5.0 RESULTS

5.1 Preparation of database for Identification of Isoline zones of Fluoride contaminations in Ground water

5.1.1 Introduction

Water is one of the major and essential resources. The surface water and groundwater resources of the country play a major role such as in agriculture, hydropower generation, livestock production, industrial activities, forestry, fisheries, navigation and recreational activities. According to National Water Policy, (2002) in the planning and operation of systems, water allocation priorities should be broadly as: (i) drinking water, (ii) irrigation, (iii) hydropower, (iv) ecology, (v) agro-industries and non-agricultural industries, and (vi) navigation.

The water sources or alarming by the climate change is expected to affect precipitation and water availability. Due to spatial and temporal variability in precipitation the country faces the problem of flood and drought syndrome. Overexploitation of groundwater is leading to reduction of low flows in the rivers, declining of the groundwater resources, and salt water intrusion in aquifers of the coastal areas. With rapid growing population and improving living standards the pressure on our water resources is increasing and per capita availability of water resources is reducing day by day. Among these the surface water and groundwater are in extinct level.

The quality of surface and groundwater resources is also deteriorating because of increasing pollutant loads from point and non-point sources. The ground water and surface waters have fluoride concentrations well below 0.5 mg/L, there are numerous situations, worldwide, where levels exceed the World Health Organization maximum acceptable concentration of 1.5 mg/L (WHO 2004). In a few cases elevated fluoride
levels can be attributed to groundwater contact with rocks that have particularly high fluorine contents. But most fluoride-rich waters are found in sandy aquifers where the rocks have fluorine levels that are typical of background—a few hundred ppm at most.

Studies on the structural, petrological and mineralogical properties of the Eastern ghat ranges of India have revealed the presence of fluoride bearing minerals (Rao, 1976; Rao et al. 1979, 1980; Sriramdas and Rao, 1979). While reviewing the past for this study shows about the occurrence of fluoride in the water resources of the country, it was realized that a detailed investigation on the occurrence and behaviour of fluoride in specific geological settings would provide valuable information to design effective mitigation techniques.

The problem of ground water pollution in several parts of the country has become very acute and it demands immediate and detailed identification and control measures to save available or existing ground water resources of the country. Fluoride levels in India’s ground water vary from 1 to 60 mg/l. The problem of fluorosis is scattered across the state of Tamil Nadu. Fluoride is one of the critical chemical parameters, which influences the quality of ground water in most of the districts in Tamil Nadu.

As the traditional sources like wells have dried up people in this area have become increasingly dependent on bore wells that tap ground water. In Dharmapuri district, majority of the people in the rural areas depend on ground water for their drinking purposes. The natural occurrence of fluoride in water is generally through the direct contact with fluoride containing minerals in ground water resources. Fluoride compounds, widely used in several industries such as ceramics, insecticides, chemicals and fertilizers also lead to the contamination of air, water and soil in the vicinity of these areas. The combustion of coal can also introduce fluoride in the environment. Fluoride has only one oxidation state (F -). Fluorite (CaF2) is the principal mineral of fluorine. The dissolution of fluorite takes place in the following way.
CaF$_2$ Ca$^{2+}$ + 2F$^-$

The solubility constant for the reaction is \( \log K_{\text{Fluorite}} = \log [\text{Ca}^{2+}] + 2 \log [\text{F}^-] = -10.57 \)

The Ca$^{2+}$ vs F$^-$ plot could also be used to understand and apply the Principle behind the use of gypsum (CaSO$_4$2H$_2$O) or dead burnt magnesite (MgCO$_3$), or combinations of alum and lime to defluoridate the fluorous waters. Gypsum is more soluble than fluorite.

CaSO$_4$ Ca$^{2+}$SO$_4$

5.1.2 Data Preparation

The main aim of this chapter is to detect fluoride content from the collected samples of ground water sources of Dharmapuri district. The data which has been collected in different block for the year 2006 to 2008. The total number of sampling locations is 417 from five taluks. Under the five taluk expect there are eight blocks. Except Nallampalli the remaining blocks namely Dharmapuri, Harur, Morappur, Palacode, Pappireddipatti, Karimangalam and Pennagaram in Dharmapuri district are taken for our study. The block wise population, area and the overall recorded primary and secondary of ground water sampling data for identification of fluoride contaminations for the month of January and May are shown in the Table 5.1.1.

5.1.3 Methodology

The study will estimate F concentrations and variability in Dharmapuri district, of TamilNadu has been identified through different area based samples in each of seven taluk from five blocks of ground water. This multi-center effort has collected more than 417 samples from 37 locations for three years from 2006 to 2008. The primary data collected from different sources of well for three years are collected as for the seasonal studies by (post-monsoon and pre-monsoon) are in January 108 and May 95. The secondary data were collected from the reviews of the water quality samples are collected.
for three years which has been handled by TWAD board (post-monsoon and pre-monsoon) are in January 134 and May 80. The primary and secondary data has been intersecting for the similar location to exclude the number of sampling locations at the source level for the further analysis which has presented as in the Table 5.1.2. Both the samples (n=307) have been collected and prepared for the analysis. The physio-chemical characteristics study has been carried out for the pattern to identify better correlations of hazard risk of the study area. The primary analysis of the physio-chemical characteristics has to be analyzed and the detail summary statistics of the data have been identify for the parameters such as pH, TDS, T.Alk, TH, Ca and Na.

Further the analysis has been extended to identify the risk zones of fluoride contaminations have been analyzed by using SPADNS for the collected of data Post monsoon (January) and Pre monsoon (May) of January-May 2006, January-May 2007, January-May 2008. Based on the primary and secondary data of the fluoride contaminated water sources of the area are to be mapped for the better visualization of the risk zones. This, through publicity, will help people to avoid using water sources, contaminated with fluoride, for drinking purpose. Cases of dental fluorosis due to the use of water contamination with fluoride have been reported from the primary health centers of the area.

From the ground water chemistry data are collected from TWAD board for 36 well sample locations in Dharmapuri district, the fluoride availability in ground water in mg/l has been used for the preparation of fluoride contamination map with the help of ArcGIS software. Following the monsoon seasons of Tamil Nadu, it is intended to prepare these fluoride distribution maps for pre monsoon (May) and post monsoon (January) periods for three years (2006, 2007 and 2008). In ArcGIS, isoline maps for the fluoride distribution during the above said six periods have been prepared using contour option after the generation of raster image of the same using the IDW (Inverse Distance weighted) module.
To extent for the better spatial pattern in correlation of the physio-chemical study and the geographical pattern of analysis has been carried out to find the linkages between the associations factors are to be identified. The geographical study has been identified for the following parameters such as, the identification of Groundwater level (Pre-monsoon), Groundwater table, TDS, Sodium, Lithology, Lineament, slope, geomorphology, drainages network tanks, tanks and reservoir. The geographical study area has been identified and further plotted as maps in this section I and further this source of maps are to be analyzed in the subsequent section II to V.

5.1.4 Preliminary Preparation of Geographical Base Map

Taluk map of the study area was prepared from the Survey of India topography sheets and digitized using ArcGIS software. The preliminary preparation of the digitized Map 5.1.1 which shown eight taluks in the Dharmapuri district such as Dharmapuri, Harur, Karimangalam, Morappur, Nallampalli, Palacode, Pappedipatti and Pennagaram.

5.1.4.1 Fluoride

The ground water level data collected from TWAD board is averaged for post monsoon (January) and pre monsoon (May) periods and is plotted, rasterized using IDW (Inverse Distance Weighed) method was applied and the output were presented in the Map 5.1.2. From the Map 5.1.2 shows Fluoride in Ground water for the Post and Pre-Monsoon of the study period which clearly obtained a pattern for three years during 2006, 2007 and 2008, it is clear that there are some patch of areas where fluoride content seems to be less in Ground water were shown on the colour pattern as, (Yellow, Orange and light Red shades) falling in western half of the study area in general and also in a small strip of land aligned towards North East (NE) and South West (SW) in the middle of Dharmapuri district.
5.1.4.2 Groundwater level

The ground water level data collected from TWAD board is averaged for post monsoon (January) and pre monsoon (May) periods and is plotted, rasterized using IDW (Inverse Distance Weighted) method was applied and the output were presented in the Map 5.1.3 and Map 5.1.4. Map 5.1.3 which presented for the Post-Monsoon Average Ground Water Level for the Year 2006 – 2008 and the Map 5.1.4 shows the Pre-Monsoon Average Ground Water Level for the Year 2006 – 2008.

From the Map 5.1.3 clearly visualize the post monsoon ground water level varies from (7.4 to 10.3m) for the entire Dharmapuri district, particularly in north of Pennagaram, Nallampalli, south of Palacode and Harur which are having (shallow) ground water level ranging from (8.0m to 8.4m). On the contrary south of Nallampalli, south east of Morappur, east of Palacode and west of Karimangalam are having post monsoon high (deeper) ground water level ranging from (9.1m to 10.3m).

The presented Map 5.1.4 shows the pre monsoon ground water level varies from (7.7m to 12.5m) for the entire Dharmapuri district particularly in north of Pennagaram, and Nallampalli, south of Palacode and Harur which are having pre monsoon low (shallow) ground water level ranging from (9.4m to 9.9m). On the contrary, the south of Nallampalli, south east of Morappur, east of Palacode and west of Karimangalam are having pre monsoon high (deeper) ground water level ranging from (11.1m to 12.5m).

5.1.4.3 Total Dissolved Solids

Keeping the natural fact that the increased availability of TDS in groundwater may indirectly indicate the increased availability of dissolved fluoride in fluoride source rock areas, the total dissolved solids maps have also been prepared. From the secondary data collected from TWAD Board on groundwater quality, the data on total dissolved solids in ground water have also been entered into computer and isolines are generated.
using IDW method in ARCGIS and then mapped in the similar way followed for the preparation of fluoride maps. The total dissolved solids availability in groundwater for the same six periods so prepared are shown in the (Map 5.1.5 to Map 5.1.10).

5.1.4.4 Sodium

The research study conducted by Shahid Naseem and Tahir Rafique (2008) shows that there is strong relation between sodium and fluoride availability in ground water. Further their study shows that the increased amount of sodium in ground water represents high weathering in and around the area. Hence the sodium availability in ground water for different seasons was plotted using spatial analyst tool in Arc GIS are shown in the Map 5.1.11).

5.1.4.5 Lithology

The lithology of an area helps us to understand the aerial distribution of different rock types, their orientation and their physical and chemical properties. The lithology map is digitized using the geology map prepared by geological survey of India for the entire Dharmapuri district. The study area contains approximately 50% of charnokites, 20% of Epitode Hornblende Gneiss and 20 %of Pink Migmatite and 10% of other rocks, including Syenite, Grantoid Gneiss, Hornblende Biotite Gneiss, etc. Amongst them, Charnokites and Gneiss are highly prone for physical weathering of rocks. There are certain rocks found to be long, slender and linear in fashion. Moreover some of them are looking like curved snakes and others are that indicates straight are presented as a map in (Map 5.1.12).

5.1.4.6 Lineament

The long and linear earth surface fractures extending a few kilometers to hundreds of kilometers are called as lineaments. These lineaments can be mapped with the help of photographs taken from high altitude (aerial photographs) or satellite images. In order to
easily delineate the lineaments the shaded relief maps showing ridges and valleys along hills has been used. In the ASTER satellite data (Map 5.1.13) having terrain elevation is used to prepare shaded relief maps. Shaded relief maps with varying directions of light source have been used for the interpretation of lineaments in the study area (Map 5.1.14).

The lineaments of Dharmapuri district are interpreted using LANDSAT Thematic Mapper FCC (False Color Composite) (Map 5.1.15) by tracing the vegetation linearities in hills and plains, soil tonal linearities, straight drainages and valleys, etc. These lineaments are important controlling parameter for rock weathering, fluoride disintegration, dissemination and movement in ground water. The lineament map has been prepared in ArcGIS (Map 5.1.16) and has got three major trending lineaments such as 1. North East-South West (NE-SW) to North North East-South South West (NNE-SSW) from 2. North North West –South South East (NNW-SSE) to North West and South East (NW-SE), 3. East-West (E-W).

5.1.4.7 Slope

The slope of the terrain need to be understood for the study of ground water recharge and the movement of ground water below the ground level and level of weathering, sediment and deposition transport, all are due to gravity. The slope map has been prepared with the input of ASTER satellite data (Advanced space borne thermal emission and reflection radiometer) showing terrain elevation for the study area using surface analysis option available in spatial analyst tool of ArcGIS. The slope range has been classified with seven classes, based on IMSD (Integrated Mission for Sustainable Development) NRSC classification as follows (i) Nearly level, (ii) Very gently sloping (iii) Gently sloping (iv) Moderately sloping (v) Strongly sloping (vi) Moderately steep to steep sloping and (vii) Very steep sloping is shown in the Map 5.1.17.
5.1.4.8 Geomorphology

To understand the ground water recharge and to plan for artificial recharge scheme the geomorphology of terrain need to be properly studied. The geomorphology map collected from TWAD Board has been used and the same is updated with the help of Landsat FCC image and ASTER Data, by preparing a FCC wrapped digital elevation model was prepared from the Map 5.1.15 and cross-checked by conducting a field check, geomorphology map has been prepared and a digitized map presented in the Map 5.1.18.

5.1.4.9 Drainage Network and Tanks

Drainage map is useful for the planning of artificial recharges schemes which will dilute the pollutants in ground water especially in our study. Drainage map was prepared using survey of India topographic sheet for the study area is presented in the Map 5.1.19. Tanks and reservoirs are surface water resources especially in the areas of fluoride source rock available in sub surface. These surface water resources are very good alternative for drinking water. With the help of survey of India toposheets and satellite FCC data, all the tanks are mapped and digital images have been generated and presented as a Map 5.1.20.

5.1.5 Results

A description of the study protocol (database generation) and the results of the analysis are presented as in the Table 5.1.3 and Table 5.1.4. Major elements of water geochemistry are analyzed and the results are shown in the Table 5.1.3 for the post-monsoon of January and Table 5.1.4 for the pre-monsoon of May. The detailed summary statistics of the result has been prepared from the analyzed parameters such as pH, TDS, T.Alk, TH, Ca, Na and Fl are shown as aforementioned Table 5.1.3 and 5.1.4. The majority of the ground waters sampled, are dominated by fluoride, although a few of other parameters pH, TDS, T.Alk, TH, Ca, Na has exceed the levels of the standard WHO, BIS are presented briefly in the Table 5.1.5. From the Table 5.1.5 the results are detailed below:
The level of pH which finds randomly from the sample at the maximum level 7.6 to 8.1 which shows the exceed level for drinking. The level of pH which shown in the post-monsoon and the pre-monsoon are at the level of the standard and the maximum level 8.1 which shows in year of pre-monsoon May 2006.

The total dissolved solids level are find mostly very high from the samples. The maximum levels of TDS are very high which carried out 2077 mg/l in 2007. The study of TDS from the sample of different taluks which shows high except Harur in post and pre-monsoon are shown below the limit and the remaining taluks of different period which shown very high which exceed of WHO standard.

Total alkalinity which exceed the level of WHO in each taluks except Harur and the maximum value which has find on the sample in the taluk of Pennagaram pre-monsoon of May is 588 mg/l in the year 2007. On that particular pre-monsoon of 2006 the minimum value which shows the level of fluoride are 340 mg/l and the remaining samples of the taluk are shown below the level of standard.

The levels of total hardness are found very high on the study period especially in Palacode 780 mg/l in 2007 of pre-monsoon and the remaining taluks are shows randomly higher except Harur in pre-monsoon remaining taluks shows above the limit of the standard.

Aquifers, but are elevated in some samples. Calcium and sodium are the major cations. Some of the samples are strongly dominated by sodium. Most of the samples of (post-monsoon and pre-monsoon) January and May in seven taluk of Dharmapuri district, Dharmapuri, Karimangalam, Palacode, Pappireddipatti, Harur, Pennagaram and Morappur are the higher level of calcium than the limit of BIS and WHO expect the Harur in (pre-monsoon) May which shown below the limit. In Palacode the samples have maximum calcium levels ranging up to 180 mg/L and in Pappireddipatti maximum sodium levels ranging up to 500 mg/L, and there is a weak negative correlation between these variables. The level of sodium is below the limit in Harur, throughout of the entire study period.
There is a positive and negative correlation between pH, TDS, T.Alk, TH, Ca and Na. The samples with sodium levels above 500 mg/L have pH below the limit, while almost all samples with sodium levels below the limit have pH less greater than 7.5. There is a positive correlation between TDS, T.Alk, TH and calcium. Most of the samples with pH above 7.5 have calcium levels above and below the limit of the standard there is positive and negative correlations have identified clearly.

There is strong positive correlation between fluoride and pH is found from the study in each taluks of our study period. The maximum level of fluoride has seen on the taluk of Karimangalam which shows 2mg/l on this taluk there is a negative correlation has been identified. Trace element water geochemistry there is a strong correlation between pH and fluoride (Figure 5.1.1). A positive pH-fluoride relationship has been observed in many other taluks with elevated groundwater fluoride levels, especially areas with rocky sandstone aquifers.

**Figure 5.1.1 The Correlation between pH and Fluoride**

The fluoride availability in ground water varies from 0 to 2mg/l, and it is clearly observed that the distribution pattern also varies from place to place and from period to period. The positive strong correlation between pH and fluoride has been further
analyzed for the Groundwater level (Pre-monsoon), Groundwater table, TDS, Sodium, Lithology, Lineament, slope, geomorphology, drainages network tanks, tanks and reservoir.

As the study area is surrounded by a series of hills in the east, south and west, the slope is ranging from 17 to 67% and it covers 50% of the entire study area. The remaining 50% of the study area is having 0-17% slope are shown on the afore-presented (Map 5.1.16).

From the detailed Map 5.1.17 says that the denudational hills and pediments in valleys are covering 50% of the study areas are identified. The remaining part of the study area covered by plains which are having buried pediments of three classes such as Shallow, Medium and Deep.

From the Map 5.1.19 which shows the clear pattern of tanks and reservoirs of the study area. The tanks are useful for the planning of artificial recharge.

5.1.6 Conclusion

Elevated levels of fluoride in ground waters from a soils or weathering, rock, Deposition of atmospheric volcanic particles, Runoff and infiltration of chemical fertilizers in agricultural areas, Septic and sewage treatment system discharges in communities with fluoridated water supplies, Liquid waste from industrial sources, sandstone and mudstone aquifer system on Dharamapuri district are largely a result of base-exchange softening and the consequent high pH levels. It is evident that this process may be responsible for elevated fluoride levels in sandy aquifers around the world.

The result shows that a pH of 8.1 in Dharamapuri taluks is identified from the result of the (pre-monsoon) May in 2006. Hence, we suggest that the pH level which has been exceeding to 8.5 as per the limit is to be used a rapid screening threshold to predict water-quality risks associated with fluoride in groundwater.
From the above results it is clear that the ground water from most parts of study area has quality problems like, high fluoride content. People have to be advised to avoid these sources, as use of these may result in dental fluorosis. To avoid cases of fluorosis like, at low concentrations fluoride can reduce the risk of dental cavities, Higher amounts of fluoride can cause dental fluorosis, Even higher intakes of fluoride taken over a long period of time can result in changes to bone, a condition known as skeletal fluorosis, Cause joint pain, restriction of mobility and Possibly increase the risk of some bone fractures from this study area of Dharmapuri. People have to be advised to use surface water especially river water supply schemes as far as possible. Serious attempts are needed to develop community based de-fluoridation systems as a permanent solution to the problem.
5.2 Identification of Spatial pattern of Fluoride and TDS Contamination in Groundwater

5.2.1 Introduction

The quality of groundwater depends on a large number of individual hydrological, physical, chemical and biological factors. Generally higher proportions of dissolved constituents are found in groundwater than in surface water because of greater interaction of ground water with various materials in geologic strata. Pollutants are being added to the groundwater system through human activities and natural processes. Solid waste from industrial units is being dumped near the factories, and is subjected to reaction with percolating rainwater and reaches the groundwater level. The percolating water picks up a large amount of dissolved constituents and reaches the aquifer system and contaminates the groundwater.

Water dissolves the minerals present in the strata of soil it filters through in the case of ground water and, in the case of surface water, the minerals present in the soil over which it flows (rivers/streams) or over which it stands (lakes, ponds, reservoirs). The dissolved minerals in water are commonly referred to as Total Dissolved Solids (TDS).

The water used for drinking purpose should be free from any toxic elements, living and nonliving organism and excessive amount of minerals that may be hazardous to health. Some of the heavy metals are extremely essential to humans, for example, Cobalt, Copper, etc., but large quantities of them may cause physiological disorders. The contamination of groundwater by heavy metals has assumed great significance during recent years due to their toxicity and accumulative behavior. These elements, contrary to most pollutants, are not biodegradable and undergo a global eco-biological cycle in which natural waters are the main pathways. The determination of the concentration levels of heavy metals in these waters, as well as the elucidation of the chemical forms in which they appear is a prime target in environmental research today.
A vast majority of groundwater quality problems are caused by contamination, over-exploitation, or combination of the two. Most groundwater quality problems are difficult to detect & hard to resolve. The solutions are usually very expensive, time consuming and not always effective. An alarming picture is beginning to emerge in many parts of our country. Groundwater quality is slowly but surely declining everywhere. Groundwater pollution is intrinsically difficult to detect, since problem may well be concealed below the surface & monitoring is costly, time consuming and somewhat hit-or-miss by nature. Many times the contamination is not detected until obnoxious substances actually appear in water used, by which time the pollution has often dispersed over a large area.

The problem of groundwater pollution in several parts of the country has become so acute that unless urgent steps for abatement are taken, groundwater resources may be damaged.

Some types of dissolved solids are specifically dangerous even in low quantities. This includes arsenic, fluorides and nitrates. There are particular standards for the acceptable amounts of these elements in water and in some cases like fluoride; there is some disagreement as to what constitutes safe levels.

Leaving aside the specific harmful chemicals fluoride and arsenic, drinking water for human beings should contain some level of minerals (TDS), but these levels should not be excessive.

5.2.2 Data Preparation

Total 417 ground water samples are collected from 37 locations of Dharmapuri district of two season post and pre-monsoon, January and May for the study period of three years 2006 to 2008 as already mentioned in the Table 5.1.1. From the samples, the primary source of data which has been collected by the individual locations is 203 in two seasons for three years and similar to the secondary data which has collected from
TWAD board for the locations are 214. The overall samples of the collected data both from primary and secondary source are 417. From the overall data the similar locations of primary and secondary are avoided to take further study. According to that the similar data were omitted and the remaining data of 307 samples Table 5.1.2 are taking into account for the better study of spatial pattern of fluoride and TDS contamination in ground water.

5.2.3 Methodology

The samples from Dharmapuri district of each locations were collected during post-monsoon (January 2006 - 2008) pre-monsoon (May 2006 - 2008) seasons from various abstraction sources at various depths covering extensively populated area, commercial, industrial, agricultural and residential colonies so as to obtain a good aerial and vertical representation and preserved by adding an appropriate reagents as and when required. The similar sample collection methodology has adopted for this section-II which are clearly explained in the previous section-I.

The standard methods (APHA, 1995) adopted for each parametric analysis of groundwater samples. The details of sampling locations and source and depth wise distribution are given at each section city wise in the following chapter.

5.2.4 Results

5.2.4.1 Generation of classified GIS Images showing Fluoride risk and safe zones

According to the BIS, 1.0mg/l is the potable limit for fluoride in ground water. The presence of high fluoride concentration in ground water is varying depending upon weathering and recharge of the terrain. In order to understand the pattern of high fluoride zone for different seasons such as pre monsoon and post monsoon all the six independent GIS layers showing fluoride availability in ground water 2006 to 2008 (Map 5.2.1) were classified based on the BIS standard as mentioned above. The areas above 1mg/l of
fluoride availability has been labeled as risk zones (represented with red colour in map) and the areas below 1mg/l as safe zones (green colour) in all the six fluoride layers using in dissolve option available in GIS (Map 5.2.1(i) to Map 5.2.1(vi))

5. 2.4.2 GIS Integration and determination of Fluoride pattern

After the classification of fluoride risk and safe zones for all the six periods, they have been integrated in five levels using union option available in analysis tool of Arc GIS. The five levels of integration is shown below: (Map5.2.2 to Map 5.2.6)

**Level 1:** GIS images showing Fl Risk & Safe zone Jan.2006 + Fl Risk & Safe zone May.2006 = **Output-1**

**Level 2:** Output-1 + Fl Risk & Safe zone Jan.2007 = **Output-2**

**Level 3:** Output-2 + Fl Risk & Safe zone May.2007 = **Output-3**

**Level 4:** Output-3 + Fl Risk & Safe zone Jan.2008 = **Output-4**

**Level 5:** Output-4 + Fl Risk & Safe zone May.2008 = **Output-5**

i.e., Final integrated Output image.

The resultant fifth level image may have 64 numbers of maximum possible classes with so many finely divided polygons. But the final image has got 43 classes with 70 Number of polygons and the same image after dissolving; it has got 43 numbers of polygons (Map 5.2.7)

i) Spatial pattern of fluoride in ground water (2006 to 2008)

The final integrated image named level five was dissolved to avoid complexities in duplication of similar classed polygons. The first class shown in (Map 5.2.8) is labeled as ‘RRRRRR’ and displayed in dark brown colour that means all the dark brown colored polygons have got high fluoride content (>1mg/l) throughout the six monsoon period of three years (2006 to 2008) Each letter either ‘R or S’ represents high Risk ness in the
particular monsoon period i.e., the first letter stands for Riskness during January 2006 and second ‘R’ stands for riskness during May 2006, third ‘R’ stands for Riskness during January 2007, Fourth ‘R’ stands for Riskness during May 2007, Fifth ‘R’ stands for Riskness during January 2008 and sixth ‘R’ stands for Riskness during May 2008. This is from the legend one can understand the areas of repeated pattern of fluoride risk and safe zones occurred during six monsoon seasons. If the letter ‘R’ is repeated many times (up to 6 times) then the same is understood as very high risk zones. Accordingly, Very high, High, Moderate, Low, Very low risk zones are reclassified based on the number of occurrences of riskness (‘RorS’).

5.2.4.3 Generation of classified GIS images showing TDS risk and safe zones

According to the BIS, 300mg/l is the potable limit for Total Dissolved Solids in ground water. The presence of high TDS concentration in ground water is depending upon weathering and recharge of the terrain. In order to understand the pattern of high TDS zone for different seasons such as pre monsoon and post monsoon all the six independent GIS layers showing TDS availability in ground water 2006-2008 (Map 5.1.5 to Map 5.1.10) were classified based on the basis of BIS standard as mentioned above.

The areas above 300mg/l of TDS availability has been labeled as risk zones (represented with red colour in map) and the areas below 300mg/l as safe zones (green colour) in all the six fluoride layers using in dissolve option available in GIS (Map 5.2.9 (i) to Map 5.2.9(vi))

5.2.4.4 GIS Integration and Determination of TDS pattern

After the classification of TDS risk and safe zones for all the six periods, they have been integrated in five levels using union option available in analysis tool of ArcGIS. The five levels of integration is shown below: (Map5.2.10 (i) to Map 5.2.10(vi)
**Level 1:** GIS images showing TDS Risk & Safe zone Jan.2006 +TDS Risk & Safe zone May.2006 = **Output-1**

**Level 2:** Output-1 + TDS Risk & Safe zone Jan.2007 = **Output-2**

**Level 3:** Output-2 + TDS Risk & Safe zone May.2007 = **Output-3**

**Level 4:** Output-3 + TDS Risk & Safe zone Jan.2008 = **Output-4**

**Level 5:** Output-4 +TDS Risk & Safe zone May.2008 = **Output-5**

i.e., Final integrated Output image

The resultant fifth level / final image has got 19 classes with 66 Number of polygons and the same image after dissolving has got 19 numbers of polygons

The final integrated image ‘level five’ was dissolved to avoid complexities in duplication of similar classed polygons. The first class shown in (Map 5.2.11) is labeled as ‘RRRRRR’ and displayed in dark brown colour that means all the dark brown colored polygons have got high TDS content (>300mg/l) throughout the six monsoon period of three years (2006-2008) Each letter either ‘R or S’ represents Risk or Safe TDS level in groundwater during the particular monsoon period. i.e., the first letter stands for Risk ness during January 2006 and second letter stands for risk ness during May 2006, third letter stands for Risk ness during January 2007, Fourth letter stands for Risk ness during May 2007, Fifth letter stands for Risk ness during January 2008 and sixth letter stands for Risk ness during May 2008. From the legend one can understand the areas of very high, high, moderate, low and very low TDS zones recorded through the groundwater chemistry data collected during the three consecutive years from 2006 -08, i.e., for six monsoon seasons. If the letter ‘R’ is repeated many times (up to 6 times) then the same is understood as very high risk zones. Accordingly, Very high, High, Moderate, risk zones are reclassified based on
the number of occurrences of riskness (‘R or S’). Entire Dharamapuri district has got higher concentrations of Total Dissolved Solids in groundwater and thus the classes such as Low risk, Very Low risk TDS zones are not resulted in this GIS analysis.

5.2.4.5 Establishing relationship between Fluoride and TDS in Ground water

After the preparation of digital GIS image showing the spatial distribution pattern of TDS in groundwater for the period of 2006 to 2008, it is intended to bring out the spatial relationship between fluoride contamination pattern and TDS pattern in groundwater. In order to do so, these two GIS layers (Map5.2.8 and Map5.2.11) have been integrated using union option in ArcGIS. The resultant integrated output is shown in (Map 5.2.12) it shows that there is maximum correlation / coincidence between TDS high in groundwater and fluoride contamination. Table 5.2.1 and the level of TDS risk is shown as a Figure 5.2.1. In order to bring out the aerial coverage of these coinciding zones, the area of each class falling in the study area has been worked out and tabulated as shown in Table 5.2.2 and the fluoride risk area are classified and present as a Figure 5.2.2 From the aerial distribution of fluoride contamination as well as TDS high zones in groundwater, it is clearly determined that where ever total dissolved solids in groundwater is higher in concentration, then the fluoride availability is also high in groundwater.

Table 5.2.1 Relationship between TDS and Fluoride in Groundwater

<table>
<thead>
<tr>
<th>TDS CLASS</th>
<th>FL CLASS</th>
<th>TDS +FL PATTERN</th>
<th>AREA SQ.KM</th>
</tr>
</thead>
<tbody>
<tr>
<td>Very High Risk</td>
<td>Moderate risk</td>
<td>TDS Very High Risk +FL Moderate Risk</td>
<td>641.6413</td>
</tr>
<tr>
<td>Very High Risk</td>
<td>Very high risk</td>
<td>TDS Very High Risk +FL Very high Risk</td>
<td>1181.359</td>
</tr>
<tr>
<td>Very High Risk</td>
<td>High risk</td>
<td>TDS Very High Risk +FL High Risk</td>
<td>865.0286</td>
</tr>
<tr>
<td>High Risk</td>
<td>High risk</td>
<td>TDS High Risk +FL High Risk</td>
<td>80.19647</td>
</tr>
<tr>
<td>High Risk</td>
<td>Moderate risk</td>
<td>TDS High Risk +FL Moderate Risk</td>
<td>41.57998</td>
</tr>
<tr>
<td>High Risk</td>
<td>Very high risk</td>
<td>TDS High Risk +FL Very high Risk</td>
<td>33.6984</td>
</tr>
<tr>
<td>Moderate Risk</td>
<td>High risk</td>
<td>TDS Moderate Risk+ FL High-Risk</td>
<td>3.539324</td>
</tr>
<tr>
<td>Moderate Risk</td>
<td>Moderate risk</td>
<td>TDS Moderate Risk+ FL Moderate Risk</td>
<td>2.667005</td>
</tr>
</tbody>
</table>
Figure 5.2.1 The figure shows the level of TDS risk level

![Diagram showing TDS risk level]

Table 5.2.2 The fluoride risk area in Ground water

<table>
<thead>
<tr>
<th>FL RISK CLASS</th>
<th>AREA SQ.KM</th>
</tr>
</thead>
<tbody>
<tr>
<td>VERY HIGH RISK</td>
<td>1780.480507</td>
</tr>
<tr>
<td>HIGH RISK</td>
<td>1388.140583</td>
</tr>
<tr>
<td>MODERATE RISK</td>
<td>1011.981242</td>
</tr>
</tbody>
</table>

Figure 5.2.2 The figure shows the level of Fluoride risk

![Diagram showing Fluoride risk level]
5.2.5 Conclusion

The fluoride concentration in ground water in this area varies between 0-3.5 mg/l during January 2006 up to May 2008. Hence, the fluoride distribution pattern over a period of three consecutive years has been derived using GIS (Map 5.2.5). It shows that the area of southwestern part and eastern half of Dharmapuri district has got Very high and High fluoride contamination in groundwater during these three years.

Fluoride and TDS are having very good correlation in their level of dissolution / concentration in ground water contamination. Thus, a similar GIS layer showing TDS concentration pattern has been prepared and presented as a Map. 5.2.11. Similar like that for fluoride concentration pattern in Dharmapuri district are also prepared. Though it shows that almost entire area of Dharmapuri district has got very high concentration of TDS, but there are some pockets of Moderate TDS concentration zones seen in western half of the study area (relatively covering little more aerial coverage than the moderate TDS pockets seen in the eastern half). The relationships between fluoride distribution pattern and TDS pattern have also been brought out using GIS integration technique. It shows that there is very high direct correlation is existing between fluoride and TDS concentration pattern in Dharmapuri districts.
5.3 Identification of Source Rock and Fluoride Dissemination in Ground Water

5.3.1 Introduction

Fluoride is one of the contaminants in groundwater from natural geological sources, which is most hazardous, if found in excess. It raises considerable interest due to its unique character as regard to its impact on physiological system of living things. During weathering and circulation of water in rocks and soils, fluorine can be leached out and dissolved in groundwater and thermal gases. The fluoride content of groundwater varies greatly depending on the geological settings and type of rocks. The most common fluorine-bearing minerals are fluorite, apatite and micas. Therefore fluoride problems tend to occur in places where these minerals are most abundant in the host rocks.

Igneous and volcanic rocks have a fluorine concentration from 100 ppm (ultramafic) up to >1000 ppm (alkalic) (Frencken, 1992). In general fluorine accumulates during magmatic crystallization and differentiation processes of the magma. Consequently, the residual magma is often enriched in fluorine. Groundwater from crystalline rocks, especially (alkaline) granites (deficient in calcium) are particularly sensitive to relative high fluoride concentrations. Such rocks are found especially in Precambrian basement areas.

The fluorine, which cannot be incorporated in crystalline phase during crystallization and differentiation of magmas, will be accumulated in hydrothermal solutions. These fluids may form hydrothermal fluorite deposits and veins. Fluorine transport in these aqueous solutions is controlled mainly by the solubility of CaF2 (Allmann et al, 1974).

Further, of the volcanic series, the (calc-) alkaline volcanoes, typical of a continental rift (East Africa), hot spot, continental margin (Andes) or island arc (Japan), produce relative fluorine rich lava. (Rosi et al, 2003). Sedimentary rocks have a fluorine
concentration from 200 ppm (limestone) up to 1000 ppm (shales) (Frencken et al, 1992). In carbonate sedimentary rocks the fluorine is present as fluorite. Clastic sediments have higher fluorine concentrations as the fluorine is concentrated in micas and illites in the clay fractions. High concentrations may also be found in sedimentary phosphate beds (shark teeth) or volcanic ash layers (Frencken et al, 1992). Metamorphic rocks have a fluorine concentration from 100 ppm (regional metamorphism) up to more than 5000 ppm (contact metamorphism). In these rocks the original minerals are enriched with fluorine by metasomatic processes (Frencken et al, 1992).

Naturally occurring fluorides in groundwater are a result of the dissolution of fluoride containing rock minerals by water while artificially high soil fluoride levels can occur through contamination by application of phosphate fertilizers, sewage sludge, or pesticides (EPA, 1997). The major source of fluoride in the groundwater is fluoride bearing rocks from which it get weathered and /or leached out and contaminates the water. Fluorides occur in three forms, namely, fluorospar or calcium fluoride (CaF2), apatite or rock phosphate \([\text{Ca}_3\text{F}(\text{PO}_4)_3]\) and cryolite (Na3AlF6). Concentration of fluorides is five times higher in granite than in basalt rock areas. Similarly, shale has a higher concentration than sandstone and limestone. Alkaline rocks contain the highest percentage of fluoride (1200 to 8500mg/kg) (Chand, 1998).

The geological survey of India as brought out considerable data wic reveal that fluoride, topaz, apatite, rock phosphate, phosphatic nodules and phosphorites are widespread in India and contain high percentage of fluorides.

5.3.2 Data Preparation

The data preparation is focus towards on the main aim of this chapter is to detect fluoride source through rock and dissemination in groundwater content from the collected samples of ground water sources of Dharmapuri district. The data which has been collected in different block for the year 2006 to 2008. The total number of sampling
locations is 417 from five taluks as mentioned in 4.0 data used methodology. Under the five taluk expect there are eight blocks in Dharmapuri district are taken for our study are shown in the aforementioned Table 5.1.1 in the chapter 5.1.

5.3.3 Methodology

The map showing lithological features is used as input layer for the preparation of fluoride source rock map. The “create layer from selected features” option available in layer properties pop-up menu in ArcGIS has been used to generate the map showing fluoride source rocks availability in Dharmapuri district.

In order to understand the fluoride dissemination of ground water it is necessary to study and understand the aerial distribution of fluoride source rock. The lithology map prepared for the Dharmapuri district from the district resource map of Geological Survey of India is used to delineate the fluoride source rock.

The Integration of Source Rocks and Fluoride Dissemination using GIS to identify the delineation of zones of high weathering leads to fluoride dissemination in groundwater

5.3.4 Identification of Fluoride source rock through base map preparation

The present study area is totally covered with igneous and metamorphic rocks. Amongst them the igneous rock Granite and metamorphic rocks such as Epidote Hornblende Gneiss, Grantoid Gneiss and Hornblende Biotite Gneiss are containing fluoride as accessory element. Map 5.3.1 clearly understood from the resultant map that the fluoride source rocks are mainly covered in the middle parts of south west and north east regions. There is a small cap of Grantoid Gneiss found in north western corner of Dharmapuri district covering 63 sq.km. The total area covered by these fluoride source rocks is 1077.6 sq.km i.e., around 20% of the total study area. From the above mentioned Map 5.3.1 it has identified that the total source rock the Epidote Hornblende Gneiss is
covering maximum area ie., around 834.6 sq.km. The Epidote Hornblende Gneiss is
trending in north east south west direction. The igneous rock Granite is covering a
minimum area of only 4.9 sq.km as small packets in the south east and south west part of
Dharmapuri district i.e., south west of Nallampalli and east of Pappireddipatti

5.3.5 Identification of minerals on rocks for the sources of Fluoride

The fluoride available in igneous rocks are in the form of fluoride associated with
other chemical elements as minor accessory minerals ((Fluorspar (CaF2), Cryolite
(Na3AlF6) and Fluorapatite (Ca3 (PO4)2, Ca (F, Cl)2). Amphiboles are classified as
Hornblende and Tremolite. The rocks that contain the fluoride minerals are listed as
shown in the following Table 5.3.1

Table 5.3.1. The classification of source rock for fluoride, area and the percentage of
risk Covered at the source rock for fluoride

<table>
<thead>
<tr>
<th>Name of the Source rock</th>
<th>Area coverage in sq.km</th>
<th>Fluoride risk</th>
<th>Fluoride Risk Area covered in Source rock polygons (calculated from integrated output) in sq.km</th>
<th>Total Fl Risk area falling in Source rock area (in sq.km)</th>
<th>Percentage of Fl risk area covered in source rock area</th>
</tr>
</thead>
<tbody>
<tr>
<td>Epidote Hornblende Gneiss</td>
<td>1077</td>
<td>Very High</td>
<td>376.99 sq.km 350.81 sq.km 84.49 sq.km</td>
<td>812.29 sq.km</td>
<td>75.42%</td>
</tr>
<tr>
<td>Granite</td>
<td>4.9</td>
<td>Very High</td>
<td>2.3 sq.km 2.07 sq.km 0.51 sq.km</td>
<td>4.88 sq.km</td>
<td>99.59%</td>
</tr>
<tr>
<td>Hornblende Biotite Gneiss</td>
<td>161</td>
<td>Very High</td>
<td>137.57 sq.km 22.05 sq.km 1.38 sq.km</td>
<td>161 sq.km</td>
<td>100%</td>
</tr>
<tr>
<td>Grantoid Gneiss</td>
<td>76.78</td>
<td>Moderate</td>
<td>74.76 sq.km</td>
<td>74.76 sq.km</td>
<td>97.75%</td>
</tr>
</tbody>
</table>
From the above mentioned Map 5.3.1 has been identified the structural pattern of minerals present in different level of area has been the source for contaminations are can be identified easily. Further the study explained details of minerals presence for contaminations and the causes of fluoride are identified the fluoride source rock layers which are presented as in the (Map 5.3.2).

5.3.6 Integration of Source Rocks and Fluoride Dissemination in Ground water Using GIS

Fluoride availability in ground water is only from the fluoride minerals that are dissolved from the weathered source rocks through percolated rainwater. Hence, the fluoride dissemination in ground water should very high in and around the regions, having fluoride source rocks. In order to bring out the relation between fluoride source rock and fluoride dissemination in ground water, a GIS overlay was performed. The input data used for this analysis are the fluoride source rock layer map as above mentioned in Map 5.3.1 from that the fluoride pattern layer has generated as a (Map 5.3.2). From the resultant Map 5.3.2 shows that there is very good correlation between them. Almost all the very High, High and Moderate fluoride risk areas are seen along the areas of fluoride source rock.

5.3.7 Assessment of Sodium availability in Ground water

With reference to the research work carried out by the Shahid Naseem and Tahir Rafique (2008), the threshold value of sodium in ground water depicting high weathering is 75mg/l. That means, if the ground water in an area having more than 75mg/l of sodium indirectly represents high availability of fluoride. In order to demonstrate this relationship GIS layer showing sodium concentration in groundwater is prepared for two seasons for three years are presented as a (Map 5.3.3 (i) to Map5.3.3 (vi)).

By averaging these six seasonal raster images of sodium in ground water, and plotting using contour option in surface analysis menu of spatial analyst tool in Arc GIS,
a comprehensive GIS layer showing the areas where dissolved Na is prepared. By keeping 75mg/l of sodium availability in ground water as threshold, a regrouped map has been prepared indicating the zones of high weathering where Na is >75 mg/l (map5.3.4)This map shows that the north western and eastern part of study area has got greater than 75 mg/l sodium dissolved in ground water.

5.3.8 Areas of High Weathering

The fluoride minerals should be dislodged from it source rock so that they can readily dissolve in the rain water/surface water which is percolating into the subsoil where the fluoride minerals are freely available. In order to get dislodge from the igneous and metamorphic source rocks, such as Granite, Epidote Hornblende Gneiss, Grantoid Gneiss and Hornblende Biotite Gneiss need to be fractured, weathered and then only the fluoride minerals can get removed from its parental rock and disintegrated so that the rainwater can dissolve, carry downward and add fluoride into ground water. Hence, it is necessary to find out the areas where weathered soil through which percolating rainwater is carrying dissolved fluoride along with other minerals need to be identified. It is also possible by quantifying the neighbour/associated element dissolved in groundwater which can indirectly indicate and suggest the relative intensity of weathering which brings fluoride into groundwater. As per the study carried out by Shahid Naseem and Tahir Rafique (2009), the high sodium availability in groundwater clearly depicts high weathering in the area and hence, it is easy to indirectly confirm the maximum availability of dissolved fluoride in groundwater due to high weathering in that area. To understand the same an analysis has been done and the same is mentioned below.

5.3.9 Delineation of high weathering zones to identify Fluoride Dissemination in Ground water

The delineation of weathering zones are identify for the fluoride dissemination in groundwater using GIS. After the generation of GIS layer showing the zones where Na
availability in groundwater is greater than 75 mg/l, the same is integrated with the GIS layer showing fluoride risk zones. By doing so, the areas where Na is greater than 75mg/l as well as very high, high and moderate Fl risk zones are seen, and they have been identified spatially and displayed in map5.3.5. It shows that there is a very good correlation between high Na availability in groundwater and the fluoride risk zones in Dharmapuri district. Along the eastern part of the study area, there is occurrence of very high and high fluoride risk area coinciding with zones where Na is >75 mg/l. The north eastern half strip of area is covered with the combination of moderate fluoride risk zone with Na >75mg/l is seen. That means, weathering of the source rock is greater along these areas where fluoride contamination is also high in groundwater.

5.3.10 Results

The GIS image showing the areas of high fluoride risk in groundwater coincided with the zones of fluoride source rock (Map5.3.1) has established the fluoride source for groundwater contamination which is nothing but the metamorphic rocks such as Epidote Hornblende Gneiss and Hornblende Biotite Gneiss located in the south eastern part of the study area. Another GIS output image showing the combined areas where both fluoride risk and the Na >75 mg/l gives an idea about the relationship between weathering and the fluoride contamination in groundwater, i.e., weathering and high fluoride contamination are seen in the northeastern diagonal half of the study area.

Both output images suggested that the area has got weathered source rock containing fluoride minerals supplying fluoride to groundwater is maximum from the eastern half of the study area.

In this section, the spatial arrangement of fluoride source rocks, such as Granite, Epidote Hornblende Gneiss, Grantoid Gneiss and Hornblende Biotite Gneiss in Dharmapuri district was prepared in GIS environment. Then, by integrating the GIS layer showing fluoride risk areas with the GIS layer showing fluoride source rocks, the areas of
fluoride risk in groundwater contaminated by source rock is derived and map showing source rocks for fluoride contamination in Dharmapuri district has been prepared. From the same, the aerial coverage of very high, high and moderate fluoride risk zones in fluoride source rock locations have been calculated, tabulated (Table 5.3.1) and plotted in bar graph (Fig.5.3.1). The direct spatial relationship between the fluoride source rocks and the areas of fluoride risk in groundwater has very well been established. From this tabulated details, it is very clearly understood that the fluoride input to the groundwater is maximum through the source rocks.

**Figure 5.3.1 The Graphical representation shows the relationship between source rocks and area of fluoride risk in Groundwater**

<table>
<thead>
<tr>
<th>Spatial Relationship between Aerial Extent of Fluoride Source Rocks and Areas of Fluoride Risk in Groundwater</th>
</tr>
</thead>
<tbody>
<tr>
<td>EHG</td>
</tr>
<tr>
<td>1077</td>
</tr>
<tr>
<td>161</td>
</tr>
</tbody>
</table>

EHG- Epidote Hornblende Gneiss/GRT-Granite/HBG- Hornblende Biotite Gneiss/GRN- Grantoid Gneiss

### 5.3.1 Conclusion

The study revealed that high fluoride concentration more than 1.5 mg/l in groundwater causes serious health hazards. So far as the origin of fluoride contamination is concerned; it can mainly attribute to be of natural rather than anthropogenic. High profile of fluorides in shallow zone groundwater is due to the geochemical disposition. The toxicity of fluoride is also influenced by high ambient temperature, alkanity, calcium...
and magnesium contents in the ground water. Abnormal level of fluoride in water is common in fractured Epidote Hornblende Gneiss, Hornblende Biotite Gneiss and Grantoid Gneiss, which petro chemically contains higher concentrations of fluorides.

In general ground water contains more fluoride than surface water resources due to greater contact times with fluoride bearing minerals. The occurrences of fluoride concentration are always point specific. It is observed that within one village different wells often show wide variation in fluoride content. This indicates that geological formation is not the only factor responsible for fluoride in ground water. The weathering of rocks, local hydrogeological conditions govern the fluoride content of ground water.
5.4 Assessment of Fluoride dissemination in groundwater in relations between rainfall recharge and lineament

5.4.1 Introduction

Fluoride is particularly available in rocks, soils, water and biological chains in living organisms. It has higher electronegativity and reactivity. Fluoride occurs naturally in water due to weathering of rock that contain fluoride rich minerals such as, hornblende, biotite, apatite and fluorite (Breiter et al., 2006; Totsce et al., 2000 and Zhu et al., 2007).

Abundance of fluoride in water depends on several factors. Fluoride is readily available in water with lower Ca and higher Na (Larsen et al.1985). The physical and chemical parameters of water are closely linked to the climatic variations hence the water quality tends to vary in these regions. The mean annual rainfall over India is about 105 cm and exceeds the global average rainfall of 70 cm. Even then, about 80% of the Indian territories fall under semi-arid conditions. This is because of spatial and temporal distribution of rainfall, overall variability of monsoon, topographic variations, prevailing semi-arid to arid climatic conditions and varied nature of hydrogeology. Lineament density modeling was done to identify high potential aquifers in hard rock areas of Dharmapuri district. Several studies have been carried out to investigate sources, spatial distribution and movement patterns of fluoride (Dissanayake, 1986; Dissanayake, 1991; Dissanayake et al., 1993 and Dharmagunawardhane, 1993). The scope of this study was to investigate physical and chemical properties of groundwater in high and low-fluoride regions in order to study natural influences on fluoride chemistry of groundwater.

5.4.2 Data Preparation

The main aim of this chapter is to detect fluoride source through rock and dissemination in groundwater content from the collected samples of ground water sources
of Dharmapuri district. The data which has been collected in different block for the year 2006 to 2008. The total number of sampling locations is 417 from five taluks as mentioned in 4.0 data used methodology. Under the five taluks expect there are eight blocks in Dharmapuri district are taken for our study are shown in the aforementioned Table 5.1.1 in the chapter 5.1.

5.4.3 Methodology

In order to identify the relations between rainfall and the contamination of fluoride in ground water are analyzed through by the collected information of rainfall data for the month of August 2005 to December 2007. These seasonal variations are categorized for three years for the present chapter. The first category is from the month of August 2005 to February 2006. The second category is August 2006 to February 2007 and the third category is August 2007 to December 2007. In order to find the relationship of rainfall for fluoride contamination the average map has been prepared for three years from august 2005 to December 2007. From that average map of rainfall the integration map between rainfall and fluoride has been prepared for better identification of relations between seasonal variations was the play a major role for the causes of fluoride in high level.

The identification of relations between groundwater recharge and fluoride in groundwater are analyzed from the collected data for the seasonal variation for the Pre-monsoon and post-monsoon water level data. The map has been prepared for the recharge pattern for the pre-monsoon May 2006 to post-monsoon January 2007, May 2007 to post-monsoon January 2008, May 2008 to post-monsoon January 2009, from this the average map as been prepared for the better pattern of understanding the recharge zones. From the average map for the recharge pattern are integrated with the fluoride source map for the better identification.
GIS integration of lineament using the density value and average fluoride contamination using distribution maps. Relation between lineament and fluoride contamination through the density map for linear map using shaded relief map. Classifications of risk level are categories and presented as a map are prepared from that the value are categorized as relief map.

5.4.4 PREPARATION OF SEASONAL RAINFALL MAPS

This chapter is intended to understand the spatial relations between rainfall occurrences recharge and discharge pattern with fluoride contamination pattern in groundwater of the study area. In order to bring out the spatial relations, it is necessary to prepare maps on rainfall and quantify the recharge and discharge habits of Dharmapuri district. The rainfall data collected from TWAD board for the period for 3 years from 2005 to 2007 has been used for the preparation of rainfall layer. The study area has experienced rainfall occurrence during the months of August to February of every year are shown in the Table 5.4.1 and the annual rainfall are shown as a (Figure 5.4.1). Hence, using the available data, raster rainfall image and isoline layers are prepared for three subsequent seasons, viz.: August 2005 to February 2006, August 2006 to February 2007 and August 2007 to December 2007. Maps are prepared and shown as (Map 5.4.1 to Map 5.4.3).

From the Map 5.4.1 showing the rainfall occurrence during August 2005 to February 2006, it is very clear that the rainfall intensity increases from west and east towards middle part from the minimum of 749 mm to a maximum of 1405.5 mm during this period. Similarly, from the Map 5.4.2 depicting the rainfall occurrence during August 2006 to February 2007, it is clear that the area received 261.9 mm to 684.5 mm. The rainfall intensity is increased from west east.

From the Map 5.4.3 showing rainfall during August 2007 to December 2007, it is clearly understood that the rainfall intensity is increasing towards southeast from northwest with a minimum value of 520.4 mm to a maximum amount of 779 mm.
Though the rainfall occurrence seems to have similar trend in this period, for further GIS analysis, the data for these three years have been averaged and GIS image showing average rainfall occurrence is prepared Map5.4.4 It shows that the average rainfall varies from 515 to 930 mm with intensity increases from west to east.

5.4.5 GIS Integration of Seasonal Rainfall and Fluoride contamination in Groundwater

After the generation of average rainfall layer in GIS having 3 classes of rainfall, i.e., Low (515 to 655 mm), Medium (655 to 790) and High (790 to 930mm), the same is integrated with GIS layer showing fluoride contamination in groundwater. The resultant integrated image is shown in (Map 5.4.5).

From the Map 5.4.5 it is noted that where ever Medium, High rainfall occurs these areas also have in Moderate, High, Very high fluoride risk in ground water that means as the rainfall occurred with high intensity then there is high fluoride contamination seen in ground water in the same area. This suggest that the eastern half of the study area is not only receiving high rainfall but also the area has got highly porous and weathered fluoride source rock which can lead to ground water contamination through high infiltration of rain water. Hence it is decided to analyze the recharge-discharge pattern of the study area and bring out the relations between fluoride contaminations in ground water and recharge behaviour of Dharmapuri district.

5.4.6 Identification of fluoride in groundwater with relationship between recharge and discharge patterns

In order to bring out the relations between recharge behaviour and fluoride contamination pattern in ground water, a GIS based digital layer showing recharge-discharge pattern has been prepared. To do the same, the pre monsoon and post monsoon water level data have been used, for the calculation of recharge-discharge.
From the pre-monsoon and post-monsoon water level data collected from TWAD board by differentiating them recharge-discharge values are calculated and plotted using ‘IDW’ (Inverse Distance Weighed) Method available in spatial analyst tool of Arc GIS. Then from the resultant raster GIS image showing recharge-discharge pattern, an isoline map has been prepared using ‘Contour’ option. After vectorization, classified recharge-discharge layers Map 5.4.6 to Map 5.4.8 for three periods have been prepared. In order to do the GIS integration of recharge-discharge and fluoride contamination in ground water, a reclassified GIS layer showing average recharge-discharge for Dharmapuri district has been prepared from the Table 5.4.2 and as the same presented for average are shown as (Map 5.4.9). This image shows that maximum recharge (6-8m) is seen in the eastern half of the study area.

5.4.7 GIS Integration of Recharge and Fluoride Distribution Maps

After the generation of average recharge-discharge GIS layer Map 5.4.9 the same is integrated with the GIS layer showing fluoride contamination in ground water fluoride risk pattern). The resultant image is shown Map 5.4.10 the aerial coverage of 9 classes of polygons derived from the integrated output has been worked out. It is easy to understand the spatial relationship between ground water recharge and fluoride contamination risk in ground water in Dharmapuri district, i.e., wherever the ground water recharge is above 4m (classified as high recharge), the fluoride contamination is also high (Moderate risk, High risk and Very high risk) are distinguish between risk classification and lineament density range are shown as in the Table 5.4.3 that means, the areas where ground water recharge is high then the fluoride contamination in ground water is also high are shown as Map 5.4.11.
Table 5.4.3 Distinguish between Risk classification and Lineament Density Range

<table>
<thead>
<tr>
<th>RISK CLASSIFICATION</th>
<th>LINEAMENT DENSITY RANGE</th>
</tr>
</thead>
<tbody>
<tr>
<td>Very low</td>
<td>0-2200 m/.09sq.km</td>
</tr>
<tr>
<td>Low</td>
<td>2201-5800 m/.09sq.km</td>
</tr>
<tr>
<td>Moderate</td>
<td>5801-9800 m/.09sq.km</td>
</tr>
<tr>
<td>High</td>
<td>9801-14700 m/.09sq.km</td>
</tr>
<tr>
<td>Very high</td>
<td>14701-29100 m/.09sq.km</td>
</tr>
</tbody>
</table>

5.4.8 Generation of Classified Image on Lineament Density of Maxima Zones and Fluoride Distribution Maps

From the reclassified GIS images of lineament density only 3 classes were buffered having lineament density Moderate, High, Very high and separate GIS layers showing three classes has been prepared (Map 5.4.12). Now this GIS layers has been integrated with fluoride contamination in ground water and output layer is shown in map 5.4.13. This integrated output image shows that the lineaments located in the south east; south middle and south west parts of the study area are acting as conduits/passage ways for recharge through which disintegrated fluoride minerals are taken inside by dissolving and infiltration actions and contaminates the ground water.

5.4.9 Results

In this chapter the relationship between rainfall, ground water recharge and lineaments with fluoride contamination pattern in ground water have been brought out. In all these 3 models, it is very clearly seen that the eastern and south western part of the study area has got very strong positive relationships with fluoride contamination in ground water over rainfall, recharge and lineament density.
5.4.10 Conclusion

Fluoride content in water depends not only on the geochemical background and climate-biological factors such as hydrological condition, landform, rainfall, and evaporation, but also on the adsorption and leaching of fluoride in soil. The adsorption-leaching process directly affects fluoride migration and exchange from soil to water. Studies on adsorption or desorption of fluoride have shown that the nature of soil or rock relates to the release of fluoride from soils and rocks, but to date there has been no study on adsorption and leaching effects of typical soils in China and their relation to fluorosis. We have reported the results with investigation of adsorption and leaching of fluoride in typical Chinese soils and their relation to physico-chemical soil parameters.
5.5 Management Plans in Dharmapuri District

5.5.1 Introduction

Ground water plays an important role in augmenting water supply to meet the ever-increasing water supply demands in India. Share of groundwater supply for domestic use in rural area amounts to > 80%. Over 50% of irrigation and industrial requirements are met from groundwater resources. In all probability the future expansion of groundwater uses will continue because of population growth and corresponding growth in agricultural and industry. Delineation of aquifers is the pre-requisite for the assessment of regional/local groundwater potential.

Delineation of aquifers and subsequently their groundwater potential assessment were carried out in different part of the country by using different geophysical, geological, geochemical, remote sensing and GIS methods depending on the local hydro-geological conditions.

Like any other country of the world, India has also derived great socio-economic benefits by making use of water supply to meet the ever-increasing demands for domestic, agricultural and industrial uses. Consumption of water has increased manifold since the onset of green revolution in late sixties. As a result, scarcity of water supply and deterioration of water quality is seen in many parts of the country. To cope up with such problems, it was the nation’s endeavour to promote the activities of sustainable development, management and governance of water resources to achieve the goals of safe and secured water supplies and to maintain the pace of developments in agricultural and industrial sectors. Several institutions of federal and state governments such as Central Groundwater Board (CGWB), Central Groundwater Authority (CGWA), Central Water Commission (CWC), National Geophysical Research Institute (NGRI), National Institute of Hydrology, State groundwater departments, Civil and Earth science
departments of universities, Indian Institutes of Technology (IITs), NGOs and other institutions are engaged in assessment, development and management of surface/ground-water resources to meet the demands of water supply from available water resources.

5.5.2 Data Preparation and Methodology

The main aim of this chapter is to detect fluoride source through rock and dissemination in groundwater content from the collected samples of ground water sources of Dharmapuri district. The data which has been collected in different block for the year 2006 to 2008. The total number of sampling locations is 417 from five taluks as mentioned in 4.0 data used methodology. Under the five taluks expect there are eight blocks in Dharmapuri district are taken for our study are shown in the aforementioned Table 5.1.1 in the chapter 5.1.

The methodology adapted in different stages the first stage is to find on the relations between Fluoride contaminations and TDS distribution patterns are analyzed for understanding the relationship, second stage of the methodology is to find the relations of Fluoride contamination with source Rock availability and Weathering and third stage of the methodology is to find on relations of Fluoride contamination with Rainfall, Recharge and Lineament density.

From different stages output the Fluoride Management Plans suggested from this study in Dharmapuri for better management through suitable sites for Groundwater recharge without Fluoride contamination. For this identification of Fluoride safe zones has been analyzed by different methods. The first method is through Delineation of Lineaments falling in Fluoride safe zones. In addition to that the condition were analyzed for the identification of favorable Geomorphic features for recharge falling in Fluoride safe zones has observed by using GIS integration and identification of suitable sites for recharge. The second suitable methods for fluoride contamination less in Groundwater by recharge are analyzed through artificial recharge Ponds to minimize fluoride contamination.
contamination has been observed in Groundwater. With respect to artificial recharges through check Dams / partial check Dams to minimize fluoride contamination in Groundwater and artificial recharge through batteries of wells in Groundwater are also analyzed in this chapter. In addition to this the alternate mechanisms for rain water harvesting has been analyzed to minimize fluoride contamination problem. The desiltation of existing tanks located in fluoride safe and risk zones are also analyzed for the better identification of safe areas in the downstream of natural DYKES. In similar to the identification of areas in Fluoride risk zones for recharge to dissipate its concentration in groundwater are to be analyzed. In this chapter the elaborated methodology has been adapted for the identification of relevant methods for minimizing fluoride contamination has been analyzed for detailed structural outcome through fluoride precipitation from groundwater, Precipitation methods, Nalgonda method, Limestone reactor, Adsorption methods, Activated alumina, Membrane process and Electro coagulation/Flotation

5.5.3 Results

5.5.3.1 Findings on relations between Fluoride contaminations and TDS distribution Patterns

The eastern half and the southwestern part of the study area is contaminated with high fluoride concentration in groundwater. The entire eastern half of the study area and most of the western half of the study area are having very high concentrations of TDS dissolved in groundwater. The GIS analysis between these two layers have brought out the spatial relationships between fluoride contamination and the TDS concentration in groundwater, i.e., if the TDS concentration in groundwater is high, then the area having fluoride source rock will also have higher concentration of fluoride in groundwater.
5.5.3.2 Findings on relations of Fluoride contamination with source Rock availability and Weathering

The rock availability among four source rocks, the Epidote Hornblende Gneiss is covering large aerial coverage in the middle part and a portion of east middle of Dharmapuri district along the NE-SW corridor. The same is identified as the supplier / parental rock supplying fluoride to groundwater causing contamination in the eastern and western portions. The second important metamorphic rock supplying fluoride to groundwater is the Hornblende Biotite Gneiss located in the SW side of the study area. With reference to the literature collection, it is understood and identified that the area having high Na in groundwater lead to the maximum weathering of source rock and in turn contaminates the groundwater with high fluoride concentrations. From this analysis, it is identified that the northwestern part and the eastern half of Dharmapuri district are highly weathered in nature having high Na as well as high fluoride dissolved in groundwater leads to contamination.

5.5.3.3 Findings on relations of Fluoride contamination with Rainfall, Recharge and Lineament density

The Very high, High and Moderate fluoride contaminated areas of groundwater is showing direct spatial relationship with rainfall. Wherever the rainfall intensity is high, then it is found and recorded, that the fluoride contamination is also very high in those areas. In Dharmapuri district, the eastern half of the area is receiving good amount of rainfall and hence, the same area has got high concentrations of fluoride in groundwater. Due to the movement of groundwater, there is a possibility of fluoride contamination is also seen in the southwestern part of Dharmapuri district. As far as groundwater recharge is concerned, again the eastern half of the study area has got good amount of average annual recharge of 6-8m. The same area is coinciding with high fluoride contamination thus indicates there is also a direct relation between groundwater recharge and fluoride contamination pattern in groundwater.
The southeastern portions of the study area has got Very high, High lineament density and the same areas are coinciding with high fluoride concentrations in groundwater shows that their direct spatial relationship. Similar relationship is identified in the southwestern part of the study area with moderate lineament density with very high fluoride concentration in groundwater.

5.5.3.4 Fluoride Management Plans suggested through this study in Dharmapuri District

Thus, from the above GIS based analysis for the identification of relations between terrain and groundwater chemistry parameters, such as TDS, lithology (for source rock), weathering (through Na), rainfall, groundwater recharge and lineament density with fluoride contamination pattern in Dharmapuri district, it is very easy to understand the controlling and inducing parameters for fluoride contamination and thus, it would be very easy to plan for the further management activities so as to minimize fluoride contamination in groundwater. Keeping the established relations between terrain and groundwater chemistry parameters with fluoride contamination pattern in groundwater in mind, several management plans are prepared using GIS as discussed in the following paragraphs.

5.5.4 Suitable sites for Groundwater recharge without Fluoride contamination

5.5.4.1 Identification of Fluoride safe zones

The areas of fluoride contamination in ground water can be preserved from further fluoride contamination through natural recharge by understanding the ground water flow pattern and the areas where fluoride contamination is meager. Hence, the areas of low and very low fluoride contamination in ground water are identified from where the recharge is high and ground water movement is towards high fluoride contaminated areas in ground water. Thus initially the areas of low and very low fluoride
risk in ground water are identified as shown in (Map. 5.5.1). The same area has got radially diverging movement of ground water from these areas. Hence these areas need to be prioritized for improving ground water recharge through different recharge mechanisms such as construction of check dams across the upstream of drainage converging areas, construction of recharge pits and recharge ponds etc. For the same the following GIS based analysis has been done and the proper areas and the mechanisms for ground water recharge have been identified.

5.5.4.2 Delineation of Lineaments falling in Fluoride safe zones

The lineaments falling in fluoride low risk zones have been identified by integrating lineament density layer (Map 5.4.11) with the GIS layer showing low fluoride risk in ground water (Map 5.5.1). The resultant image showing the common polygon areas having the property of low fluoride risk with lineament density medium is shown in Map 5.5.2. This resultant layer is kept as such for further integration of other suitable conditions.

5.5.4.3 Identification of favourable Geomorphic features for recharge falling in Fluoride safe zones

Though the lineaments will quickly allow rain water to infiltrate inside to recharge the ground water, it is necessary to identify loose and unconsolidated materials available in this area need to be identified with help of GIS layer showing Geomorphology (Map.5.1.18) with the help of ‘Intersection’ option available in Arc tools of GIS, the geomorphology layer and GIS layer showing low fluoride risk have been integrated. The output image is displayed in Map 5.5.3 it shows that the areas surrounding and 5kms west of Palacode and 3kms west of Dharmapuri town are found with such geomorphic feature having loose and unconsolidated soil materials on the surface such as buried pediment shallow, buried pediment medium and buried pediment deep in low fluoride risk areas.
5.5.5 GIS integration and identification of suitable sites for recharge

Finally in order to identify the suitable sites for ground water recharge without/minimum fluoride contamination, the GIS layers showing lineament density medium zones (Map.5.5.2) and the areas of favourable geomorphic features (Map 5.5.3) are integrated in GIS environment using union option in ArcGIS. The resultant integrated image is shown in Map 5.5.4. From this GIS output it is identified that dark, medium and light blue coloured areas (as shown in Map.5.5.4) located 3 km west of Dharmapuri town and 15 km north east of Pennagaram town are seems to be most suitable sites for artificial recharge of ground water so as to minimize the fluoride contamination in ground water through dilution because of the recharged ground water.

5.5.6 Suitable methods for fluoride contamination less Groundwater recharge

Once the suitable sites for the safe ground water recharge is identified, it is also important to identify suitable mechanisms to be adopted for artificial recharge based on the terrain conditions. Hence, a GIS based analysis has been done with terrain parameters and the GIS layer showing suitable mechanisms for artificial recharge has been prepared as discussed in the succeeding paragraphs.

5.5.7 Artificial recharge through recharge Ponds to minimize fluoride contamination in Groundwater

The recharge ponds can be created in the areas where the terrain slope is almost plain (i.e., <6 degree slope). Hence a GIS layer showing plain slope has been prepared (Map 5.5.5) and integrated with suitable sites for artificial recharge. (Map 5.5.4). The resultant image has been displayed as Map 5.5.6 is showing 3 prioritized areas for implementing artificial recharge through construction of recharge ponds.
5.5.8 Artificial recharges through check Dams / partial check Dams to minimize Fluoride contamination in Groundwater

One among the common artificial recharge structures found in many places of TamilNadu is check dam. The check dam is constructed to stop the fast flowing rainwater along drainages during rainy season. By doing so major part of the running water is stagnated the upstream area which in turn increases the infiltration capability the area and also to arrest loose sediment such as pebble, sand, silt and clay materials brought down from the upstream catchments due to soil erosion and avoids siltation in major reservoirs located in the downstream areas. In order to construct check dam in suitable area, the area should have sufficient amount of rain water collected from drainages from the upstream area and the slope condition should be gently sloping terrain have 3 degrees up to 11 degrees. In order to identify such terrain condition having 3-11 degree slope and drainage convergence, the two GIS images developed during GIS data base generation (Maps 5.1.17 and 5.1.19)) have been used. From these two layers, the areas having 3-6 and 6-11 degrees slope areas are filtered and drainages are superposed so as to identify drainage convergence areas (Map.5.5.7) from the same, a GIS map showing suitable locations for the construction of check dams is prepared and shown in Map 5.5.8

5.5.9 Artificial recharge through batteries of wells in Ground water

In the areas of hard rock aquifer system, where igneous and metamorphic rocks are exposing with a lot of sets of criss-crossing lineaments and fractures systems, artificial recharge can be attained to a maximum level, through digging a serious of bore holes along particular lineament density maximum areas. Hence the study area has got hard rocks criss-crossed with a number of lineament sets (Map 5.1.12 and Map 5.1.16). In order to identify such suitable sites for digging series of bore wells called batteries of wells, lineament density maximum axes were drawn (Map.5.5.9) from the lineament density contours map (Map. 5.4.11). Then the same lineament density maxima axes
image has been intersected with the GIS image showing suitable sites for artificial recharge (Map 5.5.4) the resultant GIS output has got a number of prioritized lineament maxima axes were in, a series of bore wells can be dug all along them and thus maximum ground water recharge can be attained with dilution of fluoride concentration (Map 5.5.10).

5.5.10 Alternate mechanisms for rain water harvesting to minimize fluoride contamination problem

There are other techniques then artificial recharges to ground water so as to increase the ground water potential of the area but also dilute the fluoride contamination in that area. The mechanisms like, 1. Desiltation of existing tanks, grouting of lineaments that are crossing desilted tanks in the fluoride high risk area, so as to utilize the surface water directly without fluoride contamination. 2. Utilize the existing naturally ground water flow barriers such as dykes and reef rocks safeguarding fluoride low risk zones from becoming high and very high risk zones if the ground water movement brings fluoride contaminated ground water in low risk zones, and 3. Artificial recharge in high risk areas so as to dilute the fluoride contamination in ground water.

5.5.11 Desiltation of existing Tanks located in fluoride safe and risk zones

All the tanks, lakes and other stable water bodies need to be desilted prior to monsoon season regularly so as to increase the storage capacity and recharge capability. But the areas of very high, high and moderate fluoride risk should be analyzed for the availability and usage of tanks and lakes located in that area. If the people residing in very high, high and moderate fluoride risk areas are in need of potable water from the tanks and lakes nearby, and the monsoon rain water could not be stored for longer period, then apart from desiltation, a GIS integration of tanks and lineaments can be performed and the tanks crossed by lineaments need to be grouted by concrete so as to retain rainwater in these tanks without much loss due to fracture recharge. Accordingly a Gis
analysis had been performed to identify the tanks that are falling in very low and low fluoride risk areas for simple desiltation regularly and for the tanks located in very high, high and moderate fluoride risk areas for the identification of criss-crossing lineaments through these tanks, grouting them and desiltation for effective storage of monsoon rainwater for direct usage without fluoride contamination.

Similar GIS based analysis has been done for the entire Dharmapuri district by integrating tanks and lakes map with lineaments map. The tanks and rivers that are located in very low and low fluoride risk areas are separated out and mapped as shown in Map 5.5.11. These tanks and rivers can be directly desilted and their banks and bands can be strengthened and raised so as to increase the storage capacity of them.

In the same way, the tanks located in fluoride moderate, high and very high risk zones are identified (Map5.5.12) and then lineaments map is overlaid so as to identify whether the lineaments are crossing through these tanks (Map5.5.13). Such lineaments crossed tanks are clearly shown by zooming a small part of the study area is shown in Map 5.5.14. Hence these tanks need to be used only for storing monsoon rainwater for longer period so as to directly utilized stored surface water without much loss due to ground water recharge along the criss-crossing lineaments and get further contaminated by adding up of fluoride, so as to minimize the recharge along lineaments, the exact location and their directions need to be confirmed by conducting field survey and the grouted by cement concrete packing along these lineaments. (Map.5.5.14)

5.5.12 Identification of safe areas in the downstream of natural Dykes

The study area is consisting of different variety of long, linear, detached and criss-crossing dykes /reef rocks such as Dolerite, Granite, Pyroxene granulites and Quartzite (Map.5.5.15), by using lithology map (Map.5.1.12). These “dykes’ rocks are not only acting as barriers for ground water movement but also deflecting agent for ground water movement which may bring fluoride contaminated ground water to safe
ground water area. In order to identify such situation in the study area, GIS images showing ground water movement for six periods during January 2006 to May 2008, and the average ground water movement has been brought out (Map.5.5.16)

Now the average ground water flow map has been superposed over fluoride contamination map (Map.5.2.8). The resultant image shown in Map 5.5.17, provides the details of ground water flow directions from different levels of fluoride contamination in the study area. From this image it is understood that the ground water flow is always starting from low fluoride risk zones and crossing through moderate, high and very high fluoride risk zones. There is no prominent zone where the ground water flow is from high fluoride risk zones to low risk zones where in ground water contamination due to high fluoride concentration brought through this ground water movement is possible. It needs further deep research so as to decide up on utilizing the existing natural dykes and reefs for controlling ground water movement in the study area

5.5.13 Identification of areas in Fluoride risk zones for recharge to dissipate its concentration in groundwater

In order to minimize fluoride contamination in the other parts of the study area a GIS analysis involving integration of fluoride risk map, favorable geomorphology map and map showing deep ground water areas of Dharmapuri district (Map 5.5.18) the resultant GIS output image (Map 5.5.18) has got 14317 number of dissected polygons with 27 classes. This image has been reclassified based on the favorable combination of Fluoride risk (Very high, high, moderate) Geomorphology(Buried pediment deep, medium, shallow) and Ground water level (Moderate, deep and very deep) and then prioritized as priority area I II and III based on suitability condition (Map5.5.19). Hence according to the requirement and reducing vulnerability to fluoride contamination, artificial recharge plans can be designed and implemented based on this GIS image shown in Map 5.5.19.
5.5.14 Other relevant methods for minimizing fluoride contamination

Existing Technologies to treat fluoride there are various methods for adopting fluoride and improve the water quality, such as precipitation, adsorption, ion exchange, and membrane processes such as reverse osmosis and Nanofiltration, electro dialysis and the Nalgonda technique.

5.5.14.1 FLUORIDE PRECIPITATION FROM GROUNDWATER

(a) Precipitation methods

Precipitation methods are based on the addition of chemicals (coagulants and coagulant aids) and the subsequent formation of insoluble fluoride precipitates. Fluoride removal is accomplished with solids separation from liquid. Various chemicals involved in the precipitation process are lime, alum, alum and lime, poly aluminium chloride, poly aluminium hydroxysulphate and polyelectrolyte. The major problem associated with precipitation process is the generation of massive amounts of sludge.

(b) Nalgonda method

In the Nalgonda method lime and alum are added to the raw water. Fluoride attaches itself to the flocs of aluminium hydroxide, which are formed and can be removed from the water together with precipitated flocs. The use of the Nalgonda method has apparently had some success in India and the method can be implemented both in households and water works. The main advantages in the Nalgonda technique are, its low cost and the availability of the lime and alum. There are some major drawbacks like the lack of required efficiency, the requirement of adding chemicals continuously and the high amount of residual sulfate and needs disposal of large amount of sludge and pH is relatively high in treated water.
(c) Limestone reactor

Most natural waters in contact with calcareous material are under saturated with respect to fluorite (CaF\textsubscript{2}). However, a strong inverse relationship has been shown to exist between calcium and fluoride concentrations in fresh and brackish groundwater in carbonate terrains, indicating that fluorite solubility likely controls the upper level of fluoride in natural waters. In geographical areas where fluorosis is endemic, some surface and groundwater are supersaturated with respect to fluorite. Persistence of supersaturated conditions can be due to unfavorable nucleation and precipitation kinetics—a common occurrence at low temperatures for anhydrous, sparingly soluble mineral phases such as fluorite. Fluorite precipitation can be induced for such supersaturated waters, however, and for waters under saturated with respect to fluorite by substantially increasing the activity of Ca\textsuperscript{2+} ion in some manner. In this study, we accomplish this by equilibrating the target water with CO\textsubscript{2} gas to increase its carbonic acid concentration and then direct it through a column of crushed limestone or other form of calcium carbonate. As water flows through the column, the carbonic acid dissolves calcium carbonate, increases the Ca\textsuperscript{2+} activity, and precipitates fluorite. After exiting the column, the water is directed into the top of a second aerated column where it travels via unsaturated flow, degasses, and precipitates the calcium carbonate dissolved in the first column. Thus the water is returned to its approximate original composition after flow through the two-column reactor but with a substantially reduced fluoride concentration. The major shortcoming of liming is the resulting high pH of the treated water and reduction of F\textsuperscript{−} is only up to 2 mg/l.

(d) Adsorption methods

Adsorption is still one of the most extensively used methods for defluoridation of water. The removal of fluoride by adsorption methods has been widely studied in recent years. Fluoride can be removed by adsorption onto many adsorbent materials. The criteria
for selection of suitable sorbents are: cost of the medium and running costs and ease of operation, adsorption capacity, potential for reuse, number of useful cycle and the possibility of regeneration.

(e) Activated alumina

Activated alumina is a granular form of aluminium oxide ($\text{Al}_2\text{O}_3$) with very high internal surface area, typically in the range of 200-300 $\text{m}^2/\text{g}$. This high surface area allows the material a very large number of sites where adsorption can occur. Churchill (1974) was the first to report the use of activated alumina for fluoride removal from drinking water. The process is pH specific, so the best experimental pH values for water treatment were between 5 and 6.5. It has been reported that fluoride removal from solution takes place by an ion exchange mechanism involving the active sites on the surface of alumina. It has been widely used for removal of $\text{F}^-$ from drinking water.

(f) Membrane process

In the recent years, RO membrane process has emerged as a preferred alternative to provide safe drinking water without posing the problems associated with other conventional methods. RO is a physical process in which the contaminants are removed by applying pressure on the feed water to direct it through a semi permeable membrane. The process is the reverse of natural osmosis as a result of the applied pressure to the concentrated side of the membrane, which overcomes the natural osmotic pressure. RO membrane rejects ions based on size and electrical charge. The factors influencing the membrane selection are cost, recovery, rejection, raw water characteristics and pretreatment. Efficiency of the process is governed by different factors such as raw water characteristics, pressure, temperature and regular monitoring and maintenance, etc. Nanofiltration is a new process that is still little used in the water industry, but is beginning to compete with the other membrane techniques for the treatment of brackish water. The limitations are the removal of all ions present in water, though some minerals
are essential for proper growth, demineralization is required after treatment, the process is expensive in comparison to other options, the water becomes acidic and needs pH correction, lot of water gets wasted as brine and disposal of brine is a problem.

(g) Electro coagulation/Flotation

Electro coagulation/flotation (ECF), which is an electrochemical technique, in which a variety of unwanted dissolved particles and suspended matter, can be effectively removed from an aqueous solution by electrolysis.

5.5.15 Rooftop rainwater harvesting for tackling fluoride contaminated groundwater

The rural development and Panchayat Raj of Government of Karnataka proposed various strategies for fluoride mitigation including surface sources and draining water from them providing defluoridation units at habitation level (5839) and household level, designating and recharging groundwater to dilute fluoride levels in aquifer.

Figure 5.5.20 Household level rainwater harvesting

Source : (URL.www.rainwaterclub.org.)

One important strategy which could provide adequate quality water for drinking and cooking purpose could be through rainwater harvesting (Fig.5.5.20). Rainwater is the Primary source for all water and is one of the purest forms of water without any fluoride.
Harvesting rooftop rainwater and using it for drinking and cooking would ensure clean potable fluoride free water for consumption. Fluoride free water is needed only for drinking and cooking. Fluoride water could be used for other purposes such as bathing etc without any problem. The standards adopted by the Govt. of India for rural areas is 40 litres per capita per day where as the Government of Karnataka in its State Water Policy has set itself the target of 55 litres per person per day.

5.5.16 Conclusion

A strategy for managing a part of a shallow aquifer through a systematic well-schedule that is based upon the characteristics of the aquifer and their variability in space through community participation has been proposed. The chapter of this thesis proposed of the highly ambitious Groundwater-linking an detail determination of safe and risk zones of Dharmapuri in Tamil Nadu, its concern and impact not only on the States of India which has been identified with one of the important role has been adapted in application as a tool in ArcGIS to identify a better management of source for safe zones for drinking water in rest of the countries. In addition to that there are many management systems for water bodies which are integrated water-management schemes with four components viz, groundwater, rain water harvesting, desalination of sea water and solar desalination has been proposed by Najeeb (2007). Several waste-water treatment plants were made operational in some cities such as Hyderabad, Coimbatore, etc to reduce the stresses on conventional sources of water supply. Treated waste water is used for gardening, industrial uses and diverted into percolation tanks for groundwater recharging for better management of water throughout the year. Desalinized sea water is the other alternative source of potable water. More and more such water treatment plants have to be planned for the beneficial source of water management.