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A Preliminary Investigation for Groundwater Quality and Health Effects—A Case Study

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Abstract: The study is an integrated GIS approach on groundwater quality and its health effects. The groundwater quality is a problem in different parts of our country. In Tamil Nadu the ground water is the only alternative source when surface water become scarce in pre-monsoon. Concentration greater than their permissible limits in drinking water have been linked to health problems, especially in infants. Tannery is one of the major industries in Tamil Nadu leading to water quality problems. In order to elucidate the status of groundwater quality, geochemical seasonal variation of ground water have been investigated. The diseases such as Acute Gastro Enteritis (AGE), Gastro Enteritis with dehydration, AGE with mild dehydration, AGE with moderate dehydration, AGE with severe dehydration and other diseases like enteric fever, malaria were classified and they were arranged according to ward wise in the study area. The tremendous power of analysis, map querying and presentation of data were applied in this study. Based on map query, water quality zones were demarcated as 'Affected Area' and 'Not affected Area' based on quality of water and diseases. The objective of this work is to analyze the water quality and the health effects in the study area using GIS.

Key words: Ground water, Health, GIS, AGE.

Introduction

Ground Water

Water is an important limiting factor for the ecosystem, agriculture, human settlements and human health. Nearly 700 thousand children die of diarrheal diseases every year directly as a result of drinking unsafe water or living in unhygienic environment. Nearly, 44 million people are affected by water quality problems either due to growing population, or the prevalence of fluoride, arsenic, nitrate or iron deposits, or due to ingress of salt water or due to discharge of effluent. In 13 states, drinking water sources are contaminated with excessive fluoride affecting thousands of children with dental and skeletal fluorosis. Excess nitrate in drinking water sources, which causes 'Blue Baby Syndrome' in children, has been observed in a number of states. Hence it becomes very much necessary to study about water quality and its conservation. In such areas it becomes very important to study the groundwater quantity and quality.

Groundwater Quality

All the water beneath the land surface is referred to as underground or subsurface water or ground water. Both natural and human factors influence the quality of a water source. The quality of the ground water is affected in two ways. Excess fluoride, arsenic and iron fall under this category. Groundwater pollution is caused by human intervention (anthropogenic), like over-exploitation of shallow groundwater in the coastal area and discharge of untreated domestic sewerage and industrial effluents. The surface water is having high turbidity and suspended matter; it contains less Total Dissolved Solids (TDS) and by taste and chemical content is more acceptable. Refer Tables 1 and 2.

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Table 1: Water Quality Analysis Data for Pre-Monsoon

Sample No.	*TDS mg/L*	*$CaCO_3$ mg/L*	*Ca mg/L*	*Mg mg/L*	*NO_3 mg/L*	*SO_4 mg/L*
1	2345	750	180	72	168	175
2	2318	743	169	72	162	175
3	2324	500	128	43	66	150
4	1792	710	180	62	29	145
5	2373	680	160	67	279	177
6	2954	850	180	96	214	154
7	1428	550	152	41	89	79
8	2338	800	176	86	122	172
9	2145	726	162	68	128	171
10	1008	360	99	27	85	48
11	462	234	65	17	6	12
12	2318	743	169	72	162	175
13	1407	580	152	48	79	75
14	1071	348	78	36	1	72
15	1785	428	152	65	50	128
16	1792	552	148	70	50	125
17	2688	500	240	58	282	231
18	1348	444	112	38	58	61
19	2314	875	195	58	290	179
20	2139	955	148	70	176	191
21	1995	360	160	58	201	111

Table 2: Water Quality Analysis Data for Post-Monsoon

Sample No.	*TDS mg/L*	*$CaCO_3$ mg/L*	*Ca mg/L*	*Mg mg/L*	*NO_3 mg/L*	*SO_4 mg/L*
1	2720	820	196	82	173	177
2	2755	813	185	82	161	177
3	2940	570	144	53	71	152
4	2440	780	196	72	34	147
5	2544	750	176	77	284	179
6	7230	920	196	106	221	156
7	2030	620	168	51	94	81
8	3540	870	192	96	127	174
9	2290	796	178	78	132	173
10	4030	430	115	37	90	50
11	2200	304	81	27	11	14
12	2560	813	185	82	167	177
13	1780	650	168	58	84	77
14	1810	418	94	46	6	74
15	1940	720	168	75	55	130
16	3010	730	164	80	55	127
17	2940	910	256	68	284	231
18	3030	510	128	48	63	62
19	2790	750	211	68	297	183
20	3140	830	164	80	181	191
21	2380	810	176	68	207	113

On the contrary the ground water has mostly high Total Dissolved Solids. The groundwater quality is directly related to public health management. The groundwater quality plays a major role in planning, water supply, public health management, environmental management and water quality management.

Groundwater Contamination

The groundwater contamination is due to seasonal variations, hydro geological processes, discharge rate affecting the quality, industrial pollution, domestic and agricultural activities, eutrophication in surfacewater bodies, seawater intrusion, sand quarrying in river beds etc. The environmental impacts of these groundwater contamination seriously affect the socio-economic conditions of the country.

Health Effects due to Groundwater Contamination

The health of human populations reflects the complex interplay between population characteristics and the environment. The water acts as the passive carrier of the infectious or chemical agent. Chemical poisonings and methemoglobinemia may also be caused by contaminated water supply systems. In addition chronic ingestion of low levels of some chemical contaminants in drinking water has been associated with adverse health effects.

A number of inorganics are essential to human nutrition at low doses; yet they demonstrate adverse health effects at higher doses. These include arsenic, selenium, chromium, copper, molybdenum, nickel, zinc and sodium. Numerous reports have also shown an inverse relationship between water hardness and hypertensive heart disease. In excessive amounts, arsenic causes acute Gastro Intestinal (GI) track damage and cardiac diseases. Nitrate in drinking water causes two adverse health effects—induction of methemoglobinemia, especially in infants, and the potential formation of carcinogenic nitro amines. Methemoglobinemia occurs because nitrate is reduced to nitrite in saliva and in GI tract. A caution is necessary for analyzing the groundwater quality; it is intended as an introductionary overview of health effects information. It is studied carefully, the public health officials consulted prior to making any decisions regarding specific water contamination problems with proper references and adequate knowledge on public health environment.

Geographical Information System (GIS)

Geographic Information Systems (GIS) have become important tools in efficiently solving many problems in

which spatial data are important. Natural resources and environmental concerns, including ground water have benefited greatly from the use of GIS. It is becoming powerful computer tools for varied applications ranging from sophisticated analysis and modelling of spatial data to simple inventory and management. GIS incorporates data that describes population characteristics, socio-economic conditions and the landscape and analyse the spatial relationship of these factors. The most significant difference between GIS and other information systems and databases is the spatial nature of the data in a GIS. The analysis functions in a GIS allow manipulation of multiple themes of spatial data to perform overlays, buffering and arithmetic operations on the data. With its spatial analysis capabilities, GIS technology can play an important role in human services research thereby ensuring better service delivery for clients.

Study Area

The study area fully covered by Arcot town is located in Vellore district of Tamil Nadu, India, which covers an area of 10.08 km^2 (Figure 1). It lies in the Survey of India topographic map no. 57 P/5. The study area lies within latitude: 12°53′ 30″ to 12° 54′ 15″ and longitude: 79° 18′ 30″ to 79° 19′ 30″.

Silk weaving, woolen druggets, carpets and cane works (rattan) are important industries in the town. This town is noted for its hides and skins rearer. Arcot is a reputed commercial centre. It is divided into 30 wards according to Arcot municipality. The population of the study area as per 2001 census is 50,267 (Figure 2). The study area is located down streamside of the river Palar and western side of Ranipet Industrial Area and eastern side of Visharam. The temperature raises slowly recording maximum in summer month up to May after which it drops slowly. The soil type is sand and sandy loam of eight per cent; red loam soil 10 per cent; clay and clayed loam 54 per cent; and black cotton soil 28 per cent. The minimum water table during pre-monsoon was 9.2 m and maximum water table was 19 m. The minimum water table during post monsoon was 7.9 m and maximum water table was 17 m.

Only one primary health centre that is Arcot Government Hospital, having 42 beds, is located in this study area, four primary health officials working with the health centre.

Present Investigation

The groundwater quality and health effects due to groundwater contamination have been studied. Conventional groundwater quality and health effects data handling is tedious and time consuming in input of data. The groundwater quality analysis using any of package has voluminous data input consisting of both spatial and non-spatial data. Geographic information system can handle the spatial and non-spatial data in an effective manner. The input parameters used in groundwater quality are spatially varying and GIS is effective in handling data. The role of GIS in representing the spatial variability and its role in simplification of inputs is explored in this study.

Water Sample Collection

Under this circumstance, preliminary survey forms a prerequisite for selection of the study area. Groundwater samples were collected from 21 wells distributed in the study area. Water samples were collected from the area of nearly 0.25 km^2 intervals.

These samples were collected during the pre-monsoon and post monsoon seasons of 2002. The physio-chemical parameters of groundwater samples were analyzed in the laboratory based on the procedures described as standard method (AWWA, 1998). The parameter pH was measured using pH meter and Electrical Conductivity (Ec) with a conductivity meter. The water quality parameter such as major ions concentrations TDS, NO_3, Ca, Mg, Na, K, SO_4 of the samples were analyzed. The results of the analysis are given in Tables 1 and 2.

Total Dissolved Solids are determined as the residue left after evaporation at 100°C and subsequent drying of the filtered sample. The known volume of filtered sample was taken and placed in the dish and evaporated at 100°C on water bath, and dried in oven at 103°C at one hour. After drying, the dish was cooled in desiccators and TDS (mg/L) was calculated.

Total Hardness

Hardness is the resistance of the water for the formation of lather with soap. It is caused mainly by the multivalent metallic cation like Ca^{2+}, Mg^{2+}, Fe^{2+}, Sr^{2+}, Al^{2+}, and Mn^{2+}. The test was based on the fact that Ca and Mg ions form a weak complex with the blue dye, Erichrome black-T and a more stable complex with EDTA. When the dye was added to hard water a wine red complex was

formed, and then EDTA was added, the wine red complex was disrupted with the release of the dye. The end point was wine red to blue in colour. With the volumetric analysis using standard method (AWWA, 1998), calcium and magnesium was calculated.

Nitrate

Dissolve 25 gm of white phenol in 150 ml of conc. H_2SO_4 and then again add 85 ml of concentrated sulphuric acid. Heat it for about two hours on a water bath, cool and keep the solution in a dark bottle. The sample 25 mg was taken in a porcelain dish (50 ml capacity) and it was evaporated in hot water bath. Then 3 ml phenol disulphonic acid was added to this and was dissolved. The intensity of yellow colour was read in calorimeter at 420 mm. Thus nitrate concentration was found out.

Discussion of Test Results

Payment, P. (1997) has worked on epidemiological study of gastrointestinal health effects due to the total hardness in drinking water. Due to high dissolved solids in irrigation water, gastrointestinal problems will occur (ICMR, 1975). In this study during pre-monsoon the maximum concentration of 2954 mg/L was recorded for the sample no. 6 and minimum concentration of 462 mg/L for sample no. 11. The average concentration of TDS was 1921 mg/L. There were 16 samples above the permissible limit prescribed by Indian Council for Medical Research (ICMR, 1975). It was also found that the maximum concentration of TDS for post monsoon was 7230 mg/L and it was noted for sample no. 6, the average concentration of TDS was 2861 mg/L. In this study during post monsoon, all the samples were above the permissible limits prescribed by ICMR, 1975, CPEEO, BIS-1991.

The use of GIS by human service professionals is comparatively less. Existing evidence on the usage of GIS technology in human services highlights its usage for research related purposes as opposed to administrative or direct practices dealing with the provision of services (Queralt and Witte, 1998).

In recent past several countries have implemented GIS in public health applications. GIS can provide a mechanism to bring changes to communities and provide ability to do precise spatial analysis. It helps to ensure the accuracy of the spatial information so that public information maps are clear and concise (Gould, 1993).

One of the most advantageous applicability in using GIS for water quality management and human health environment is onscreen query. The spatial query involves two aspects: the onscreen query and the simple SQL query. The onscreen query involves obtaining details pertaining to any object, which is seen on the screen. Whereas the simple query relates to identification and location of objects, which are not seen immediately, but only after a request has been made. However SQL requires some knowledge about the actual application and it involves one or more objects.

In this study the following steps were made to create spatial query.

1. The 'Map query' tool from the 'Spatial Analyst' menu was selected for making the Map Query over the Grid themes of Diseases and TDS as shown in Figure 3.
2. The Query 'where TDS and disease were at the maximum value?' has been made like TDS Pre-post = 1 (maximum) and Disease May = 1 (maximum) like or Disease June = 1 (maximum) or Disease July = 1 (maximum) or Disease August = 1 (maximum) or Disease September = 1 (maximum). This has been shown in Figure 4.
3. Finally, a map (theme) was directly created as the result with the classification as 'True' and 'False' areas. This has been shown in Figure 5.

Figure 6 shows the values of TDS concentration for various samples. Series-1 pre-monsoon, Series-2 post monsoon.

Figure 7 shows the values of nitrate concentrations for various samples. Series-1 pre-monsoon, Series-2 post monsoon.

It may be noted from Table 1 that the TDS suddenly increases for the sample at No. 6 at a concentration of 2954 ppm. Similarly minimum is observed at No. 14 concentration of 1071 ppm.

It is evident that highly concentrated sulphate solutions can cause detrimental effects on untreated and lime treated kaolinite by causing high swelling. The effect is more pronounced for lime treated soils even with low concentrations of sulphate in surrounding water.

The Surveillance Disease Distribution and Its Tendency

The secondary data of epidemiological surveillance cases from 30 wards in Arcot town was used for selection of diseases with highest incident ranking cases. The data for the epidemiological disease was collected from 'Patient Record form'. There are 16 epidemiological surveillance diseases in 'Patient Record form' and out

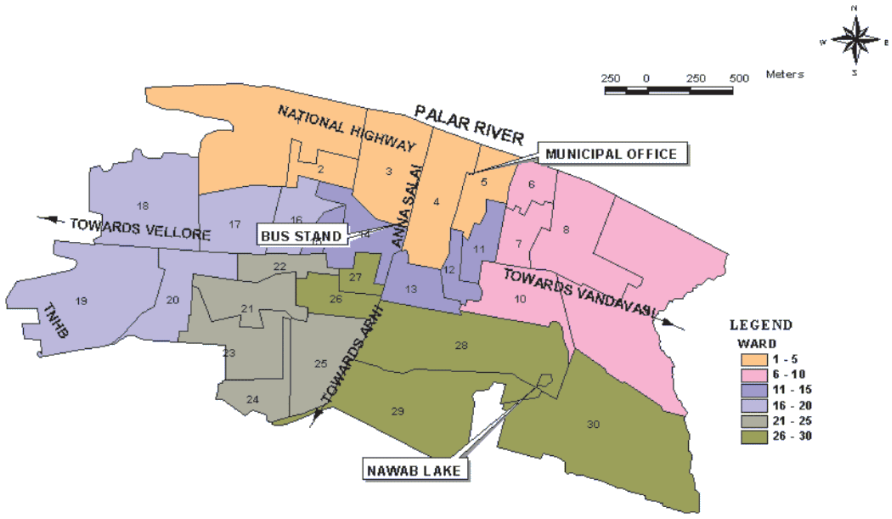

Figure 1: Base Map of Arcot Town.

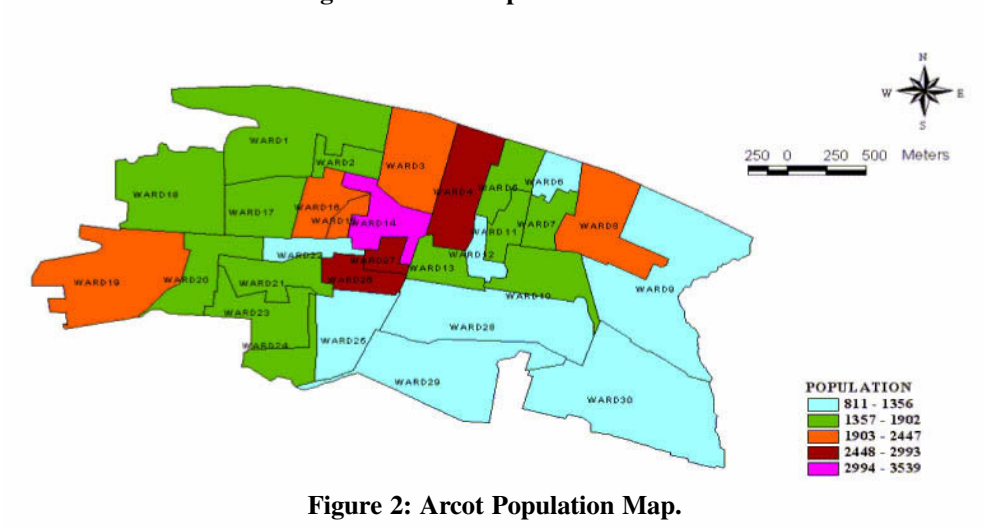

Figure 2: Arcot Population Map.

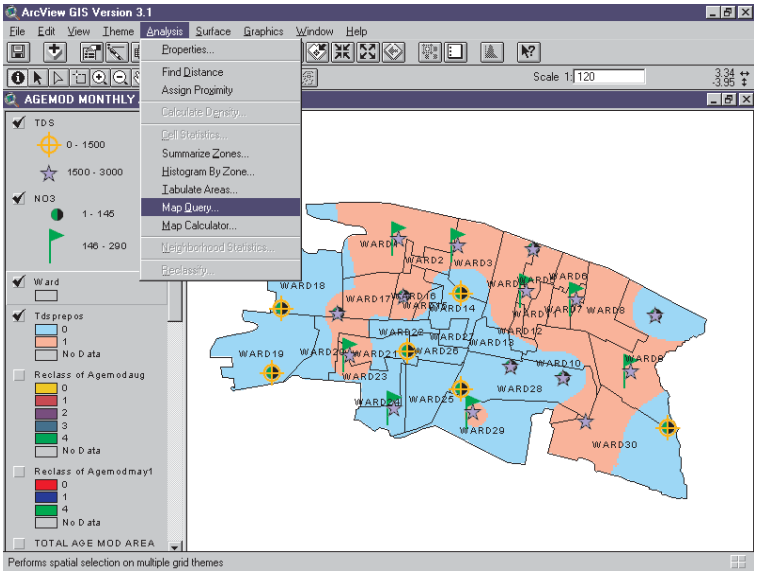

Figure 3: Query map I.

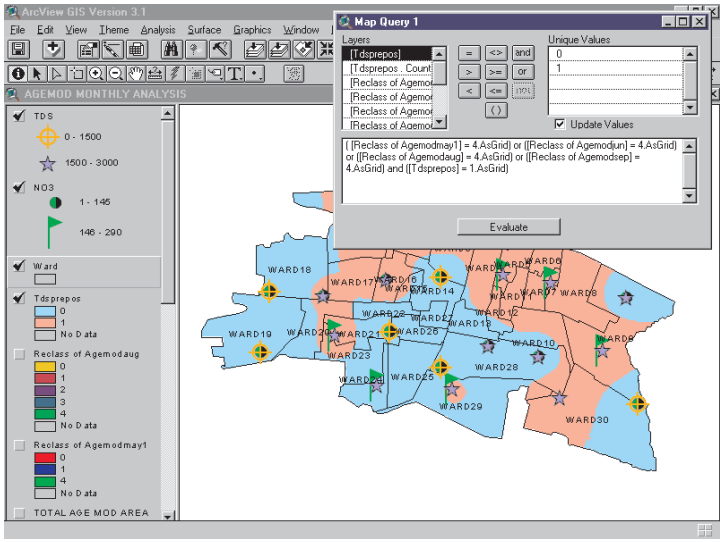

Figure 4: Query map II.

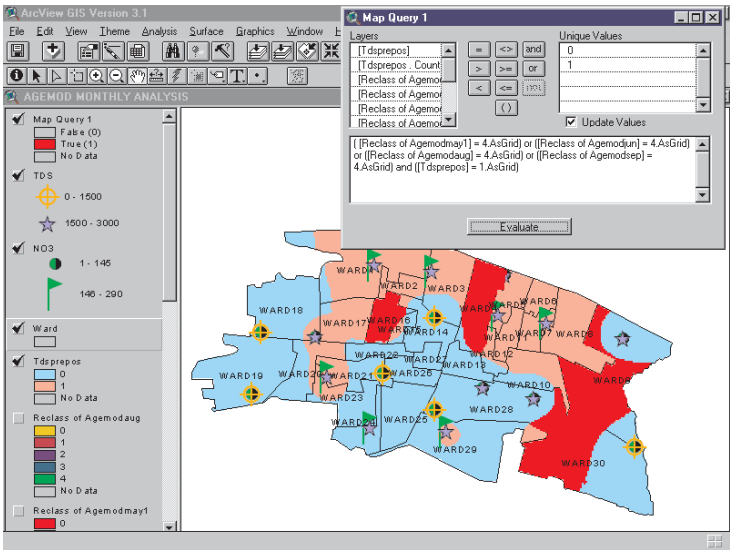

Figure 5: Query map III.

of those eight surveillance disease occurred in Arcot town (monthly provincial report). The disease selection category has confirmed that disease used to occur and widely spread in the part and it continues to spread unabated. Acute gastro enteritis with moderate dehydration is predominant within the wards that was high pre-monsoon. The prediction shows that the diffusion of Acute Gastro Enteritis with dehydration spreads from ward no. 18, 19 and 20. The other diseases like entric fever, viral fever, typhoid fever were seen in ward no. 30, 9 and partly ward no. 8. The above said wards groundwater quality of TDS and nitrate was above prescribed permissible limits. Most of these wards with low density population and moderate population growth, while agricultural areas, poor sanitation, drainage, solid waste dumping site, are located in the ward no. 30, ward no. 9 and ward no. 4 respectively. During analysis of TDS that is greater than 3000 mg/L and disease Acute Gastro Enteritis (AGE) with dehydrations, the wards 30, 8 and ward nos. 1, 17, 4 were affected. Some of wards like 12, 19, 17, 1, 4, 9, and 30 were affected by both groundwater quality and more reports of AGE was from above wards and patients record. The females were mostly affected by 72.3 per cent due to AGE with moderate dehydration and males 21.8 per cent and infants were affected less than one per cent.

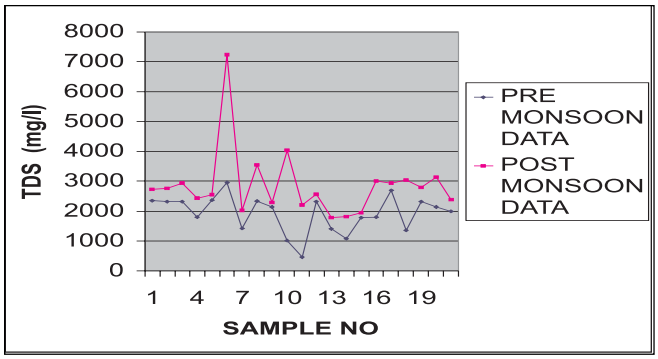

Figure 6: Graph showing the TDS comparison.

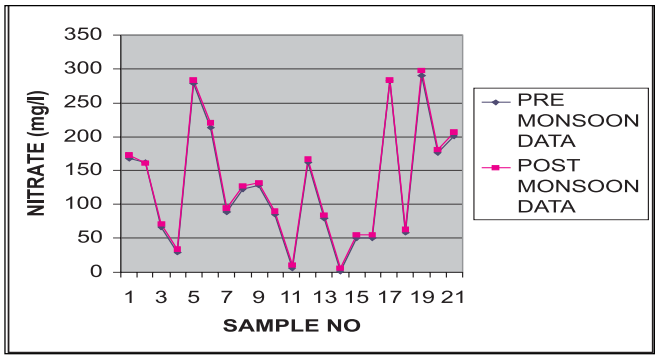

Figure 7: Graph showing NO_3 comparison.

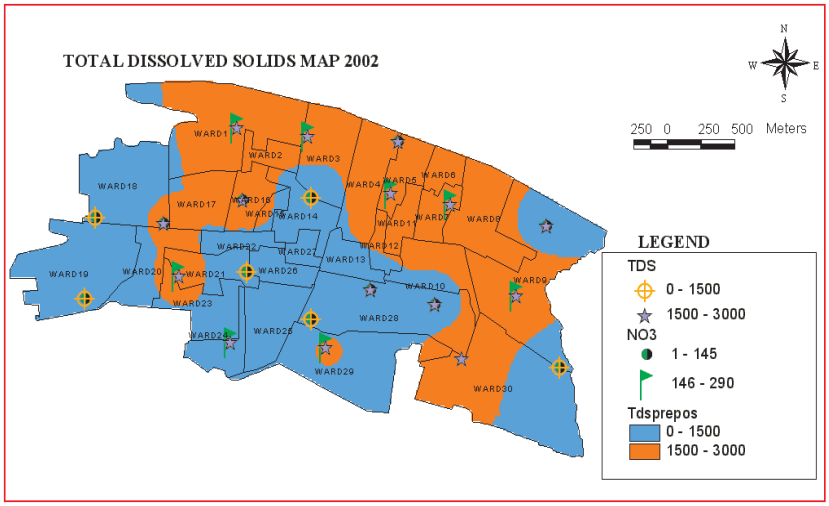

Figure 8: TDS map.

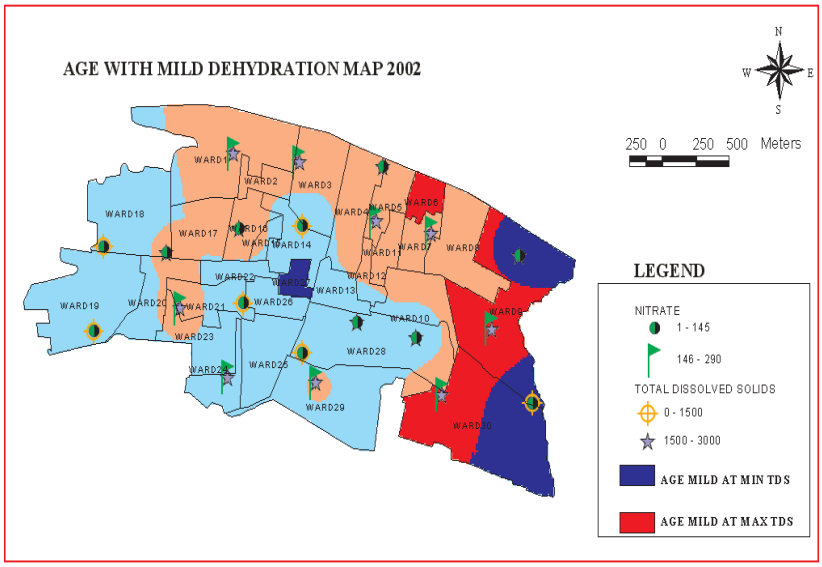

Figure 9: AGE and TDS map.

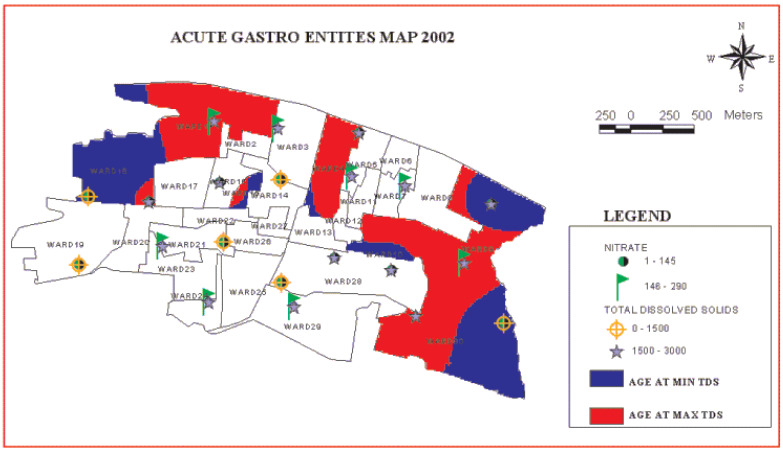

Figure 10: AGE with Gastroenties map.

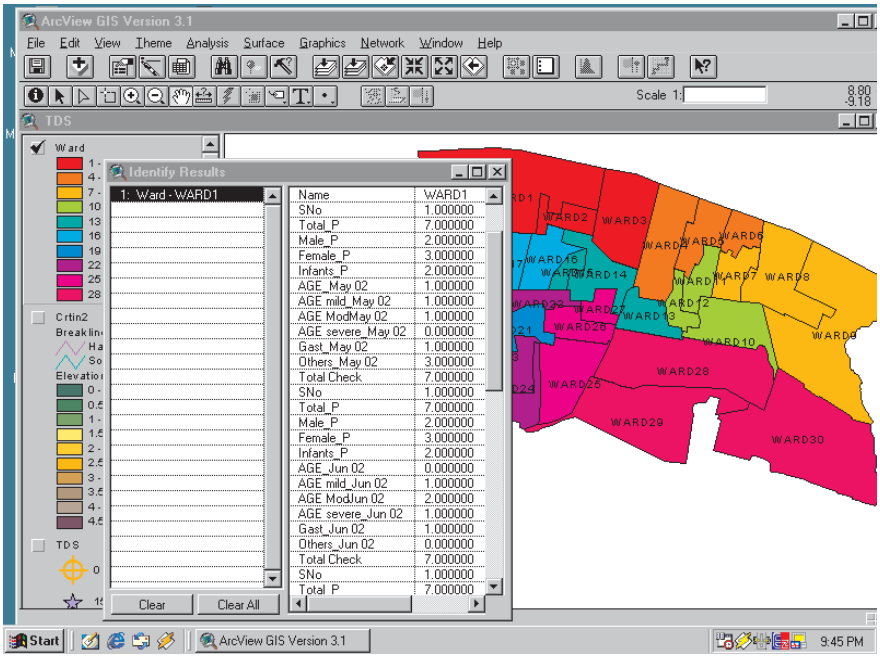

Figure 11: Integrating spatial and non-spatial data in unique relational manner.

Geographic Information System (GIS)

Geographic Information Systems (GIS) have become important tool in efficiently solving many problems in which spatial data are important. GIS incorporates data that describes population characteristics, socio-economic conditions and analyzing the spatial relationship of these factors. The analysis functions in a GIS, allows manipulation of multiple themes of spatial data to perform overlays, buffering and arithmetic operations on the data. GIS is thus a versatile tool for human service professionals providing a competitive edge particularly in the areas of planning and evolution and community development.

GIS serves as a useful tool in delineating the groundwater quality. The tool can provide valuable information for decision-making and be further used to develop user defined set of rules and thus create a decision support system. It goes beyond computer cartography and helps integrating spatial and non-spatial data in unique relational manner. (Refer Figures 8, 9, 10, and 11).

Conclusions

The saying "A picture is worth a thousand words" is true for GIS applications in the field of human services as

visual maps on client communities and their needs as an alternative to tables of numbers, charts or anecdotes not only make information easier to grasp but also provide more dimensions to study human service data. Customized maps created by using GIS software can help human service professional to gain a better understanding of the client communities they serve, as illustrated by the needs assessment project. Apart from querying information on spatial and non-spatial data, print output of the maps at user defined scales and extent, making of an integrated analysis on spatial and non-spatial data, performing query on multiple themes simultaneously are some of the features of the health GIS model. It is difficult to understand the issues related to epidemic diffusion simply by groundwater quality analysis as it lacks spatial information. Therefore, combination of both groundwater quality parameters and GIS methods is very useful to researchers to model the health related issues as GIS provides efficient capacity to visualize the spatial data. The main result shows that the Acute Gastro Enteritis was found to be widely spread disease because of groundwater quality, especially in poor drainage areas, lack of good drinking water facility and solid waste yard. Refer Figure 9.

In the study area's water quality data, TDS values ranges from 462 mg/L to 2954 mg/L in pre-monsoon. In the post monsoon minimum was 1780 mg/L and nitrate minimum concentration of 6 mg/L and maximum of 297 mg/L were observed.

During pre-monsoon period about 76.2 per cent of the samples exceed the TDS concentration of 1500 mg/L and 85 per cent of the samples exceed the concentration of nitrate 100 mg/L. During post monsoon all the samples exceed the TDS concentration of 1500 mg/L and 85 per cent of nitrate concentration exceeds the limit 100 mg/L (ICMR, 1975).

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