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## RESEARCH ARTICLE

# THE GROUNDWATER QUALITY MONITORING OF NAGAPATTINAM TALUK, TAMIL NADU, INDIA

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**ABSTRACT**

The Present Study is intended to estimate Groundwater Quality Index for Nagapattinam Taluk. In order ascertain the quality of groundwater for public consumption, recreation and other purpose. There are several ways to assess the quality of water as deemed fit for drinking, irrigation and industrial use. Water quality index indicating the in terms of index numbers, offers a useful representation of overall quality of water for public or for any intended use as well as in the pollution abatement programmes and in water quality management. A number of parameter affects the usability of water for a particular purpose. In this study water quality index determined on the basis of various physical and chemical parameters like pH, Electrical Conductivity, Total Dissolved Solids, Nitrate, Calcium, Sulfate, Magnesium, Fluoride, Total Hardness, Sodium, Chloride, Carbonate and Bicarbonate. Especially in the coastal regions the availability of fresh water is always threatened by over drafting or by sea water intrusion and in some cases the risk is from the agricultural and industrial activities.



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## INTRODUCTION

Groundwater is used for domestic and industrial and irrigation purposes all over the world. In the last few decades, there has been a tremendous increase in the demand for fresh water due to the rapid growth of population and the accelerated pace of industrialization. Human health is threatened by most of the agricultural development activities particularly in relation to the excessive application of fertilizers and unsanitary conditions. Rapid urbanization, especially in developing countries like India, has affected the availability and quality of groundwater due to its overexploitation and improper waste disposal, especially in urban areas. According to WHO organization, about 80% of all the diseases in human beings are caused by water. Once the groundwater is contaminated, its quality cannot be restored by stopping the pollutants from the source. It therefore becomes imperative to monitor regularly the quality of groundwater and to devise ways and means to protect it. Water quality index is one of the most useful tools 1-4 to communicate information on the quality of water to the concerned citizens and policy makers. It, thus, becomes an important parameter for the assessment and management of groundwater.

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WQI is defined as a rating reflecting the composite influence of different water quality parameters. WQI is calculated from the point of view of the suitability of groundwater for human consumption. The objective of the present work is to discuss the suitability of groundwater for human consumption based on computed water quality index values.

### Study Area Description

Nagapattinam coastal District of Tamil Nadu., 326 K.M, from south of Chennai, lies between Northern Latitude 10.7906 degrees and 79.84 Degrees Eastern Longitude. A District is known for its Rich Religious Heritage and Communal Harmony. In Nagapattinam Taluk total population 2011 is 282784.male is 139917 and female is 142867. Number of house hold in Nagapattinam Taluk is 70683. The Taluk receives rainfall under the influence of both southwest and northeast monsoon. A good part of the precipitation occurs as during very intensive storms resulting mainly from cyclones generated in the Bay of Bengal especially during the northeast monsoon. The rainfall pattern in the district shows interesting features. Annual precipitation, which is1500 mm at Vedaranyam, the southeast corner of the Taluk, rapidly decreases to about1100 mm towards the west of the district. The area enjoys humid and tropical climate with hot summers, significant to mild winters and moderate to heavy rainfall.

The temperatures various from 40.6 to 19.3° C with sharp fall in night temperatures during monsoon period. The relative humidity ranges from 70 / 77% and it is high during the period from during October to November.

Bureau of Indian Standards (BIS), and Indian Council for medical research (ICMR).The Weighted arithmetic index method (Brown et.al..) has been used for calculation of WQI of the Taluk.

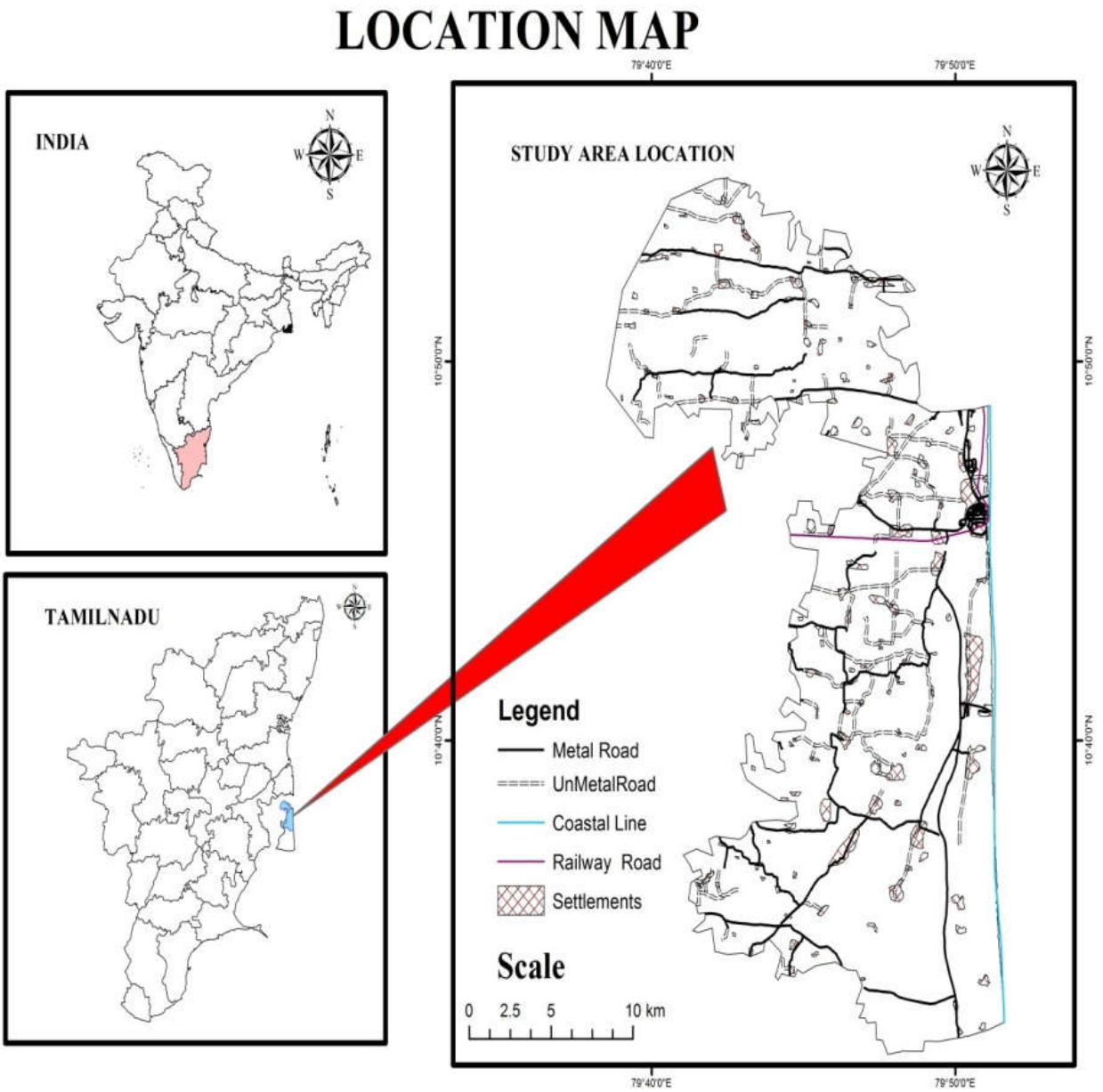



**Fig.1. Study area map**

## MATEIALS AND METHODS

Groundwater Quality were collected from Ground Water Surface and Data Source Centre, Taramani, Chennai. During pre-monsoon and Post Monsoon period (1998 to 2007) (Figure 3). Each of the groundwater samples was analyzed for 14 parameters such as pH, electrical conductivity, TDS, total hardness, bicarbonate, carbonate, chloride, sulphate, phosphate, nitrate, fluoride, calcium, magnesium, sodium, potassium, iron and manganese using standard procedures recommended by APHA. In this study for the calculation water quality index,14 important parameters were choosen.the WQI has been calculated by using standard of drinking water quality recommended by the world health organization (WHO),

Further quality rating or Sub index (qn) was calculated using the following expression.

**qn=100{vn-vio}/{sn-vio}**

**(**Let there be n water quality parameters and quality rating of sub index (qn) corresponding to nth parameters is a number reflecting the relative value of this parameter in the polluted water to respect to its Standard permissible Value.)

**qn=**quality rating for the nth water quality parameters.
**Vn=**estimated value of the nth parameters at a given sampling station.
**Sn=**standard permissible value of the nth parameter.

**Vio=**Ideal value of nth parameter in pure water.(i.e.,0 for all other parameters except the parameters pH and Dissolved oxygen (7.0 and 41.6 mg/l respectively.)

Unit weight was calculated by a value inversely proportional to the recommended standard value sn of the corresponding parameters.

**Wn=**k/sn
**Wn=**unit weight for the nth parameters.
**Sn=**standard value for nth parameters.
**K=**constant for proportionality.

The overall water quality was calculated by aggregating the quality rating with the unit weight linearly.

**WQI = ∑qn= Wn/∑Wn**

**Table.1. Water quality Index (WQI) and status of water quality (Chatterji and Razuiddin 2002)**

| Water Quality Index Level | Water Quality Status |
|---|---|
| 0-25 | Excellent Water quality |
| 26-50 | Good Water quality |
| 51-75 | Poor Water quality |
| 76-100 | Very Poor Water quality |
| >100 | Unsuitable for drinking |

## Ground water Quality

The Intrusion of seawater into the inland aquifers due to the over-exploitation of groundwater along the coastal area is an environmental issue. To protect coastal groundwater, the sources of saline water and mechanisms of mobility need to be identified and investigated for sustainable development of groundwater resources.

Ahmed and others (2002) have compared the analytical results of groundwater in Rajshahi city of Bangladesh with the recommended limits suggested by World Health Organization (WHO 1971). They have classified groundwater into various types. Anbazhagan and Nair (2004) have used the geographical information system (GIS) to represent and understand the spatial variation of different geochemical elements in Panvel Basin, Maharashtra, India. Ground water quality parameters were studied for pollution due to Industry, saltpan, sea water intrusion, agriculture, brackish water aquaculture and municipal sewage water on the east coast of Nagapattinam Taluk, Tamilnadu. Over a period of 3 years interval. Years (1998,2003,2007), groundwater data were collected from ground water department, PWD, Chennai and prepared the spatial mapping using Geographical information system (GIS). In The present study, at certain places various parameters exceeds the WHO / Indian standards of potable water.

## Spatial Distribution of Ground Water Quality (1998 to2007)

### pH

The pH of 90% of the water samples shows within the desirable limit of 6.5 – 8.5 given by WHO/BIS standard and most of the samples were slightly alkaline in nature, pH of water samples varied from 7.2 to 8.6. Over a period of 10 years, the Groundwater data were used for spatial distribution The pH vales were classified in three classes such as low (<6.5), medium (6.5-8.5) and high (>8.5). Nagapattinam areas are falls under high pH (>8.6). Increase of pH during the post-monsoon season shows that dissolution has been enhanced due to high interaction between soil and rainwater (Subramanian and Saxena 1983).

**Table 2.Drinking Water standards recommending Agencies and Unit weights (All value except pH and Electrical Conductivity are in mg/L)**

| Sr.no | Parameters | Standard Values ($s_n$) | Recommended Agency | Unit Weight |
|---|---|---|---|---|
| 1 | $P^H$ | 6.5-8.5 | ICMR/ BIS | 0.2190 |
| 2 | EC | 300 | ICMR | 0.371 |
| 3 | Total dissolved Solids | 500 | ICMR/ BIS | 0.0037 |
| 4 | Total Alkalinity | 120 | ICMR | 0.0155 |
| 5 | Total Hardness | 300 | ICMR/ BIS | 0.0062 |
| 6 | Total suspended soils | 500 | WHO | 0.0037 |
| 7 | Calcium | 75 | ICMR/ BIS | 0.025 |
| 8 | Magnesium | 30 | ICMR/ BIS | 0.061 |
| 9 | Chloride | 250 | ICMR | 0.0074 |
| 10 | Nitrate | 45 | ICMR/ BIS | 0.0412 |
| 11 | Sulphate | 150 | ICMR/ BIS | 0.01236 |
| 12 | Dissolved Oxygen | 5.00 | ICMR/ BIS | 0.3723 |
| 13 | Biological oxygen demand | 5.00 | ICMR | 0.3723 |

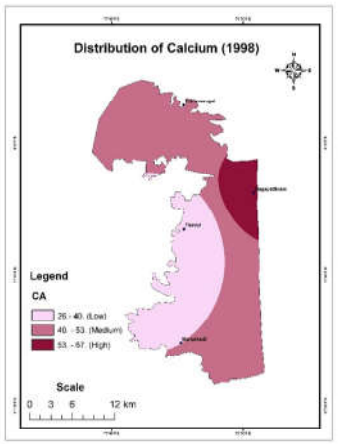
Ground water extraction, leading to a drying-up of the wells in that area. The quality of groundwater is equally important to its quantity owing to the suitability of water for various purposes. Variation of groundwater quality in an area is a function of physical and chemical parameters that are substantially influenced by geological formations and anthropogenic activities. Sujatha and Rajeswara Reddy (2003) have studied groundwater and its suitability for irrigation in the southeastern part of the Ranga Reddy district, Andra pradesh, India.

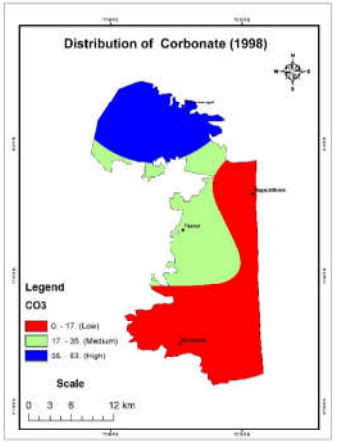
### Electrical conductivity

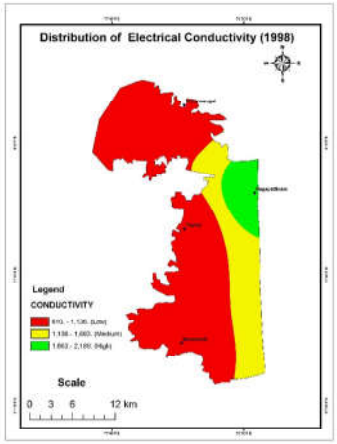
Electrical conductivity (EC) is the most important parameter in determining the suitability of water for drinking water and irrigation use. EC in water is due to ionization of dissolved inorganic solids and becomes a measure of total dissolved solids. It is used as a primary index to select the suitability of water for all purposes. In this area EC values in ground water ranged from minimum 360$\mu$S/cm to maximum 7200 $\mu$S/cm.

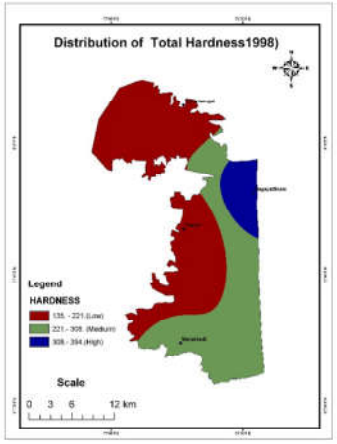
**Table 3. Spatial Distribution of Groundwater Quality in (1998)**

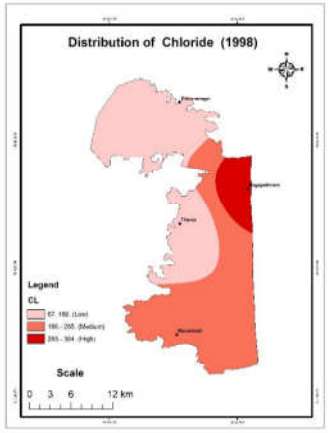
| LOCATION | Year | Groundwater Quality Parameters | | | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | Ca (Mg/L) | Mg (Mg/L) | Na (Mg/L) | K (Mg/L) | $HCO_3$ (Mg/L) | $CO_3$ (Mg/L) | $SO_4$ (Mg/L) | CL (Mg/L) | $NO_3$ (Mg/L) | F (Mg/L) | TDS (Mg/L) | TH (Mg/L) | EC ($\mu$S/cm) | pH |
| Nagapattinam | 1998 | 68 | 55 | 253 | 109 | 519 | 0 | 115 | 365 | 4 | - | 1243 | 395 | 2190 | 8.1 |
| Thirumarugal | 1998 | 44 | 16 | 51 | 109 | 238 | 54 | 14 | 85 | 1.4 | - | 498 | 175 | 770 | 8.3 |
| Manakkudi | 1998 | 40 | 30 | 152 | 14 | 293 | 0 | 45 | 206 | 1 | - | 640 | 225 | 1120 | 8.2 |
| Thevur | 1998 | 26 | 17 | 69 | 36 | 189 | 36 | 14 | 67 | 3.2 | - | 324 | 135 | 610 | 8.4 |

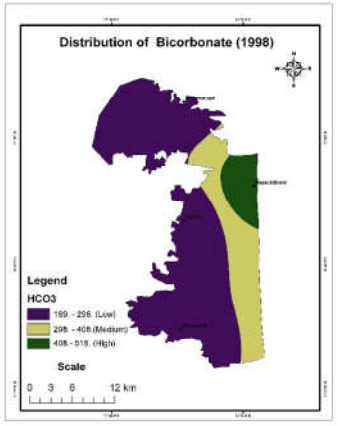


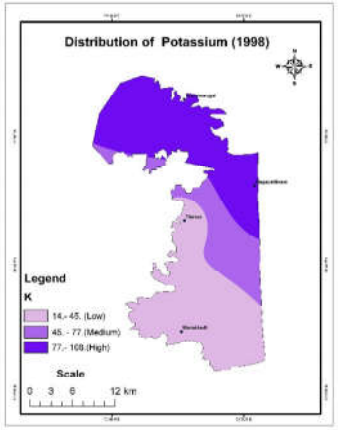



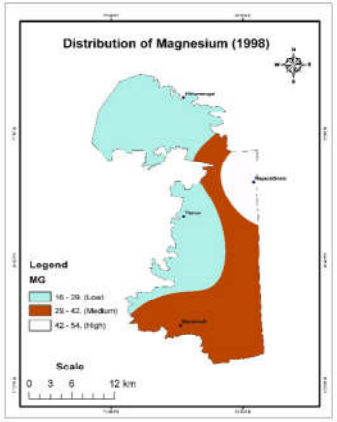



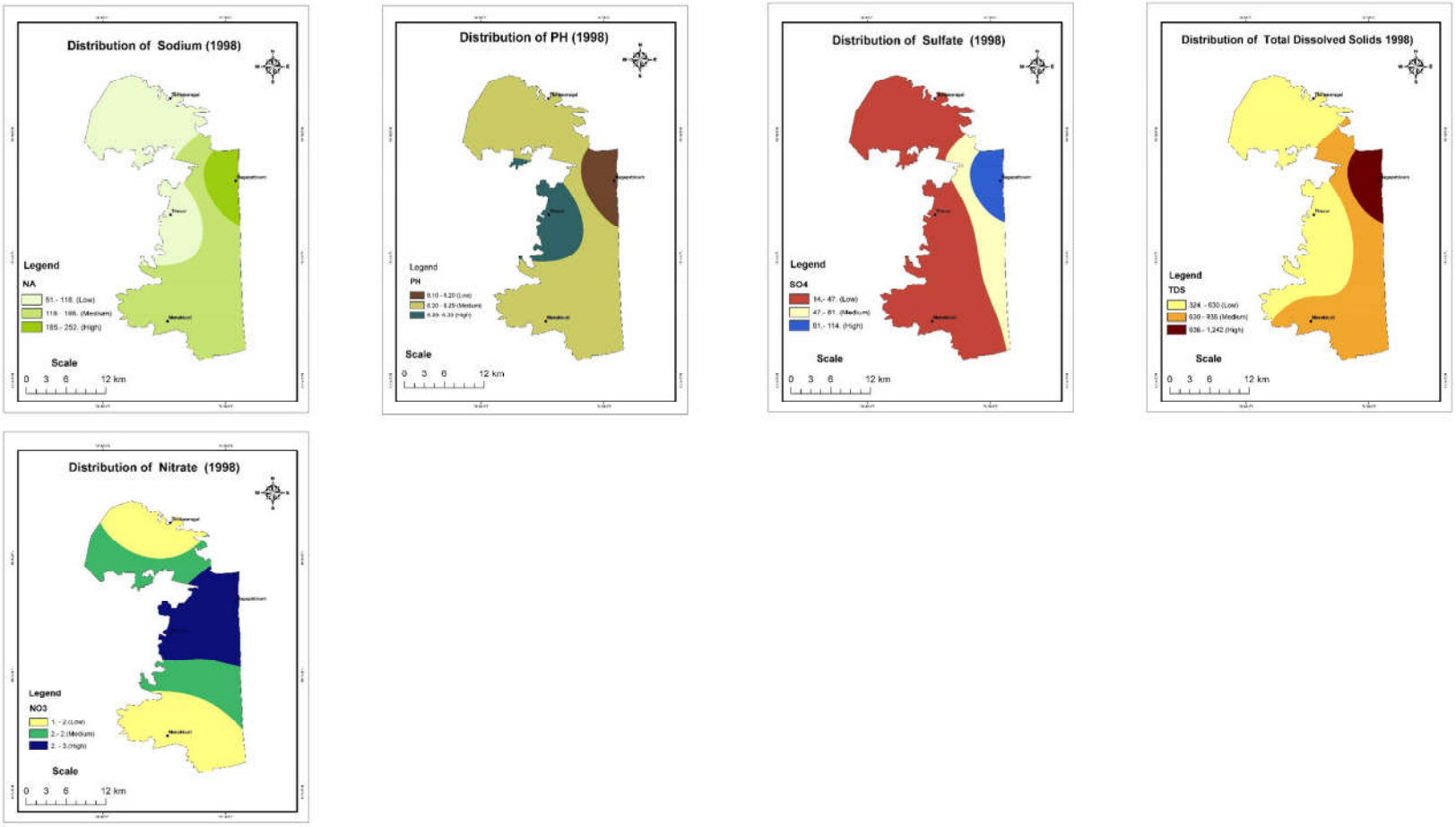
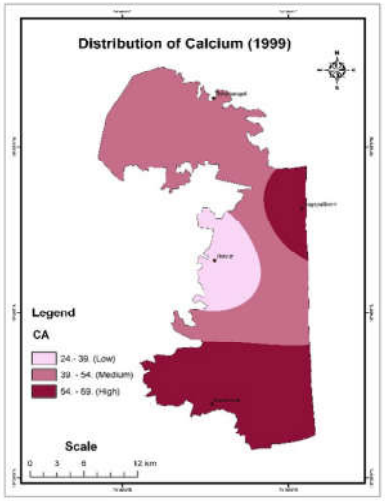
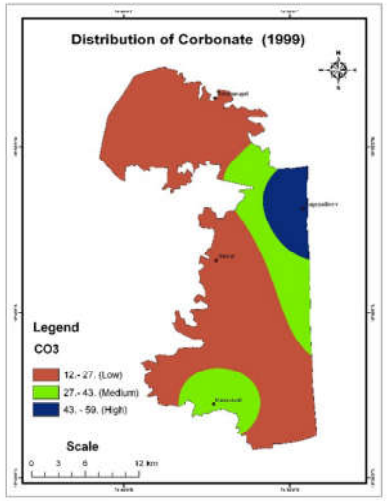


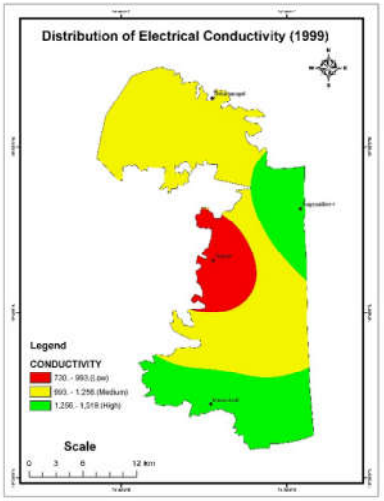

**Fig.2.Spatial Distribution of Ground Water quality in (1998)**

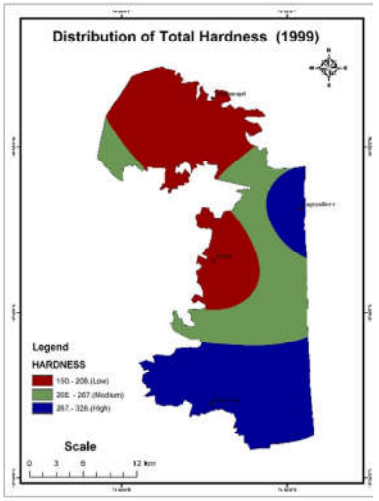
**Table 4. Spatial Distribution of Groundwater Quality in (1999)**

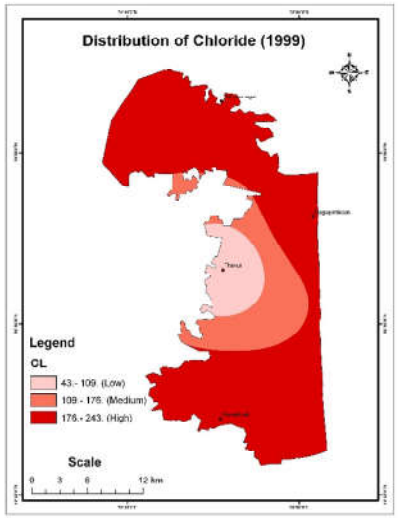
| LOCATION | Year | Groundwater Quality Parameters | | | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | Ca (Mg/L) | Mg (Mg/L) | Na (Mg/L) | K (Mg/L) | $HCO_3$ (Mg/L) | $CO_3$ (Mg/L) | $SO_4$ (Mg/L) | CL (Mg/L) | $NO_3$ (Mg/L) | F (Mg/L) | TDS (Mg/L) | TH (Mg/L) | EC ($\mu$S/cm) | pH |
| Nagapattinam | 1999 | 64 | 34 | 168 | 94 | 311 | 60 | 79 | 234 | 8 | - | 925 | 300 | 1520 | 8.6 |
| Thirumarugal | 1999 | 44 | 10 | 156 | 82 | 287 | 18 | 24 | 206 | 6.2 | - | 711 | 150 | 1140 | 8.5 |
| Manakkudi | 1999 | 70 | 29 | 168 | 15 | 342 | 30 | 58 | 209 | 3 | - | 762 | 295 | 1270 | 8.5 |
| Thevur | 1999 | 24 | 22 | 64 | 102 | 397 | 12 | 8 | 43 | 3.7 | - | 490 | 150 | 730 | 8.4 |

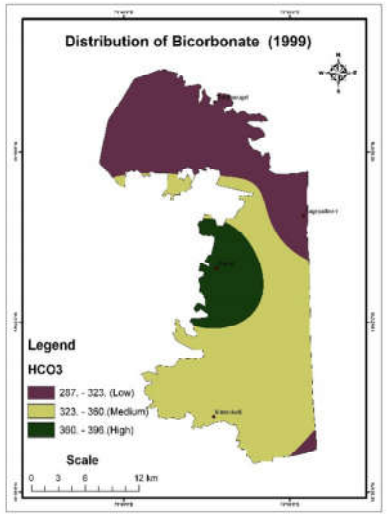

Distribution of Calcium (1999)
Legend
CA
24 - 39. (Low)
39 - 54. (Medium)
54 - 69. (High)
Scale
0 3 6 12 km

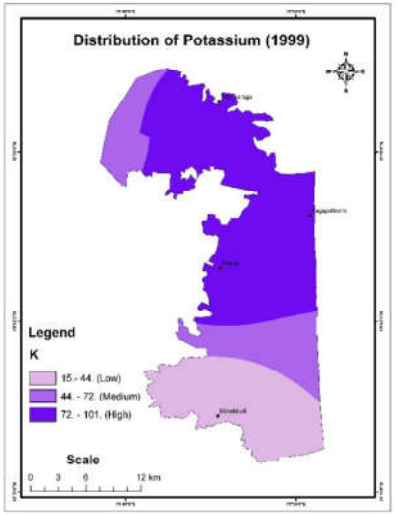

Distribution of Corbonate (1999)
Legend
CO3
12 - 27. (Low)
27 - 43. (Medium)
43 - 59. (High)
Scale
0 3 6 12 km

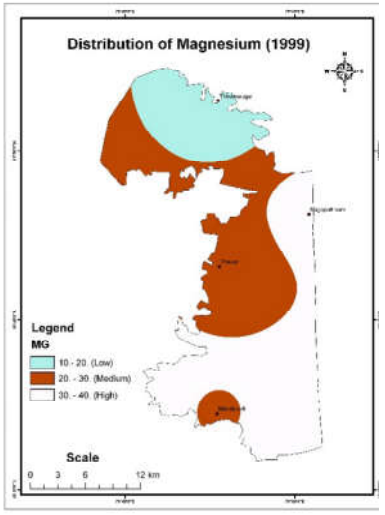

Distribution of Electrical Conductivity (1999)
Legend
CONDUCTIVITY
720 - 993.(Low)
993 - 1,256.(Medium)
1,256 - 1,519.(High)
Scale
0 3 6 12 km


Distribution of Total Hardness (1999)
Legend
HARDNESS
150 - 208.(Low)
208 - 267.(Medium)
267 - 326.(High)
Scale
0 3 6 12 km


Distribution of Chloride (1999)
Legend
CL
43 - 109. (Low)
109 - 176. (Medium)
176 - 243. (High)
Scale
0 3 6 12 km


Distribution of Bicorbonate (1999)
Legend
HCO3
287 - 323. (Low)
323 - 360.(Medium)
360 - 396.(High)
Scale
0 3 6 12 km


Distribution of Potassium (1999)
Legend
K
15 - 44. (Low)
44 - 72. (Medium)
72 - 101. (High)
Scale
0 3 6 12 km


Distribution of Magnesium (1999)
Legend
MG
10 - 20. (Low)
20 - 30. (Medium)
30 - 40. (High)
Scale
0 3 6 12 km

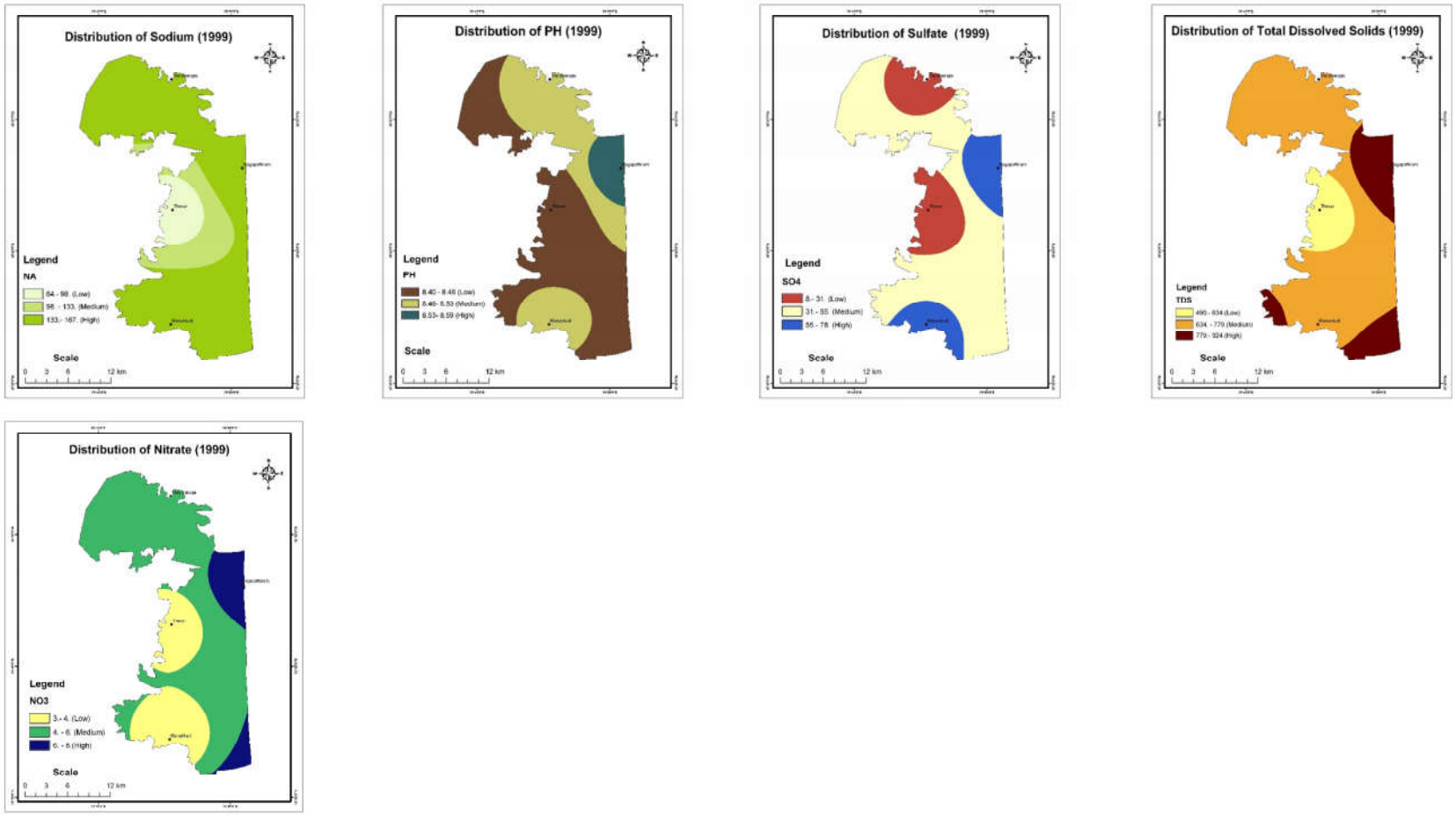
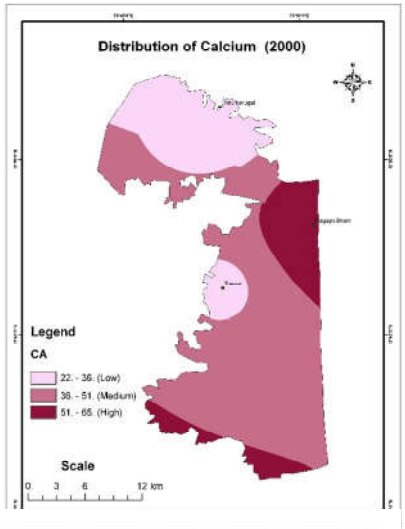
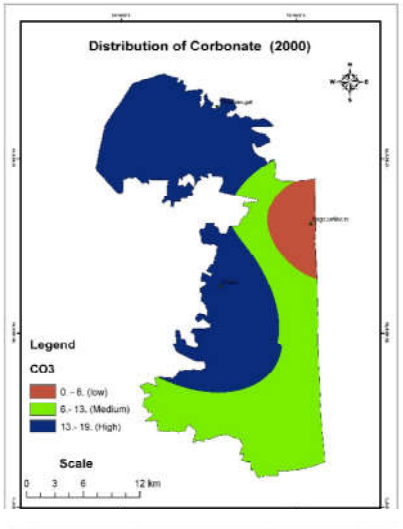


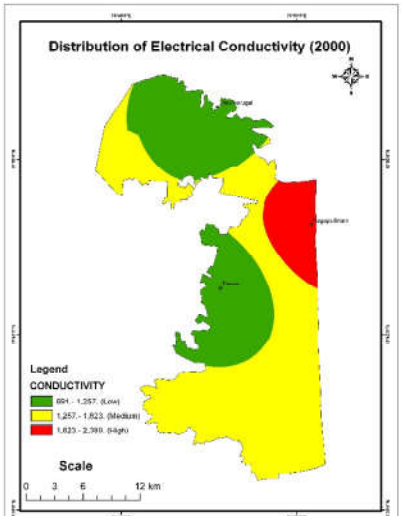

**Fig. 3. Spatial Distribution of Ground Water quality in (1999)**

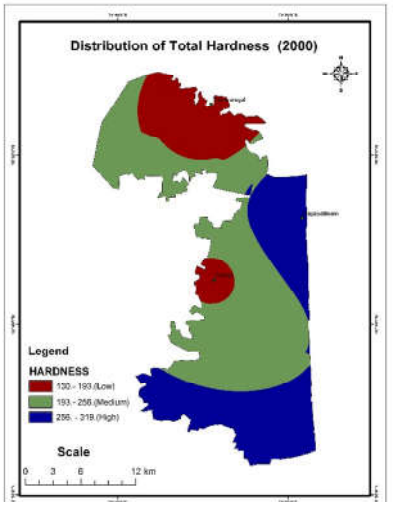
**Table 5. Spatial Distribution of Groundwater Quality in (2000)**

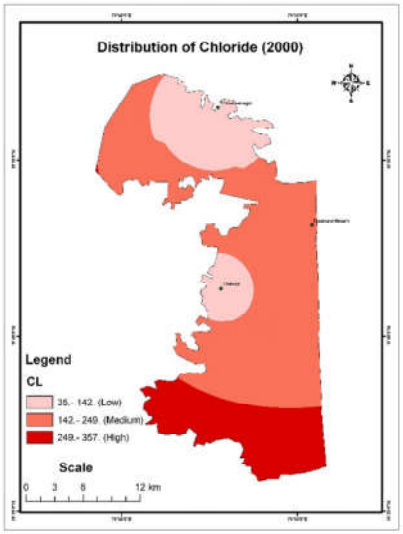
| LOCATION | Year | Groundwater Quality Parameters | | | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | Ca (Mg/L) | Mg (Mg/L) | Na (Mg/L) | K (Mg/L) | $HCO_3$ (Mg/L) | $CO_3$ (Mg/L) | $SO_4$ (Mg/L) | CL (Mg/L) | $NO_3$ (Mg/L) | F (Mg/L) | TDS (Mg/L) | TH (Mg/L) | EC ($\mu$S/cm) | pH |
| Nagapattinam | 2000 | 66 | 37.2 | 311 | 78 | 231.8 | 0 | 408 | 184 | 8.7 | 0.1 | 1238.5 | 320 | 2390 | 8.1 |
| Thirumarugal | 2000 | 22 | 18 | 37 | 94 | 251.7 | 18 | 5 | 35 | 0.8 | 0.1 | 358.6 | 130 | 690 | 8.8 |
| Thevur | 2000 | 34 | 24 | 78 | 28 | 146.7 | 18 | 27 | 124 | 6.9 | 0.1 | 436.7 | 185 | 740 | 8.5 |

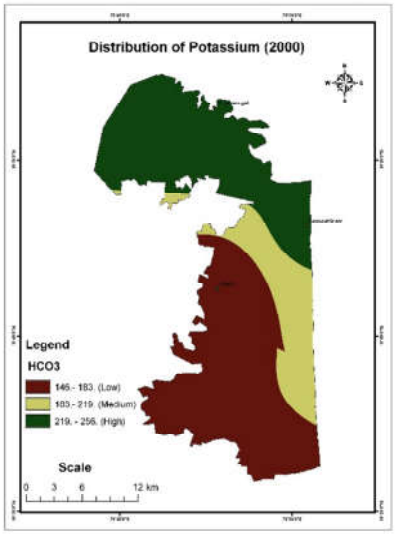

Distribution of Calcium (2000)
Legend
CA
22. - 36. (Low)
36. - 51. (Medium)
51. - 65. (High)
Scale
0 3 6 12 km

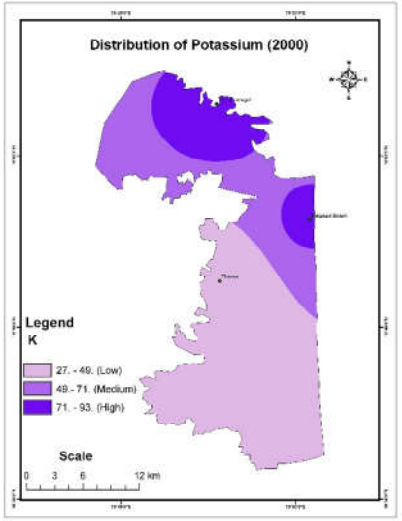

Distribution of Corbonate (2000)
Legend
CO3
0. - 6. (low)
6. - 13. (Medium)
13. - 19. (High)
Scale
0 3 6 12 km

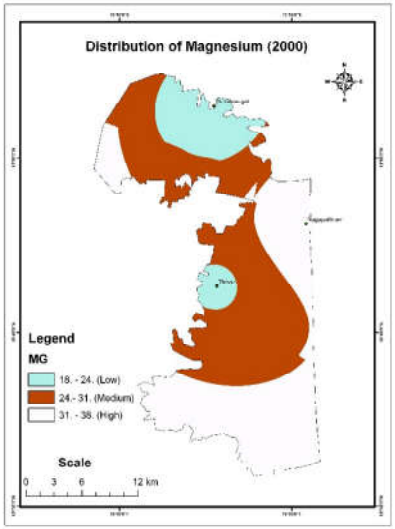

Distribution of Electrical Conductivity (2000)
Legend
CONDUCTIVITY
Scale
0 3 6 12 km


Distribution of Total Hardness (2000)
Legend
HARDNESS
130. - 193.(Low)
193. - 256.(Medium)
256. - 318.(High)
Scale
0 3 6 12 km


Distribution of Chloride (2000)
Legend
CL
35. - 142. (Low)
142. - 249. (Medium)
249. - 357. (High)
Scale
0 3 6 12 km


Distribution of Potassium (2000)
Legend
HCO3
146. - 183. (Low)
183. - 219. (Medium)
219. - 256. (High)
Scale
0 3 6 12 km


Distribution of Potassium (2000)
Legend
K
27. - 49. (Low)
49. - 71. (Medium)
71. - 93. (High)
Scale
0 3 6 12 km


Distribution of Magnesium (2000)
Legend
MG
18. - 24. (Low)
24. - 31. (Medium)
31. - 38. (High)
Scale
0 3 6 12 km

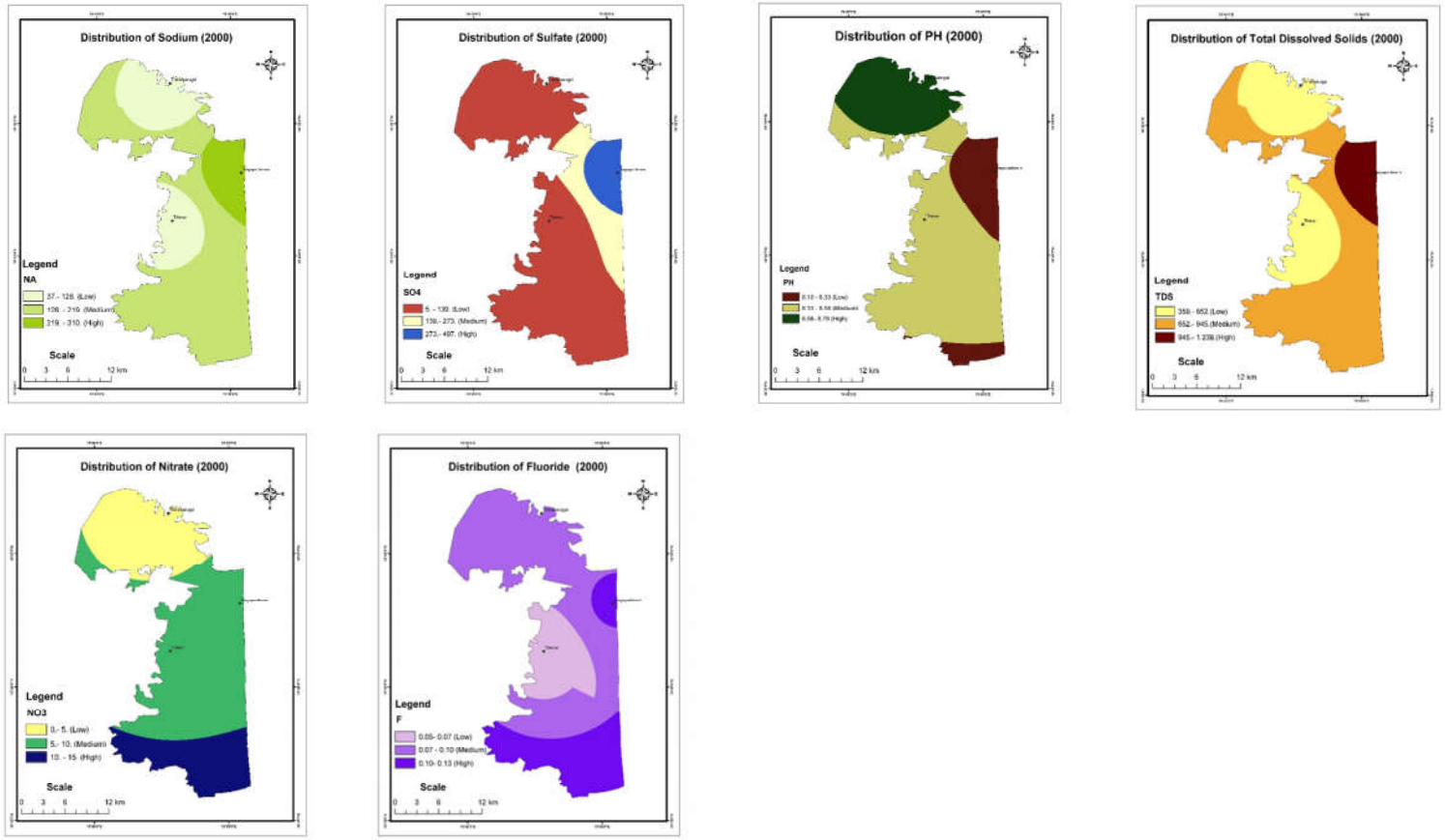
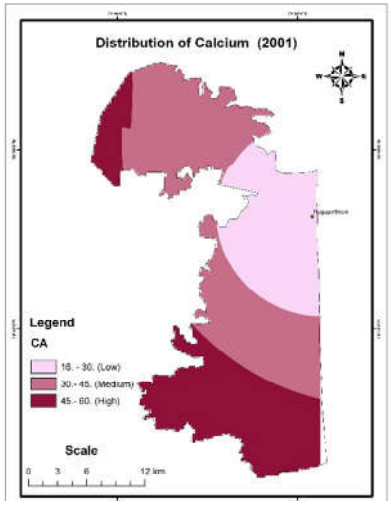
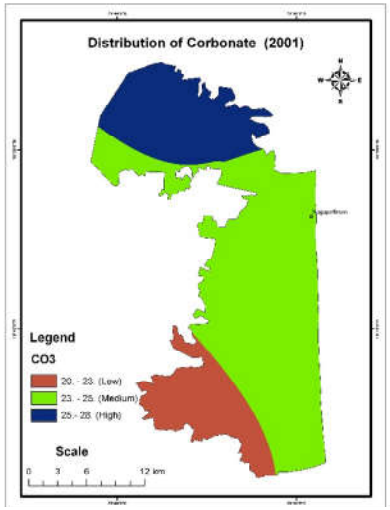


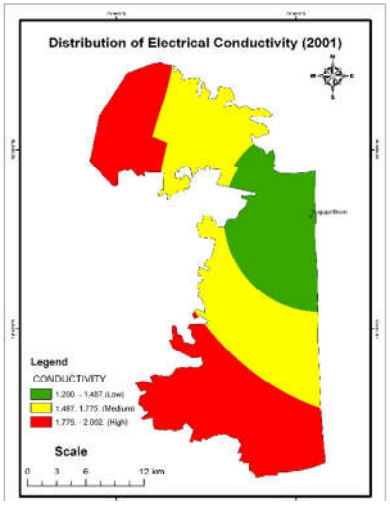

**Fig.4.Spatial Distribution of Ground Water quality in (2000)**

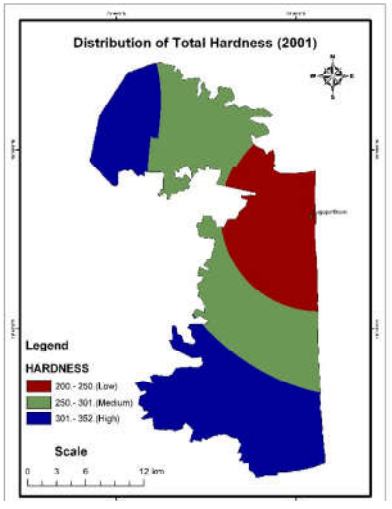
**Table 6.Spatial Distribution of Groundwater Quality in (2001)**

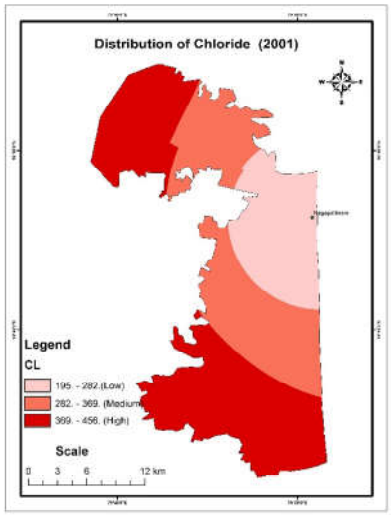
| LOCATION | Year | Groundwater Quality Parameters | | | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | Ca (Mg/L) | Mg (Mg/L) | Na (Mg/L) | K (Mg/L) | $HCO_3$ (Mg/L) | $CO_3$ (Mg/L) | $SO_4$ (Mg/L) | CL (Mg/L) | $NO_3$ (Mg/L) | F (Mg/L) | TDS (Mg/L) | TH (Mg/L) | EC ($\mu$S/cm) | pH |
| Nagapattinam | 2001 | 16 | 38.4 | 150 | 98 | 160.6 | 24 | 154 | 195 | 7 | 0.1 | 786.7 | 200 | 1200 | 8.5 |

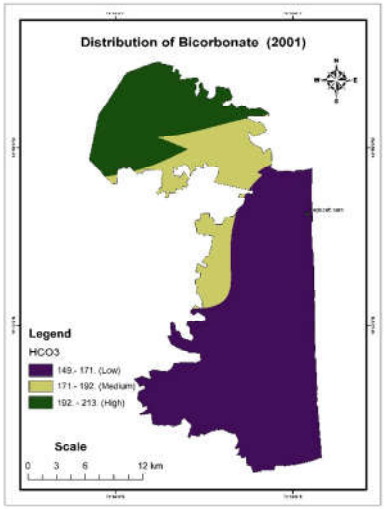

Distribution of Calcium (2001)
Legend
CA
16. - 30. (Low)
30. - 45. (Medium)
45. - 60. (High)
Scale
0 3 6 12 km

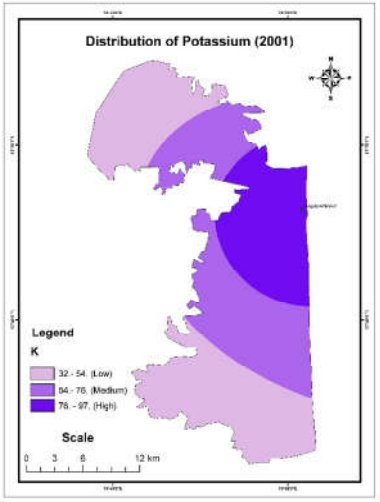

Distribution of Corbonate (2001)
Legend
CO3
20. - 23. (Low)
23. - 25. (Medium)
25. - 28. (High)
Scale
0 3 6 12 km

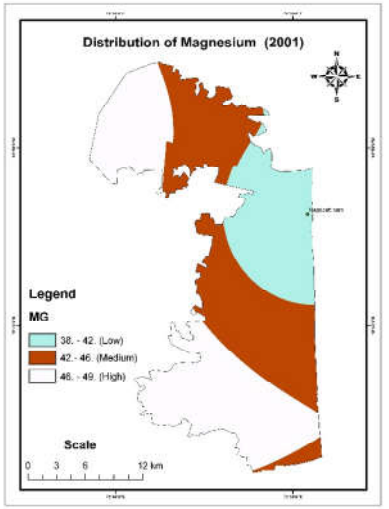

Distribution of Electrical Conductivity (2001)
Legend
CONDUCTIVITY
1,200. - 1,487. (Low)
1,487. 1,775. (Medium)
1,775. - 2,062. (High)
Scale
0 3 6 12 km


Distribution of Total Hardness (2001)
Legend
HARDNESS
200 - 250 (Low)
250 - 301 (Medium)
301 - 352 (High)
Scale
0 3 6 12 km


Distribution of Chloride (2001)
Legend
CL
195. - 282. (Low)
282. - 369. (Medium)
369. - 456. (High)
Scale
0 3 6 12 km


Distribution of Bicorbonate (2001)
Legend
HCO3
149. - 171. (Low)
171. - 192. (Medium)
192. - 213. (High)
Scale
0 3 6 12 km


Distribution of Potassium (2001)
Legend
K
32. - 54. (Low)
54. - 76. (Medium)
76. - 97. (High)
Scale
0 3 6 12 km


Distribution of Magnesium (2001)
Legend
MG
38. - 42. (Low)
42. - 46. (Medium)
46. - 49. (High)
Scale
0 3 6 12 km

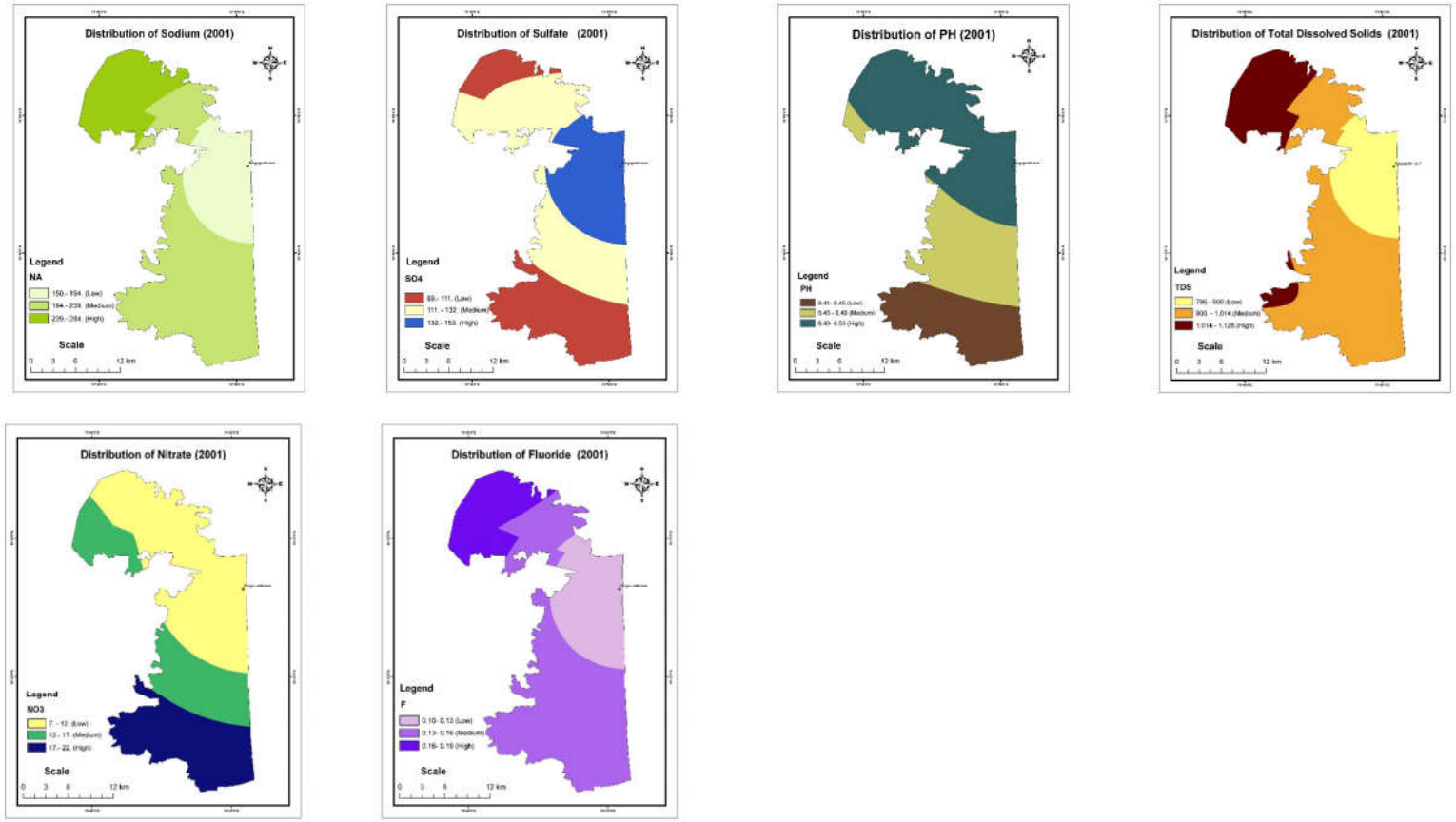
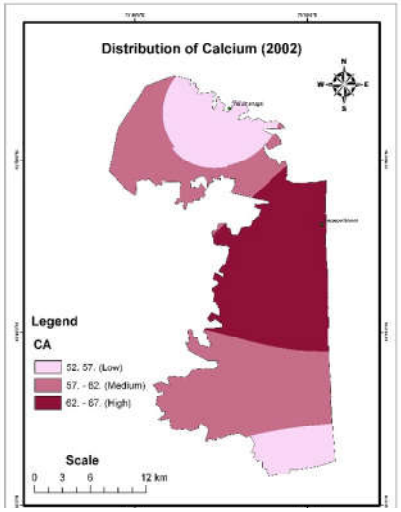


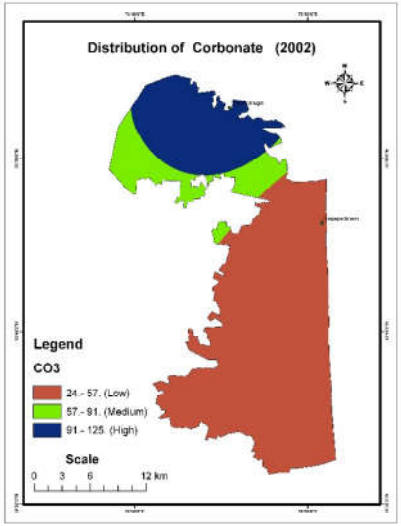

**Fig. 5. Spatial Distribution of Ground Water quality in (2001)**

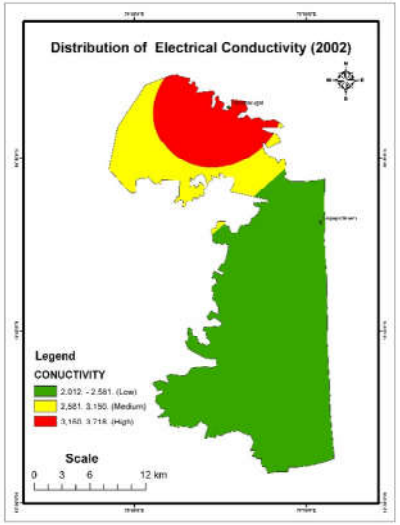
**Table.7.Spatial Distribution of Groundwater Quality in (2002)**

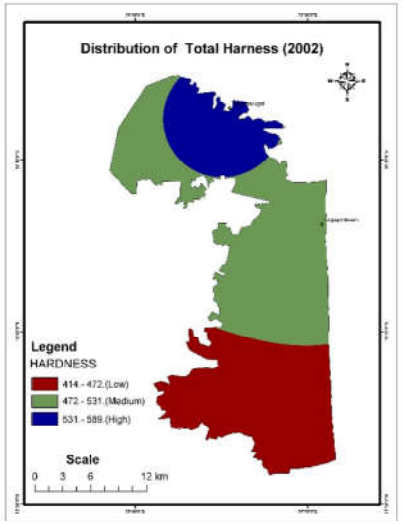
| LOCATION | Year | Groundwater Quality Parameters | | | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | Ca (Mg/L) | Mg (Mg/L) | Na (Mg/L) | K (Mg/L) | $HCO_3$ (Mg/L) | $CO_3$ (Mg/L) | $SO_4$ (Mg/L) | CL (Mg/L) | $NO_3$ (Mg/L) | F (Mg/L) | TDS (Mg/L) | TH (Mg/L) | EC ($\mu$S/cm) | pH |
| Nagapattinam | 2002 | 68 | 85.1 | 173 | 66 | 158.6 | 24 | 132 | 355 | 49 | 0.1 | 1200 | 520 | 2100 | 8.4 |
| Thirumarugal | 2002 | 52 | 111.8 | 483 | 164 | 506.3 | 126 | 96 | 752 | 25 | 0.1 | 2149 | 590 | 3720 | 8.3 |

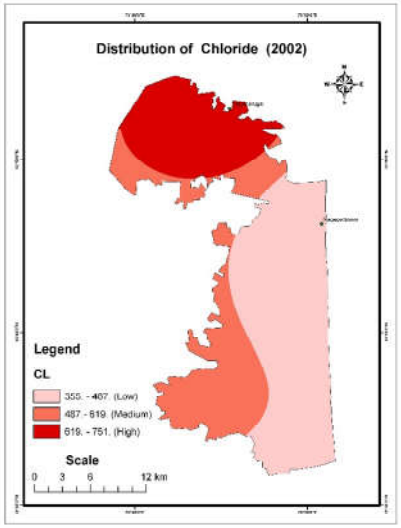
.

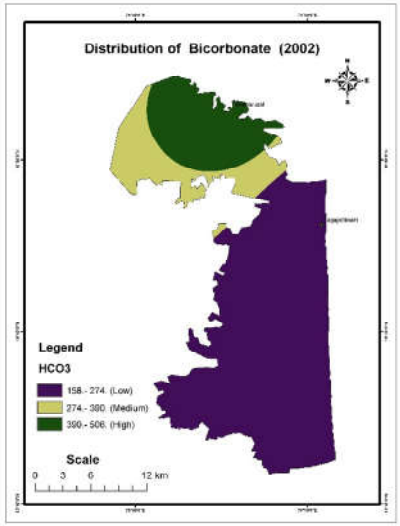

Distribution of Calcium (2002)
Legend
CA
52. 57. (Low)
57. - 62. (Medium)
62. - 67. (High)
Scale
0 3 6 12 km

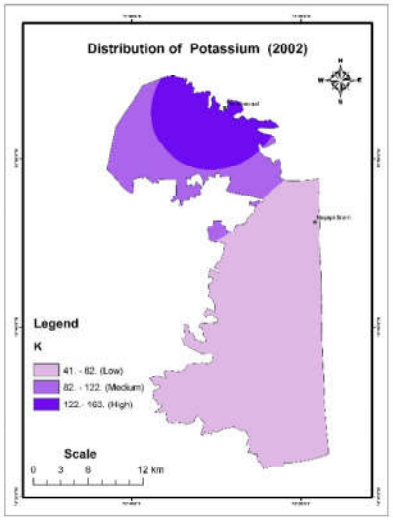

Distribution of Corbonate (2002)
Legend
CO3
24. - 57. (Low)
57. - 91. (Medium)
91 - 125. (High)
Scale
0 3 6 12 km

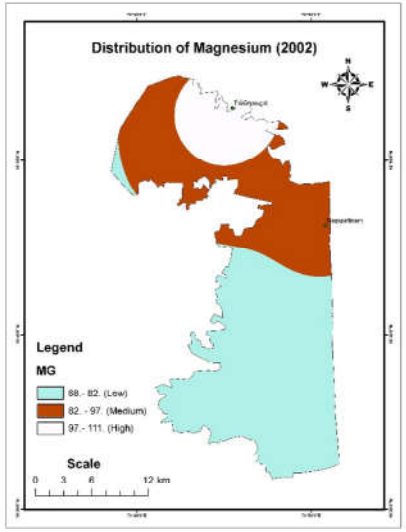

Distribution of Electrical Conductivity (2002)
Legend
CONUCTIVITY
2,012. - 2,581. (Low)
2,581. 3,150. (Medium)
3,150. 3,718. (High)
Scale
0 3 6 12 km


Distribution of Total Harness (2002)
Legend
HARDNESS
414 - 472.(Low)
472 - 531.(Medium)
531 - 589.(High)
Scale
0 3 6 12 km


Distribution of Chloride (2002)
Legend
CL
355. - 407. (Low)
407 - 619. (Medium)
619. - 751. (High)
Scale
0 3 6 12 km


Distribution of Bicorbonate (2002)
Legend
HCO3
158. - 274. (Low)
274. - 390. (Medium)
390 - 506. (High)
Scale
0 3 6 12 km


Distribution of Potassium (2002)
Legend
K
41. - 82. (Low)
82. - 122. (Medium)
122. - 163. (High)
Scale
0 3 6 12 km


Distribution of Magnesium (2002)
Legend
MG
88. - 82. (Low)
82. - 97. (Medium)
97. - 111. (High)
Scale
0 3 6 12 km

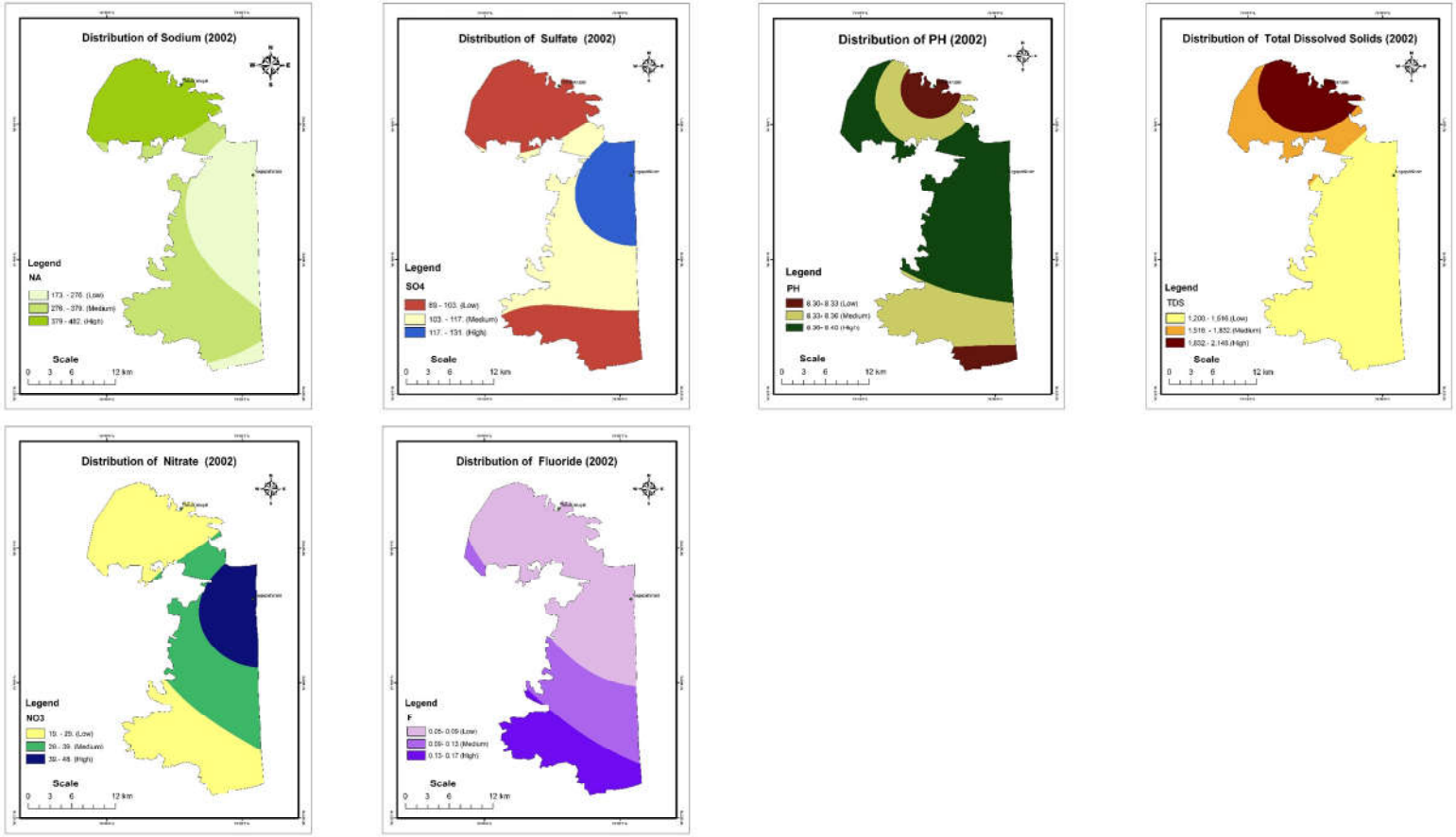
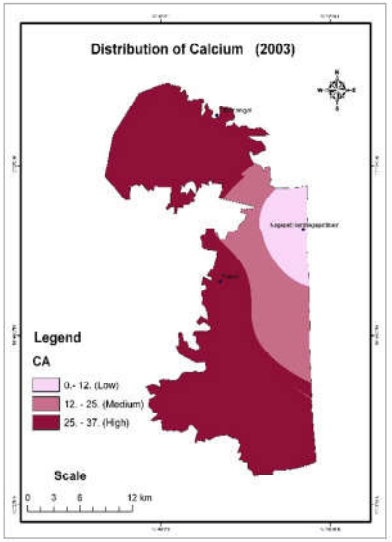
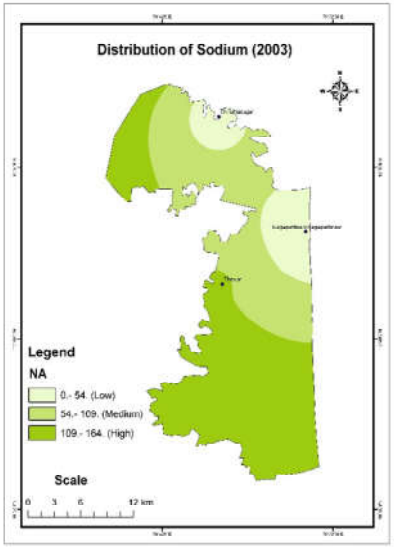


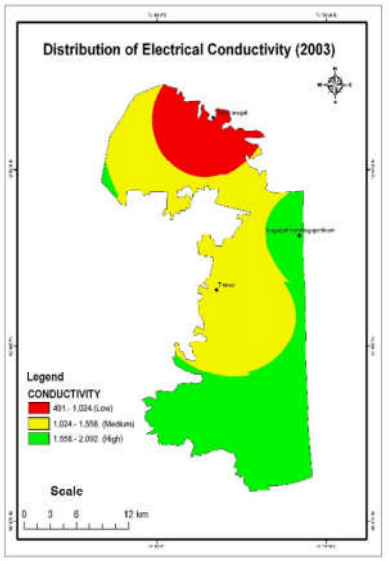

**Fig. 6. Spatial Distribution of Ground Water quality in (2002)**

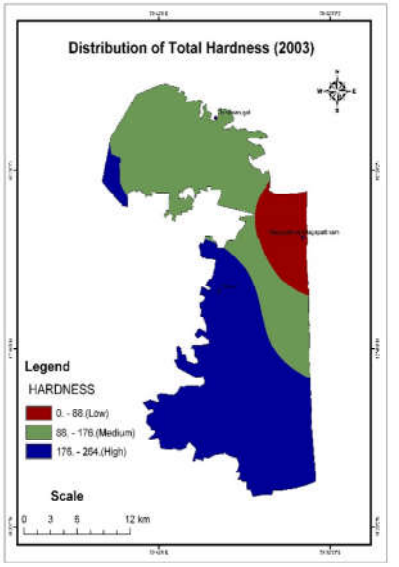
**Table 8. Spatial Distribution of Groundwater Quality in (2003)**

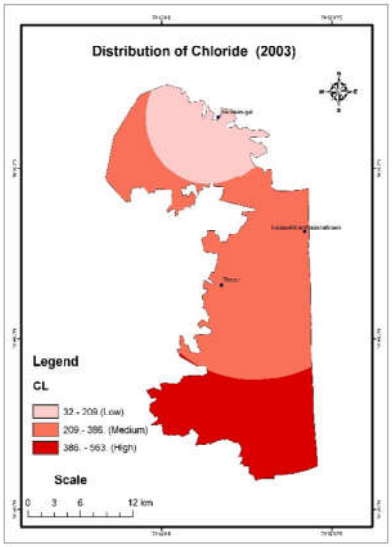
| LOCATION | Year | Groundwater Quality Parameters | | | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | Ca (Mg/L) | Mg (Mg/L) | Na (Mg/L) | K (Mg/L) | $HCO_3$ (Mg/L) | $CO_3$ (Mg/L) | $SO_4$ (Mg/L) | CL (Mg/L) | $NO_3$ (Mg/L) | F (Mg/L) | TDS (Mg/L) | TH (Mg/L) | EC ($\mu$S/cm) | pH |
| Nagapattinam | 2003 | 40 | 43 | 170 | 86 | 262 | 0 | 168 | 216 | 29.4 | 0.05 | 882 | 275 | 1470 | 8.2 |
| Thirumarugal | 2003 | 38 | 4 | 32 | 70 | 146 | 24 | 9 | 32 | 9.4 | 0.05 | 291 | 110 | 490 | 8.3 |

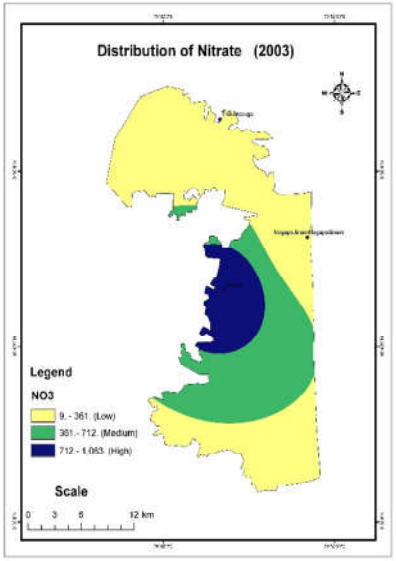

Distribution of Calcium (2003)
Legend
CA
0.- 12. (Low)
12. - 25. (Medium)
25. - 37. (High)
Scale
0 3 6 12 km

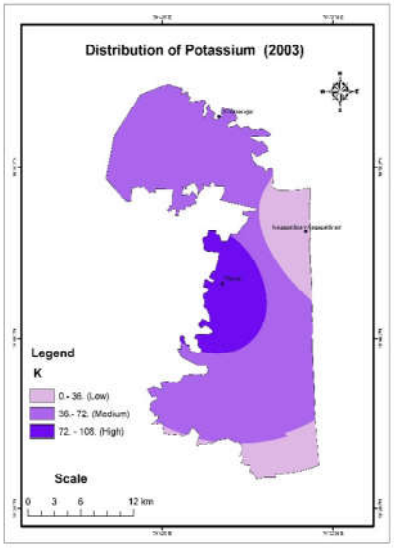

Distribution of Sodium (2003)
Legend
NA
0.- 54. (Low)
54.- 109. (Medium)
109.- 164. (High)
Scale
0 3 6 12 km

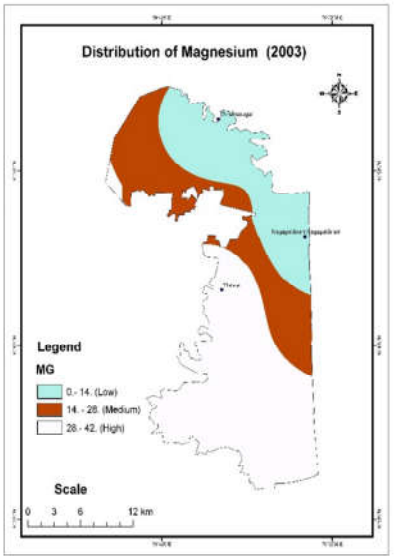

Distribution of Electrical Conductivity (2003)
Legend
CONDUCTIVITY
491.- 1,024.(Low)
1,024.- 1,558. (Medium)
1,558.- 2,092. (High)
Scale
0 3 6 12 km


Distribution of Total Hardness (2003)
Legend
HARDNESS
0. - 88.(Low)
88. - 176.(Medium)
176. - 264.(High)
Scale
0 3 6 12 km


Distribution of Chloride (2003)
Legend
CL
32 - 209 (Low)
209 - 386. (Medium)
386. - 563. (High)
Scale
0 3 6 12 km


Distribution of Nitrate (2003)
Legend
NO3
9. - 361. (Low)
361. - 712. (Medium)
712 - 1,063. (High)
Scale
0 3 6 12 km


Distribution of Potassium (2003)
Legend
K
0 - 36. (Low)
36. - 72. (Medium)
72. - 108. (High)
Scale
0 3 6 12 km


Distribution of Magnesium (2003)
Legend
MG
0. - 14. (Low)
14. - 28. (Medium)
28. - 42. (High)
Scale
0 3 6 12 km

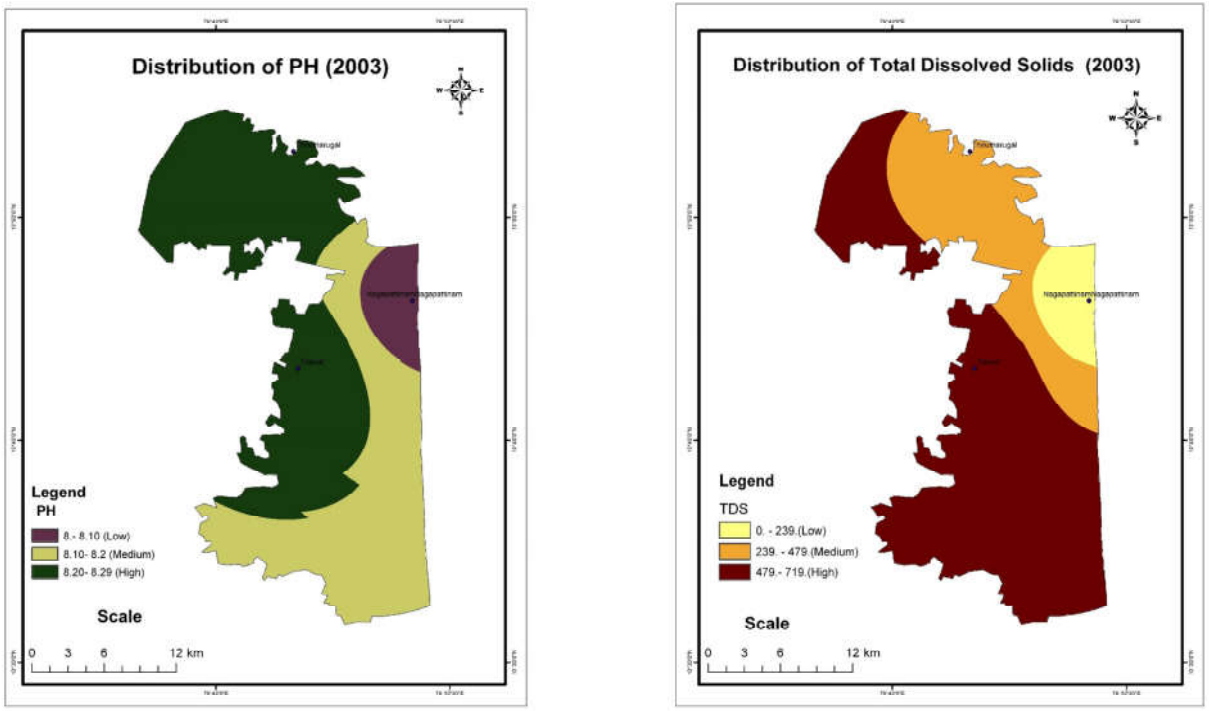
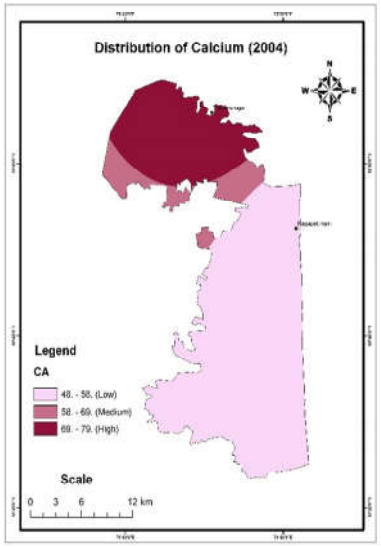
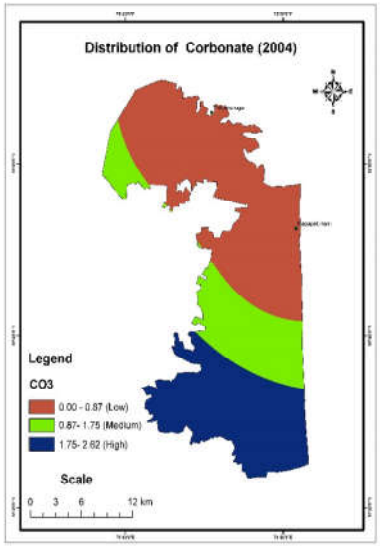


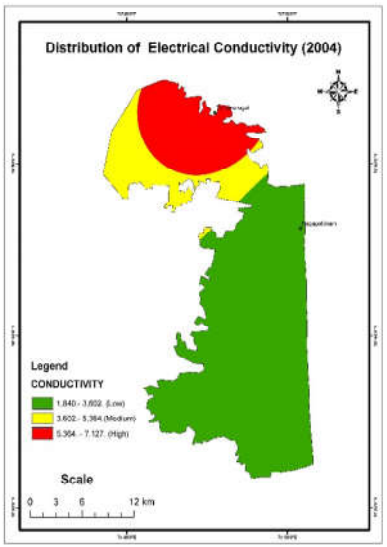

**Fig.7. Spatial Distribution of Ground Water quality in (2003)**

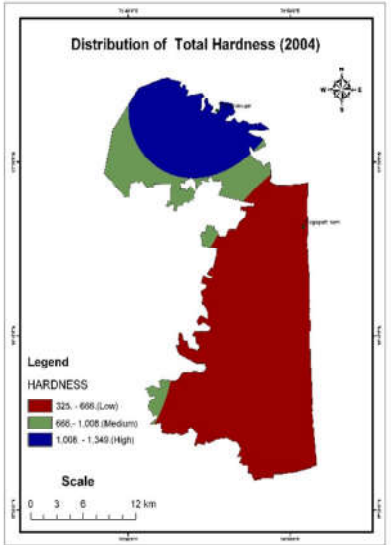
**Table 9. Spatial Distribution of Groundwater Quality in (2004)**

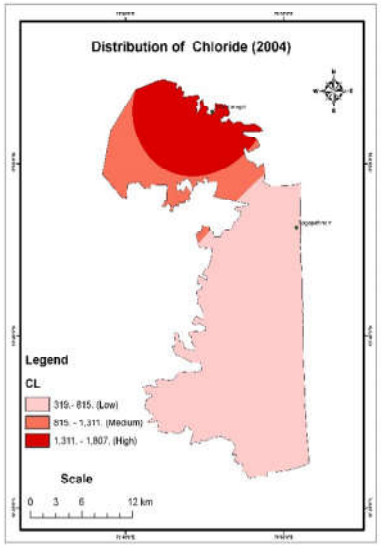
| LOCATION | Year | Groundwater Quality Parameters | | | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | Ca (Mg/L) | Mg (Mg/L) | Na (Mg/L) | K (Mg/L) | $HCO_3$ (Mg/L) | $CO_3$ (Mg/L) | $SO_4$ (Mg/L) | CL (Mg/L) | $NO_3$ (Mg/L) | F (Mg/L) | TDS (Mg/L) | TH (Mg/L) | EC ($\mu$S/cm) | pH |
| Thirumarugal | 2004 | 80 | 279.5 | 961 | 313 | 1207.8 | 0 | 326 | 1808 | 4.2 | 0.3 | 4375 | 1350 | 7130 | 7.8 |
| Nagapattinam | 2004 | 48 | 49.8 | 253 | 37 | 122 | 0 | 209 | 319 | 25.2 | 0.1 | 1002 | 325 | 1840 | 7.2 |

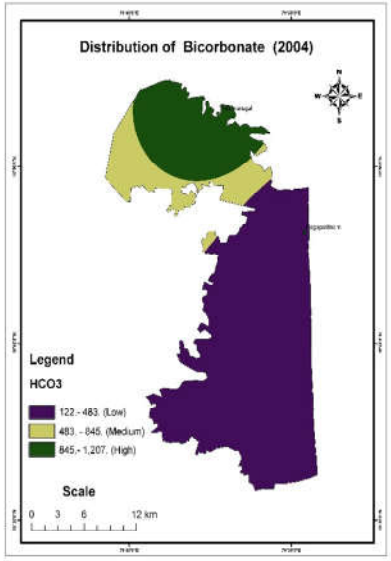

Distribution of Calcium (2004)
Legend
CA
48. - 58. (Low)
58. - 69. (Medium)
69. - 79. (High)
Scale
0 3 6 12 km

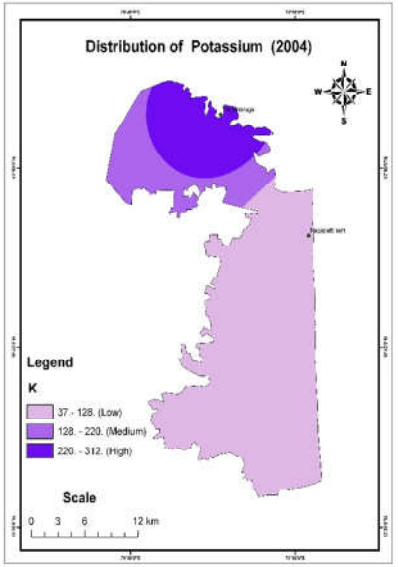

Distribution of Corbonate (2004)
Legend
CO3
0.00 - 0.87 (Low)
0.87- 1.75 (Medium)
1.75- 2.62 (High)
Scale
0 3 6 12 km

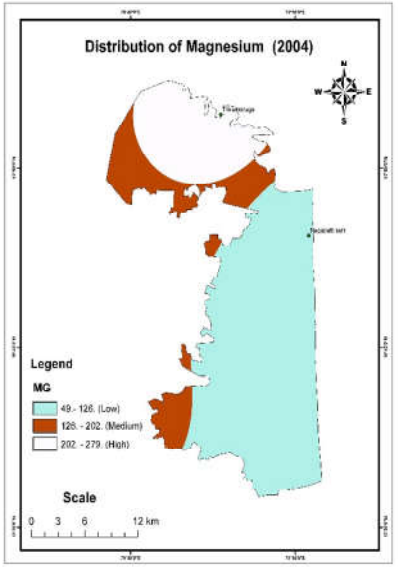

Distribution of Electrical Conductivity (2004)
Legend
CONDUCTIVITY
1,840 - 3,602. (Low)
3,602. - 5,364.(Medium)
5,364. - 7,127. (High)
Scale
0 3 6 12 km


Distribution of Total Hardness (2004)
Legend
HARDNESS
325. - 668.(Low)
668. - 1,008.(Medium)
1,008. - 1,349.(High)
Scale
0 3 6 12 km


Distribution of Chloride (2004)
Legend
CL
319. - 815. (Low)
815. - 1,311. (Medium)
1,311. - 1,807. (High)
Scale
0 3 6 12 km


Distribution of Bicorbonate (2004)
Legend
HCO3
122. - 483. (Low)
483. - 845. (Medium)
845. - 1,207. (High)
Scale
0 3 6 12 km


Distribution of Potassium (2004)
Legend
K
37 - 128. (Low)
128. - 220. (Medium)
220. - 312. (High)
Scale
0 3 6 12 km


Distribution of Magnesium (2004)
Legend
MG
49 - 126. (Low)
126. - 202. (Medium)
202. - 279. (High)
Scale
0 3 6 12 km

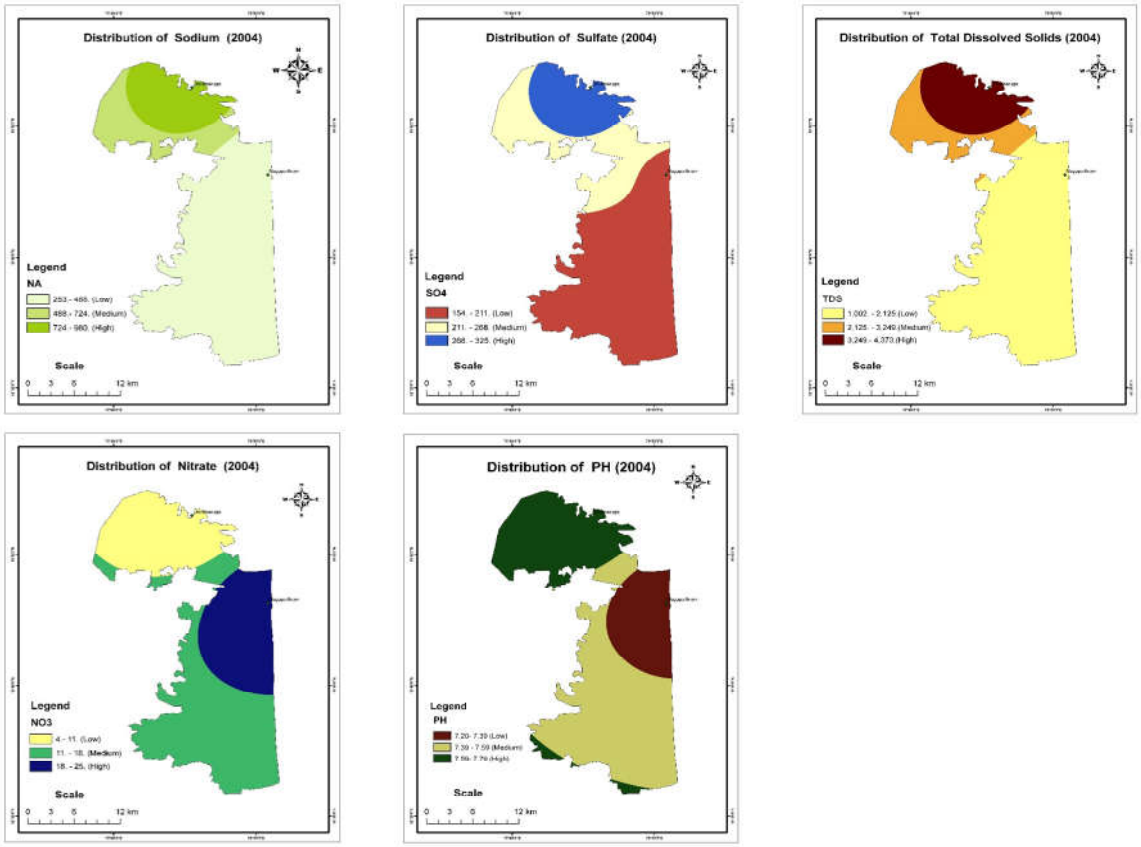
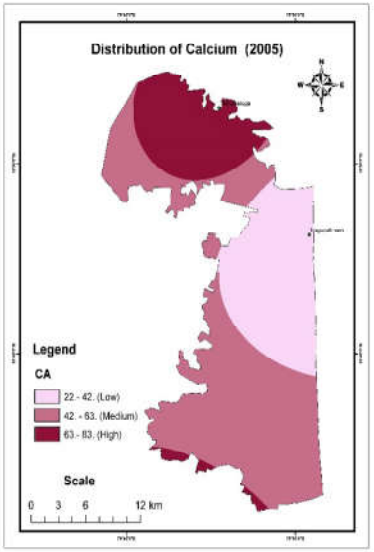
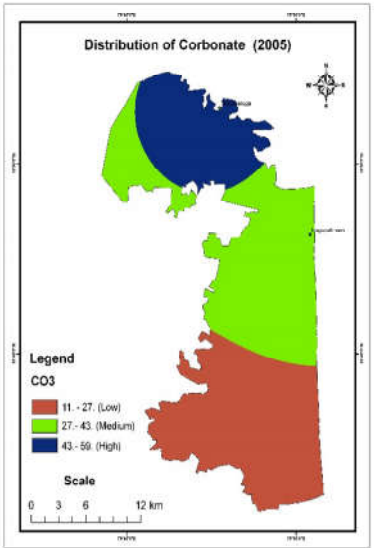


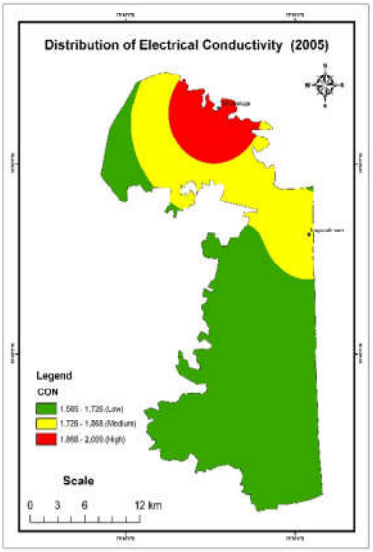

**Fig. 8. Spatial Distribution of Ground Water quality in (2004)**

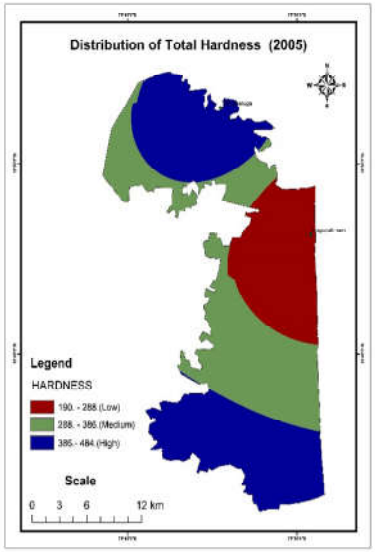
**Table 10. Spatial Distribution of Groundwater Quality in (2005)**

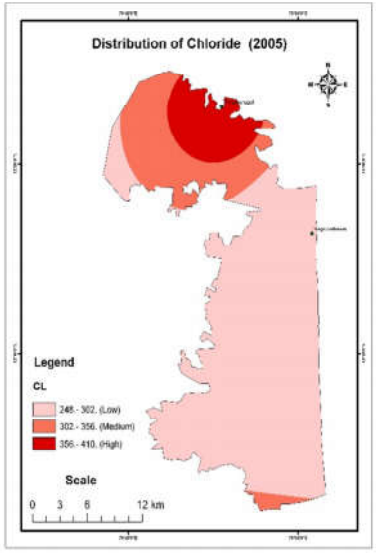
| LOCATION | Year | Groundwater Quality Parameters | | | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | Ca (Mg/L) | Mg (Mg/L) | Na (Mg/L) | K (Mg/L) | $HCO_3$ (Mg/L) | $CO_3$ (Mg/L) | $SO_4$ (Mg/L) | CL (Mg/L) | $NO_3$ (Mg/L) | F (Mg/L) | TDS (Mg/L) | TH (Mg/L) | EC ($\mu$S/cm) | pH |
| Thirumarugal | 2005 | 84 | 65.6 | 262 | 0 | 378.2 | 60 | 38 | 411 | 5.2 | 0.1 | 1115 | 480 | 2010 | 8.4 |
| Nagapattinam | 2005 | 22 | 32.8 | 344 | 0 | 201.3 | 36 | 94 | 248 | 74.2 | 1.3 | 952 | 190 | 1750 | 8.6 |

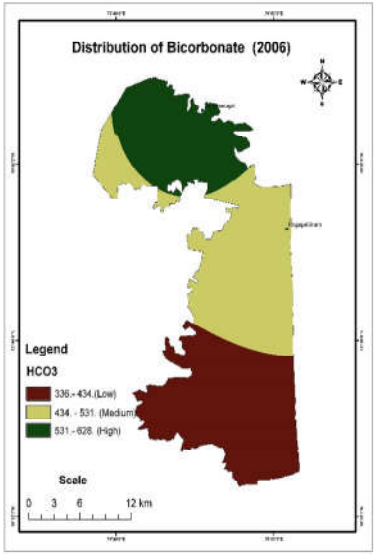

Distribution of Calcium (2005)
Legend
CA
22 - 42. (Low)
42 - 63. (Medium)
63 - 83. (High)
Scale
0 3 6 12 km

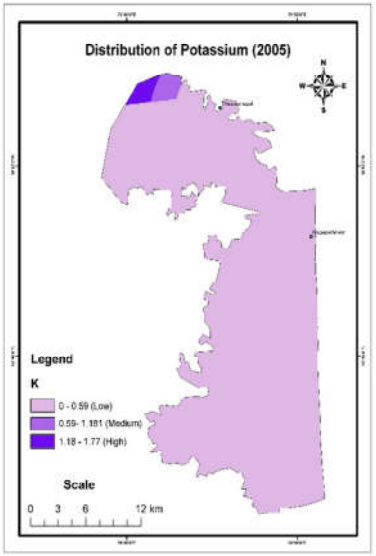

Distribution of Corbonate (2005)
Legend
CO3
11. - 27. (Low)
27. - 43. (Medium)
43. - 59. (High)
Scale
0 3 6 12 km

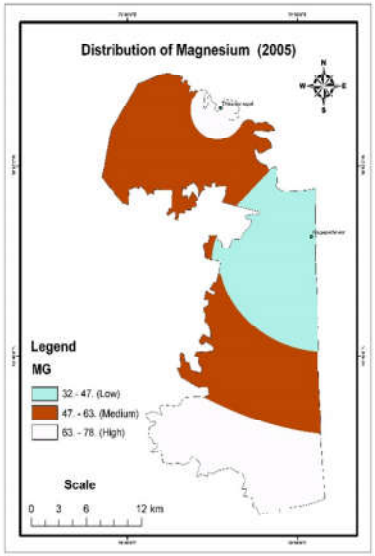

Distribution of Electrical Conductivity (2005)
Legend
CON
Scale
0 3 6 12 km


Distribution of Total Hardness (2005)
Legend
HARDNESS
190. - 288 (Low)
288. - 386 (Medium)
386. - 484 (High)
Scale
0 3 6 12 km


Distribution of Chloride (2005)
Legend
CL
248. - 302. (Low)
302. - 356. (Medium)
356. - 410. (High)
Scale
0 3 6 12 km


Distribution of Bicorbonate (2006)
Legend
HCO3
336.- 434.(Low)
434. - 531. (Medium)
531 - 628. (High)
Scale
0 3 6 12 km


Distribution of Potassium (2005)
Legend
K
0 - 0.59 (Low)
0.59- 1.181 (Medium)
1.18 - 1.77 (High)
Scale
0 3 6 12 km


Distribution of Magnesium (2005)
Legend
MG
32. - 47. (Low)
47. - 63. (Medium)
63. - 78. (High)
Scale
0 3 6 12 km

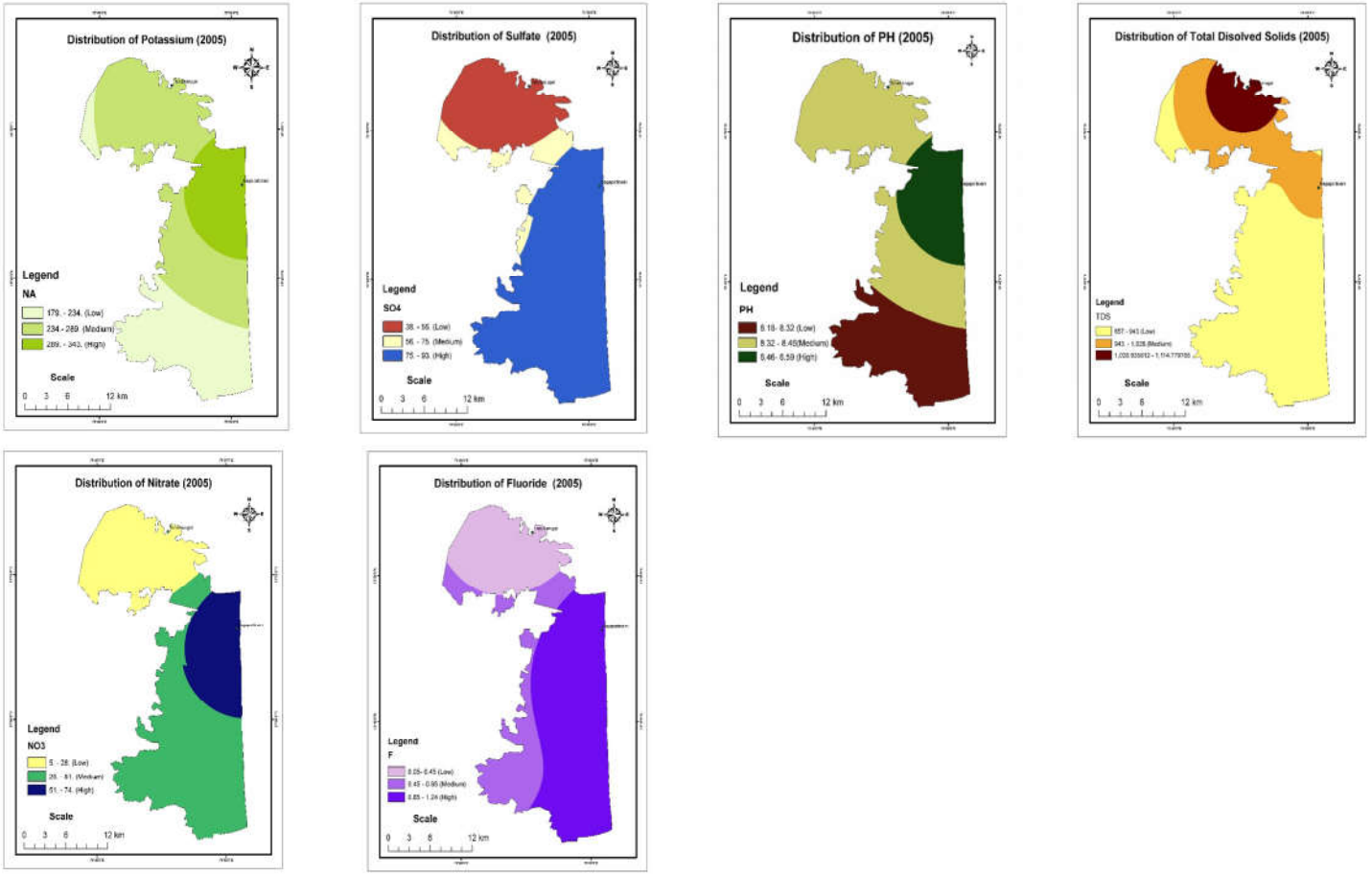
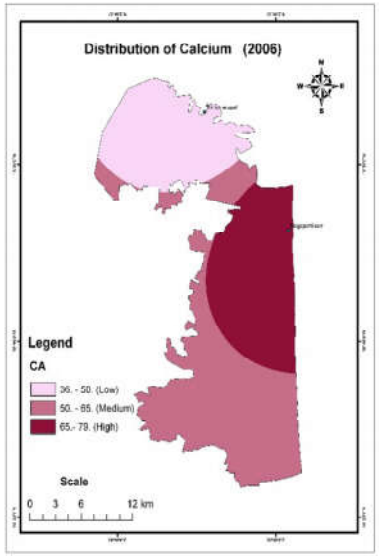
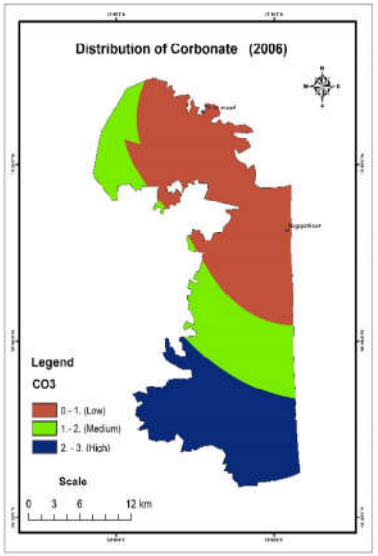


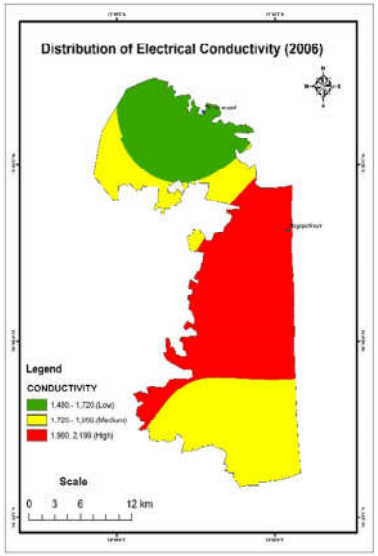

**Fig. 9. Spatial Distribution of Ground Water quality in (2005)**

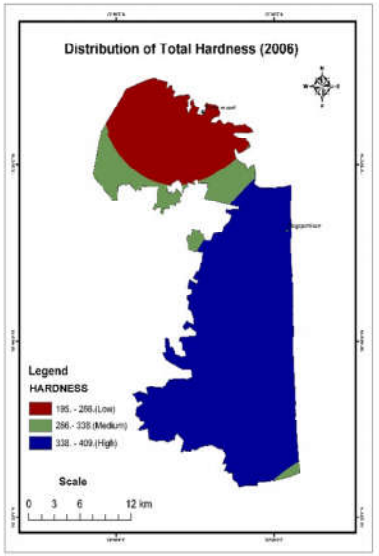
**Table 11.Spatial Distribution of Groundwater Quality in (2006)**

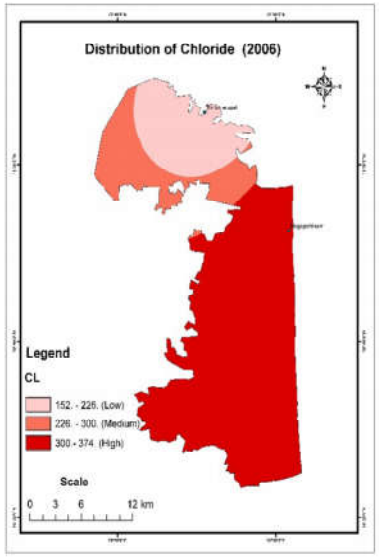
| LOCATION | Year | Groundwater Quality Parameters | | | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | Ca (Mg/L) | Mg (Mg/L) | Na (Mg/L) | K (Mg/L) | $HCO_3$ (Mg/L) | $CO_3$ (Mg/L) | $SO_4$ (Mg/L) | CL (Mg/L) | $NO_3$ (Mg/L) | F (Mg/L) | TDS (Mg/L) | TH (Mg/L) | EC ($\mu$S/cm) | pH |
| Nagapattinam | 2006 | 80 | 51 | 327 | 16 | 488 | 0 | 168 | 347 | 17.5 | 0.2 | 1251 | 410 | 2200 | 7.8 |
| Thirumarugal | 2006 | 36 | 25.5 | 263 | 22 | 628.3 | 0 | 23 | 152 | 2.7 | 0.4 | 838 | 195 | 1480 | 8.2 |

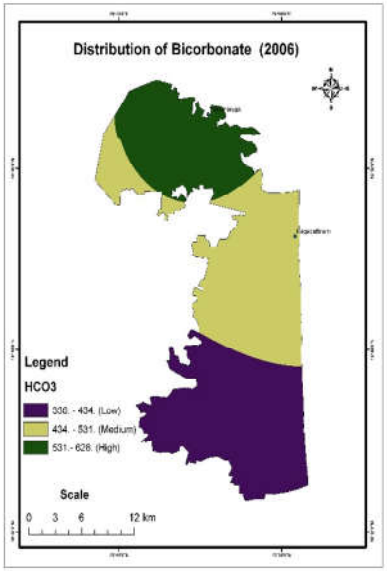

Distribution of Calcium (2006)
Legend
CA
36. - 50. (Low)
50. - 65. (Medium)
65. - 78. (High)
Scale
0 3 6 12 km

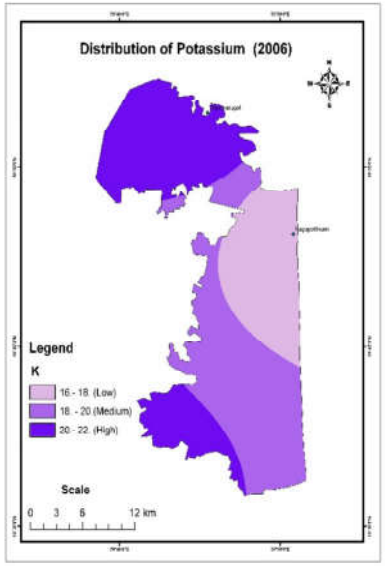

Distribution of Corbonate (2006)
Legend
CO3
0. - 1. (Low)
1. - 2. (Medium)
2. - 3. (High)
Scale
0 3 6 12 km

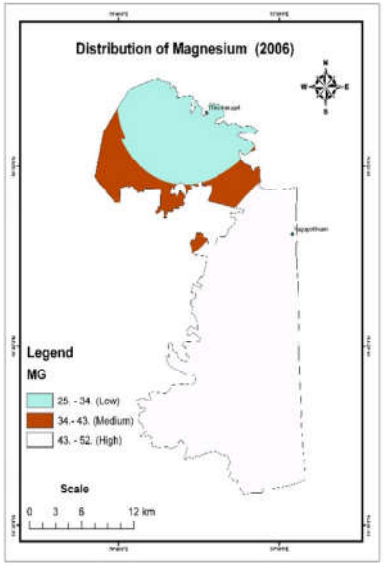

Distribution of Electrical Conductivity (2006)
Legend
CONDUCTIVITY
1,480. - 1,720.(Low)
1,720. - 1,950.(Medium)
1,960. 2,199.(High)
Scale
0 3 6 12 km


Distribution of Total Hardness (2006)
Legend
HARDNESS
195. - 268.(Low)
268. - 338.(Medium)
338. - 409.(High)
Scale
0 3 6 12 km


Distribution of Chloride (2006)
Legend
CL
152. - 226. (Low)
226. - 300. (Medium)
300. - 374. (High)
Scale
0 3 6 12 km


Distribution of Bicorbonate (2006)
Legend
HCO3
330. - 434. (Low)
434. - 531. (Medium)
531. - 628. (High)
Scale
0 3 6 12 km


Distribution of Potassium (2006)
Legend
K
16. - 18. (Low)
18. - 20 (Medium)
20. - 22. (High)
Scale
0 3 6 12 km


Distribution of Magnesium (2006)
Legend
MG
25. - 34. (Low)
34. - 43. (Medium)
43. - 52. (High)
Scale
0 3 6 12 km

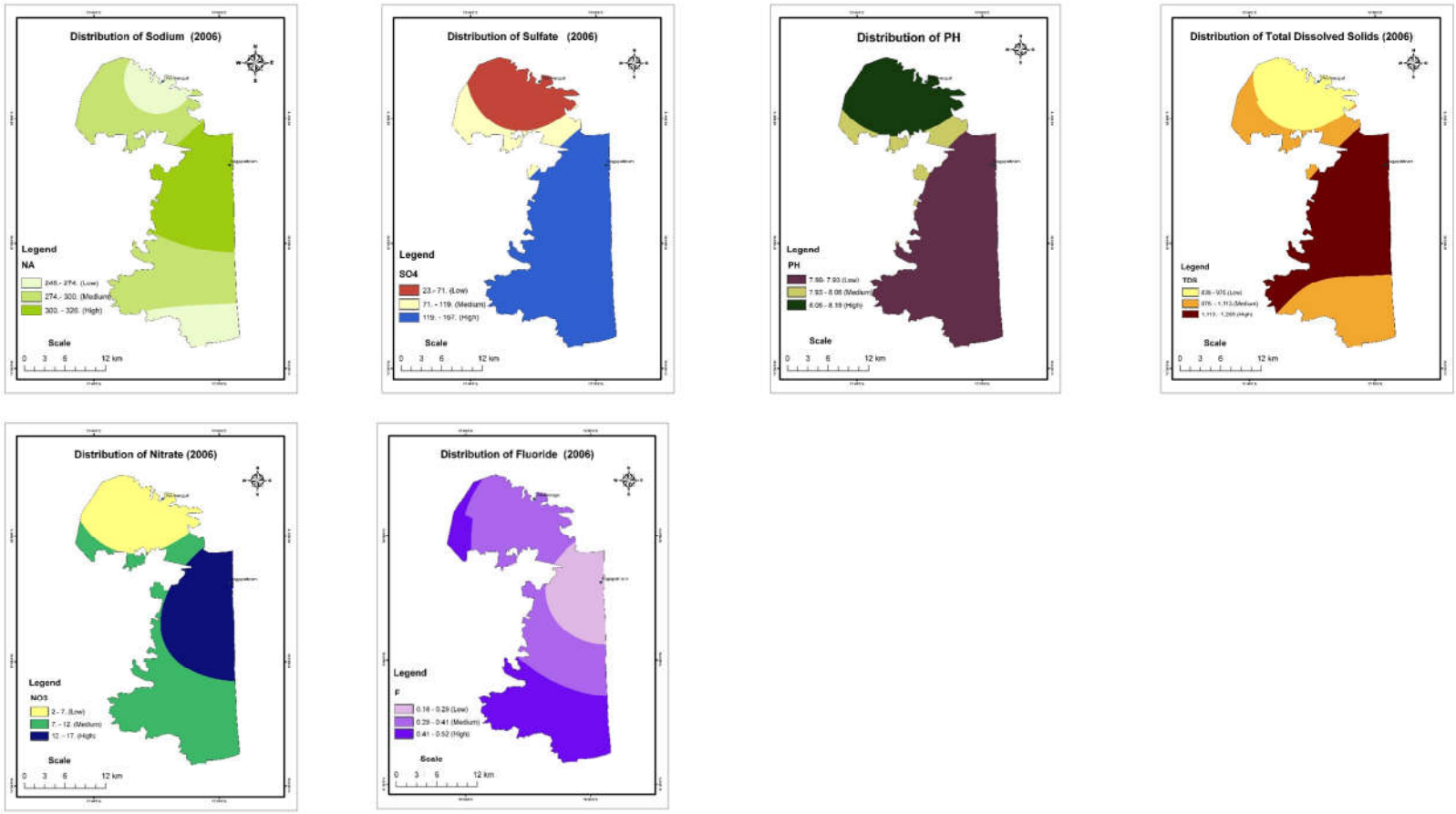
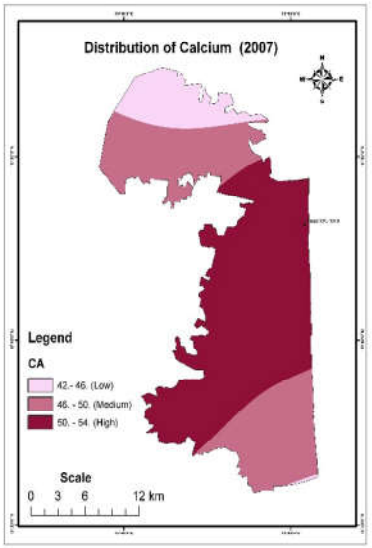
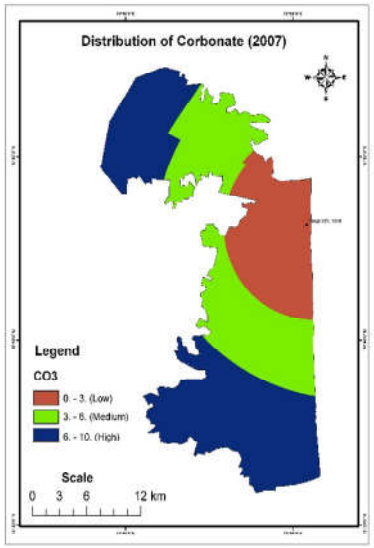


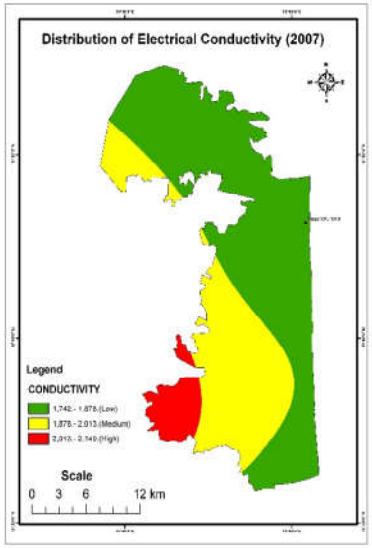

**Fig. 10. Spatial Distribution of Ground Water quality in (2006)**

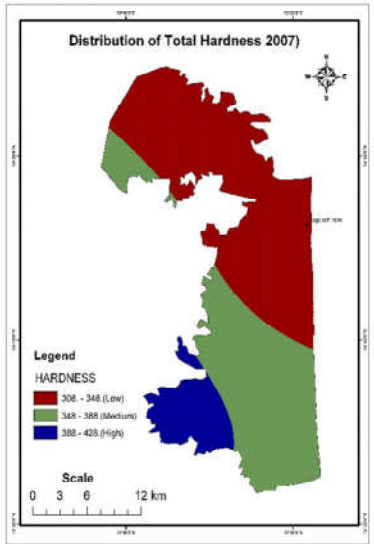
**Table 12. Spatial Distribution of Groundwater Quality in (2007)**

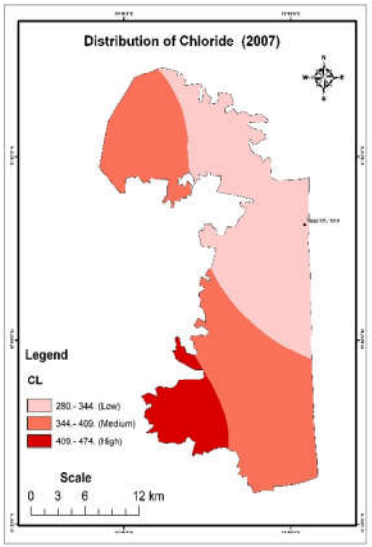
| LOCATION | Year | Groundwater Quality Parameters | | | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | Ca (Mg/L) | Mg (Mg/L) | Na (Mg/L) | K (Mg/L) | $HCO_3$ (Mg/L) | $CO_3$ (Mg/L) | $SO_4$ (Mg/L) | CL (Mg/L) | $NO_3$ (Mg/L) | F (Mg/L) | TDS (Mg/L) | TH (Mg/L) | EC ($\mu$S/cm) | pH |
| Nagapattinam | 2007 | 54 | 46.2 | 251 | 35 | 341.6 | 0 | 96 | 280 | 37.8 | 0.3 | 977 | 325 | 1820 | 8.1 |

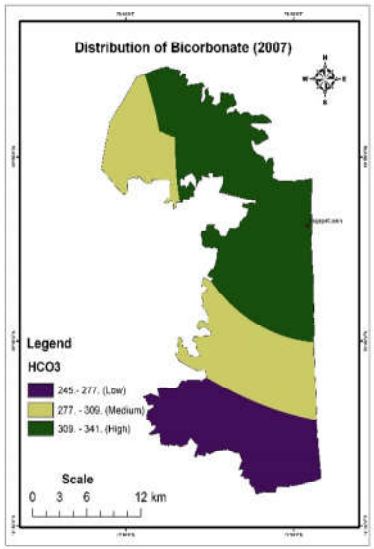

Distribution of Calcium (2007)
Legend
CA
42. - 46. (Low)
46. - 50. (Medium)
50. - 54. (High)
Scale
0 3 6 12 km

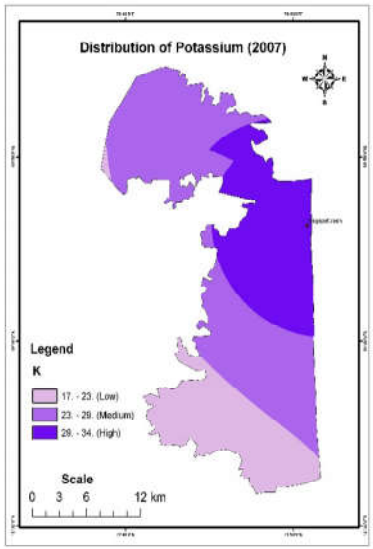

Distribution of Corbonate (2007)
Legend
CO3
0. - 3. (Low)
3. - 6. (Medium)
6. - 10. (High)
Scale
0 3 6 12 km

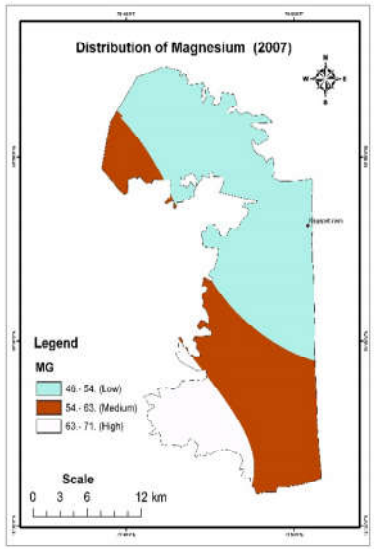

Distribution of Electrical Conductivity (2007)
Legend
CONDUCTIVITY
1,742. - 1,878.(Low)
1,878. - 2,013.(Medium)
2,013. - 2,149.(High)
Scale
0 3 6 12 km


Distribution of Total Hardness 2007)
Legend
HARDNESS
308. - 348.(Low)
348. - 388.(Medium)
388. - 428.(High)
Scale
0 3 6 12 km


Distribution of Chloride (2007)
Legend
CL
280. - 344. (Low)
344. - 409. (Medium)
409. - 474. (High)
Scale
0 3 6 12 km


Distribution of Bicorbonate (2007)
Legend
HCO3
245. - 277. (Low)
277. - 309. (Medium)
309. - 341. (High)
Scale
0 3 6 12 km


Distribution of Potassium (2007)
Legend
K
17. - 23. (Low)
23. - 29. (Medium)
29. - 34. (High)
Scale
0 3 6 12 km


Distribution of Magnesium (2007)
Legend
MG
49. - 54. (Low)
54. - 63. (Medium)
63. - 71. (High)
Scale
0 3 6 12 km

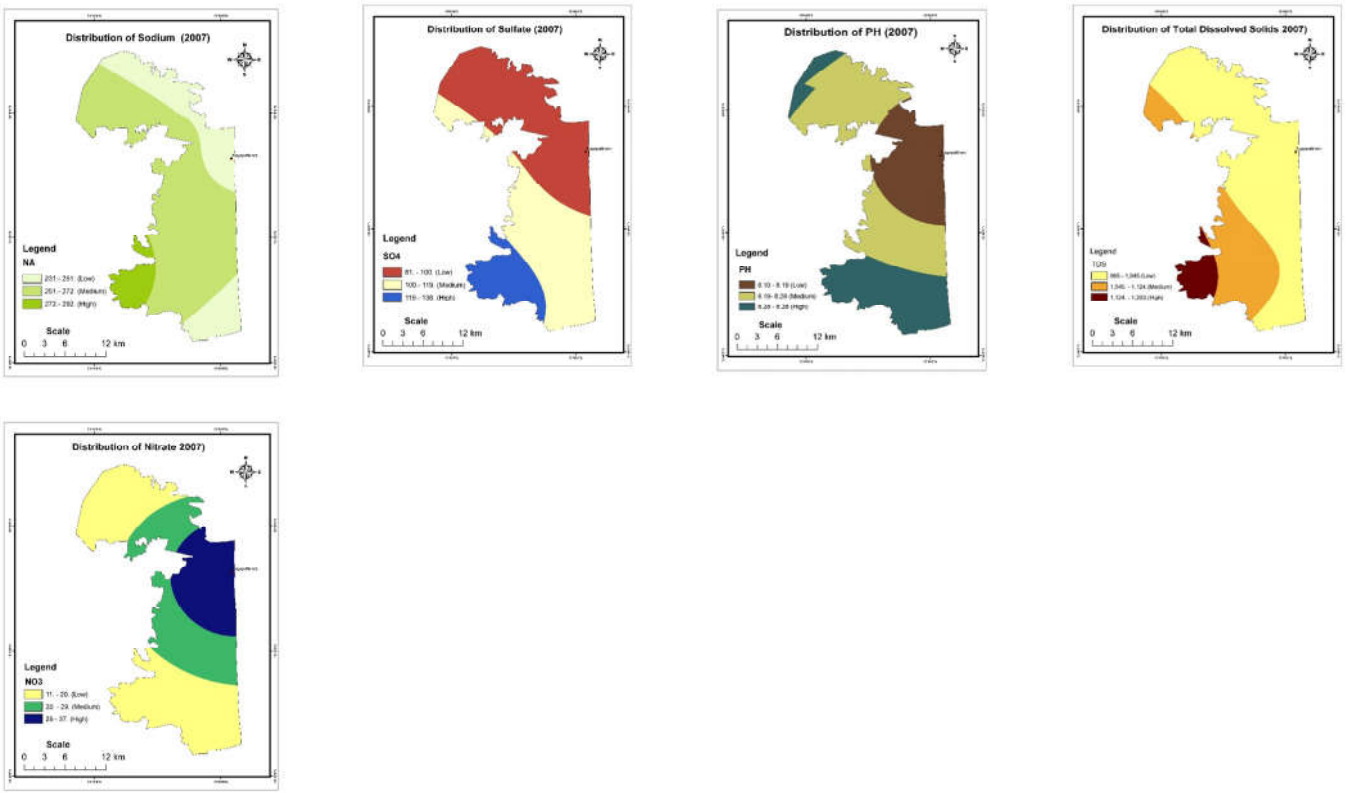



**Fig. 10.S patial Distribution of Ground Water quality in (2007)**

**Table 13.water quality index during (1998-2007)**

| Sr.no | Villages | 1998 | 1999 | 2000 | 2001 | 2002 | 2003 | 2004 | 2005 | 2006 | 2007 |
|---|---|---|---|---|---|---|---|---|---|---|---|
| **1** | Nagappattinam | 327.66 | 232.08 | 346.13 | 193.19 | 321.15 | 232.70 | 278.65 | 290.34 | 340.42 | 278.95 |
| **2** | Tirumarugal | 133.59 | 176.87 | 122.83 | 0 | 19.49 | 95.09 | 1010.93 | 299.94 | 228.25 | 0 |
| **3** | Manakkudi | 176.09 | 201.72 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| **4** | Thevur | 110.84 | 131.48 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |

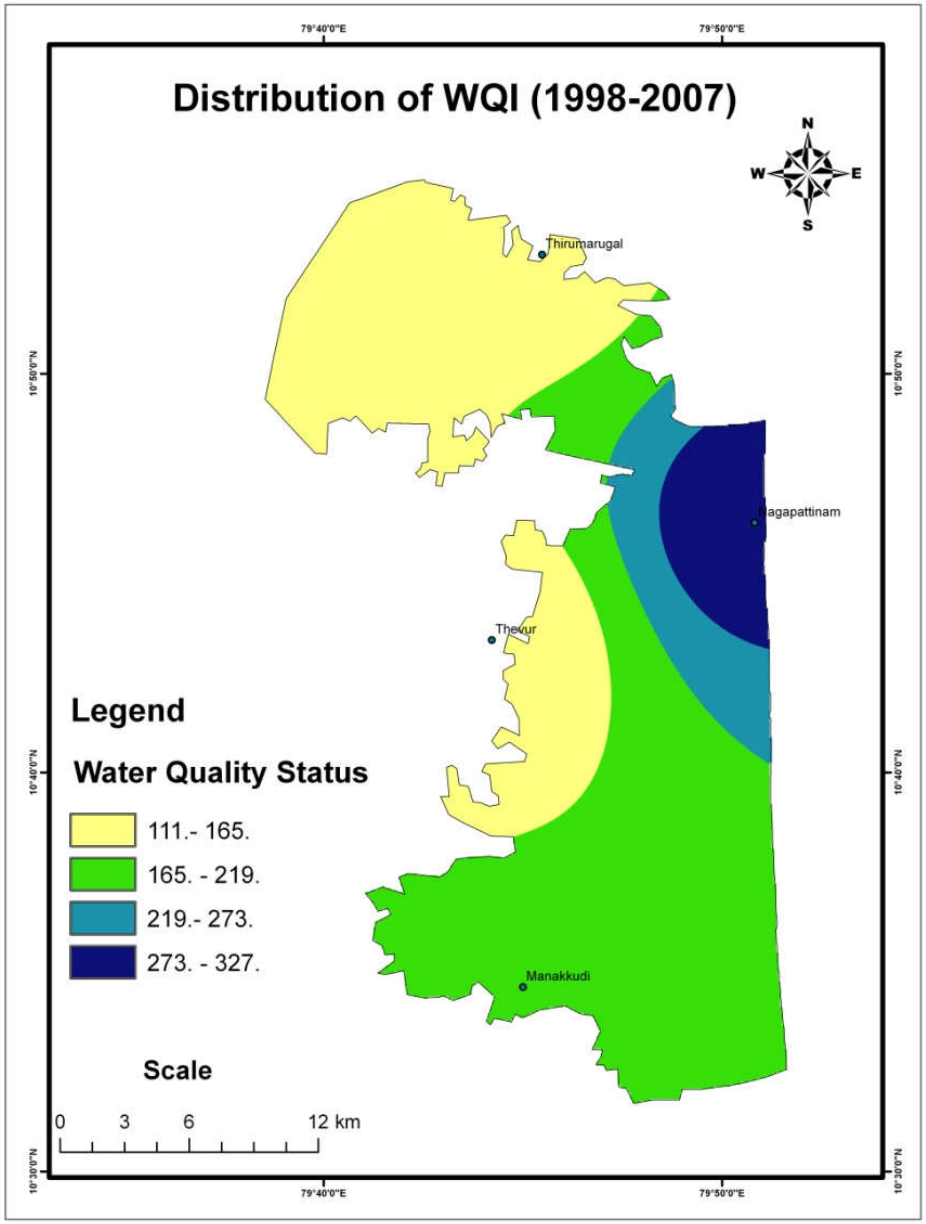



**Fig.11. Spatial Distribution of Water quality index**

The EC reached 490 to 7130 $\mu$S/cm in the year of 1998 and 2007 respectively. The higher value of EC from (2004) Tirumarugal suggests the enrichment of salt due to evaporation effect. Like pH, EC is also higher Nagapattinam, Tirumarugal, because of additional leaching from sand dunes, municipal wastes and intense agricultural activities compared to other areas.

**Chloride**

Chlorides are considered to be pollution indicating parameter (Krishnamurthy, et al., 1994; Manikya Reddy et al., 1987). In the study area concentration varied from 35 to 1808 mg/L. The high concentration of chlorides imparts salty taste to water.

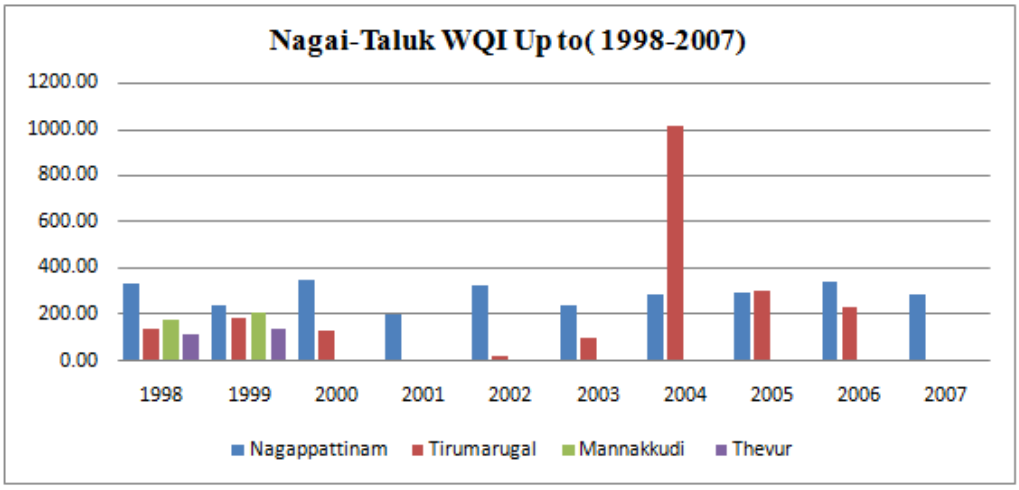



**Fig.12. Spatial Distribution of Water quality index**

**Total dissolved solids (TDS)**

TDS is mostly due to dissolve ionic matter and bear a relationship with the electrical conductivity of water (Kapil and Bhattacharyya 2008). The acceptable value of TDS in groundwater 500mg/L. In the present study, TDS values varied between 291and 4375 mg/l indicating excess input of ionic matter into groundwater samples, even though local geological settings (Saltpan, Aquaculture & sea water interruption), soil characteristics, and even lithology of the study area may also be contributed to total dissolved solids content in groundwater. In general, TDS increased from rainy to winter and summer seasons. There was a sudden rise in the TDS value (>4375 mg/l) at Tirumarugal, which receive the sewage directly. The domestic sewage which had very high TDS made the water more contamination particularly during summer and winter seasons.

**Total hardness**

Total Hardness is due to the presence of divalent metallic cations like calcium, magnesium, strontium, ferrous and manganese ions. Hardness is determined as CaCO3 mg /l. Mainly Total Hardness due to Calcium, Magnesium, Iron and strontium concentration in water. Though hardness is not harmful to health, but suspected for chances of heart disease. In the study area the total hardness values ranging from minimum of 135 mg/l and the maximum of 590 mg/l. The value of total hardness in Nagapattinam, Thevur, Tirumarugal, Manakudi were above the tolerance limit for drinking water and irrigation purpose during the year 1998-1999, 2001-2004 and 2005-2007. In the year of 1998, all the area showed within the permissible range. There was a sudden rise in the Total Hardness value (>590 mg/l) at Tirumarugal.

For people who are not accustomed to high chloride are subjected to the laxative effect. Hence, the limit is fixed as 250 mg/L in which water is not salty. The high concentration of chlorides in the bore well waters of the area may be due to the seepage from municipal solid waste. High chloride weathering of material also contributed to the salinity problem in this area. The large the lateral variations of chloride concentration indicate recharge and discharge zones of lateral flow regime. Local recharge to the unconfined aquifer is more dominant than recharge from lateral flow (Datta and Tyagi 1996). Groundwater is under-saturated with respect to NaCl. Therefore, physical processes such as mixing with another aquifer of different (Cl) concentration and change in evaporation rate during recharge either spatially or temporally may cause the changes in the chloride content of groundwater. The chloride concentrations were found higher in the area covered by sand dunes. Over the period of ten years (1998-2007) the Chloride concentration was high on the part such as Tirumarugal area.

**Sodium**

The higher concentrations of sodium can be related to cardiovascular diseases and in women toxemia associated with pregnancy. The percentage of Na+ is often taken as an important parameter in deciding the suitability of water for irrigation. The drinking water standard for sodium is 200 mg/l. The Na levels were ranged between 32-961mg/L in most of Tirumarugal, Nagapattinam areas. Most of the sampling stations the concentration of sodium were found in more than the WHO permissible limit (>200 mg/l). The higher level recorded in the study area from 1998 to 2007 but Manakudi area shows within the limit in 1998and 2007. Thevur has obtained within the permissible range in 1998 and 2007.

Manakudi shows medium concentration of sodium in 2005. Weathering of silicate rocks in the region is one of the important processes responsible for the higher concentration of Na in groundwater of this area. In general, it is expected that the evaporation process would cause an increase in concentrations of all species in water.

**Potassium**

Potassium is the most important mineral occurring naturally. The primary source of this action may be weathering of rocks beside the sewage and industrial effluents. In the study area concentration varied from 5 to 10 mg/L. suitable for irrigation and domestic purposes. The entire study area shows higher values (10 mg/l) in most of the stations owing to the precipitation or absorption of both the action by soils or coating on the minerals and also due to the effluent percolation. The lower and medium concentration of potassium obtained in Thevur, Manakudi. The potassium concentration ranged from 16 to 313 mg/l in the year of 1998 and 2007 respectively.

**Calcium**

Calcium and magnesium originate solely from dissolution of carbonate in the aquifer from the weathering of accessory pyroxenes and amphibole minerals. In this area calcium concentration of water samples in Nagapattinam Taluk varied from 16 to 84 Mg/L. The concentration of calcium in potable water ranges from 75 to 200 Mg/L. The high value (>84 mg/l) was recorded in Thirumarugal on 2004 to 2006. The other area shows the small and medium concentration of Calcium during 1998, 1999 and from 2002 to 2003.

**Magnesium**

Magnesium tolerances by the human body are lower than that of calcium. High concentration of magnesium in drinking water gives unpleasant taste to the water. The concentration of magnesium in potable water ranges from 30-100 Mg/L. In this area magnesium concentration of ground water samples varied from 4 to 279.5 Mg/L. Over the period of ten years (1998-2007) the Magnesium level shows above the permissible limit in Tirumarugal. Generally Calcium and magnesium maintain a state of equilibrium in most waters. MoreMg2+ present in waters will adversely affect the soil quality converting it to alkaline and decreases crop yields.

**Fluoride**

High concentration of fluoride in drinking water can cause an adverse effect on human beings. Continuous consumption of water having high fluoride content can cause diseases, like fluorosis, dental carries and bone diseases. The concentration ranges observed in this study were 0.01 to 1.3 Mg/L Nagapattinam Taluk. The spatial variation of fluoride content with different sampling points is shown in figure. The high concentration of Fluoride values (>1.3 mg/l) obtained in Nagapattinam on 2005. High concentrations of fluoride, often significantly above 0.19mg/l, constitute a severe problem over large parts of India. The trend is contrary to observations from high-fluoride groundwater elsewhere which commonly show increasing fluoride concentrations with depth due to increased chemical reaction with increasing groundwater residence time. Nonetheless, the depth relationship is an interesting observation and may be of practical significance in southern India if found to be a representative phenomenon. Fluoride concentrations in streams have been observed high during the dry season as a result of increased proportion of groundwater base flow to streams during dry periods.

**Sulphate**

It is the common ion in water. Sulphate can produce bitter taste at high concentration. Sodium and magnesium sulphate exert a cathartic action in human beings. It is also associated with respiratory diseases. The permissible limit of sulphate in drinking is 200 to 400 Mg/L. In this study minimum recorded value of sulphate were 5 Mg/L and maximum 326 Mg/L. The highest concentration (>326 mg/l) has been registered in Tirumarugal on 2004.

**Nitrate**

The nitrate ion concentration is very critical in public water supplies because it causes methemoglobinemia in children. The concentration varied from 0.8 – 74.2 mg/L which is much above the permissible limit of 45 to 100 mg/L. The higher concentration obtained Nagapattinam area from 2003 to 2005. Most of the area records within the allowable range during 1999 to 2002 and 2006 to 2007.

**Carbonate and bicarbonate**

The carbonate (CO3) alkalinity is absent in most of the stations throughout the study area and it is detectable only above pH 8.3. Therefore the total alkalinity is mostly due to the presence of bicarbonate. The highest carbonate value (>126 mg/l) was recorded in Tirumarugal (2002), All the stations show bicarbonate values within the permissible limit of WHO (500 ppm), due to the exchange of atmospheric CO2 with water. The carbon dioxide entering the system changes to $H_2CO_3$. The latter subsequently reacts with primary minerals and increases the bicarbonate concentration.

**Water Quality Index Model**

Water quality index (WQI) is defined as a Technique rating which gives a complex influence of individual water quality parameters on the overall quality of water for human consumtion.The standard for drinking purposes as recommended by WHO (1984) and ISI (1983) have been considered for the calculation of WQI (Table.). Water quality Index is the most efficient tools to communicate information on the quality of any water body. It is a mathematical equation used to transform a large number of water quality data into a single number. (Stambug –Giljanovic,1999). It is simple and easy to understand for decision makers about quality and possible uses of any water body (Bordalo, 2001).Also its serves the understanding of water quality issues by integrating complex data and generating a score that describes the water quality status (Table.).

In this method weight age for various kinds of Water proportional to the recommended standard for the corresponding parameters (Mishra, 2001).

**The Weight age of ith Parameters.**

**Wi=K/Si**

Where Wi is the unit Weight age and Si is recommended standard for ith parameter. Water quality Index study is established from Important Various Chemical Parameters in different Season. The values of Different Physicochemical Parameters for calculation of Water Quality Index are tabulated. It is also observed that the pollution loading relatively high during summer season compared to winter. The above water quality is also supported by the following physical-chemical parameters variations observed during the different seasons of the study. Among the all physical-chemical parameters selected for the water quality index calculations, pH is important parameters that determine the suitability of water for various purposes. In the present study ph ranged between (7.2 -8.6). In many of the collection pH is remains exactly neutral. Average values for the seasons are taken into account the study area slightly alkaline. Chloride is the most important parameter in assessing the water quality. Munawar (1970) is of the opinion that higher concentration of chloride indicates the higher degree of pollution. In the study area chloride fluctuated between (35 to 1808 mg/l.) seasonally chloride was found to be high during the summer season and little rainy season. A similar observation has been made by shastri et.at.,(1970). And sinha (1995). Shardendu and Ambasht (1988), Swarnalatha and Narasingarao (1993), and Sinha (1995) have also made similar observation in their studies on different waterbodies. Electrical conductivity and total dissolved solids also found to be very high. Season wise it to be high during the summer season.

**Conclusion**

Water quality index indicating in terms of index numbers, offers a useful representation of overall quality of water for public or for any intended use as well as in the pollution abatement programmes and in water quality management. Water quality index was calculated based on the basis of various physical chemical parameters like pH, electrical conductivity, total dissolved solids, nitrate, calcium, sulfate, magnesium, fluoride, total hardness, sodium, chloride, carbonate and bicarbonate. This water quality rating study clearly shows that the Status of the study area is eturophic and it is unsuitable for the human use. It is also observed that the pollution loading relatively high during summer season compared to winter. Average values for the seasons are taken into account the study area slightly alkaline. Chloride is the most important parameter in assessing the water quality. Since 2002 (19.49-excellent water quality) Tirumarugal only suitable for drinking purpose and other areas not suitable for the Period of (1998-2007). This will affect the polluted water, land use changes and climate changes. Result shows the change that has been occurred during 11 years of period mud land and swampy land, waterlogged areas totally converted to aquaculture activities.

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