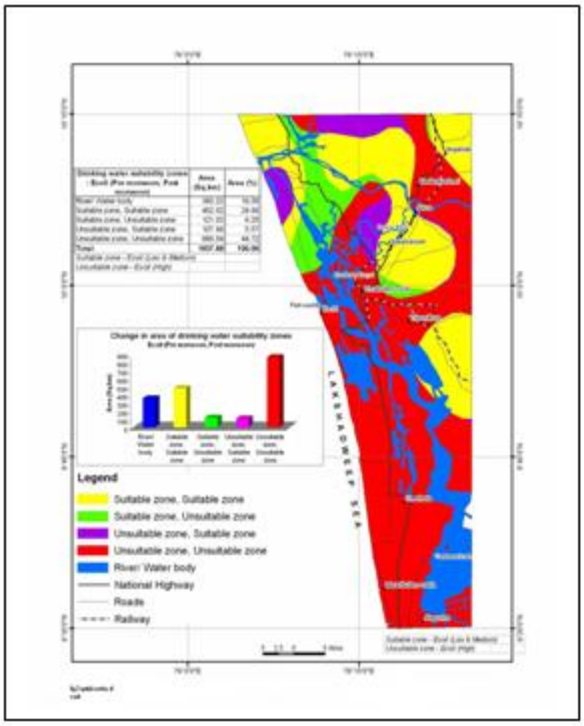
Legend
Suitable zone, Suitable zone
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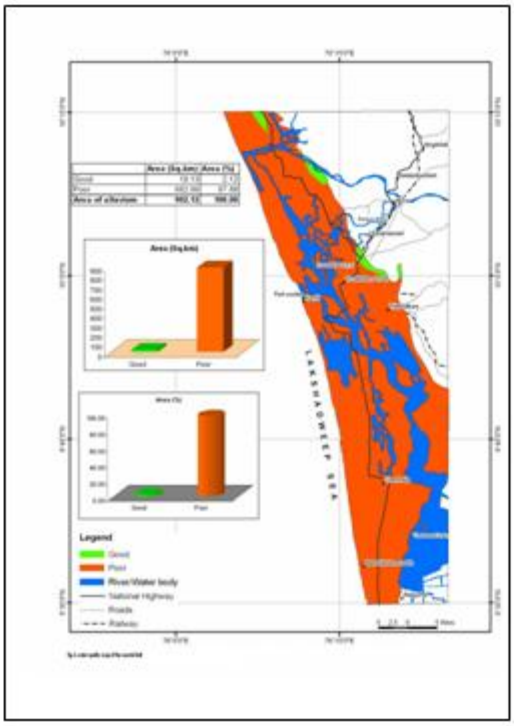
Unsuitable zone, Unsuitable zone
River/ Water body
National Highway
Roads
Railway
LAKSHADWEEP SEA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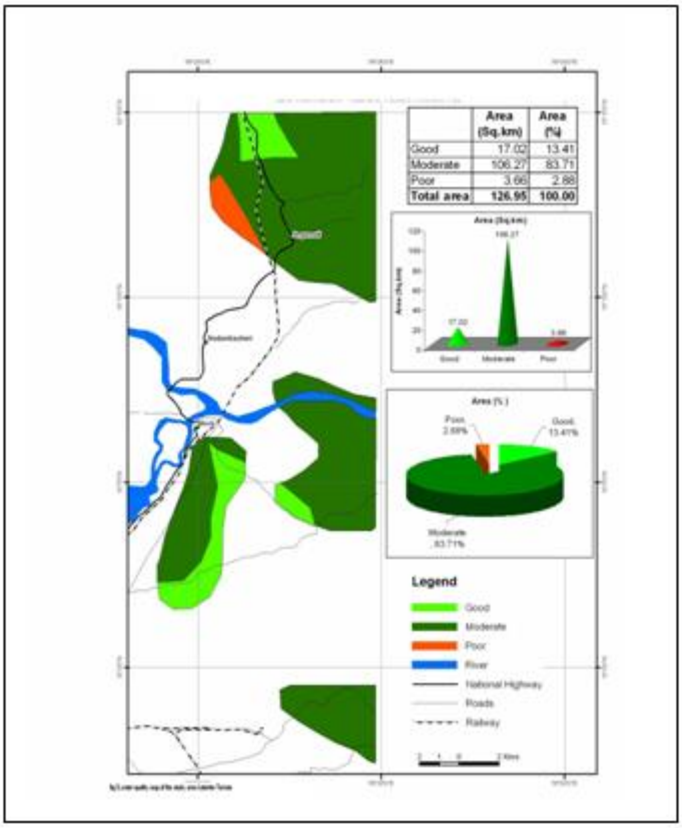
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Moderate 106.27 83.71
Poor 3.66 2.88
Total area 126.95 100.00
Legend
Good
Moderate
Poor
River
National Highway
Roads
Railway