Analysis and interpretation of groundwater contamination using remote sensing and GIS :A case study

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ABSTRACT

The human activities are constantly adding industrial, domestic and agricultural wastes to the ground water reservoirs at an alarming rate. In the last few decades, rapidly developing technologies, increase in population and urbanization have been witnessing alarmed phenomena all over the world. Anthropogenic activities like generation and indiscriminate disposal of solid wastes and extensive use of fertilizers have resulted in increasing levels of air, water and soil pollution, changing land use patterns, decrease in arable land and other dominant problems. The problems of groundwater quality arise with changing land use patterns and are acute in areas that are densely populated and thickly industrialized, which affect the ground water resources and quality. The present study is aimed at generating physical characters and water quality by using remote sensing and GIS.

The thematic map of the study area was prepared from linearly enhanced fused data of IRS-ID PAN and LISS-III merged satellite imagery and Survey Of India (SOI) toposheets on 1:50,000 scale using visual interpretation technique using AutoCad and Arc/Info GIS software forming the spatial database. Groundwater samples were collected from the predetermined sampling locations and analyzed for physico-chemical parameters for the generation of attribute database. The spatial and attribute database thus generated are integrated and maps showing spatial distribution of selected water quality parameters were prepared. Water quality index (WQI) is calculated to assess the suitability of ground water for drinking purpose in the environmental stress areas with respect to water quality . suitable remedial measures are suggested.

Key words: Thematic maps, groundwater quality, remote sensing and GIS.

INTRODUCTION

Water is the most ubiquitous material in nature and is the most vital and fascinating of all God's creation. It is the most important raw material for mankind and is called "Liquid Gold". It is mainly because of this magical substance only that earth's temperature is maintained reasonably uniform at an average of 16 °C. Without water its temperature would have varied as on moon where it is 100°C during days and - 130°C during nights. Man can survive for five weeks without food but for less than five days without water.

Man needs water for domestic purposes such as cooking, cleaning utensils, gardening, washing clothes and above all for drinking. It is also needed for commercial, industrial and recreational purposes. Water used for such purposes should not be polluted, but should be of good quality. Urbanization and industrialization have directly or indirectly polluted most of the water sources on a

global scale. It may be noted that 90% of the world population is living without safe water which gives rise to water borne diseases which kills nearly 30,000 people every day. This is an alarming trend, which will lead to over exploitation and rapid depletion of groundwater resulting in acute fresh water scarcity apart from disturbing the ecological balance. Impact studies can contribute to improve urban development and environmental planning at the project and policy levels and it also introduces analytical tools to support such planning. Remote sensing applications have been operationalized in most of the natural resource management themes and at present the trend is on integrated surveys to arrive at sustainable developmental packages. Keeping this in view, an attempt is made to evaluate the water quality.

Study area

        The Maripeda Mandal lies geographically between latitudes 17° 20' 00" and 17° 35' 00" and longitudes 79° 45' 00" to 80° 00' 00" is covered in the Survey of India toposheet numbers 56 O/14 and 56 O/15. It is one of the 51 Mandals of Warangal district, in Andhra Pradesh. The major crops grown in the study area are Rice, Jowar, Cotton, Turmeric, Maize, Chilies and Sesame. Because of long range of dry periods and less number of rainy days the area suffers from poor soil moisture condition, resulting in frequent drought and famines. Due to erratic

nature of rainfall and impermeable nature of rocks the stream channels are formed into shallow and wider valley floors. The Drainage pattern is dendritic as a whole. Most of the stream courses are controlled by geological structures.

Study objectives
•   To prepare the digital thematic maps namely Base map, slope, soil, Geology , Geomorphology map, Ground Water Potential map, Land use/ Land cover, Drainage map etc. using satellite data, collateral data and field data on ARC/INFO GIS platform. This constitutes the spatial database.
•   Physico chemical Analysis of the water samples. This constitutes the Attribute database.
•   Creation of Water Quality Index.

Methodology
Data collection

        Different data products required for the study include Survey of India (SOI) toposheets bearing with numbers 56O/14 and 56O/15 on 1:50,000 scale. Fused data of IRS–1D PAN and LISS-III satellite imagery obtained from National Remote Sensing Agency (NRSA), Hyderabad, India. Collateral data collected from related organizations, comprises of water quality and demographic data.
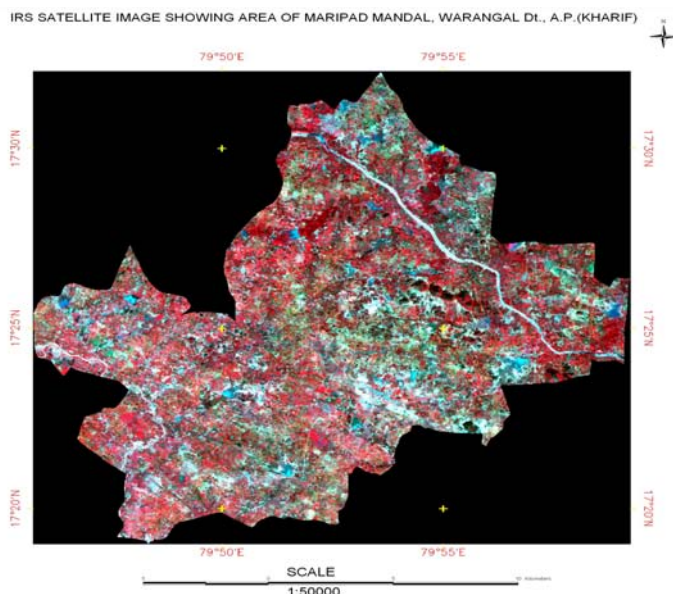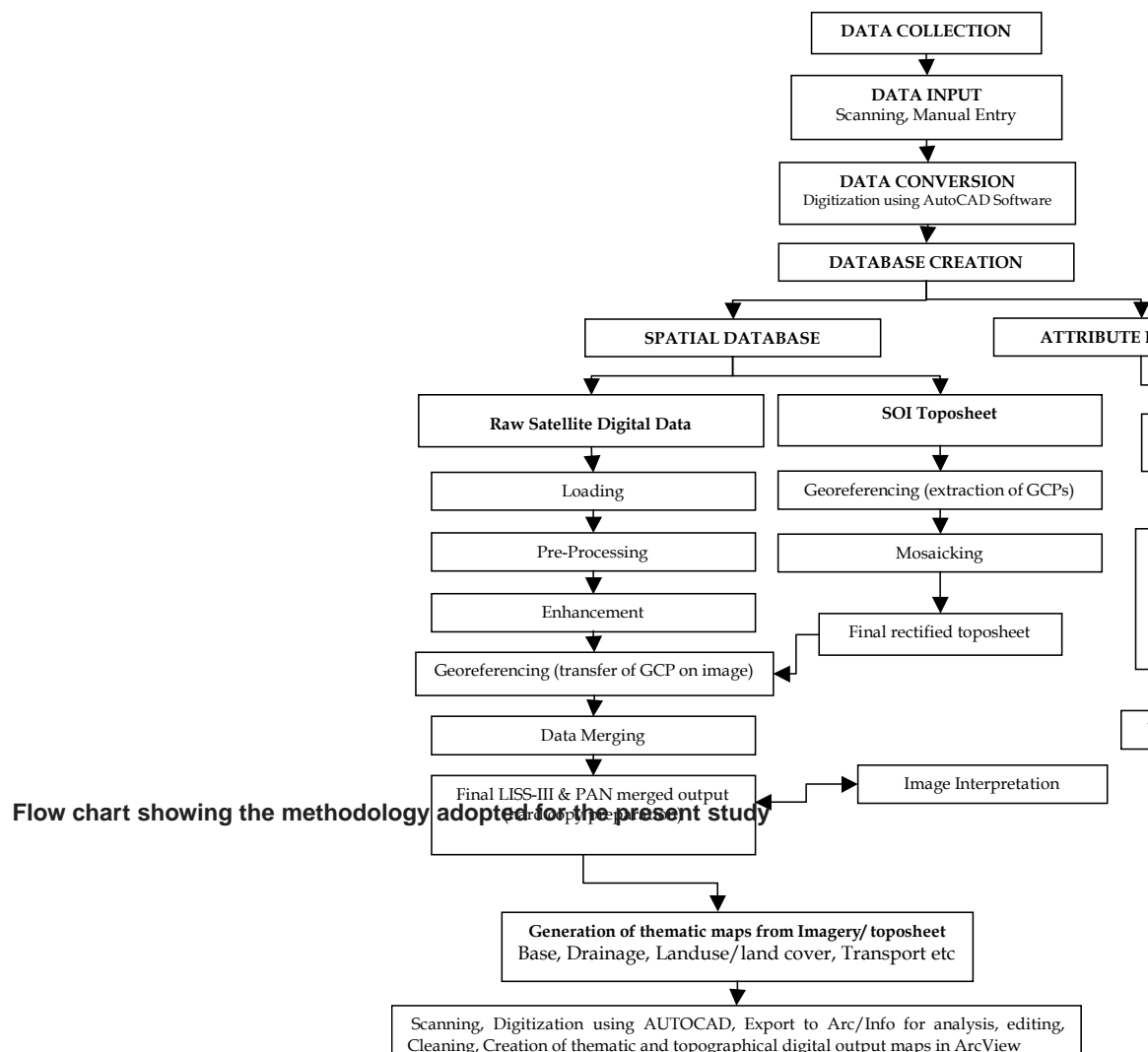

Fig. 1.

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                                    ┌─────────────────────────┐
                                    │     DATA COLLECTION      │
                                    └─────────────────────────┘
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                                                 ▼
                                    ┌─────────────────────────┐
                                    │       DATA INPUT         │
                                    │  Scanning, Manual Entry  │
                                    └─────────────────────────┘
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                                    ┌──────────────────────────────┐
                                    │      DATA CONVERSION          │
                                    │ Digitization using AutoCAD Software │
                                    └──────────────────────────────┘
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                                    │    DATABASE CREATION     │
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| SPATIAL DATABASE | ATTRIBUTE |

Raw Satellite Digital Data	SOI Toposheet
Loading	Georeferencing (extraction of GCPs)
Pre-Processing	Mosaicking
Enhancement	Final rectified toposheet
Georeferencing (transfer of GCP on image)	
Data Merging	
Final LISS-III & PAN merged output	Image Interpretation

Flow chart showing the methodology adopted for the present study

Generation of thematic maps from Imagery/ toposheet
Base, Drainage, Landuse/land cover, Transport etc

Scanning, Digitization using AUTOCAD, Export to Arc/Info for analysis, editing,
Cleaning, Creation of thematic and topographical digital output maps in ArcView

Database creation

Satellite imageries are georeferenced using the ground control points with SOI toposheets as a reference and further merged to obtain a fused, high resolution (5.8m of PAN) and colored (R,G,B bands of LISS-III) output in EASI/PACE Image processing software. The study area is then delineated and subsetted from the fused data based on the latitude and longitude values and a final hard copy output is prepared for the generation of thematic maps using visual interpretation technique as shown in Fig. 1. These thematic maps (raster data) are converted to vector format by scanning using an A0 flatbed deskjet scanner and digitized using AutoCAD software for generation of digital thematic maps using Arc/Info and ARCVIEW GIS software. The GIS digital database consists of thematic maps like land use/land cover, drainage, road network using Survey of India (SOI) toposheets and fused data of IRS - ID PAN and IRS-ID LISS-III satellite imagery.

Spatial Database

Thematic maps like base map and drainage network maps are prepared from the SOI toposheets on 1:50,000 scale using AutoCAD and Arc/Info GIS software to obtain a baseline data. Thematic maps of the study area was prepared using visual interpretation technique from the fused satellite imagery (IRS-ID PAN + IRS-ID LISS-III) and SOI toposheets along with ground truth analysis. All the maps are scanned and digitized to generate a digital output Fig. 1.

Attribute database

Fieldwork is conducted and ground water samples are collected from predetermined locations based on the land use and drainage network maps in the study area. Care is taken in collecting the water samples for uniform distribution and density of sampling locations. The water samples were analyzed for various physico-chemical parameters adopting standard protocols (APHA, AWWA, WPCF 1998). The water quality data thus obtained forms the attribute database for the present study Table 1.

Estimation of water quality index (WQI)

To determine the suitability of the groundwater for drinking purposes, Water Quality Index (WQI) is computed adopting the method proposed by Tiwari and Mishra, 1985 (Mahuya Das Gupta, 2001, Pradhan, S.K, 2001, Srivastava, A.K., 1994). WQI is computed using the formula given in equation (1), and a water quality index map is prepared.

$$WQI = Antilog \left[\Sigma W^n_{n=1} \log_{10} q_n \right] \quad ...(1)$$

Where,

Weightage factor (W) is computed using equation (2)

$$W_n = K / S_n \quad ...(2)$$

Where,

S_n = Standard value of the parameter

K, Constant = $[1 / (\Sigma^n_{n=1} 1/S_i)]$

S_i = Standard value of the parameter

Quality rating (q) is calculated by the formula given in equation (3)

$$q_{ni} = \{[(V_{actual} - V_{ideal}) / (V_{standard} - V_{ideal})] * 100\} \quad ...(3)$$

Where,

q_{ni}	=	Quality rating of ith parameter for a total of 'n' water quality parameters
V_{actual}	=	Value of the water quality parameter obtained from laboratory analysis
$V_{standard}$	=	Value of the water quality parameter obtained from the standard tables.
V_{ideal} for pH	=	7 and for other parameters it is equalent to zero.

MATERIAL AND METHODS

Groundwater samples were collected from different locations from predetermined study area. Sampling bottles were cleaned with 10 % nitric acid followed by distilled water to avoid any accidental contamination. Samples were collected in 1.5 litre of pet bottles from selected sampling sites and were scaled highly and labeled properly. The groundwater samples were collected according to standard methods and analyzed for physical and chemical parameters APHA (1998).

RESULTS AND DISCUSSION

Base map

A topographic map is a representation of the shape, size, position and relation of the physical features of an area (IMSD Technical Guidelines 1995). The base map is prepared using SOI toposheet on 1:50,000 scale and updated with the

help of satellite imagery. It consists of various features like the road network, settlements, water bodies, canals, railway track, vegetation etc. delineated from the toposheet. The map thus drawn is scanned and digitized to get a digital output. The information content of this map is used as a baseline data to finalize the physical features of other thematic maps.

Drainage

Drainage map is prepared by using Survey of India Topographic maps on 1:50,000. All the streams and tanks existing in the study area are marked in this map. These streams further classified based on stream ordering. Up to fourth order streams exist in the study area.Most of the streams right side of the state highway flow NorthEast to SouthWest in the study area and left side of the state highway SouthWast to NorthEast Canals. Only two minor rivers namely Palleru and Akeru exists. The drainage system existing is dendritic Fig. 2.

Slope map

Slope classes 1, 2 and 3 are observed in the study area. Most of the study area is covered by nearly level, very gently, gently slope class (92%). Small part of the study area (4%) comes under moderately sloping class 4 and (2%) study area comes under the strongly sloping class 5 (IMSD Technical Guidelines, 1995).

Land Use/Land Cover:

The land use/land cover categories such as built-up land, agriculture, forest, water body and wastelands have been identified and mapped from the study area Fig. 3. Major part of the study area is covered with single crop and double crop (93%). About (0.015%)of the study area is under built-up land and Industrial area is(0.017%). From the satellite data the agriculture area (96.05%) could be clearly delineated as four categories, single crop, double crop, fallow land and plantations. Though
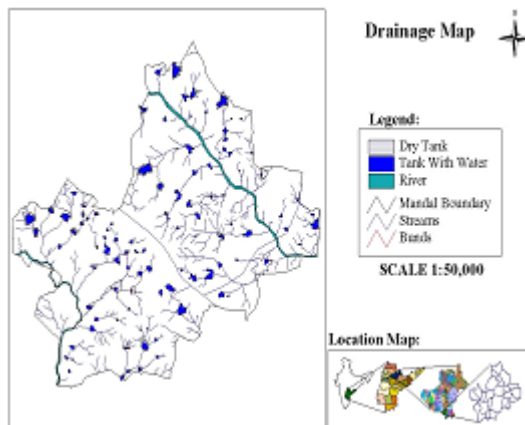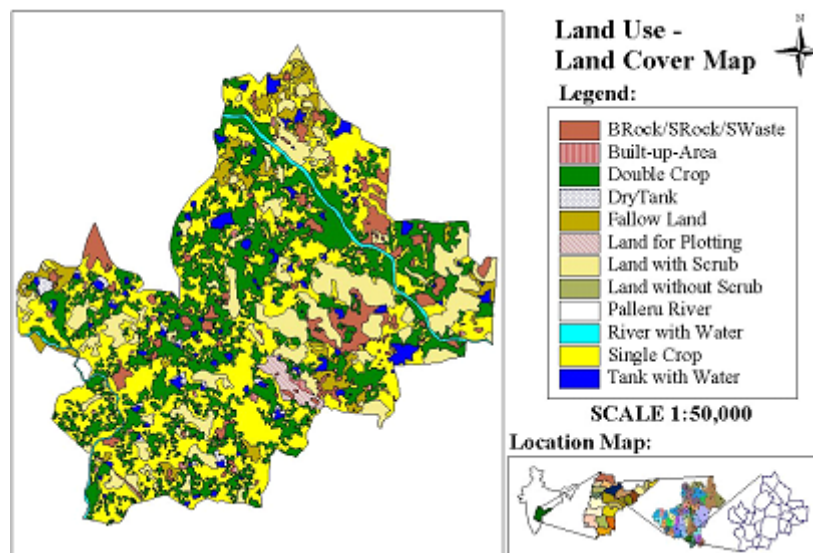

Fig. 2:

Fig. 3:

Table 1: Water quality data of the study area

S. No.	Village name	Parameters											
		Turbidity	pH	EC	TDS	Hardness	Alkalinity	Cl^-	SO_4^{2-}	NO_3^-	F^-	PO_4^{3-}	MPN
1	Uggampalli 1	5	6.6	612	379	1640	1440	264	21	8.7	0.72	0.98	NIL
2	Uggampalli 2	6	6.5	614	372	1638	1443	265	22	8.6	0.73	0.98	NIL
3	Uggampalli 3	5	6.2	620	370	1648	1452	266	20	8.6	0.75	0.99	NIL
4	Uggampalli 4	4	6.7	612	365	1622	1456	264	24	8.8	0.75	0.95	NIL
5	Chinagudur 1	5	6.4	1610	998	1070	1550	350	25	8.2	0.96	1.12	NIL
6	Chinagudur 2	5	6.5	1612	997	1069	1551	352	25	8.3	0.95	1.11	NIL
7	Chinagudur 3	4	6.4	1616	995	1070	1550	354	24	8.4	0.94	1.12	NIL
8	Chinagudur 4	5	6.6	1620	989	1072	1550	350	22	8.5	0.93	1.10	NIL
9	Jayyaram 1	5	7.6	997	618	370	1120	50	19	3.3	1.14	0.98	NIL
10	Jayyaram 2	6	7.5	992	612	366	1121	48	19	3.2	1.15	0.98	NIL
11	Jayyaram 3	5	7.6	996	621	358	1125	45	18	3.3	1.14	0.95	NIL
12	Jayyaram 4	6	7.5	991	598	357	1122	52	21	3.4	1.14	0.88	NIL
13	Vismpalli 1	5	7.6	1426	884	540	1000	145	36	2.3	0.56	1.2	NIL
14	Vismpalli 2	4	7.8	1422	882	541	1010	146	35	2.4	0.52	1.1	NIL
15	Vismpalli 3	5	7.9	1423	883	538	1020	149	35	2.5	0.51	1.2	NIL
16	Vismpalli 4	5	7.8	1425	884	535	1001	145	36	2.4	0.50	1.1	NIL
17	Yellempet 1	10	6.3	1257	779	230	510	200	23	6.3	0.74	1.32	NIL
18	Yellempet 2	10	6.4	1255	770	231	511	210	22	6.4	0.75	1.32	NIL
19	Yellempet 3	12	6.2	1260	778	232	512	220	25	6.5	0.74	1.31	NIL
20	Yellempet 4	10	6.3	1252	769	230	510	200	26	6.4	0.75	1.40	NIL
21	Anepuram 1	10	6.7	356	220	190	520	70	6.5	3.7	0.60	0.76	NIL
22	Anepuram 2	12	6.5	355	220	192	522	69	6.6	3.8	0.59	0.75	NIL
23	Anepuram 3	15	6.7	356	225	194	526	69	6.7	3.9	0.61	0.75	NIL
24	Anepuram 4	16	6.5	370	240	199	550	75	5.8	3.2	0.61	0.76	NIL
25	Nilkurti 1	10	6.7	1578	978	570	1460	120	25.5	2.5	0.96	0.98	NIL
26	Nilkurti 2	10	6.5	1575	977	579	1458	121	25.3	2.6	0.95	0.94	NIL
27	Nilkurti 3	12	6.7	1576	978	576	1460	122	25.6	2.5	0.94	0.95	NIL
28	Nilkurti 4	08	6.1	1570	960	578	1452	115	25.4	2.7	0.95	0.97	NIL
29	Chillamcherla 1	10	6.8	562	348	190	570	50	13.5	9.0	0.66	1.08	NIL
30	Chillamcherla 2	10	6.5	563	346	190	573	50	13.3	9.2	0.65	1.09	NIL

No.	Name												
31	Chillamcherla 3	12	6.6	562	342	186	572	48	12.8	8.9	0.48	0.09	NIL
32	Chillamcherla 4	13	6.8	562	340	186	569	49	12.6	8.9	0.48	0.08	NIL
33	Rampuram 1	5	6.7	805	499	990	740	95	18	2.0	0.58	0.68	NIL
34	Rampuram 2	9	6.5	810	501	998	745	96	20.02	2.2	0.59	0.65	NIL
35	Rampuram 3	8	6.8	798	509	995	748	98	19	2.2	0.53	0.68	NIL
36	Rampuram 4	5	6.8	809	498	979	746	96	19	2.5	0.54	0.65	NIL
37	Talla Ukal 1	5	7.8	1902	1179	620	1580	165	29.8	5.3	1.37	0.54	NIL
38	Talla Ukal 2	5	7.9	1898	1201	632	1498	178	29.5	5.9	1.38	0.54	NIL
39	Talla Ukal 3	6	7.8	1906	1203	635	1486	159	25.9	5.4	1.36	0.55	NIL
40	Talla Ukal 4	8	6.5	1551	1102	198	1284	120	15	2.9	0.09	0.05	NIL
41	Tanam Charla 1	10	6.3	340	210	820	1270	35	33	6.6	0.84	1.4	NIL
42	Tanam Charla 2	09	5.9	298	212	828	1280	38	33	6.5	0.85	1.6	NIL
43	Tanam Charla 3	09	5.6	315	215	830	1257	34	31	6.6	0.88	1.9	NIL
44	Tanam Charla 4	10	5.0	350	216	846	1260	35	33	6.7	0.89	1.8	NIL
45	Bhuranapuram 1	5	6.6	532	330	140	540	40	17	9.5	0.45	0.98	NIL
46	Bhuranapuram 2	6	6.5	538	336	138	448	42	18	9.5	0.46	0.84	NIL
47	Bhuranapuram 3	5.	6.7	537	335	139	498	44	16	8.9	0.45	0.85	NIL
48	Bhuranapuram 4	8.1	7.4	650	420	149	551	50	25	12.3	1.56	1.8	NIL
49	Gundipudi 1	10	7.3	920	570	240	950	70	11	5.9	1.33	1.12	NIL
50	Gundipudi 2	09	7.2	889	562	255	956	68	11	5.8	1.35	1.09	NIL
51	Gundipudi 3	09	7.3	890	548	256	957	65	15	5.6	1.35	1.25	NIL
52	Gundipudi 4	16	7.4	1020	987	556	1020	85	29	12.3	3.02	3.12	NIL
53	Giripuram 1	5	7.2	340	210	90	340	50	24	6.0	0.34	1.22	NIL
54	Giripuram 2	6	7.3	348	215	89	345	65	25	6.5	0.35	1.23	NIL
55	Giripuram 3	5	7.4	349	216	79	346	58	24	6.4	0.37	1.24	NIL
56	Giripuram 4	6	7.6	346	215	89	348	52	25	6.3	0.36	1.25	NIL
57	Maripeda 1	5	6.2	330	205	590	420	255	31	4.6	0.65	1.26	NIL
58	Maripeda 2	8	7.9	580	475	695	3(9	386	48	8.4	1.54	2.45	NIL
59	Maripeda 3	9	7.8	579	498	686	379	387	47	8.6	1.98	2.42	NIL
60	Maripeda 4	9	7.8	587	489	689	380	386	45	8.9	1.45	2.32	NIL
61	Viraram 1	5	6.9	1805	1119	540	1800	115	28	8.2	0.92	1.36	NIL
62	Viraram 2	5	6.8	1556	998	489	1785	116	30	9.0	1.25	1.45	NIL
63	Viraram 3	8	6.9	1567	982	498	1779	115	29	8.7	1.24	1.6	NIL
64	Viraram 4	8	7.7	1023	1021	321	1625	102	30	9.0	2.52	2.01	NIL
65	Ullepalli 1	5	6.7	1346	835	490	1250	115	22.5	9.3	0.89	1.44	NIL

Sr	Location	Turbidity	pH										
66	Ullepalli 2	7	6.2	1342	850	495	1248	112	22.6	9.5	0.92	1.45	NIL
67	Ullepalli 3	6	6.6	1345	865	498	1321	109	23	9.4	0.96	1.46	NIL
68	Ullepalli 4	10	7.3	1521	920	520	1289	154	26.12	9.8	1.03	2.01	NIL
69	Edcharla 1	5	6.4	1500	930	740	1550	250	17	7.0	0.97	1.02	NIL
70	Edcharla 2	8	7.7	1620	940	820	1489	289	20	9.2	1.20	2.0	NIL
71	Edcharla 3	8	7.9	1625	996	822	1625	290	21	9.3	1.22	2.1	NIL
72	Edcharla 4	8	7.8	1630	1020	824	1626	292	22	9.4	1.9	2.1	NIL
73	Dharmaram 1	5	6.7	1435	890	430	1250	115	30.5	8.9	0.86	1.2	NIL
74	Dharmaram 2	8	7.3	1534	921	521	1265	201	32	9.2	1.21	2.5	NIL
75	Dharmaram 3	8	7.9	1589	925	524	1278	225	32.48	9.3	1.20	2.4	NIL
76	Dharmaram 4	9	7.9	1589	926	526	1279	245	32.45	9.3	1.22	2.5	NIL
77	Bichrajpalli 1	5	6.9	1408	873	350	1350	111	23.5	6.7	0.72	0.84	NIL
78	Bichrajpalli 2	5	6.8	1409	882	358	1351	121	23.9	6.8	0.98	0.92	NIL
79	Bichrajpalli 3	6	6.9	1410	887	357	1349	109	24.5	6.7	0.98	0.89	NIL
80	Bichrajpalli 4	5	6.8	1415	889	358	1289	110	25.6	6.8	0.85	0.79	NIL
81	Purushothamguda 1	5	7.5	938	582	260	1050	131	16	8.6	0.83	1.38	NIL
82	Purushothamguda 2	6	7.6	939	589	268	1080	129	18	8.9	0.92	1.23	NIC
83	Purushothamguda 3	5	7.8	942	587	269	1079	139	19	8.7	0.96	1.25	NIC
84	Purushothamguda 4	6	7.8	944	586	268	1082	140	20	9.2	0.94	1.24	NIC
85	Abbaipalem 1	5	6.7	1438	892	510	1510	100	22.5	7.3	1.02	1.12	NIL
86	Abbaipalem 2	6	6.8	1445	895	515	1515	108	23.6	8.5	1.05	1.15	NIL
87	Abbaipalem 3	8	6.9	1452	896	520	1612	109	22.4	8.6	1.06	1.26	NIL
88	Abbaipalem 4	5	7.0	1456	895	521	1620	110	21.6	8.7	1.08	1.24	NIL
89	Galivari gudem 1	5	8.0	1325	821	440	1210	85	29	3.6	0.57	1.36	NIL
90	Galivari gudem2	5	8.3	1326	825	442	1212	91	30	4.2	0.68	1.42	NIL
91	Galivari gudem3	6	8.2	1324	826	446	1234	89	32	4.3	0.67	1.45	NIL
92	Galivari gudem4	9	9.2	1554	836	521	1521	102	45	5.2	1.23	2.54	NIL
	Desirable Limit	5 NTU	6.5 to 8.5	-	500	300	200	250	200	45	1.0	-	1
					mg/l	mg/l	mg/l	mg/l	mg/l	mg/l	mg/l		mg/l
	Permissible Limit	10 NTU	No relaxation	2000	600	600	1000	400	100	1.5	1	-	10
				mg/l	mg/l	mg/l	mg/l	mg/l	mg/l	mg/l	mg/l		mg/l

1) All the parameters, except turbidity, unless otherwise specified, are expressed in mg/l.
2) Turbidity expressed in Nephelometric Units (NTU).

single crop and double crop has been observed at various parts of the study area and plantations are observed at some places of the study area. Water bodies occupied (0.18%). About (0.46%) of the study area is under scrub forest and(4.21%) of area is under wasteland. Under this category land with scrub (3%), land without scrub (0.24%) and barren sheet rock area (0.09%) are observed.

Geomorphology

The geomorphological classes observed in the study area are Pediplain with moderate weathering (PPM) (42%), Pediplain with shallow weathering (PPS) (31%), valley (v) (14%), pediment (PD) (8%), pediment inselberg complex (PIC) (2%) ,inselberg (1%) ,pediment (1%) and dyke and dyke ridge (0.12%) .

Geology

The study area constitutes mainly a granitic terrain (pink-grey) exposive a variety of archaean granitorides of peniusular gneissic complex (PGC) and schistoic (older metamorphic) rocks. They are intruded by basic dykes (Proterozoic) and covered locally by the deccan traps (upper cretaceous to lower Eocene). The geological categories observed in the study area are mainly granite (98%), basalt (2%), and some of lineaments, dolerites and pegmatites .

Soil

The specific objectives of soil mapping are identification, characterization and classification of the soils of the area. The soil types identified in the study area are (1) loamy-skelital,mixed, rhodic paleustalfs (55%). (2) fine loamy, mixed, fluventicustropepts (10%) (3) fine, montmorillonitic, typichaplusterts (35%).

Groundwater potential

The groundwater potential map is prepared based on the analysis of various themes such as geomorphology, land use / land cover, lineament, intersection points, drainage pattern, lithological evidences by using converging evidence concept, besides the collateral data obtained from State Groundwater Board with necessary field checks. The groundwater potential map reveals the available quantum of groundwater and is delineated into zones showing high (53%),medium (30%), low (17%), groundwater potential areas (Krishnamurthy, 1996).

Ground water quality variation in the study area

Field work was conducted in the study area from where 92 groundwater samples were collected at different locations. The water samples were analyzed for various physico-chemical parameters. The results obtained are presented in Table 1 and depicted in Fig. 4.
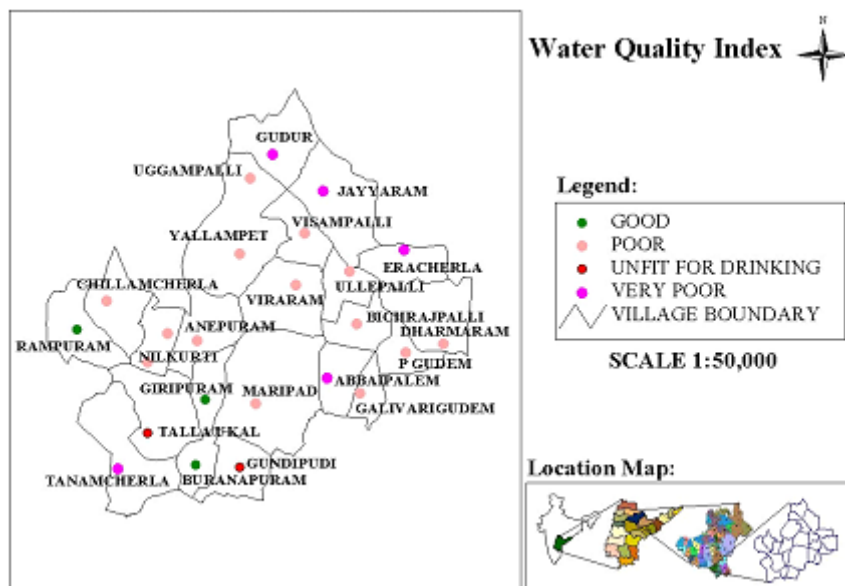

Fig. 4:

Turbidity

In ground water samples ranged from 4-16 NTU. The high concentration of turbidity is seen in few samples which might be due to colloidal materials which is objectionable because of aesthetic considerations.

pH

pH of groundwater samples was ranging from 6.2-7.5 which shows the alkaline nature of water. The pH is an important variable in water quality assessment as it influences many biological and chemical processes with in a water body and all processes associated with water supply and treatment.

Electrical conductivity

EC of groundwater ranged from 340-1906 mg/l. The high concentration of EC may be due to high concentration of ionic constituents present in water bodies and reflects contributions from salinity intrusions as well as industrial effluents.

Total dissolved solids

The TDS values of groundwater sample ranged from 192-1203 mg/l. The observed TDS values in most of the groundwater samples are exceeding the permissible limits of ICMR. The suspended solids values indicated the presence of organic and inorganic solids that can provide adsorptive sites for certain chemicals and biological agents.

Hardness

The hardness in the groundwater samples ranged from 79 – 1648 mg/l. The concentration of hardness is above the prescribed limit of 300 ppm in most of the samples collected from study area. Hard water is high in dissolved minerals, both calcium and magnesium. As water moves through soil and rock, it dissolves small amounts of these naturally-occurring minerals and carries them into the ground water supply. Water is a great solvent for calcium and magnesium, so if the minerals are present in the soil around well and its water supply, can end up with hard water EPA (1996).

Alkalinity

The alkalinity values of groundwater samples ranged from 285 – 1800 mg/l, respectively.

Large amount of alkalinity imparts a bitter taste to water and usually unpalatable and consumer acceptance decreases with this water.

Chlorides

Chlorides values of groundwater samples ranged from 21-387 mg/l, respectively which is above the prescribed standards NEERI (1990) in few samples. Water containing chloride in excess of 250 mg/l are considered to be undesirable for drinking purposes. Sodium chloride exerts a salty taste to water and excess chloride causes cardio vascular diseases.

Sulphate

Sulphate are under permissible limits according to standards which ranged from 11-48 mg/l.

Nitrates

Nitrate are under control at locations in ground water samples. High concentration of nitrates is potent toxins that cause a wide range of health problems, including 'blue-baby syndrome.

Fluorides

Fluoride is above the prescribed limits in almost all ground water samples which is ranging 0.1- 2.5 mg/l. If fluoride is more than 1.5 mg/l it leads to discoloration of teeth called "molting". Fluoride in excess of 5 ppm causes bone flurosis and skeletal abnormalities. The high concentration of F may be due to domestic waste and wastewater, which are contaminated by effluents from glass and aluminum manufacturing industries.

Phosphates

Phosphate in ground water sample range from 0.04-3.12 mg/l which is below the prescribed limits.

MPN

The most important parameter to be consider for drinking water is MPN (most probable number) and it was found that all the ground water samples showed negative for the MPN test and potable for drinking purpose.

The above investigation reveals that water quality parameter like Hardness, Alkalinity, TDS and Fluoride are beyond the permissible limits and found

that the pollution of groundwater is more in the study area.

Water quality index variation in the study area

Water quality rating, reflecting the influence of different water quality parameters on the overall quality of water and Water Quality Index (WQI), a very useful and efficient method for assessing the quality of water (Abassi, 1999) are determined in the present study. The water quality of the study area varied from good to unfit for drinking (Fig. 4.). All the samples exhibited good water quality with the index ranging from 0-50 observed in 12 samples in areas like Giripuram, Buranapuram, Rampuram. Poor water quality with the index ranging from 50-75 obseved in 52 samples at Uggampalli, Yellampet, Visampalli, Chillamcherla, Viraram, Ullepalli,Anepuram, Nilkurti, Maripad, Galivarigudem, P.gudem, Dharmaram, Bichrajpalli areas. where the water quality was found to be very poor with WQI ranging from 75-100 observed in 20 samples at Eracherla, Jyarram, Gudur, Abbaipalem, Tanamcherla areas. Unfit for drinking 8 samples were found with the WQI ranging above 100 in Talaukal,Gundipudi areas.the poor to unfit for drinking samples were observed in areas which are all residential and Agricultural areas. where the

domestic waste generated is increasing day by day and using the pesticides in the agricultural lands Improper management of these waste, pesticides may have a greater impact on ground water quality.

Conclusions and recommendations

From the results obtained from the physico-chemical analysis of ground water and the water quality index, the areas under impact i.e., areas where high concentration of water quality parameters is observed were identified. The results indicate that certain parameters like nitrates, TDS, hardness and alkalinity exceeded the permissible limit as given by Bureau of Indian Standards. The concentration of Sodium, Potassium, Chloride, Sulphates however was within permissible limits. The poor quality which all lie in the residential and Agricultural areas of the study area. Modification and maintenance of the existing septic systems, proper disposal of domestic waste generated from households, pre-treatment of the industrial effluents prior to their disposal and controlled land management prohibiting land use practices and to control the using the pest ices in the Agricultural lands which degrade the environmental quality are a few recommendations suggested to improve the water quality in the study area.

REFERENCES

1.   District Census Handbook of Hyderabad, Directorate of Census Operations, Andhra Pradesh, Census of India (1991).

2.   APHA, AWWA, WPCF, Standard Methods for the Examination of Water and Wastewater. (20th edition). *American Public Health Association,* Washington DC, New York (1998).

3.   Tiwari, T.N and Mishra, M, A preliminary assessment of water quality index to major Indian rivers. *Indian Journal of Environmental Protection,* **5**(4): 276-279 (1985).

4.   Mahuya Das Gupta Adak, Purohit KM, Jayita Datta, Assessment of drinking water quality of river Brahmani. *Indian Journal of*

Environmental Protection, **8**(3): 285-291 (2001).

5.   Pradhan, S.K., Dipika Patnaik and Rout, S.P, Water quality index for the ground water in and around a phosphatic fertilizer plant. *Indian Journal of Environmental Protection,* **21**: 355-358 (2001).

6.   Srivastava, A.K., and Sinha, D.K, Water Quality Index for river Sai at Rae Bareli for the premonsoon period and after the onset of monsoon. *Indian Journal of Environmental Protection,* **14**: 340-345 (1994).

7.   Kurian Joseph, An integrated approach for management of Total Dissolved Solids in reactive dyeing effluents. *Proceedings of International Conference on Industrial*

Pollution and Control Technologies, Hyderabad (2001).

8. Abassi S. A, Water Quality Indices: State-of-the art. *J.IPHE*, No.1 (1999).

9. APHA, Standard method for the examination of water and wastewater 20th ed, American public health association, Washington, DC (1998).

10. EPA, Guidelines for Environmental Monitoring, Groundwater monitoring at landfills is meant to detect unacceptable groundwater contamination resulting from landfill operations. at Municipal Solid Waste Landfills (1996).

11. NEERI, Waste quality studies of the Jheel in Kolkata port area, National Enviornment Engineering Reasearch Institute, Nagpur (1990).