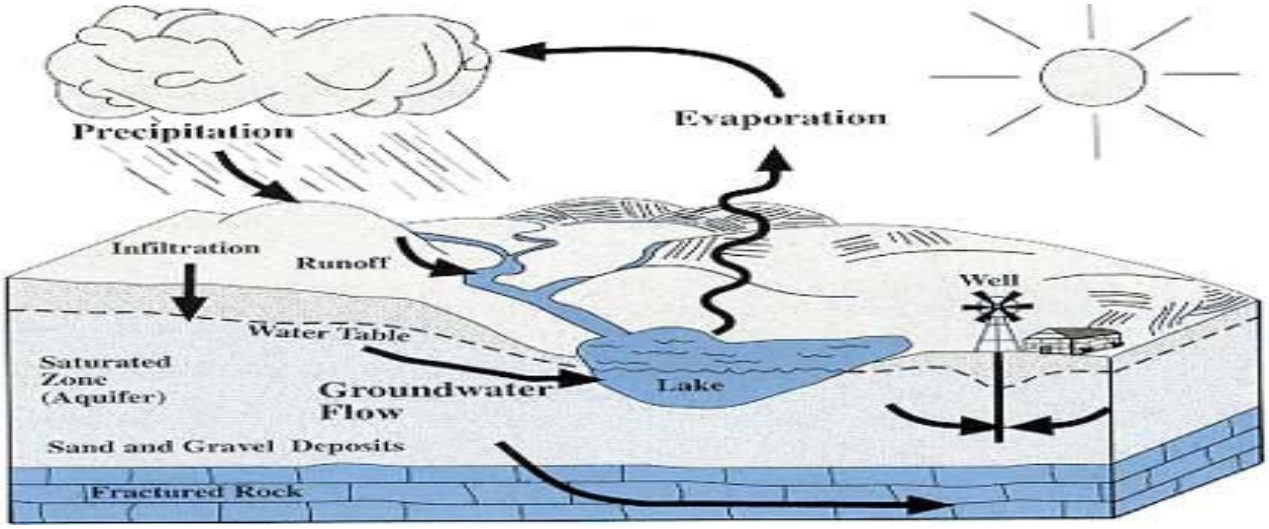
GROUNDWATER QUALITY SERIES:
GWQS/ 09/2006-2007

STATUS OF GROUNDWATER QUALITY IN INDIA -Part - I



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FOREWORD

In recent years, the increasing threat to groundwater quality due to human activities has become a matter of great concern. A vast majority of groundwater quality problems present today are caused by contamination and by over-exploitation, or by combination of both. Rapid urbanization and industrialization in India has resulted in steep increase of generation of wastes. Due to lack of adequate infrastructure and resources the waste is not properly collected, treated and disposed; leading to accumulation and infiltration causing groundwater contamination. The problem is more severe in and around large cities as also various clusters of industries. In many of these areas groundwater is only source of drinking water, thus a large population is exposed to risk of consuming contaminated water. In this background Central Pollution Control Board with the help of its Zonal offices, the National Institute of Hydrology (NIH) and the Pollution Control Research Institute (PCRI) of Bharat Heavy Electricals Ltd. (BHEL) initiated a detailed survey of groundwater quality in problem areas of industrial clusters and metro cities of India. The results of this Survey with respect to 16 problem areas and 8 metro cities are summarized in this Report.

The Report presents the environmental profiles of metropolitan cities and Problem Areas identified by CPCB and their groundwater quality status. The groundwater quality data obtained during Survey were evaluated against drinking water quality requirements [BIS 10500, (1991) & WHO (1996) Standards]. Salinity, nitrate, Coliform & Fluoride are the main water quality issues in the metro cities and problem areas of the country. Considering the competing demand on this scarce resource, the Report highlights the judicious use of groundwater and also remedial measures needed to overcome the problems.

We hope the information contained in the Report would be useful to all concerned.

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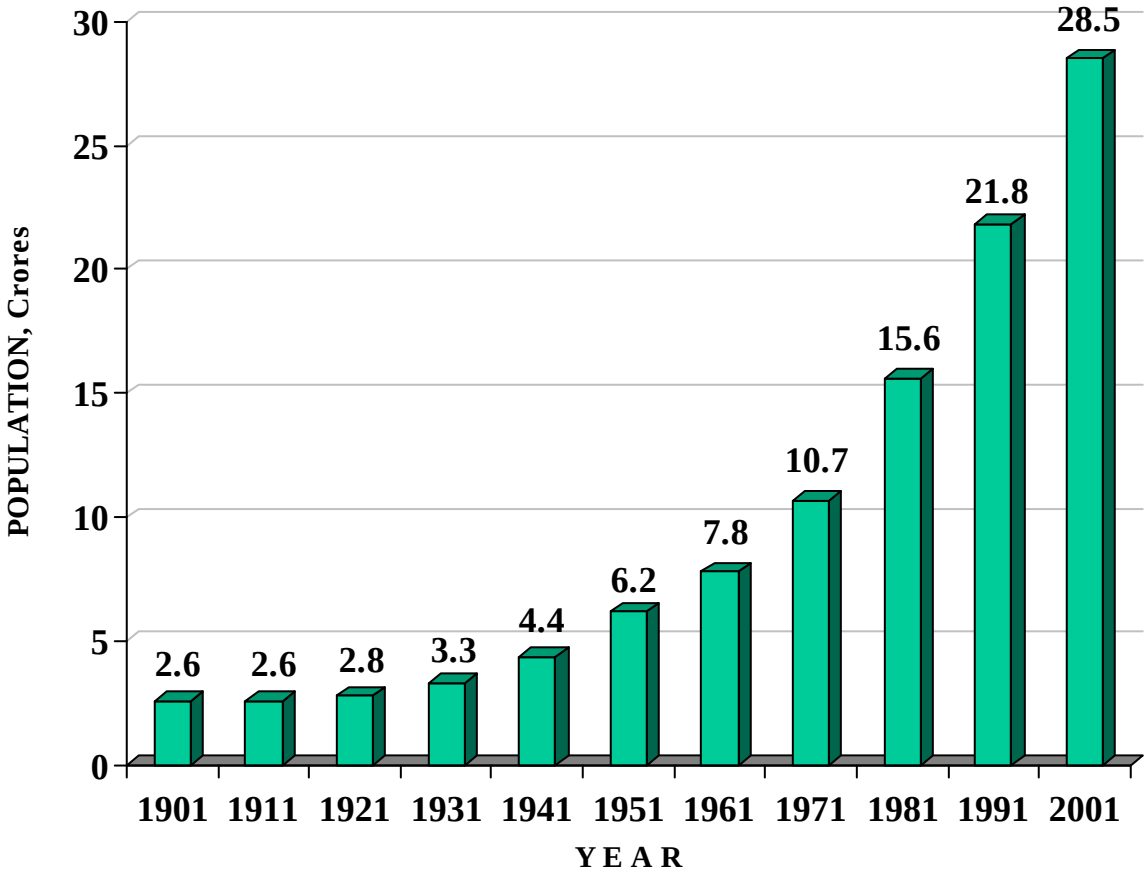
CHAPTER I

INTRODUCTION

1.1 BACKGROUND

The urbanization rate in India is very fast. It has increased from 10.84% in 1901 to 28.5% in 2001. According to the Census figure of 2001, the number of class I cities and class II towns was around 900. One of the conspicuous features of urbanization in India is the skewed distribution of population with as much as 28.3% of the urban population in 35 metropolitan cities. Unregulated growth of urban areas, particularly over the last two decades, without infrastructural services for proper collection, transportation, treatment and disposal of domestic waste water led to increased pollution and health hazards. Fast urbanisation followed by increase in prosperity resulting in steep increase in waste generation. The growth of urban population from 1901 to 2001 is given in Figure 1.

Figure 1 : Growth of Urban Population 1901-2001



The municipalities and such other civic authorities are responsible for management of the waste that have not been able to cope up with this massive task and could be attributed to various reasons

including erosion of authority, inability to raise revenues and inadequate managerial capabilities. That is why; it became necessary to launch the Ganga Action Plan and subsequently the National River Conservation Plan, which are essentially addressed to the task of trapping, diversion and treatment of municipal wastewater.

As per the latest estimate of Central Pollution Control Board, about 29,000 million litre/day of wastewater generated from class-I cities and class-II towns out of which about 45% (about 13000 mld) is generated from 35 metro-cities alone. The collection system exists for only about 30% of the wastewater through sewer line and treatment capacity exists for about 7000 million litre/day. Thus, there is a large gap between generation, collection and treatment of wastewater. A large part of un-collected, un-treated wastewater finds it way to either nearby surface water body or accumulated in the city itself forming cesspools. In almost all urban centres cesspools exist. These cesspools are good breeding ground for mosquitoes and also source of groundwater pollution. The wastewater accumulated in these cesspools gets percolated in the ground and pollute the groundwater. Also in many cities/towns conventional septic tanks and other low cost sanitation facilities exists. Due to non-existence of proper maintenance these septic tank become major source of groundwater pollution. In many urban areas groundwater is only source of drinking. Thus, a large population is at risk of exposed to water borne diseases of infectious (bacterial, viral or animal infections) or chemical nature (due to fluoride or arsenic). Water born diseases are still a great concern in India.

Pollutants are being added to the groundwater system through human activities and natural processes. Solid waste from industrial units is being dumped near the factories, and is subjected to reaction with percolating rainwater and reaches the groundwater level. The percolating water picks up a large amount of dissolved constituents and reaches the aquifer system and contaminates the groundwater. The problem of groundwater pollution in several parts of the country has become so acute that unless urgent steps for abatement are taken, groundwater resources may be damaged.

The quality of groundwater depends on a large number of individual hydrological, physical, chemical and biological factors. Generally higher proportions of dissolved constituents are found in groundwater than in surface water because of greater interaction of ground water with various materials in geologic strata. The water used for drinking purpose should be free from any toxic elements, living and nonliving organism and excessive amount of minerals that may be hazardous to health. Some of the heavy metals are extremely essential to humans, for example, Cobalt, Copper, etc., but large quantities of them may cause physiological disorders. The contamination of groundwater by heavy metals has assumed great significance during recent years due to their toxicity and accumulative behavior. These elements, contrary to most pollutants, are not biodegradable and undergo a global eco-biological cycle in which natural waters are the main pathways. The determination of the concentration levels of heavy metals in these waters, as well as the elucidation of the chemical forms in which they appear is a prime target in environmental research today.

A vast majority of groundwater quality problems are caused by contamination, over-exploitation, or combination of the two. Most groundwater quality problems are difficult to detect & hard to resolve. The solutions are usually very expensive, time consuming & not always effective. An

alarming picture is beginning to emerge in many parts of our country. Groundwater quality is slowly but surely declining everywhere. Groundwater pollution is intrinsically difficult to detect, since problem may well be concealed below the surface & monitoring is costly, time consuming & somewhat hit-or-miss by nature. Many times the contamination is not detected until obnoxious substances actually appear in water used, by which time the pollution has often dispersed over a large area. Essentially all activities carried out on land have the potential to contaminate the groundwater, whether associated with urban, industrial or agricultural activities. Large scale, concentrated sources of pollution such as industrial discharges, landfills & subsurface injection of chemicals & hazardous wastes, are an obvious source of groundwater pollution. These concentrated sources can be easily detected & regulated but the more difficult problem is associated with diffuse sources of pollution like leaching of agrochemicals & animal wastes subsurface discharges from latrines & septic tanks & infiltration of polluted urban run-off & sewage where sewerage does not exists or defunct. Diffuse sources can affect entire aquifers, which is difficult to control & treat. The only solution to diffuse sources of pollution is to integrate land use with water management. Once pollution has entered the sub-surface environment, it may remain concealed for many years, becoming dispersed over wide areas & rendering groundwater supplies unsuitable for human uses. Land use activity along with potential threat to Groundwater is presented in Table 1.

Table 1: Land-use activities & their potential threat to groundwater quality

Land Use	**Activities potential to groundwater pollution**
Residential	• Un-sewered sanitation • Land & stream discharge of sewage • Sewage oxidation ponds • Sewer leakage, solid waste disposal, landfill leachate • Road & urban run-off, aerial fall out
Industrial & Commercial	• Process water, effluent lagoon etc. • Land & stream discharge of effluents • Tank & pipeline leakage & accidental spills. • Well disposal of effluent • Aerial fall out • Landfill disposal & solid wastes & Hazardous wastes • Poor housekeeping • Spillage & leakages during handling of material
Mining	• Mine drainage discharge • Process water, sludge lagoons • Solid mine tailings • Oilfield spillage at group gathering stations
Rural	• Cultivation with agrochemicals • Irrigation with wastewater • Soil Stalinizations • Livestock rearing
Coastal areas	• Salt water intrusion

1.2 Common Groundwater Contaminants

1) **Nitrates**: Dissolved nitrate is most common contaminant in groundwater. High level can cause blue baby disease (Methamoglobinamia) in children, may form carcinogens & can accelerate eutrophication in surface waters. Sources of nitrates include sewage, fertilizers, air pollution, landfills & industries;

2) **Pathogens**: bacteria & viruses that cause water borne diseases such as typhoid, cholera, dysentery, polio, and hepatitis. Sources include sewage, landfills, septic tanks & livestock's;

3) **Trace metals**: include Lead, Mercury, Cadmium, Copper, Chromium & Nickel. These metals can be toxic & carcinogenic. Sources include industrial & mine discharges, fly ash from thermal power plants either due to fall out or disposal in ash ponds. Industrial solid waste dumping and leaching into groundwater through rainwater;

4) **Inorganic Constituents**: Inorganic dissolved salts accumulation such as SO_4, Chloride, etc. along with Na, K, building up high dissolved solids and combination of Carbonates, Bicarbonates along with Ca and Mg building up high hardness of water and converting soft/sweet water in to hard water creating gastrointestinal problems in human being if they consume groundwater as drinking source;

5) **Organic compounds**: include volatile & semi-volatile organic compounds like petroleum derivatives, PCBs pesticides. Sources includes agricultural activities, street drainages, sewage landfills, industrial discharges, spills, vehicular emissions fall out etc.

Realizing the importance of groundwater quality in urban areas and its deterioration, CPCB initiated groundwater quality survey in problem areas (industrial pockets) of the country during 1994. The findings were published as CPCB publications. During 2001-2003, the survey was repeated. The findings of the survey are presented in this report.

The Central Pollution Control Board (CPCB) with the help of National Institute of Hydrology, Roorkee, Pollution Control Research Institute (PCRI), BHEL, Haridwar and Thane Municipal Corporation, Thane initiated similar survey for Metro-cities. Metro-cities are the cities having population of 1 million and above. There are 35 such cities in India. The list of metro-cities and critically polluted areas is given in the following chapters on Findings.

Continued

CHAPTER II

METHODOLOGY FOR GROUNDWATER QUALITY SURVEY

2.0 SAMPLING

A) Metropolitan Cities

2.1 Criteria for selection of Bore Wells/Tube Wells/Hand pumps

For selection of groundwater quality survey location the following criteria were kept in mind:

- Drinking water wells;
- Wells closer to polluting sources like industries, urban wastewater drains, garbage dumpsites etc.;
- Wells suspected for natural contaminants like fluoride, iron, arsenic or such pollutants.

2.2 Sample collection, transport, preservation and analysis

Samples were collected from one of the following three types of wells:
i) Open dug wells in use for domestic or irrigation water supply, ii) *Tube wells* fitted with a hand pump or a power-driven pump for domestic water supply or irrigation; iii) *Hand Pumps*, used for drinking. Open dug wells, which are not in use or have been abandoned, were not used for sampling. For collection of samples a weighted sample bottle or sampler was used to collect sample from an open well. Samples from the production tube were collected after running the well for about 5 minutes. For bacteriological samples, when collected from tube wells/hand pump, the spout/outlet of the source was sterilized under flame by spirit lamp before collection of sample in the container. From open wells the samples were collected directly in to the pre-sterilized glass bottles. The samples were transported to the laboratory. The samples were analyzed immediately for the parameters like Coliform, BOD, COD and nutrients. Other parameters were analyzed within a week time.

Total twenty five ground water samples from each metropolitan cities were collected each during pre-monsoon (June 2003) and post-monsoon (December 2003) seasons from various abstraction sources at various depths covering extensively populated area, commercial, industrial, agricultural and residential colonies so as to obtain a good aerial and vertical representation and preserved by adding an appropriate reagents as and when required. The hand pumps were continuously pumped prior to the sampling, to ensure that ground water to be sampled was representative of ground water aquifer. The water samples for trace element analysis were collected in acid leached polyethylene bottles and preserved by adding ultra pure nitric acid (2 mL/lit.) Samples for pesticides analysis were collected in glass bottles while samples for bacteriological analyses were collected in sterilized high-density polypropylene/Glass bottles covered with aluminum foils. All the samples were stored in sampling kits maintained at $4^{o}C$ and

brought to the laboratory for detailed chemical and bacteriological analysis. The standard methods (APHA, 20th Edition) adopted for each parametric analysis of groundwater samples. The details of sampling locations and source and depth wise distribution are given at each section city wise in the following chapter.

Sampling Locations

The groundwater quality survey locations were chosen (dug/open wells, tube well, bore well etc.) so that they depict the influence (if any) of the prevailing anthropogenic activity as well as industrial activity of the Metro city limit area. The groundwater survey covers mainly 18 dug wells, 42 tube wells, 34 bore wells, 109 hand pumps and others one well totaling to 204 groundwater sampling locations as presented in Table 2.

Table 2: Groundwater monitoring in Metropolitan cities

S. No.	Name of Metro cities	State	DW/ OW	TW	HP	BW	Others	Total
1.	Agra	Uttar Pradesh	-	-	25	-	-	25
2.	Meerut	Uttar Pradesh	-	04	21	-	-	25
3.	Chennai	Tamilnadu	01 (Open Well)	-	24	-	-	25
4.	Coimbatore	Tamilnadu	09 (Open well)	-	-	16	-	25
5.	Ludhiana	Punjab	-	29	-	-	-	29
6.	Lucknow	Uttar Pradesh	-	09	15	-	01	25
7.	Madurai	Tamilnadu	07	-	-	18	-	25
8.	Vijaiwada	Andhra Pradesh	01	-	24	-	-	25
Sub total			**18**	**42**	**109**	**34**	**01**	**-**
Grand total			**204**					

Note: On 204 sampling locations, two times samples were taken during the period i.e. Pre-monsoon and Post-monsoon

2.3.4 Sampling Period in Metropolitan Cities

The sampling was done in pre-monsoon (June) and post-monsoon (December) at all the twenty-five locations of each metropolitan city.

2.3.5 Parameters selection in Metro-cities

The physico-chemical analysis was performed following standard methods. The brief details of analytical methods and equipment used in the study are given in the Table 3.

Table 3: Analytical methods and equipment used in the study

Sl. No.	Parameter	Method	Instruments/Equipment
A.	**Physico-chemical**		
1.	pH	Electrometric	pH Meter
2.	Conductivity	Electrometric	Conductivity Meter
3.	TDS	Electrometric	Conductivity/TDS Meter
4.	Alkalinity	Titration by H_2SO_4	-
5.	Hardness	Titration by EDTA	-
6.	Chloride	Titration by $AgNO_3$	-
7.	Sulphate	Turbidimetric	Turbidity Meter
8.	Nitrate	Ultraviolet screening	UV-VIS Spectrophotometer
9.	Phosphate	Molybdophosphoric acid	UV-VIS Spectrophotometer
10.	Fluoride	SPADNS	UV-VIS Spectrophotometer
11.	Sodium	Flame emission	Flame Photometer
12.	Potassium	Flame emission	Flame Photometer
13.	Calcium	Titration by EDTA	-
14.	Magnesium	Titration by EDTA	-
15.	Boron	Carmine	UV-VIS Spectrophotometer
16.	BOD	5 days incubation at 20^oC followed by titration	BOD Incubator
17.	COD	Digestion followed by titration	COD Digestor
B	Bacteriological		
18.	Total coliform	Multiple tube fermentation technique	Bacteriological Incubator
19.	Faecal coliform		
C.	Heavy Metals		
20.	Iron	Digestion followed by Atomic spectrometry	Atomic Absorption Spectrometer
21.	Manganese		
22.	Copper		
23.	Nickel		
24.	Chromium		
25.	Lead		
26.	Cadmium		
27.	Zinc		
D.	Pesticides and Polynuclear Aromatic Hydrocarbons		
28.	Aldrin	Gas chromatography	Gas Chromatograph with ECD, NPD and FID
29.	DDT		
30.	DDE		
31.	DDD		
32.	A-BHC		
33.	B-BHC		
34.	γ-BHC		
35.	δ-BHC		
36.	Methoxychlor		
37.	Endosulphan		

Sl. No.	Parameter	Method	Instruments/Equipment
38.	Thionazin		
39.	Sulfotepp		
40.	Phorate		
41.	Dimethoate		
42.	Disulfoton		
43.	Methyl Parathion		
44.	Ethyl parathion		
45.	Famphur		
46.	Chlorpyriphos		
47.	Ethion		
48.	PAHs		

B) Groundwater quality survey in Problem areas

The groundwater quality survey locations were chosen (dug wells, tube well etc) so that they depict the influence (if any) of the prevailing industrial activity of the problem area besides views from the public were also considered. The GW survey locations covers mainly 40 dug wells, 27 tube wells, 33 bore wells, 11 hand pumps and one sump well totaling to 112 GW sampling locations as stated in Table 4) a).

Table 4) a): Groundwater survey details in Problem Areas

Sl. No.	Problem area	State	DW	TW	HP	BW	Others	Total
1.	Durgapur	W.Bengal	3	2	-	-	-	5
2.	Howrah	W.Bengal	1	4	-	-	-	5
3.	Dhanbad	Jharkhand	-	6	-	-	-	6
4.	Angul Talcher	Orissa	11	12				23
5.	Singrauli	Uttar Pradesh	1	-	4	-	1	6
6.	Vishakapatnam	Andhra Pradesh	-	-	-	7	-	7
7.	Bolaram-Patancheru	Andhra Pradesh	-	-	-	7	-	7
8.	Bhadravathi	Karnataka	-	-	-	3	-	3
9.	Greater Cochin	Kerala	7	-	-	-	-	7
10.	Manali	Tamilnadu	2	-	1	3	-	6
11.	North Arcot	Tamilnadu	10	-	3	1	-	14
12.	Ankleshwar	Gujarat	-	-	-	3	-	3
13.	Vapi	Gujarat	-	-	1	1	-	2
14.	Chembur	Maharashtra	2	-	-	4	-	6
15.	Tarapur	Maharashtra	1	-	2	4	-	7
16.	Digboi	Assam	2	3	-	-	-	5

The surveys were carried out for duration of two year. Samples were collected from the groundwater structures already in existence. Samples were transported to the laboratories and analyzed for the relevant parameters as per the procedures explained earlier.

2.3.6 Sampling period in Problem Areas

The sampling was done in post-monsoon (September), Winter (January) and pre-Monsoon (May).

2.3.7 Analytical parameters in Problem areas

The Table 4) b) below provides list of parameters that were analyzed for the groundwater samples in problem areas.

Table 4) b): Analysis of Groundwater parameters in problem areas

Heavy metals (ug/l)	Pesticides (ng/l)	Bacteriological parameters (MPN/100 ml)	Physico-chemical (mg/l except pH)
Mercury	Aldrin	F. Coliform	pH
Nickel	Dieldrin	T. Coliform	Conductivity
Zinc	Lindane		Total hardness
Cadmium	DDT		Fluoride
Copper			Chloride
Chromium			Sodium
Iron			Nitrate
Manganese			Phosphate
Lead			Magnesium
Arsenic			Calcium
			Total Dissolved Solids
			Cyanide
			Sulphate
			Alkalinity

C) Comparison of Groundwater Samples with Indian Drinking Water Standards (BIS-IS 10500: 1991 and WHO Guideline, 1996) in Metropolitan cities and Problem areas

Water is a prime natural resource, a basic human need and precious natural asset. The provision of drinking water that is not only safe is a matter of high priority. The supply of water that is un-satisfactory in this respect will undermine the confidence of consumers leading to complaints and possibility of using water from less safe sources. Looking to the seriousness of groundwater contamination is now a great concern. Therefore, all the groundwater samples collected from drinking sources have been compared with present Indian standards in this report. The BIS – 10500 and WHO Guideline has been presented in the form of Table 5 is given below:

Table 5: Indian Standards& WHO Guideline for Drinking Water

S. No.	Parameter	BIS, Indian Standards (IS 10500:1991)		World Health Organization (WHO Guideline)
		Desirable Limit	Permissible Limit	Maximum allowable concentration
1	Colour	5 Hazen Units	25 Hazen Units	15 True Colour Units
2	Turbidity	5.0 NTU	10 NTU	5.0 NTU
3	PH	6.5-8.5	No relaxation	6.5-8.5
4	Total Hardness (as $CaCO_3$)	300 mg/L	600 mg/L	500 mg/L
5	Chlorides (as Cl)	250 mg/L	1000 mg/L	250 mg/L
6	Residual Free Chlorine (When Protection against viral infection is required it should be *Min* 0.5 mg/L)	0.2 mg/L	-	-
7	Dissolved Solids	500 mg/L	2000 mg/L	1000 mg/L
8	Calcium (as Ca)	75 mg/L	200 mg/L	-
9	Sulphate (as SO_4^{2-})	200 mg/L	400 mg/L	400 mg/L
10	Nitrate (as NO_3^-)	45 mg/L	100 mg/L	10 mg/L
11	Fluoride (as F^-)	1.0 mg/L	1.5 mg/L	1.5 mg/L
12	Phenolic Compounds (as C_6H_5OH)	0.001mg/L	0.002 mg/L	-
13	Anionic Detergent (as MBAS)	0.2 mg/L	1.0 mg/L	-
14	Mineral Oil	0. 01 mg/L	0.03 mg/L	-
15	Alkalinity	200 mg/L	600 mg/L	-
16	Boron	1.0 mg/L	5.0 mg/L	-
	Micro Pollutants (Heavy Metals & Pesticides)			
17	Zinc (as Zn)	5.0 mg/L	15 mg/L	5.0 mg/L
18	Iron (as Fe)	0.3 mg/L	1.0 mg/L	0.3 mg/L
19	Manganese (as Mn)	0.1 mg/L	0.3 mg/L	0.1 mg/L
20	Copper (as Cu)	0.05 mg/L	1.5 mg/L	1.0 mg/L

S. No.	Parameter	BIS, Indian Standards (IS 10500:1991)		World Health Organization (WHO Guideline)
		Desirable Limit	Permissible Limit	Maximum allowable concentration
21	Arsenic (as As)	0.05 mg/L	No relaxation	0.05 mg/L
22	Cyanide (as CN)	0.05 mg/L	No relaxation	0.1 mg/L
23	Lead (as Pb)	0.05 mg/L	No relaxation	0.05 mg/L
24	Chromium (as Cr^{6+})	0.05 mg/L	No relaxation	0.05 mg/L
25	Aluminium (as Al)	0.03 mg/L	0.2 mg/L	0.2 mg/L
26	Cadmium (as Cd)	0.01 mg/L	No relaxation	0.005 mg/L
27	Selenium (as Se)	0.01 mg/L	No relaxation	0.01 mg/L
28	Mercury (as Hg)	0.001 mg/L	No relaxation	0.001 mg/L
29	Total Pesticides	Absent	0.001 mg/L	-

S. No.	Parameter	BIS, Indian Standards (IS 10500:1991)		World Health Organization, (WHO Guideline)
		Desirable Limit	Permissible Limit	Maximum allowable concentration
1	Sodium	-	-	200 mg/L
2	Aldrin &dieldrin	-	-	0.03 µg/L
3	DDT	-	-	1.0 µg/L
4	Lindane	-	-	3.0 µg/L
5	Methoxychlor	-	-	30.0 µg/L
6	Benzene	-	-	10.0 µg/L
7	Hexachlorobenzene	-	-	0.01 µg/L
8	Pentachlorophenol	-	-	10.0 µg/L

CHAPTER III

FINDINGS: METRO-CITIES OF INDIA

3.1 Metropolitan Cities of India:

Metro-cities are those cities having population more than one million & above. As per 2001 census there are 35 metro cities in India. The metropolitan cities along with area and population are presented in Table 6.

Table 6: PROFILE OF METROPOLITAN CITIES OF INDIA

CITIES	AREA (sq.km)	POPULATION IN THOUSAND
Greater Mumbai	437.71	16,368,084
Kolkata	187	13,216,546
Delhi	862.18	12,791,458
Chennai*	170	6,424,624
Bangalore	125.9	5,686,844
Hyderabad	172.68	5,533,640
Ahemadabad	190.94	4,519,278
Pune	198.00	3,755,525
Surat	111.16	2,811,466
Kanpur	NA	2,690,486
Jaipur	200.4	2,324,319
Lucknow*	310.1	2,266,933
Nagpur	217.17	2,122,965
Patna	99.45	1,707,429
Indore	130.17	1,639,044
Vadodara	108.26	1,492,398
Bhopal	284.9	1,454,830
Coimbatore*	314.84	1,446,034
Ludhiana*	134.67	1,395,053
Kochi	39.58	1,355,406
Vishakhapatnam	78.33	1,329,472
Agra*	NA	1,321,410
Varanasi	83.6	1,211,749
Madurai*	115.48	1,194,665
Meerut*	NA	1,167,399
Nashik	NA	1,152,048
Jabalpur	NA	1,117,200
Jamshedpur	NA	1,101,804
Asansol	NA	1,090,171
Dhanbad	NA	1,064,357
Faridabad	NA	1,054,981
Allahabad	NA	1,049,579
Amritsar	NA	1,011,327
Vijayawada*	NA	1,011,152
Rajkot	NA	1,002,160

Area: 1991and Population figures 2001 Census, The cities marked as starred taken for the study in this report.

In this report study results with respect to eight Metropolitan cities have been presented. The results are summarised below:

3.2 Agra Metropolitan city

3.2.1 Environmental Profile of Agra:

Topography/Location: The metropolitan city of Agra is one of the important industrial towns of north central India. It is situated about 200 km southeast of Delhi. The metropolitan city of Agra occupies an area of about 140 km^2 and lies between $27^o8'$ to $27^o14'$ N latitude and $77^o57'$ to $78^o04'$ E longitude. It is the 22^{nd} largest town in India (population wise), and the 3^{rd} largest town in Uttar Pradesh after Kanpur and Lucknow The urban area of Agra is divided into Nagar Mahapalika (renamed as Municipal Corporation in 1994), Agra Cantonment Area and the Dayalbagh and Swamibagh Panchayat. The municipal area is further divided into three parts, viz., the main city, the Trans Yamuna and the Tajganj. The city map is shown in figure 2.

Population: The population pressure on the city is ever growing. As per the 2001 census, the population of the metropolitan city of Agra (including cantonment area) is 13,21,410.

Climate: The study area is a characterized by semi-arid area bounded by Thar Desert on its southwest, west and northwest peripheries. The maximum temperature is attained upto 47°C in summer months (May to June) and minimum temperature as low as 3°C in winter. The average rainfall in the region is 685 mm. The city experiences extreme hot summers and extreme cold winter. The climate of the city experiences a typical extreme climate as of the plains of Uttar Pradesh. All seasonal climatic changes e.g. temperature; rainfall, wind-pattern etc. are observed throughout the year, particularly high temperature during the summer, cold weather during winters and sufficient rains in the monsoon.

Water Supply: Most of the water supply of the Agra city is met from river Yamuna. The water is taken directly from the river Yamuna by diverting its flow and pumping from the three intake wells at the Agra Water Works located on the right bank of the river Yamuna. There are two water works i.e. Jiwani Mandi & Sikandara. Treatment of the raw water includes sedimentation, filtration and chlorination. Total 225 mld of treated water is being served through 11 zonal pumping stations in which 200 mld goes to the city residents and 25 mld goes to MES, Railways, Air Force and Cantonment. The water supply covers most of the localities within the municipal area. However, most parts of the wards of Sikandra II, Bodla II & III, Shahganj III, Tajganj II & III, Trans Yamuna II and Ghawasan II are not covered by piped water supply. Out of the total water of 225 mld, 40% is lost in transmission and distribution. Hence the actual water available is about 120 mld, which comes out to be 100 lpcd whereas the requirement is 150 lpcd. There is a shortage of about 60 mld. The demand for water supply will grow by additional 20 mld by 2011. The local residents through bore wells and hand pumps currently augment water supply with groundwater. For administrative purposes, the water supply is divided into three major zones, viz., Surya Nagar - Zone I, Loha Mandi - Zone II and Taj Ganj - Zone III. The three major zones are further divided into 26 minor zones including cantonment. Out of the 26 zones, 15 zones are developed and rests of them are undeveloped.

Wastewater Management: The total sewage generated in the city is 128.6 mld. The city has three sewage treatment plants. The total area available for sewage farming is 800 Ha of which only 300 Ha is being irrigated by sewage. The Agra city has a severe sewage problem. Most of the city does not have sewerage system. The sewage is found flowing along the roads into the open drains and the total wastewater of the Agra city flows into river Yamuna through local drains. Some of the areas are even not drained and hence leading to stagnation of sewage. In the absence of sewerage system, people are using septic tanks and soak pits. In most of the places sewage is discharged into open drains without any treatment, which ultimately discharge to river Yamuna. River Yamuna in its course of 10 km in the city of Agra receives wastewater discharge through 28 points. The major contributor to the water pollution for BOD load is Mantola drain followed by Bhairon and Water Works Nala. These drains discharge both domestic and industrial wastewater from densely populated old city areas. In Trans Yamuna, the Etmadullah and the Narich drains are the major contributors and mainly carry discharges from industrial areas.

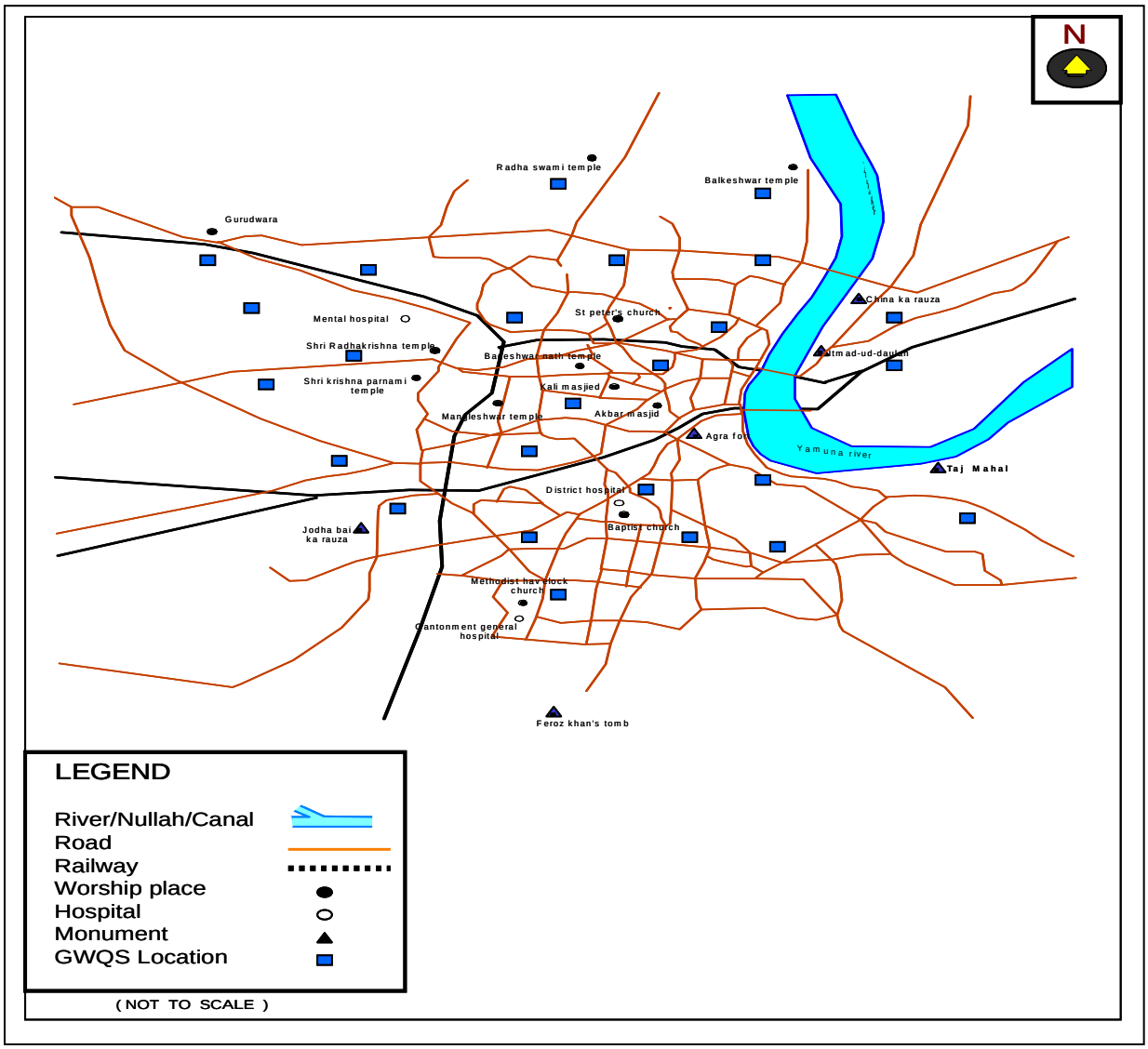


Figure 2: Map of Agra Metropolitan City

Municipal Solid Waste: The municipal solid waste generated is about 644 t/day. The Agra Nagar Nigam is facing serious shortage of waste transportation vehicles and facilities such as garages and workshops needed to maintain and repair the vehicle. The Nagar Nigam has only 47 vehicles including tractors, tippers, loaders and refuse collectors of which only 29 are in working condition. As a result, only 50% of the city waste is being transported and disposed by the Nagar Nigam daily. Due to the shortage of vehicles, many wards are not attended for days together, leading to the accumulation of the solid waste. In fact, it appeared that in many wards 60 to 80% wastes are never collected. The solid waste is also being dumped irregularly in many areas, even in residential colonies, along the highways or even in parks. The metropolitan city of Agra has only one disposal site at Shahdara near Jharna nallah, a place outside the Agra Municipal area on Agra-Firozabad road. There is no system of monitoring the dumping activities. Sweepers are also resorting to open burning due to shortage of handcarts and inadequate capacity of the bins. The landfill site at Shahdara is already filled up. According to Nagar Swastha Adikari, no area has been identified for development of any sanitary landfill in future.

Industries: There are 73 industries and 2 industrial clusters, which discharges their effluent into the river. Of these industries, only 64 industries have effluent treatment plants. The metropolitan city of Agra has the status of an important place in India in production of various handicraft items like Zari work, leather craft, and marble craft and carpet craft. Today the Agra district has 6,463 small-scale units, out of which a majority is located in Agra city. The small-scale units are mushroomed in the older city area. The estimated quantity of hazardous waste from the city is about 100 t/year from electroplating, chemical industries and the foundry units. Industrial sector of the metropolitan city comprises of textiles, hosiery items, woolen, jute, footwear, leather, metal processing, machinery parts, marble, food processing and handicrafts. There are two petroleum storages existing in Idgah Colony area, one of Bharat Petroleum Corporation Ltd. (BPCL) and the other one of Indian Oil Corporation Ltd. (IOCL). The total number of petrol pump of different agencies in the metropolitan city is 46.

Geology & Soil: The soil of Agra is loose, sandy and calcareous. The river Yamuna is the only river flowing through the metropolitan city of Agra. The river enters the city on its northern boundary and takes U-shape while crossing through the heart of the city. The area is characterized by alluvium, which is an admixture of gravel, sand, silt and clay in various proportions, deposited during the Quaternary period. The study area is a part of Indo-Gangetic alluvium of quaternary age and is made up of recent unconsolidated fluviatile formations comprising sand, silt, clay and kankar with occasional beds of gravel. There are some underground rocks of quartzite and sand stone of Vindhyan-series, in the west and south west of Agra. The topsoil is coarse and angular sand with small clay fraction. The sub-soil is sandy throughout. The stabilized topsoil is reddish brown with sand and clay mixed. The minimum depth of topsoil layer is 60 cm. Sand and silts are slightly alkaline to saline. The topography of the area is flat. Saline soils are generally brown. Alkaline soils are grey and get sticky on wetting and hard on drying, acquiring a clotted structure.

Groundwater: The groundwater in the study area occurs in unconfined state in the shallow zone. The groundwater in unconfined conditions rests at 1 m below ground level to a maximum of 29.4 m below ground level. In general deeper water level remains within 19.20 m below ground level. Groundwater in boreholes occurs at depths of 4.57 to 27.60 m below ground level.

In pre-monsoon the water level ranges from 4.89 to 12.3 m below ground level. While in the post-monsoon depth of water level varied between 2.24 m to 17.82 m below ground levels. Most of the wells in Agra have saline water except immediately after the monsoons. According to the Agra Jal Sansthan, 4298 hand pumps are in operation in the town. As per the studies carried out by the University of Roorkee under the Agra Heritage Project, the Agra Heritage area has large groundwater potential.

3.2.2 Groundwater Quality Survey

Total twenty five groundwater samples from the metropolitan city of Agra were collected each during pre-monsoon (June 2002) and post-monsoon (October 2002) seasons from various abstraction sources at various depths covering extensively populated area, commercial, industrial, agricultural and residential colonies so as to obtain a good aerial and vertical representation. The details of sampling locations and source and depth wise distribution are given in Table 7.

Table 7: Description of groundwater sampling locations in Metropolitan City – Agra

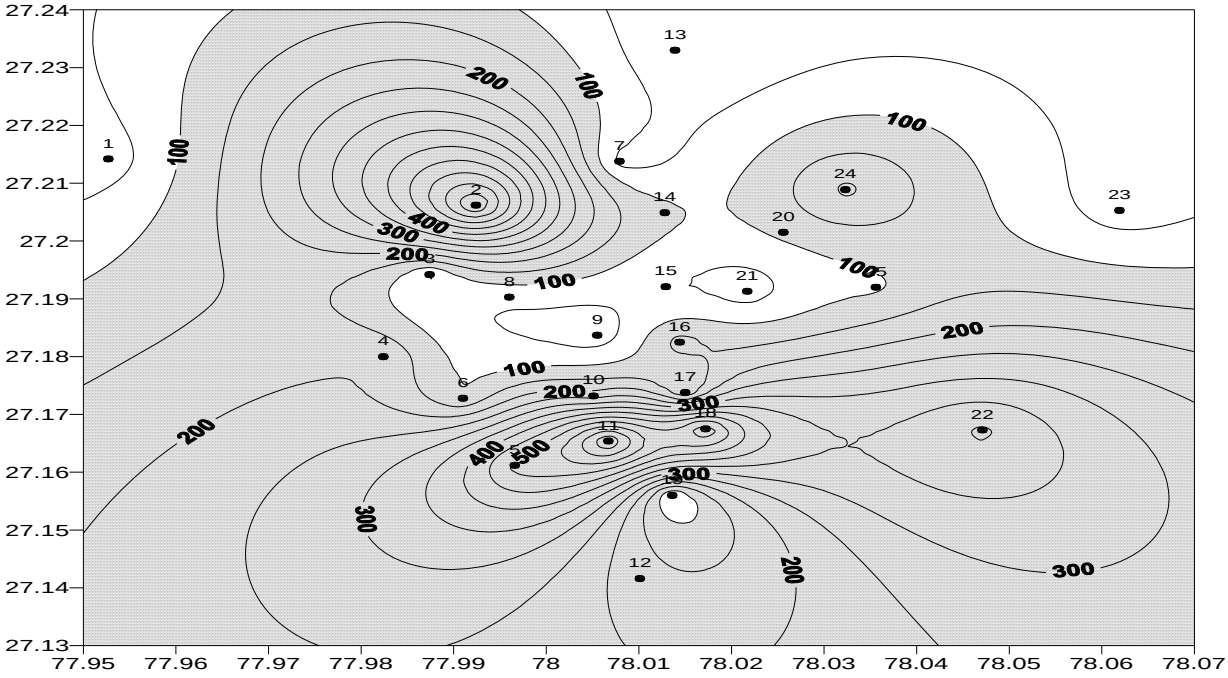
Sl. No.	Location	Identification	Source	Depth, m	Water Use	Land Use/ Specific Activity
1	Sikandra	Opp. Getwell Hospital	HP	18	Drinking	Residential
2	Khandari	Police Chowki Compound	HP	24	Cloth washing	Residential
3	Lohamandi	Saiyad Para Ground	HP	30	Drinking	Residential/ Slaughtering
4	Shahganj	Rui ki mandi Chauraha	HP	27	Drinking	Residential
5	Sultanpura	Jiva Ram Temple	HP	27	Drinking	Residential
6	Idgah Colony	Opp. IOCL Depot	HP	19	Drinking	Residential/ Petro. Storage
7	New Agra Colony	Basic Primary School	HP	21	Drinking	Residential
8	Rajamandi	Opp.Rama Swing Work	HP	38	Drinking	Residential
9	Nai ki mandi	Meera Husaini Chauraha	HP	21	Drinking	Residential
10	Rakabganj	Opp. Over Head Tank	HP	15	Drinking	Residential
11	Namner	Durga Mandir Compound	HP	21	Drinking	Residential
12	Bundu Katra	Opp. Over Head Tank	HP	24	Drinking	Residential
13	Dayalbagh	DEC Gate	HP	30	Drinking	Residential

14	Gandhi Nagar	Main Chowk	HP	18	Drinking	Residential
15	Maithan	Near City Railway Station	HP	24	Drinking	Residential
16	Mantola	Opp. Jama Masjid	HP	24	Drinking	Residential
17	Chilgarh	Opp. Agra Machhua Sahkari Samiti	HP	24	Drinking	Residential/ Slaughtering
18	Baluganj	Near Agra Montessori School	HP	24	Drinking	Residential
19	Naulakha	Near Girja Building Materials	HP	24	Drinking	Residential
20	Ratanpura	Near BSP Office	HP	12	Drinking	Residential
21	Belanganj	Main Chowk	HP	12	Drinking	Residential
22	Tajganj	Nanda Bazar Chowk	HP	30	Drinking	Residential/ Slaughtering
23	Industrial Estate	Trans Yamuna Colony	HP	10	Drinking	Industrial Area
24	Balkeshwar	Opp. S. K. Mittal Agency	HP	21	Drinking	Residential
25	Itma-Ud-Daulla	Opp. Itma-Ud-Daulla Building	HP	12	Drinking	Residential

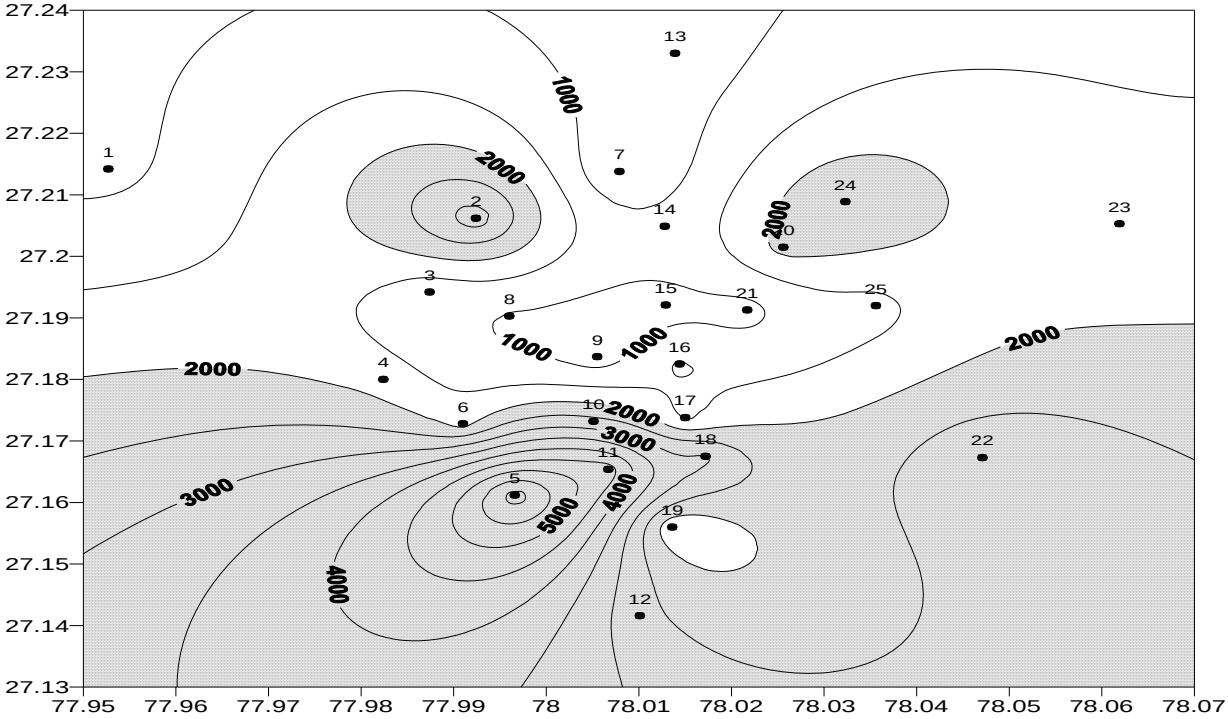
Note: HP-Hand Pump, BW - Bore Well; OW - Open Well, TW-Tube Well

3.2.3 Observations on status of Groundwater Quality in Agra City

The groundwater quality of Agra has been assessed to see the suitability of groundwater for drinking applications. The samples were analyzed for various physico-chemical and bacteriological parameters, heavy metals, pesticides and poly-aromatic hydrocarbons. The hydro-chemical and bacteriological data was analyzed with reference to BIS and WHO standards and hydro-chemical facies were determined. The quality of the groundwater varies from place to place with the depth of water table. The groundwater quality has indicated higher concentration of electrical conductivity, total dissolved solids, hardness, calcium, magnesium, chloride, sulphate, nitrate, fluoride, iron, manganese, nickel, lead and cadmium vis-à-vis drinking water quality standards. The ranges of each parameter and their percent violation along with observations on groundwater quality are presented in Table 1 of Annexure I. The distribution of critical groundwater parameters such as TDS and Nitrates of pre and post monsoon seasons has been presented in Figure 3 & 4. No poly-nuclear aromatic hydrocarbons were detected in any of the groundwater samples of the metropolitan city.

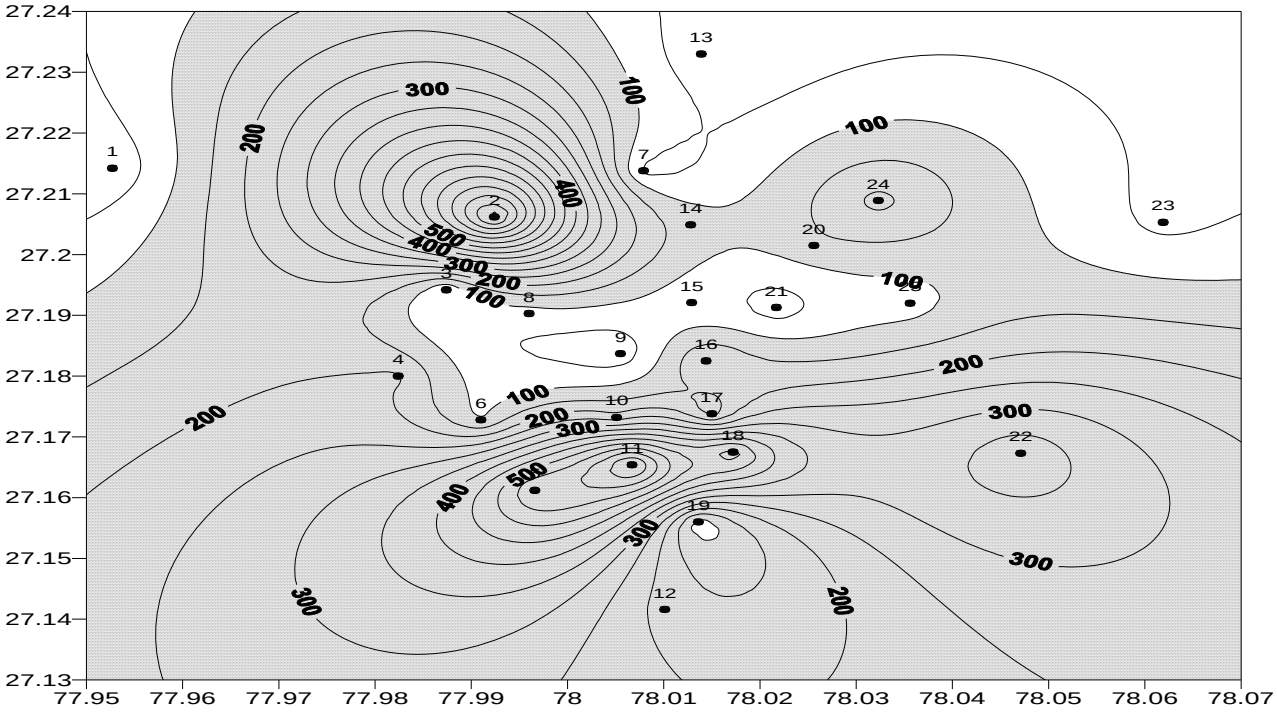


Nitrate distribution in ground water of Metropolitan City - Agra (Pre-monsoon 2002)

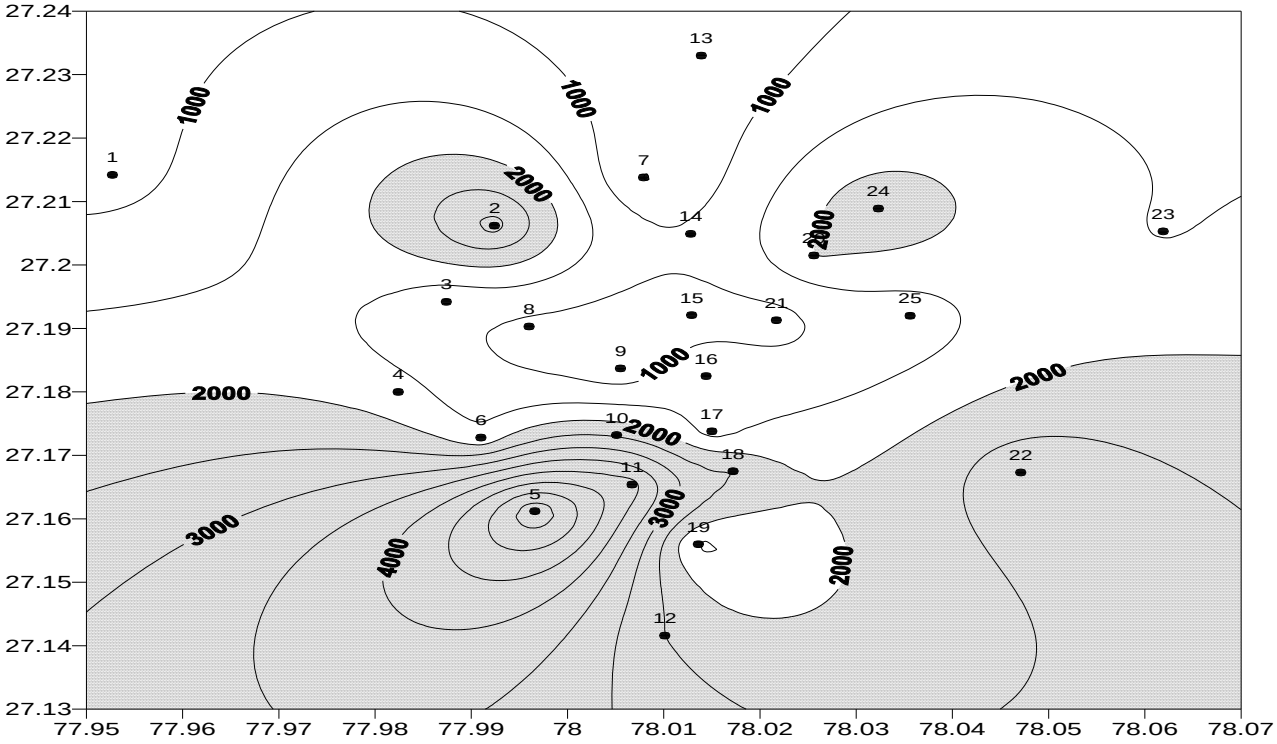


TDS distribution in ground water of Metropolitan City - Agra (Pre-monsoon 2002)

Figure 3: TDS and Nitrate distribution (Pre Monsoon) in Groundwater of Agra Metropolitan City



Nitrate distribution in ground water of Metropolitan City - agra (Post-monsoon 2002)



TDS distribution in ground water of Metropolitan City - Agra (Post-monsoon 2002)

Figure 4: Nitrate and TDS distribution (Post Monsoon) in Groundwater of Agra Metropolitan City

3.3 Meerut Metropolitan city

3.3.1 Environmental profile of Meerut

Topography: The metropolitan city of Meerut is one of the important industrial towns of the western Uttar Pradesh. It is situated about 85 km from Delhi. The metropolitan city occupies an area of about 142 km^2 and lies between $28^o57'$ to $29^o02'$ N latitude and $77^o40'$ to $77^o45'$ E longitude. The metropolitan city of Meerut is a part of Indo-Gangetic plains. The city map has been shown in Figure 5.

Population: The population pressure on the city is ever growing. As per the 2001 census, the population of Meerut (including cantonment area) is 11,67,399. It is the 25th largest town in India (population wise), and the 5th largest town in Uttar Pradesh after +Kanpur, Lucknow, Agra and Varanasi.

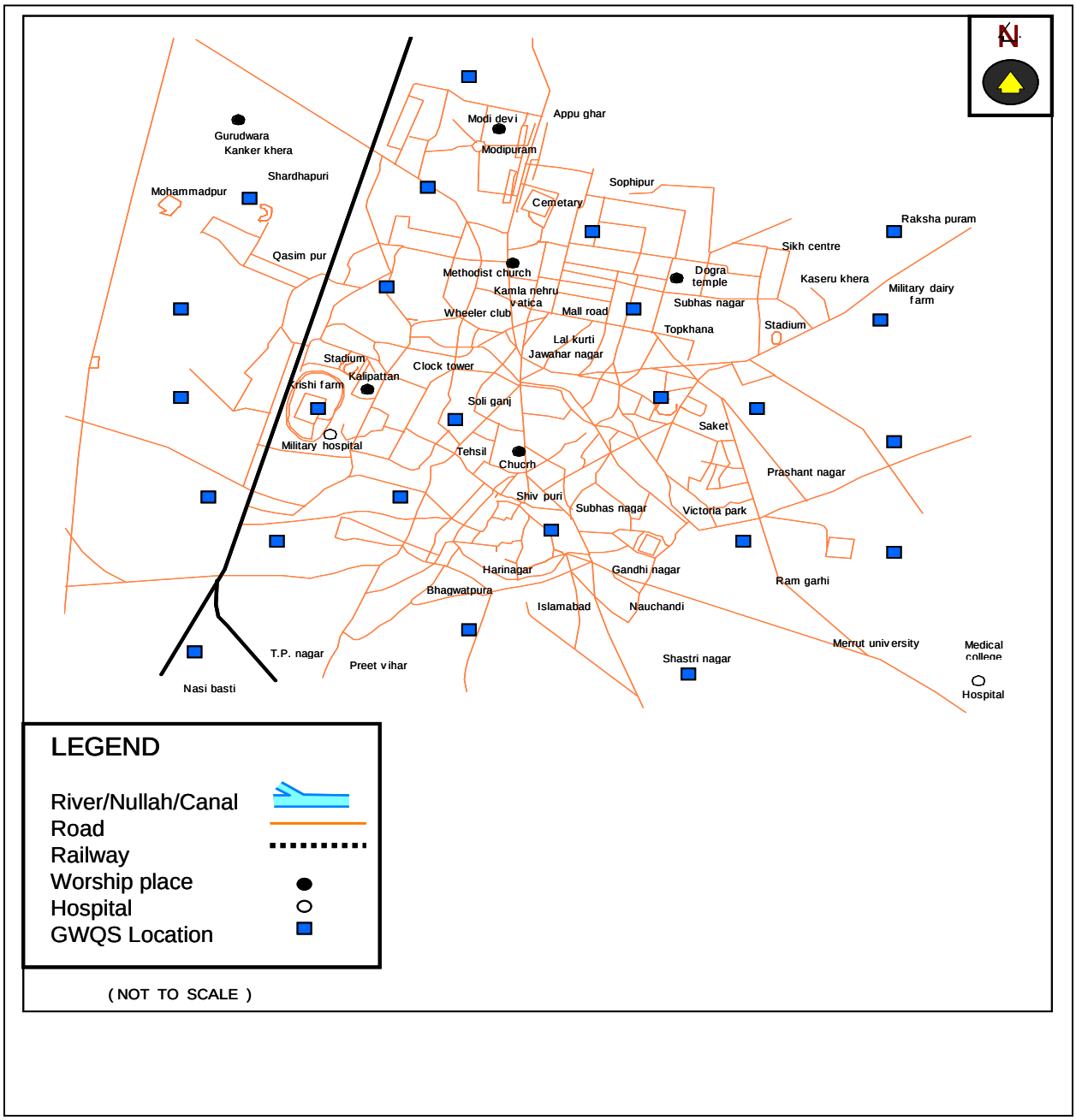
Climate: The metropolitan city has a moderate type of climate. Extreme dryness with an intensely hot summer and cold winter is the characteristics of the climate. It has a cool dry winter season from October to March, a hot dry summer season from April to June and a warm rainy season from July to September. The average annual rainfall is about 1000 mm, major part of which is received during the monsoon period (June to September). Significant diurnal variations in hydro-meteorological parameters like precipitation, temperature and relative humidity also exist. The daily maximum temperature varies from 10 to 43^OC and minimum temperature varies from 4.6 to 29.2^OC. The daily relative humidity varies from 30 to 100%.

Geology and soil type: The area is almost devoid of any significant relief features and is composed of unconsolidated alluvial deposits. The land surface lies at an elevation of 220 m from mean sea level. The city is a part of Indo-Gangetic plains, which is mainly composed of pleistocene and sub-recent alluvial sediments transported and deposited by river action from the Himalayan region. Lithologically, sediments consist of clay, silt and fine to coarse sand. The deposits of sandy horizons of varying thickness are the main source of groundwater in the area. The soils are very fertile for growing wheat, sugar cane and vegetables. However, along the sandy river course, fruit orchards are also common. In spite of enormous surface and groundwater resources, the western Uttar Pradesh faces problem scarcity of water for irrigation in dry months, when groundwater is extensively used for irrigation. Varying lithology of the geological formations considerably influences the groundwater conditions in all alluvial parts. The main sources of water, which sustains groundwater body in fine to coarse grained sands, is rainfall, the other sources of groundwater replenishment are infiltration from river, return seepage from irrigation and inflow from neighboring areas.

Water Resources: The two important rivers of the area are Yamuna and Hindon, which flow from north to south. The river Ganga and the river Yamuna form the eastern and the western boundaries of the area. However, The other two rivers flowing in the area are Kali and Krishni. Apart from these rivers, the Upper Ganga Canal also drains the area. Certainly of the above mentioned recharge sources, rainfall is probably the most important. The rate and amount of infiltration of rainwater depends on several factors. The most common groundwater structures in the area are shallow and deep tube wells. Dug wells have become almost rare in the region, the

surface water in the region are fully utilized. Regarding the occurrence of groundwater, the principal groundwater reservoir in the region is unconsolidated alluvial deposits. The recent studies in the region indicated that the top aquifers are unconfined in nature and deeper aquifers are confined to semi-confined in nature.

Water Requirement: Water requirement for Meerut city is mainly met from groundwater. There are 20 overhead tanks having a total capacity of 20,000 KL and 3 under groundwater tanks having a total capacity of 16,000 KL. The total water supply to the city is about 154 mld through Nagar Nigam and covers most of the localities within the municipal area. The municipal area has been divided in to 70 wards for water supply distribution.



Wastewater generation and Sanitation: The total municipal wastewater generation in the city is about 35 mld. Only 30% area is covered through sewerage system. In other parts of the city, people are using septic tanks and soak pits. In most of the places sewage is discharged into six major drains (Abu Nala, Suraj Kund Nala, Odian Road Nala, Clock Tower Nala, Bachcha Park Nala and Kishanpur Nala) without any treatment. These drains discharge both domestic and industrial waste water from densely populated city areas and ultimately join river Kali. The city has no sewage treatment plant.

Municipal solid waste generation: The approximate solid waste generation is around 600 MT/day. The solid waste disposal is not thoroughly systematic and the solid waste is dumped at low-lying areas. The solid waste from households and industries is dumped near the roads, parks or in municipal dalaos, from where it ultimately reaches to sanitary landfill at Kamela (opposite Karim Nagar), a place outside the Meerut municipal area on Hapur road. There is no proper system of monitoring the dumping activities.

Industries: It is estimated that there are approximately 14,000 registered industrial units in the metropolitan city of Meerut, out of which only about 9,000 units are functional at present. Most industries are located in Mukampur, Udyog Puram, Sports Complex and Partapur Industrial Estate. Distillery and small scale industries like sports goods, chemicals, food processing, surgical goods, engineering works, petrochemicals, rubber, plastic, leather goods, flour mills and readymade garments predominate in the area. There are three petroleum storages (IOCL, HPCL and BPCL) existing in Partapur Industrial Estate and Maqbara Diggi (Kesar Ganj). The total number of petrol pump of different agencies in the metropolitan city is 38.

3.3.2 Groundwater Quality Survey

Groundwater samples from the metropolitan city of Meerut were collected each during pre-monsoon (June 2002) and post-monsoon (October 2002) seasons from various abstraction sources at various depths covering extensively populated area, commercial, industrial, agricultural and residential colonies so as to obtain a good aerial and vertical representation. Location and other details for sampling points are described in Table 8.

Table 8: Description of groundwater sampling locations in Metropolitan City – Meerut

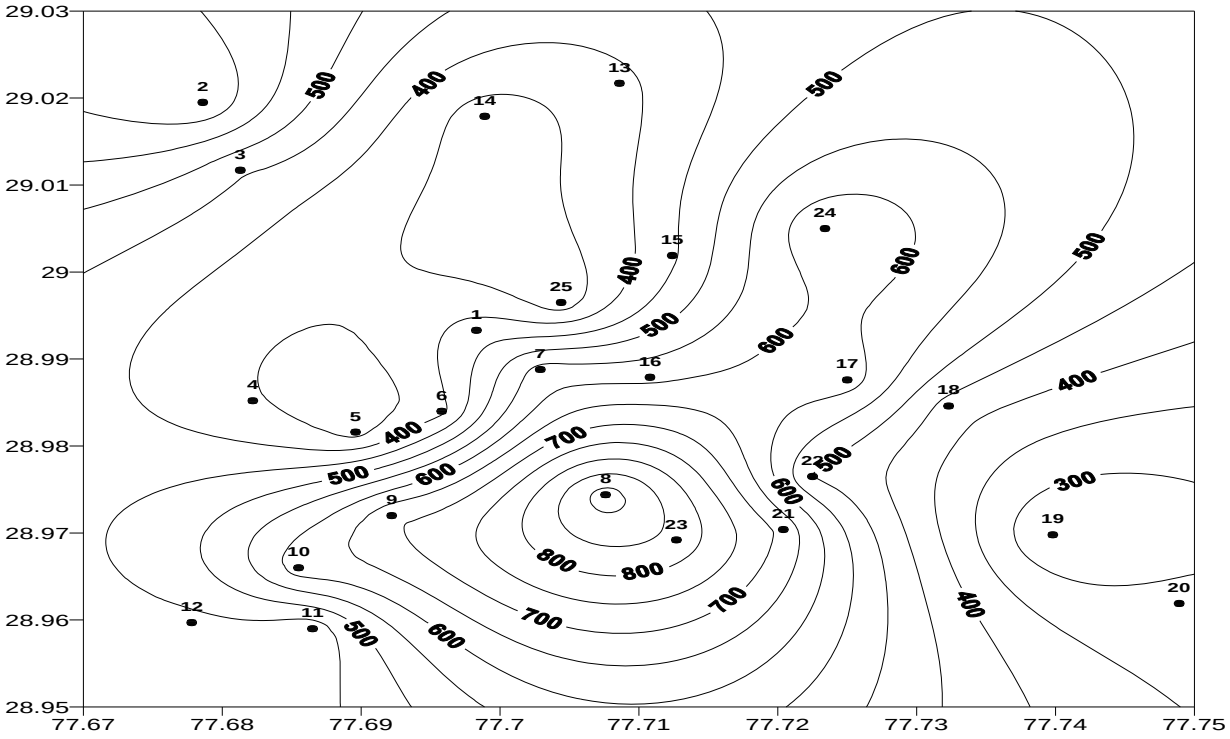
Sl. No.	Location	Identification	Source	Depth, M	Water Use	Land Use/ Specific Activity
1	Sadar Bazar	Opp. Gulathi Opticals	HP	33	Drinking	Residential
2	Kankar Khera	Opp. Saru Engineering Corp.	HP	30	Drinking	Residential
3	Central Distillery	Opp. Lal Quarters	HP	24	Drinking	Residential Area/Distillery
4	Gurudwara (Cantt Area)	Opp. Central School	HP	6	Drinking	Residential
5	Prempuri (Devpuri)	Opp. Vardhman Academy	HP	36	Drinking	Residential
6	Kesar Ganj	Opp. Kesar Ganj Mandi	HP	24	Drinking	Residential

7	Thapar Nagar	Opp. Devta Park	HP	24	Drinking	Residential
8	Mufttiyan	Back Side of Kotwali	HP	39	Drinking	Residential
9	Bharampuri	Near Shiv Temple	HP	24	Drinking	Residential
10	Sports Complex	Sports Complex	HP	15	Drinking	Industrial Area
11	Partapur Ind. Area	Opp. Sub Station	HP	30	Drinking	Industrial Area
12	IBP Depot	IBP Depot	HP	30	Drinking	Petroleum Storage
13	Vrindavan Garden	Roorkee Road	TW	42	Drinking	Residential
14	Koshal Kunj (Cantt Area)	Pump House No. 17	TW	60	Drinking	Residential
15	Lal Kurti	Bada Bazar	HP	24	Drinking	Residential
16	Vijay Nagar	Near R. G. College	HP	18	Drinking	Residential
17	Saket	Opp. Nandan Apartment	HP	15	Drinking	Residential
18	Prabhat Nagar	73 Prabhat Nagar	HP	27	Drinking	Residential
19	Meerut University	University Campus	TW	87	Drinking	Residential
20	Medical College	Medical College Campus	TW	88	Drinking	Residential
21	Kalyan Nagar	Shiv Temple	HP	14	Drinking	Residential
22	Suraj Kund	Sports Market	HP	15	Drinking	Residential
23	Islamabad	Market Area	HP	24	Drinking	Residential/ Slaughtering
24	Subhash Nagar	Near Samart Cement Agency	HP	18	Drinking	Residential
25	Begum Bridge	Opp. Dream Hotel	HP	36	Drinking	Residential

Note: HP-Hand pump, BW - Bore Well; OW - Open Well, TW-Tube Well

3.3.3 Observations on status of Groundwater Quality in Meerut City

The groundwater quality of the Metropolitan City of Meerut has been assessed to see the suitability of groundwater for domestic applications. Groundwater samples from hand pumps and tube wells were collected during pre- and post-monsoon seasons respectively and analyzed for various physico-chemical and bacteriological parameters, heavy metals, pesticides and poly-aromatic hydrocarbons. The hydro-chemical and bacteriological data was analyzed with reference to BIS and WHO standards, hydro-chemical facies were determined. The quality of the groundwater varies from place to place with the depth of water table. The groundwater quality has indicated higher concentration of nitrate, fluoride, iron, manganese and lead at few locations. The ranges of each parameter and percent violation of samples along with observations/comments on groundwater quality are presented in Table 2 of Annexure I. No poly-nuclear aromatic hydrocarbons were detected in any of the groundwater samples of the metropolitan city. An attempt has also been made to show TDS and Nitrate distribution in Meerut Metropolitan city during pre and post Monsoon seasons (Figure 6 & 7).



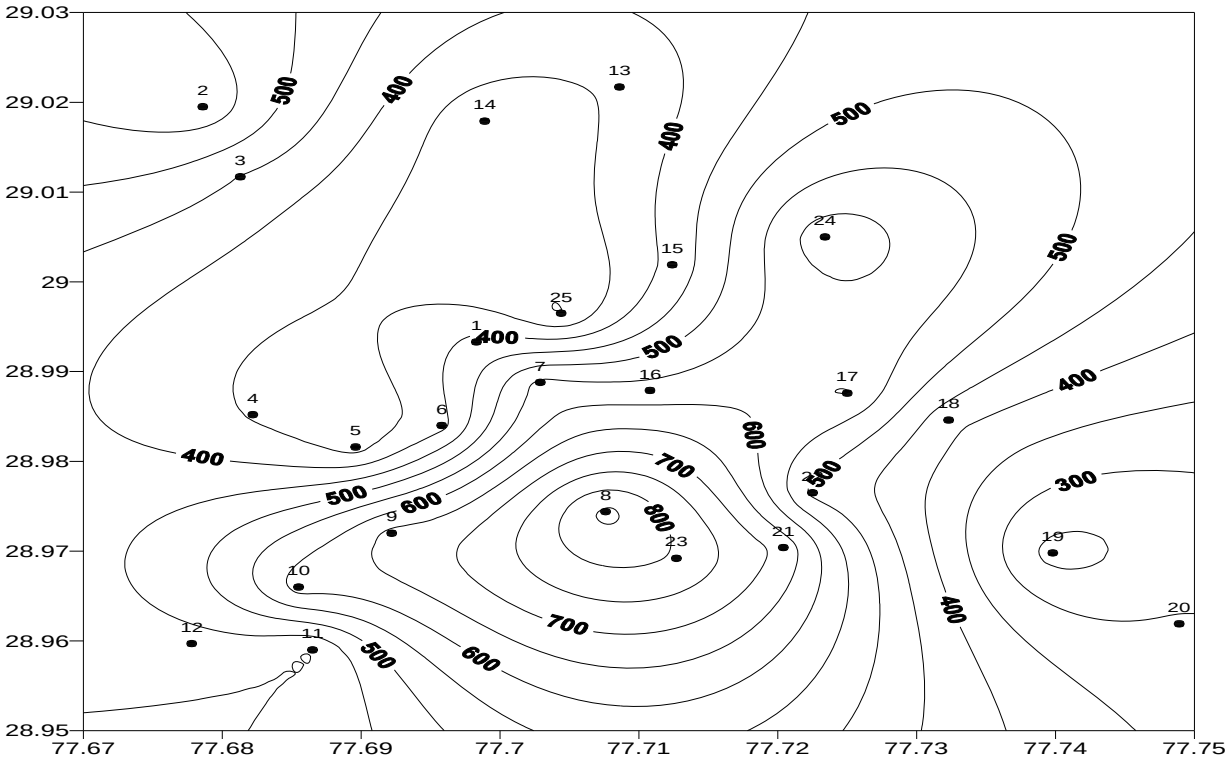
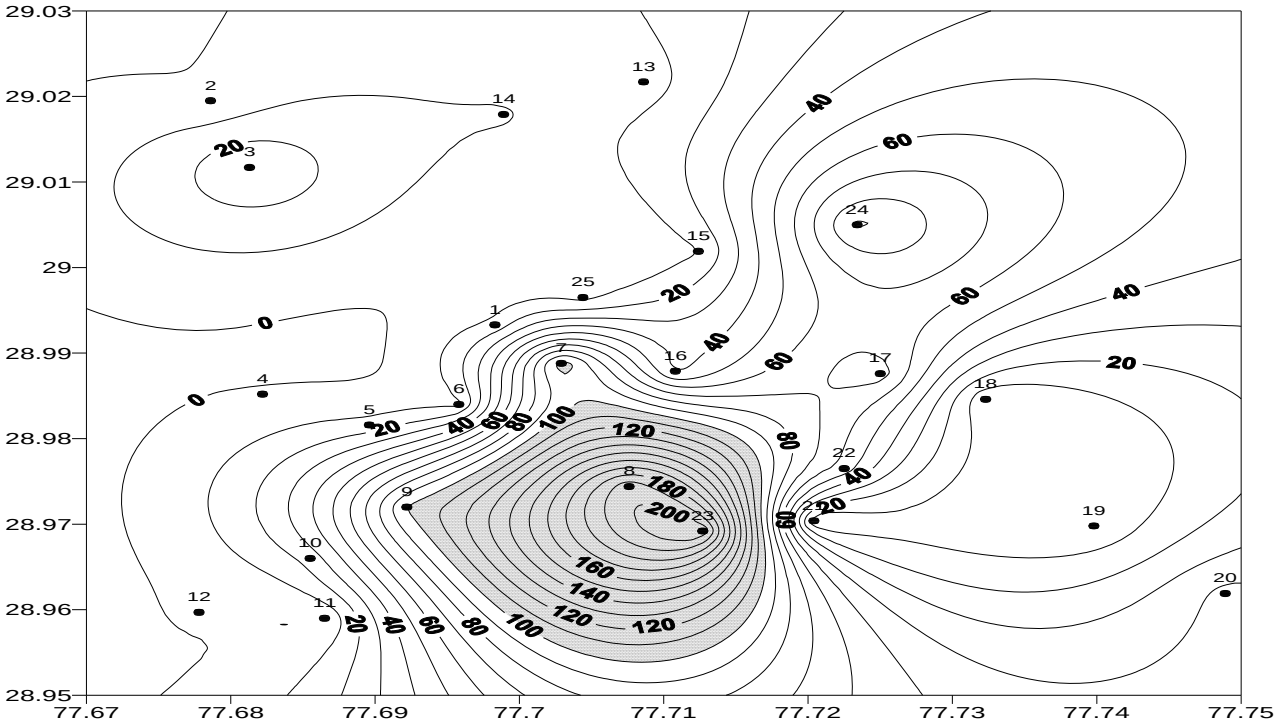


Figure 6: TDS distribution in Meerut Metropolitan City



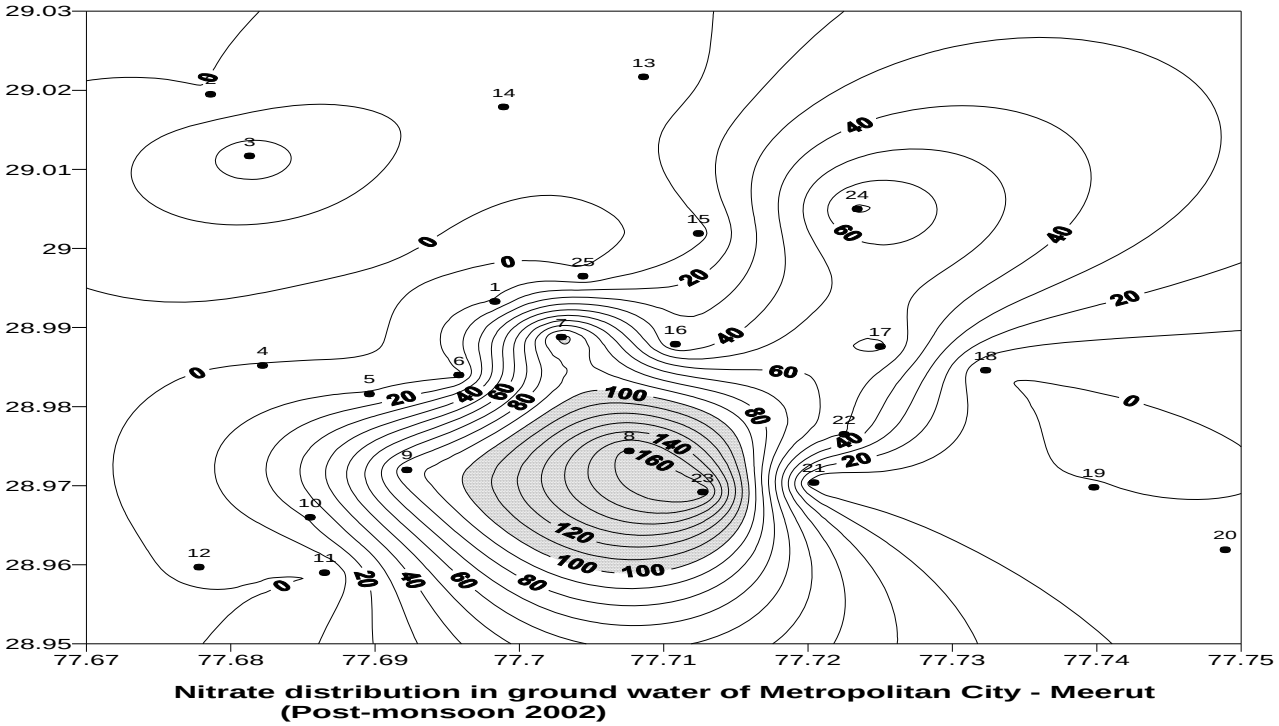


Figure 7: Nitrate distribution in Meerut Metropolitan City

3.4 Lucknow Metropolitan City

3.4.1 Environmental Profile of Lucknow

General features and Topography: Lucknow is a centrally placed district of Uttar Pradesh spread over an area of 2528 sq.kms. It lies between the parallel 26" 30' and 27" 10' north latitude and 80" 34' and 81" 12' east longitude. This elegant capital city of the state of Uttar Pradesh lies on the banks of the river Gomti that divides the city into two unequal halves, the southern half being larger than the northern part. Lucknow urban area has been divided into 40 municipal wards excluding cantonment. City map of Lucknow Metropolitan has shown in Figure 8.

Population: Lucknow has the population of about 25 lacs as per census 2001 with % decadal increase of about 49.80 %. The estimated present population density is 8065.1person/sq. km.

Climate: The climate of the city remains generally dry except during Southwest monsoon period. The hottest month is May with the mean daily maximum temperature at 41 deg C. January is the coldest with the mean daily minimum temperature being 22 deg C. Lucknow city has three main seasons namely summer, rainy and winter. The average normal maximum temperature has been observed as 44.9 deg C during May/June and minimum 4.8 deg C during January. The average wind speed ranges from 0.16 to 0.28 km/hr and from 4.0 to 4.16 km/hr during winter and summer respectively. The relative humidity of air varies from 19% in dry season to 86% during the rainy season. The average normal rainfall of the city is approximately 1100 mm.

Geology and Soil Type: Lucknow city, falls in the central Ganga alluvial plain chiefly forms a part of sai-Gomti sub basin, Hydro-geologically the city as a whole is represented by unconsolidated alluvial sediments, comprising sand of varying grades with kanker and clay and their admixtures, wherein fine grained sand mostly constitutes the aquifers, i.e. groundwater bearing strata. Jal Sansthan provides the existing water supply in the city. The city falls in the central Ganga Plain and lies in the interfuvial belt of Gomti and Sai basins. It has conspicuous natural depression in northeastern part around Janki Puram and Bakshi Ka talab. The general slope of the area is from north and northwest to south and southeast. The highest elevation is 123.5 above mean sea level in the northwest and the lowest 110 msl in the east in flood plain of river Gomti. The whole area of Lucknow may be divided into two geologic units, namely, younger and older alluvium of quaternary age. The younger alluvial plain lies all along the river Gomti and forms a wide flood plain. The older alluvial plain occupies higher elevation than the younger alluvial plain. The alluvium consists of sand, clay and kanker of different proportions.

Water supply: The drinking water supply is drawn from surface and groundwater. The source of surface water is only Gomti River, which is highly polluted mainly due to discharge of about 28 drains of the city. Deep tube wells, hand pumps and private bore wells are the main sources for extraction of groundwater in the city to cater the water demand of the population. There are about 300 tube wells and Jal Sansthan has provided 450 hand pumps. Besides this private boring is also very common. There are two sources of domestic water supply available at Lucknow use Groundwater & Surface Water (River). These water sources are also been use for Industrial

purposes, Irrigation purpose and other domestic usage of the city. U.P. Jal Nigam provided about 5435 hand pumps and 345 Tube wells. The surface water drawn from river Gomti is 280 mld and the groundwater withdrawal is 170 mld for domestic uses. The total water supply is 450 mld.

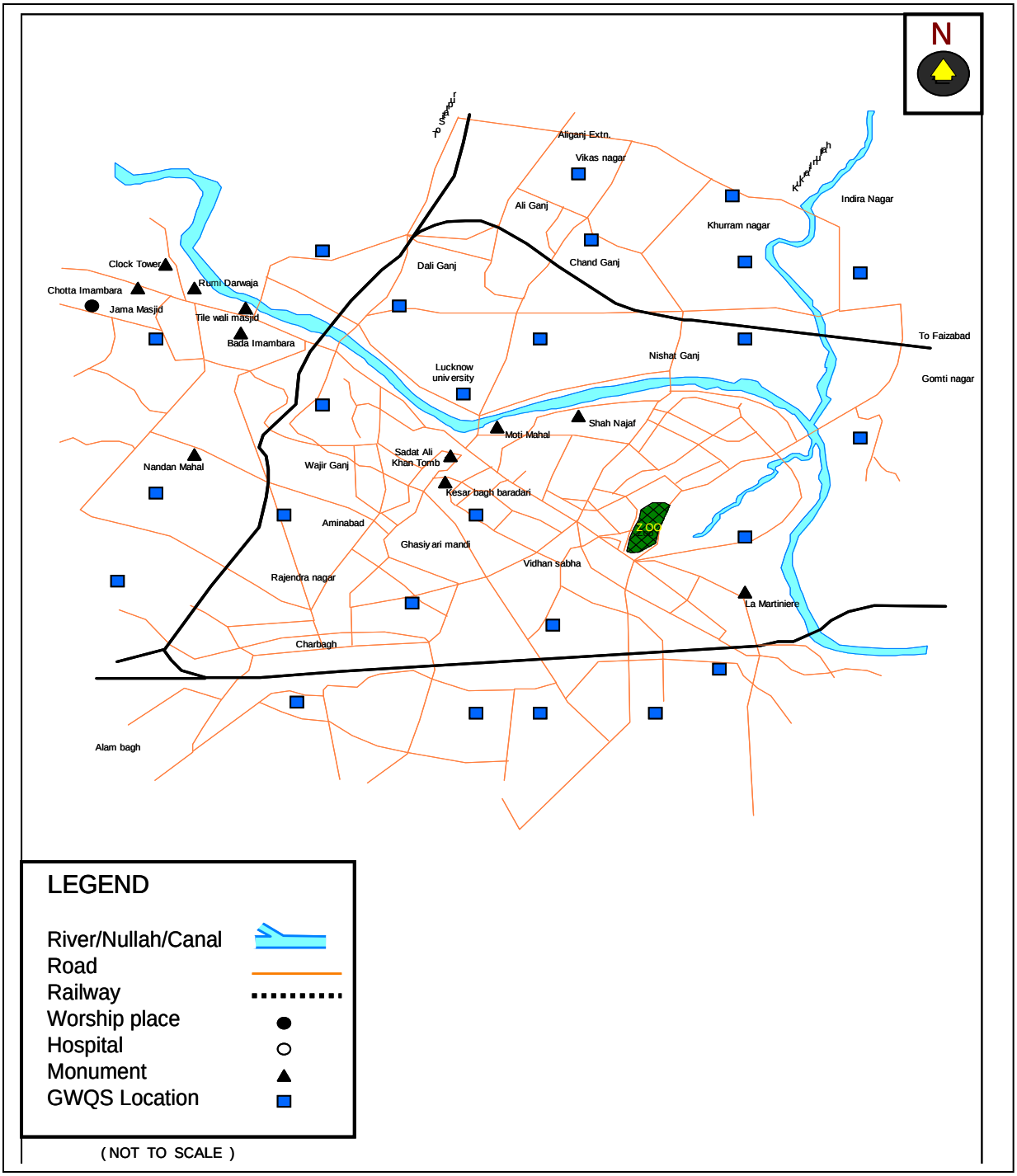


Figure 8: Map of Lucknow metropolitan city

Wastewater generation: The total wastewater generation is estimated as 360 mld. Wastewater treatment facilities are being developed under Gomti Action Plan of Govt of India. Presently the wastewater is flowing in open drains and joining Gomti river through 28 drains from the city. Since a large population is not covered under sewerage facilities the wastewater is flowing in unlined drains or stagnating in many areas, percolating in the ground and polluting the groundwater. Many areas have only septic tanks, pit latrines and even open defecation. All these led to contamination of groundwater. The river Gomti, which flows from North West to southeast, controls the drainage system in the Lucknow city. Kukrail nala is the only prominent tributary, which joins on the northern bank of river Gomti. Major part of the wastewater flows in these two water bodies.

3.4.2 Groundwater Quality Survey

Lucknow city is not dominated by industries. Only few industries are operating in the city in areas of Talkatora and Aishbagh. Most of the industries have been shifted to the outskirt of the city Chinhut. There are two sites for disposal of municipal solid waste namely Motijheel and Aishbagh. The rest comes under residential zone out of which some places are highly congested. The surveys was made more in residential areas, because of intensity of groundwater pumping and close variations in groundwater withdrawal from place to place. The quality of groundwater is widely variable in different areas of varying in quality of recharging source water. The first round of sampling during pre monsoon season for Lucknow city was carried in May 2002. The second round of sampling was done in post monsoon season in November 2002. The overall sampling includes various abstraction sources at various depths covering extensively populated area, commercial, industrial, agricultural and residential colonies so as to obtain a good aerial and vertical representation. Location and other details for sampling points are described in Table 9.

Table 9: Description of groundwater sampling locations in Metropolitan City Lucknow

INDUSTRIAL AREA	SANITARY LANDFILL	RESIDENTIAL AREA	PETROL PUMPS	SURFACE WATER
Chinhut (Hand Pump)	Motijheel (Hand Pump, Tube Well)	Indira Nagar (Tube Well, Hand Pump)	Gomti nagar (Hand pump)	Gomti river (Intake Point of Water Supply & Hand Pump along the bank)
Dalliganj (Hand Pump, Tube Well)	Ash bagh (Hand Pump)	Ashrafabagh (Hand Pump)		
Talkatora (Tube Well,Hand Pump)		Sahadatganj (Indana Kuan)		
		Alambagh (Hand Pump, Tube Well)		
		Ameenabad (Hand Pump, Tube Well)		
		Shahganj (Hand Pump)		
		Imambara (Hand Pump)		
		D/S Gomti (Bhainsa kund) (Hand Pump)		
		Gomti nagar (Tube Well, Hand Pump)		
		Charbagh (Tube Well)		

Note: BW - Bore Well; OW - Open Well, TW- Tube Well, HP-Hand Pump

3.4.3 Observations on Status of groundwater quality (GWQ) in Lucknow City

The groundwater quality of the Metropolitan City of Lucknow has been assessed to see the suitability of groundwater for domestic applications. The groundwater samples from hand pumps and tube wells were collected during pre- and post-monsoon seasons and analyzed for various physico-chemical and bacteriological parameters, heavy metals, pesticides and poly-aromatic hydrocarbons. The hydro-chemical and bacteriological data was analyzed with reference to BIS and WHO standards. The quality of the groundwater varies from place to place with the depth of water table. The groundwater quality has indicated higher concentration of hardness, TC and FC, iron, manganese and lead at few locations. The ranges of each parameter and percent violation of samples along with observations/comments on groundwater quality are presented in Table 3 of Annexure I. No poly-nuclear aromatic hydrocarbons were detected in any of the groundwater samples of the metropolitan city.

3.5 Ludhiana Metropolitan City

3.5.1 Environmental Profile of Ludhiana

Topography: Ludhiana city, the district headquarter of Ludhiana district is one of the biggest city in Punjab. It lies between north latitude 30-34' and 30" 01' and east longitude 75-18' and 76-20'. It is a central place in Punjab and is connected to all the major cities of the State through rail and roads. The general slope of the city is from East to West. The Municipal Corporation limit of Ludhiana city is 159.37 Sq. Kms. There are a large number of industries within the municipal limits of Ludhiana. It has developed into a main industrial and commercial town of the state. Ludhiana city map has shown in Figure 9.

Population: The population of the city within the Municipal Corporation area has grown at a fast pace since 1911 and has crossed one million. The population of Ludhiana city is around 13.93 lacs with 70 numbers of wards, and it also has a floating population.

Climate: The climate of Ludhiana generally ranges from semi humid in the North and North East to semi arid to arid in the South. The climate can be divided into three distinct seasons, the summer, the winter and the rainy season. There is large seasonal fluctuation of both temperature and rainfall. About 70% of the rainfall occurs from June to September. The average normal rainfall of the city is approximately 670 mm and the annual average rainfall in the district has been 437 mm.

The humidity is frequently high during the monsoon period (July-September) but is moderate to low during the rest of the year. The mean relative humidity varies from 43% in dry season to 81% during the rainy season. There is considerable variation between the normal mean maximum (June) and normal mean minimum (January) temperature. The mean maximum temperature is as high as 42.8°C and the mean minimum temperature is as below as 11.8°C. At all places the highest monthly temperature is obtained in June, followed by May and the lowest invariably in January, followed by December. The average wind speed ranges from 5.0 to 5.4 Km/hr during winter and 6.0 to 12.1 Km/hr during summer.

Geology and soil type: The geological succession found around Ludhiana is alluvium. The river Sutlej and its tributaries due to its changing courses deposit the alluvium in this part. The Sutlej River enters the Ludhiana district at Samrala tehsil, after flowing westwards along the border of Rupnagar and Hoshiarpur districts, for about 30 kms, it then flows west for about 90 kms, forming the boundary between Ludhiana and Jalandhar districts. The alluvium consists of sandy clay, gravel, pebbles and kankar. The lithology of the area is heterogeneous. Ludhiana is entirely occupied by alluvial deposits consisting of silt, clay, sand and kankar. Associated with the unconsolidated alluvium, occasionally beds of gravels and cemented sands are also present. The soils are alkaline and are deficient in nitrogen and organic matter. Tube well data show that there are alternate beds of sand and clay, with varying thickness. It is also revealed that there is occurrence of gravel and boulders at a depth varying from 60 m to 90 m.

Groundwater and Water supply: The water supply in Ludhiana is through groundwater of tube wells. The city has ample of groundwater and therefore the drinking water supply is based on deep tube wells. The depth of groundwater varies from 10 to 30 m in various parts of the city. There are about 80 functional deep tube wells, which are operated round the clock to meet the drinking water requirements of the people. The average per capita consumption of water comes to 25-30 gallons/day. Apart from municipal sources of water supply, a large number of consumers also have shallow hand pumps for augmenting their water requirements. There is no source of surface water in the study area (Ludhiana). All the requirement of water is met by the groundwater available in the area. The groundwater is mostly used for drinking purposes as well as for industrial, irrigation and other uses in the region.

Wastewater generation: The wastewater generated in the city either accumulating or flowing to the Buddha Nala passes through Ludhiana city. This drain acts as the carrier of wastewater from water polluting industries and city sewage. The Buddha Nallah is a tributary of river Satluj.

3.5.2 Groundwater Quality Survey in Ludhiana

Based on the information related to physiography, surface and subsurface hydrology, potential of groundwater, depth of shallow and deep aquifers, direction of groundwater flow the sampling locations were identified. The identification of industrial areas, residential areas, petrol pumps and bulk storage of petroleum products, if any, municipal solid waste disposal sites (landfill sites) and background area were done for the selection of identified tube wells. The samples were collected for groundwater in Pre-monsoon (May) and Post-monsoon (November) and identified about 29 numbers of locations to cover proportionately in shallow and deep aquifer regions of the city. The first round of sampling during pre monsoon season for Ludhiana city was carried out in May and the second round of sampling during post monsoon season was carried out in November. The overall sampling includes various abstraction sources at various depths covering extensively populated area, commercial, industrial, agricultural and residential colonies so as to obtain a good aerial and vertical representation. Location and other details for sampling points are described in Table 10.

The industrial areas, residential areas, municipal solid waste disposal (land fill) areas have also been identified and samples collected accordingly. There is no bulk storage depot of Petroleum products in Ludhiana city.

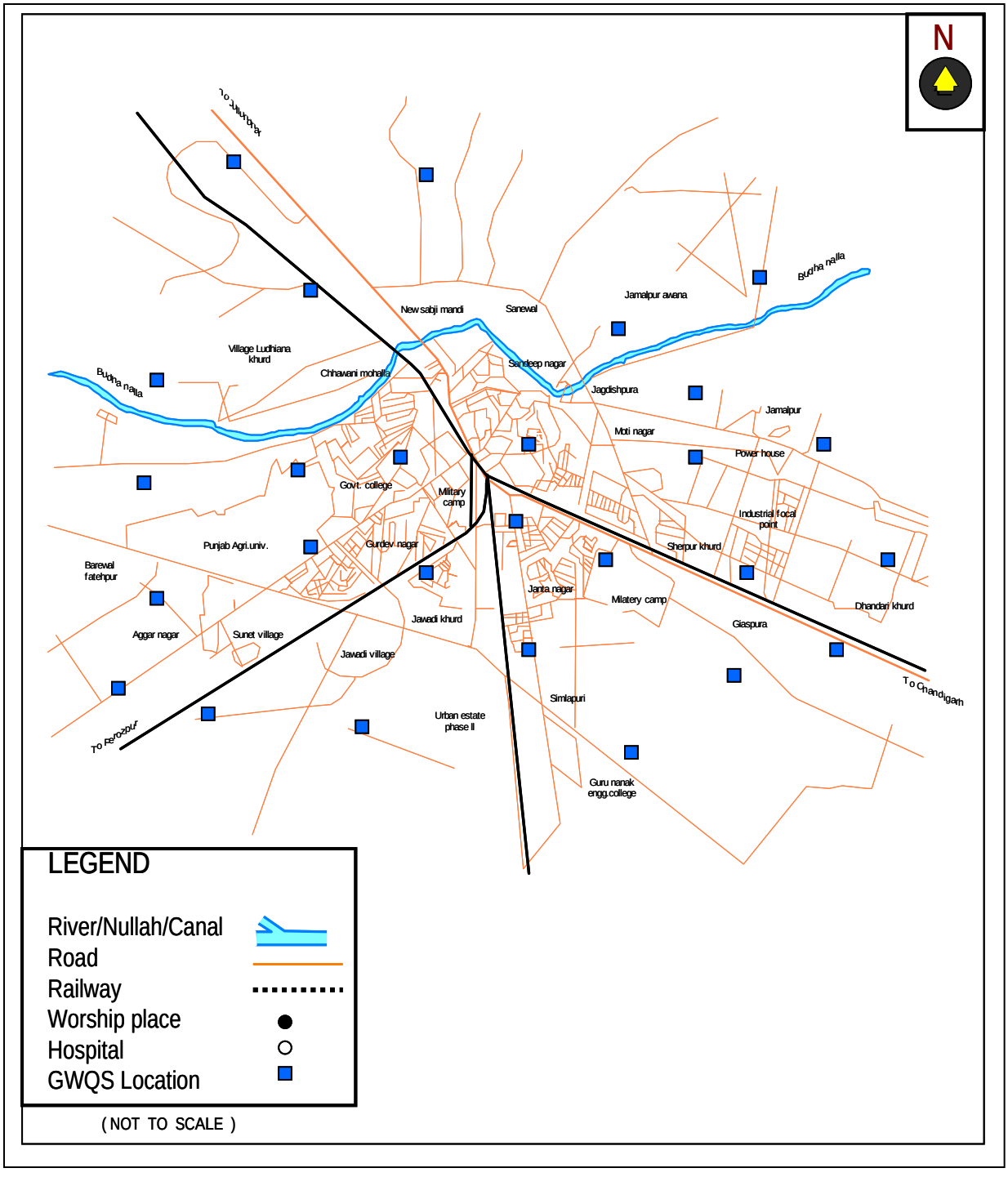


Figure 9: Map of Ludhiana Metropolitan City

Table 10: Description of groundwater sampling locations in Metropolitan City-Ludhiana

A Zone	B Zone	C Zone	D Zone
A1: 1.Darresi (T.W. No. 4), In front of Police Chowki No. 4. 2.Fatehgarh, In front of Chand Cinema (T.W. No. A-11).	**B1:** 1.Kidwai Nagar Park, Near Zone B1 Office. 2.Guru Angad Devji Park, Cheema Chowk. 3.R.K. Road, Near PSEB, Industrial Area A. 4.Narinder Nagar, Shingar Cinema Road.	**C1:** 1.Janata Nagar, Near Durga Factory. 2.Kotmangal Singh, Near Gurpal Nagar, Gali No. 25. 3.Langar Hall Daba, Near Gurdwara, New Amar Nagar.	**D1:** 1.Shahi Mohalla, Near Damoria Bridge. 2.Kitchlu Nagar. 3.Humbra Road, Mandeep Nagar.
A2: 1.New Shivpuri (T.W. No. 1) 2.Sardar Nagar, Near Corporation Dispensary (T.W. No. A-14).	**B2:** 1.Sherpur Zone b2 Office. 2.Kailash Nagar, Near Cancer Hospital (Oswal).	**C2:** 1.Char Acre Colony, Near Char Acre Scheme, Dashmesh Nagar. 2.2.5 No. Police Post, Gill Road, Near Vishwakarma Mandir Chowk. 3.Quality Centre, Industrial Area B, Near Nirankari Mohalla.	**D2:** 1.Model Town (T.W. No. 14). 2.Model Town Market.
A3: 1.Sabzi Mandi (T.W. No. 54). 2.Punjabi Bagh, Near Salim Tapri (T.W. No. A-51).	**B3:** 1.Dairy Complex, Tajpur Road. 2. MIG Sector 32-A,, Urban Estate, Samrala Road		**D3:** 1.Bhai Randhir Singh Nagar, G-Block North (T.W. No. 3). 2.Gurdev Nagar, Near Sarabha Nagar.
A4: 1.Gagan Deep Colony, Near Galewal Road. 2.Janta Colony (Park No. 5), Rahon Road.			

Note: HP- Hand Pump, BW - Bore Well; OW - Open Well, TW- Tube Well

3.5.3 Observations on status of Groundwater Quality in Ludhiana

The groundwater quality of the Metropolitan City of Ludhiana has been assessed to see the suitability of groundwater for domestic applications. The groundwater samples from hand pumps and tube wells were collected during pre- and post-monsoon seasons and analyzed for various physico-chemical and bacteriological parameters, heavy metals, pesticides and poly-aromatic

hydrocarbons. The hydro-chemical and bacteriological data was analyzed with reference to BIS and WHO standards. The quality of the groundwater varies from place to place with the depth of water table. The groundwater quality has indicated higher concentration of K, iron, manganese and lead at few locations. The ranges of each parameter and percent violation of samples along with observations/comments on groundwater quality are presented in Table 4 of Annexure I. No poly-nuclear aromatic hydrocarbons were detected in any of the groundwater samples of the Ludhiana metropolitan city.

3.6 Coimbatore Metropolitan city

3.6.1 Environmental Profile of Coimbatore

General feature & Topography: The metropolitan city of Coimbatore is one of the important industrial towns of South India**.** The metropolitan city is situated at $11^{o}00'$ N latitude and $77^{o}00'$ E longitude and occupies an area of about 140 km^2. The Coimbatore district is flanked on the northwest and south by steeply raising mountains of Western Ghats. Of these, the Nilgiris on the north west and Anamalai on the south are the important ranges, which attain a height of over 2500 m above mean sea level and the highest elevation in the valleys adjoining the hills is 600 m above mean sea level. In between the hill ranges east west trending mountain ranges pass and it is known as Palghat gap. Beside these western ghat ranges the other hill ranges of the district are Vellingiris and Botuvampatti hills. The Vellingiris are the spurs of the Nilgiri Mountains lying on the west and north west of the district. Boluvampatti hills lies on the northeastern side of the district. The city map has been shown in Figure 10.

Population: It is the 18^{th} largest town in India (population wise), and the 2^{nd} largest town in the state of Tamil Nadu after Chennai and is also called as 'Textile City' and the 'Manchester of South India'. The population pressure on the city is ever growing. As per the 2001 census, the population of the metropolitan city of Coimbatore is 14,46,034.

Climate: Generally sub-tropical climatic condition prevails throughout the district and there is no sharp variation in climate. The temperature slowly rises to its maximum up to May and afterwards shows a general decline. The maximum temperature ranges from 36 to 41°C and the minimum temperature varies from 14 to 31°C. The district receives rain both in southwest and northeast monsoon. The average annual rainfall of the district is 647 mm.

Geology and Soil Type: A wide range of high-grade metamorphic rocks of the peninsular gneissic complex underlies Coimbatore district. These rocks are extensively weathered and overlain by recent valley fills and alluvium at places. The major rock types occurring in the district are granites, complex gneise mainly Hornblende – Biotite gneiss, Sillimanite gneis which are associated with basic and ultra basic intrusives, crystalline limestone, syenite, pegmatite and quartzite veins. There are six different types of soils, viz., red calcarious soil, black soil, red non calcarious soil, alluvial and colluvial soil, brown soil and forest soil. In Coimbatore district groundwater occurs in all geological formations for the oldest Archean to recent alluvium. Diversified geological formation, lithological variation, tectonic complexity, geo-morphological and hydro-meteorological dissimilarities prevailing in the district raise to a variety of groundwater situations. However in relation to mode of occurrence, the hydro-geological frame

work met with in the district have been divided into two categories namely fissured and fractured formation both in gneiss and charnockite formations and porous formations. In hard rock formations, occurrence of groundwater depends upon secondary porosity, viz. zone of weathering, fissures, fractures, joints etc. Due to heterogenetic nature, these features generally do not occur uniformly in space and depth. They do not usually contain large and extensive groundwater reservoir. However, under favourable conditions, considerable quantity of groundwater storage is feasible in different lithological units. The most common rock types encountered in this district are gneiss and Charnockite.The porous formations in the district are represented by alluvium, colluvium and laterites. Colluvial material derived from nearby hill ranges, comprising sands and gravels, underlies the area to the western part of Coimbatore. The thickness of the layer is varies from 20 to 70 m. In these areas the groundwater is developed by means of dug wells and bore wells from the groundwater occurs under phreatic condition in the shallow aquifer, which occurs to depth ranging from 30 to 60 m. In alluvial formation groundwater occurs under water table conditions or semi-confined conditions and the formations are highly porous, permeable and developed into potential water bearing zones.

Water supply: Water requirement for Coimbatore city is mainly met from Siruvani and pilloor reservoirs. The estimated total water supply to the city is about 145 mld and covers most of the localities within the corporation area. The water supply through Siruvani reservoir is 80 mld and 65 mld through Pilloor reservoir. Also, the water supply is met through corporation bore wells. The corporation area has been divided into 72 wards for water supply distribution.

Wastewater generation: The total municipal wastewater generation in the city is about 110 mld. Only 40% area is covered through underground drainage system. In other areas of the city people are using septic tanks and soak pits. In most of the places, sewage is discharged into open drains either lined or unlined and low lying areas without any treatment. Ultimately wastewater from densely populated areas of both domestic and industries reaches at Vellalur pond near by Noyyal River. The city has no sewage treatment plant.

Municipal Solid Waste: Solid waste generation in Coimbatore city is about 800 MT/day. The solid waste disposal in Coimbatore city is not thoroughly systematic and the waste from house holds and industries is dumped in municipal waste containers located at various places of the city, low lying areas and near the roads. Initially the solid waste is transported to temporary waste transfer stations located at Ondipudur, Sathyamangalam road at Krishnarayapuram and Peelamedu. Ultimately the solid waste is transferred to main sanitary landfill at Vellalur, a place outside the Coimbatore municipal corporation. There is no proper system of monitoring the dumping activities.

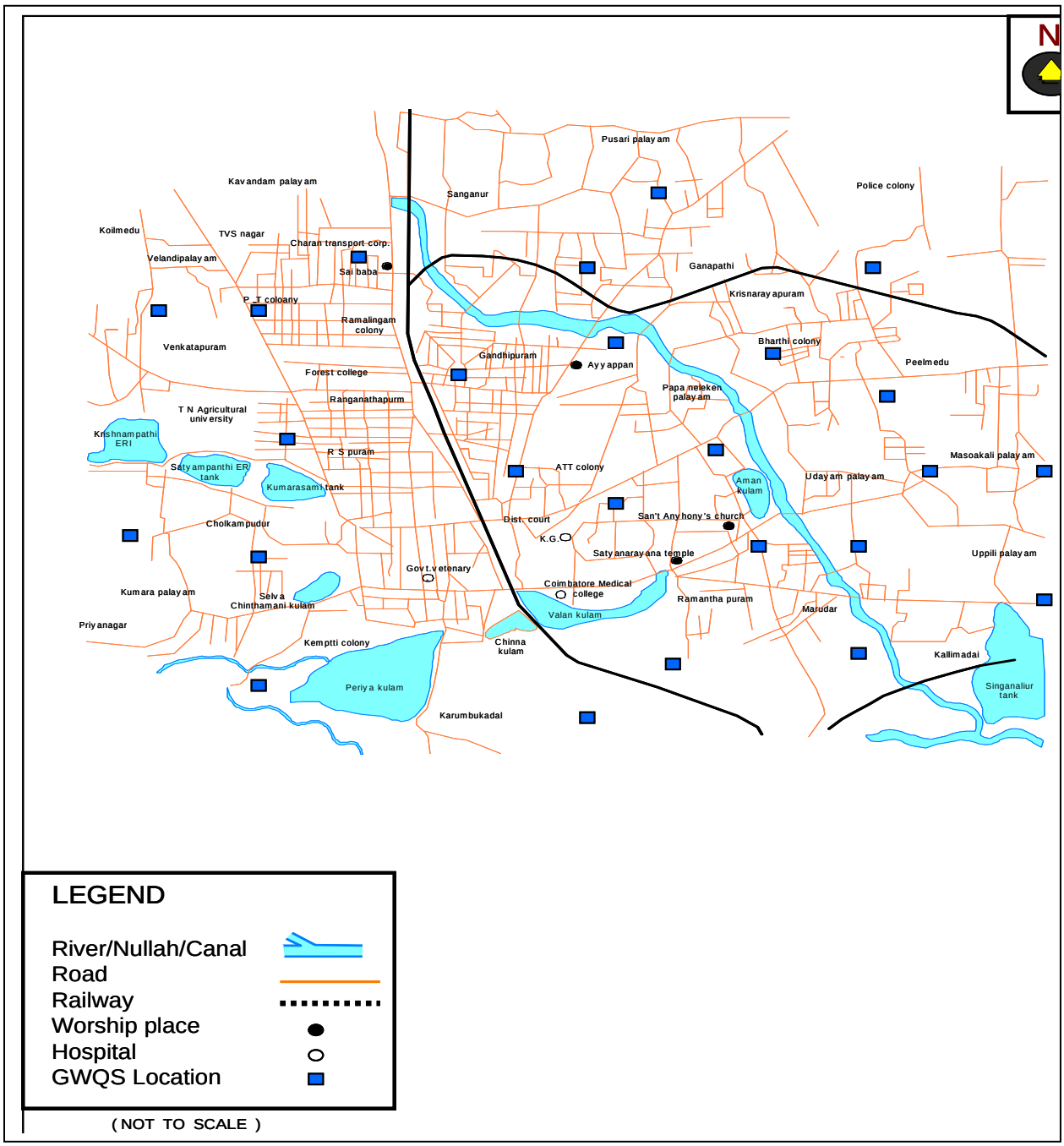


Figure 10: Map of Coimbatore Metropolitan City

Industries: The metropolitan city of Coimbatore is a burgeoning industrial centre with its famous textile mills, engineering industries and large number of small-scale industries. It is estimated that there are approximately 16000 registered industrial units in the metropolitan city of Coimbatore, out of which only about 8500 units are functional at present. Most industries are located in Peelamedu, Ganapathy, SITRA, Singanallur, Sidhapudur, Kurichi Industrial Estate (SIDCO) and Velandipalayam. Textiles, Foundries, Motor pumps, Electrical and Electronic appliances, Automobile components, Washing machines, Wet grinders, General engineering industries, Food processing units and readymade garments predominate in the area.

3.6.2 Groundwater Quality Survey in Coimbatour city

Groundwater samples from the metropolitan city of Coimbatore were collected each during pre-monsoon (June 2003) and post-monsoon (December 2003) seasons from various abstraction sources at various depths covering extensively populated area, commercial, industrial, agricultural and residential colonies so as to obtain a good aerial and vertical representation. The details of sampling locations and source and depth wise distribution are given in Table 11.

Table 11: Description of groundwater sampling locations in Metropolitan City Coimbatore

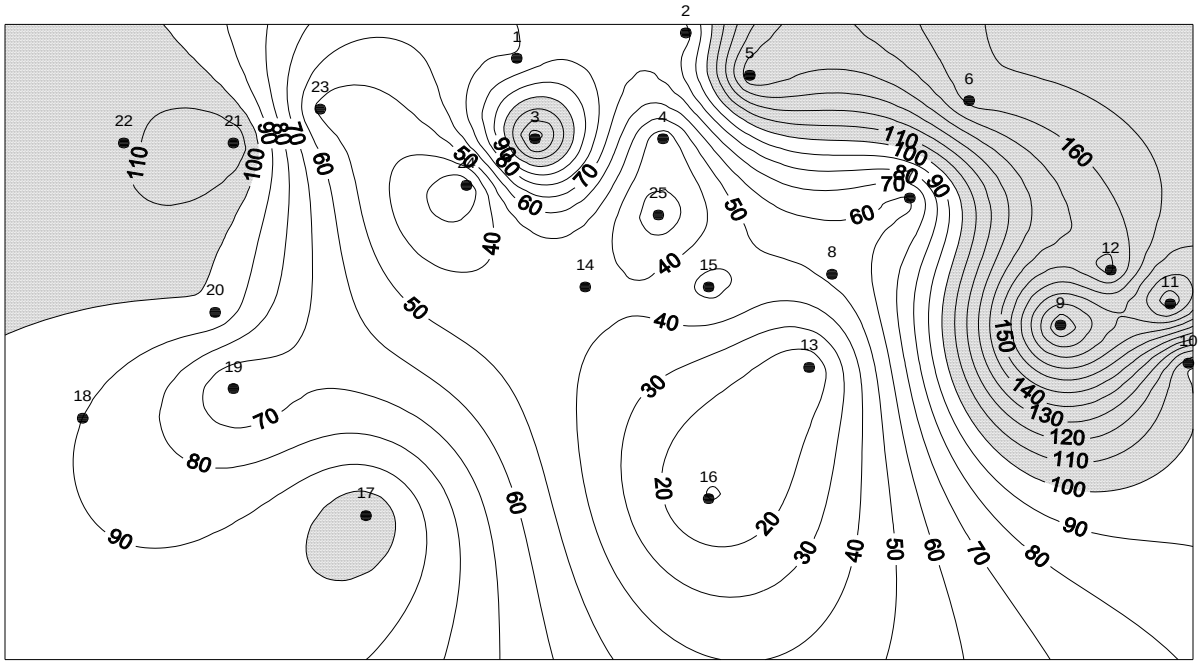
Sl. No.	Location	Identification	Source	Depth, m	Water Use	Land Use/ Specific Activity
1	Ganapathy	Near CRI Pump Road	BW	121	Domestic	Industrial
2	Bharathi Nagar	Rajarajeswari Temple	OW	15	Domestic	Residential
3	Krishnarayapuram	Near Waste Transfer Site	BW	24	Domestic	Commercial/ Solid waste Disposal
4	Pewelamedu	Ranga Nagar No.7 Residence	BW	45	Domestic	Industrial
5	Villankurichi	Kuppusamy Gounder Garden	OW	36	Domestic	Residential
6	Sitra (Kalappatti)	Panchayat Office	BW	106	Domestic	Industrial
7	Valluvar	Murugan Temple	BW	75	Domestic	Residential
8	Singanallur	Near LGB	OW	30	Domestic	Industrial
9	Ondipudur	9/47B Gandhi Nagar Residence	BW	30	Domestic	Residential
10	Irugur	BPCL side Sentha-Marai Garden	OW	18	Domestic	Agricultural
11	Irugur	IOCL, HPCL opposite	OW	30	Domestic	Agricultural
12	Irugur	Near IOCL, HPCL By-pass Road	OW	30	Domestic	Agricultural

13	Kallimadai	Trichy Road near Boat House	OW	30	Domestic	Industrial
14	Puliyakulam	Opp. Lakshmi Medicals Residence	BW	45	Domestic	Residential
15	Souripalayam	Opp. ESI Hospital	OW	30	Domestic	Residential
16	Vellalur	Asokar St. Karuppasamy Gounder	OW	13	Domestic	Residential
17	Kurichi	Palaniappa Layout Public BW	BW	30	Domestic	Industrial
18	Perur	Panchayat Office	BW	90	Domestic	Residential
19	Selvapuram	Kannan Nilayam Residence	BW	69	Domestic	Residential
20	Chokkam Pudur	Near Mariamman Temple	BW	121	Domestic	Residential
21	Venkatapuram	241/1, Saral Nursery Garden	BW	21	Domestic	Commercial
22	Velandipalayam	No.18/19, Simson Nagar Extension	BW	75	Domestic	Industrial
23	Kavundampalayam	Corporation Toilet Side MTP Road	BW	30	Domestic	Commercial
24	Gandhipuram	Saibaba Colony Residence	BW	45	Domestic	Commercial
25	Sidhapudur	No.51, Ambika Layout	BW	45	Domestic	Industrial

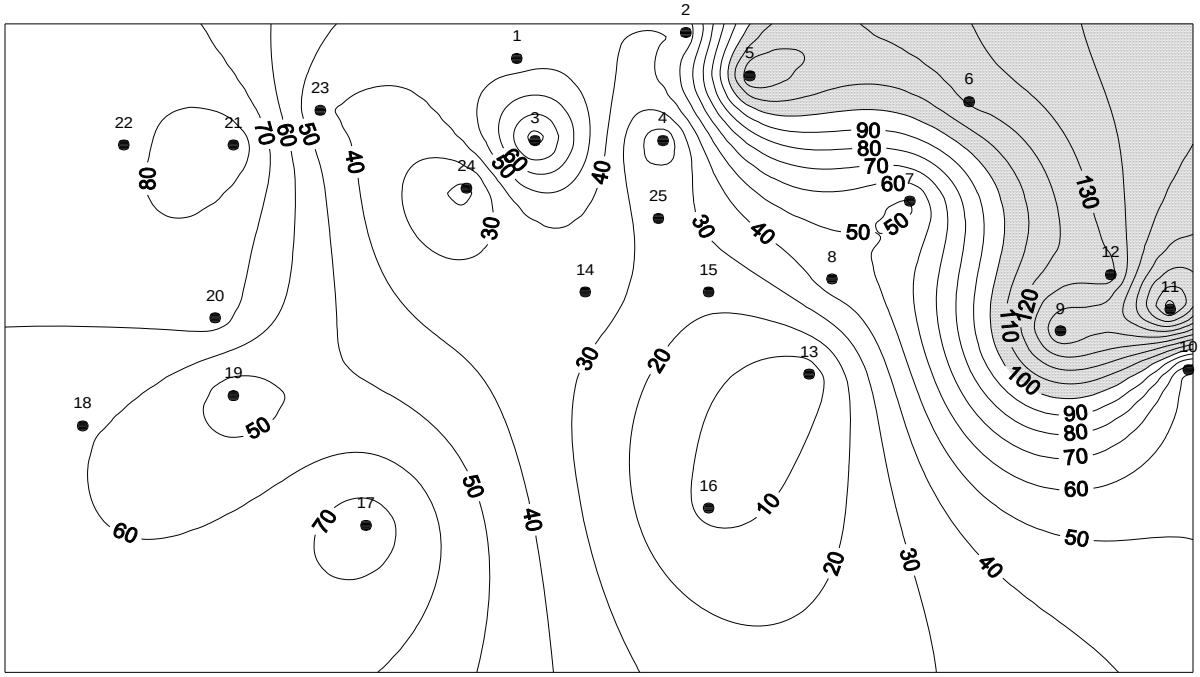
Note: BW - Bore Well; OW - Open Well; HP- Hand Pump

3.6.3 Observations on status of Groundwater Quality in Coimbatore city

The groundwater quality of the Metropolitan City of Coimbatore has been assessed to see the suitability of groundwater for domestic applications. The samples collected were analyzed for various physico-chemical and bacteriological parameters, heavy metals, pesticides and poly-nuclear aromatic hydrocarbons. The hydro-chemical and bacteriological data was analyzed with reference to BIS and WHO standards and hydro-chemical facies were determined. The quality of the groundwater varies from place to place with the depth of water table. The groundwater quality has indicated higher concentration of electrical conductivity, total dissolved solids, hardness, calcium, magnesium, chloride, sulphate, nitrate, fluoride, iron, nickel, chromium and lead vis-à-vis drinking water quality standards. No poly-nuclear aromatic hydrocarbons were detected in any of the groundwater samples of the metropolitan city. The ranges of each parameter along with observations/comments on groundwater quality are presented in Table 5 of Annexure I. An attempt has also been made to show TDS and Nitrate distribution in Coimbatore Metropolitan city during pre and post Monsoon season (Figure 11 & 12).

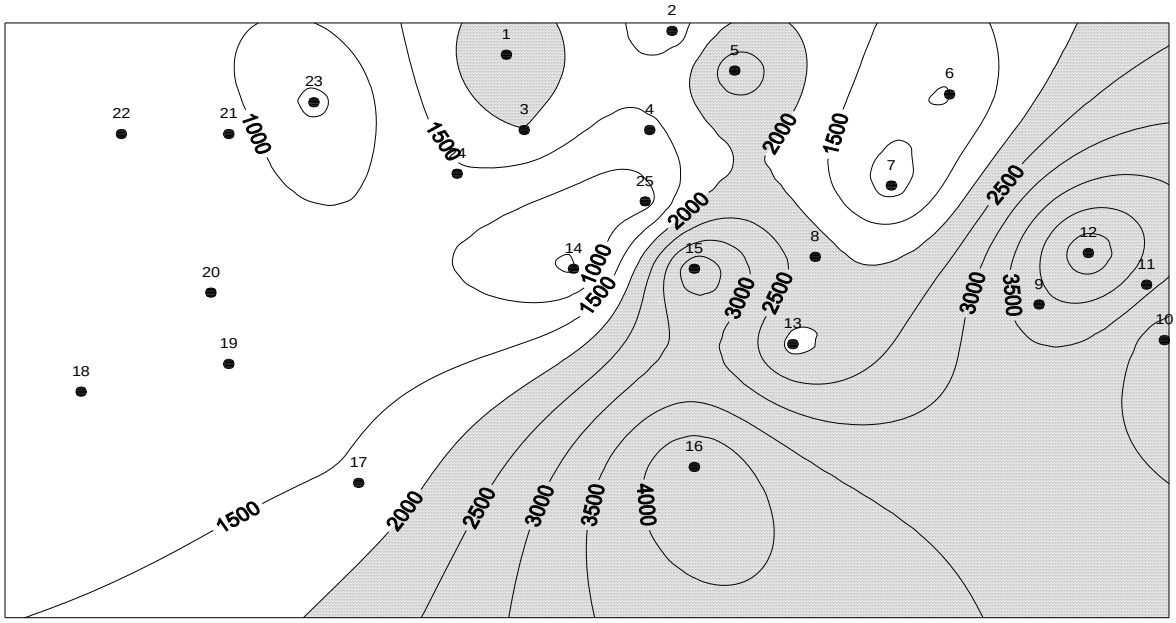


Nitrate distribution in ground water of Metropolitan City - Coimbatore (Pre-monsoon 2003)

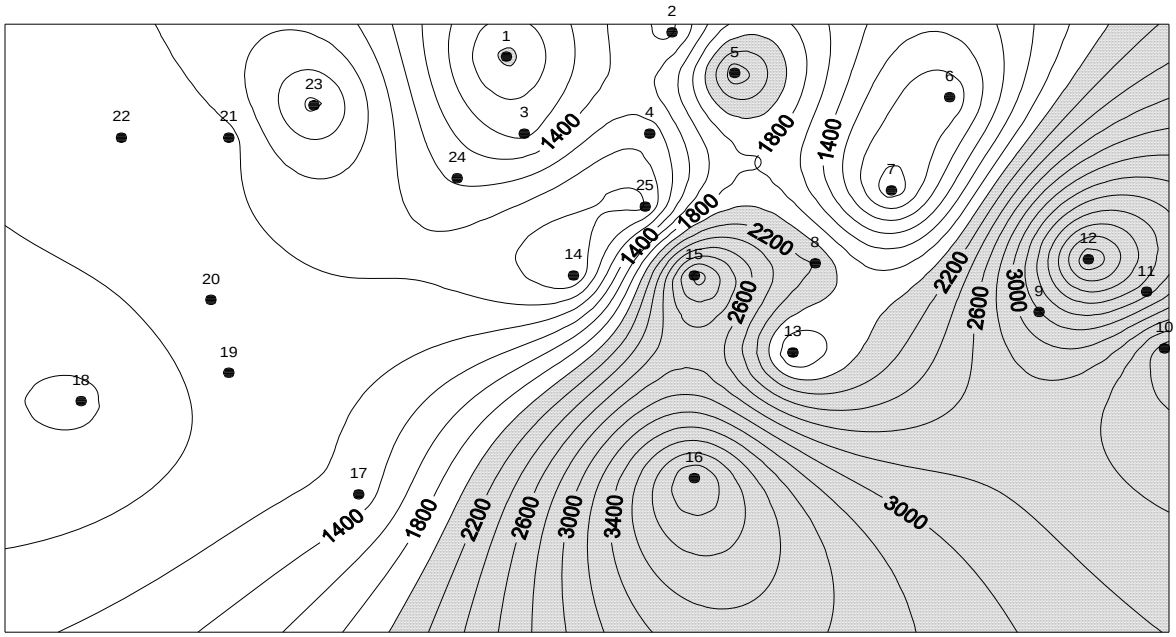


Nitrate distribution in ground water of Metropolitan City - Coimbatore (Post-monsoon 2003)

Figure 11: Nitrate distribution in Coimbatore Metropolitan City



TDS distribution in ground water of Metropolitan City - Coimbatore (Pre-monsoon 2003)



TDS distribution in ground water of Metropolitan City - Coimbatore (Post-monsoon 2003)

Figure12: Total Dissolved Solids (TDS) distribution in Coimbatore Metropolitan City

3.7 Chennai Metropolitan City

3.7.1 Environmental Profile of Chennai

Topography: The metropolitan city Chennai is the biggest city of South India with ancient culture and traditions. It is bounded by Bay of Bengal in the East and Chengai-MGR district in all the other directions. The metropolitan city of Chennai is located at $13^{o}04'$ N latitude and $80^{o}17'$E longitude and occupies an area of about 173 km^2. The city is located in the coastal plains. Major part of the city is having flat topography with very gentle slope towards east. The altitudes of land surface vary from 10m above msl in the west to sea level in the east. Fluvial, marine and erosional landforms are observed in the area. City map has been shown in Figure 13.

Population: It is the 4^{th} largest town in India (population wise), and the largest in the state of Tamil Nadu. The population pressure on the city is ever growing. As per the 2001 census, the population of the metropolitan city of Chennai is 64,24,624.

Climate: Chennai city enjoys a tropical climate with mean annual temperature of 24.3^0 C (min) to 32.9 ^{0}C (max). The hottest and driest part of the year is April-May, when temperature rises to 42^0 C. The humidity is usually in the range of 58 to 84% and sea breeze in the evening hours is a blessing to combat the high temperature and humidity during summer months. The Northeast monsoon during the months of October, November and December chiefly contributes the rainfall for the city. Most of the precipitation occurs in the form of one or two cyclones caused due to depressions in Bay of Bengal. The southwest monsoon rainfall is highly erratic and summer rains are negligible. The average annual rainfall in the region is the range from 1286 to 1233 mm.

Water Resources: The number of water bodies existed in the area in the early period of this century has been filled up with garbage (e.g., Vallur kottam area), transported sand and clay. Adayar River originates at the confluence (Thiruneermalai) of two streams that drain the upstream area of Chembarambakkam tank. It is a small river having a length of about 42 km and a catchment area of 800 km^2. The river carries flow through out the year with an average discharge of 89.43 MCM/year at Kattipara cause way. It drains the southern part of the district and remains flooded during monsoon. During high tides, the backwaters from the Bay of Bengal enter inland up to 3-4 km. Cooum is another main river flowing through the middle part of the area and carries only drainage water, which is highly polluted. It originates as surplus water from the Cooum tank in Tiruvellore taluk. The flow of Cooum River at Korattur is 40.2 MCM/year for an average duration of 31 days in a year. Otteri Nulla is another small stream flowing in the northern part of the city. Buckinghum canal is the main man-made channel used for navigational purposes in the area north of Ennore, but acts as sewerage carrier in the city.

Geology: The Chennai area is underlain by various geological formations from the ancient Archeans to Recent alluvium. The geological formations of the area can be grouped into three units, namely the Archean crystalline rocks, consolidated Gondwana and tertiary sediments and the Recent Alluvium. Most of the geological formations are concealed since overlain by the alluvial material except for a few exposures of crystalline rocks like charnockites along the railway track in Guindy area. The Archean crystalline rocks of the area comprise of Charnockites, gneisses and the associated basic and ultra basic intrusives. The Gondwana rocks

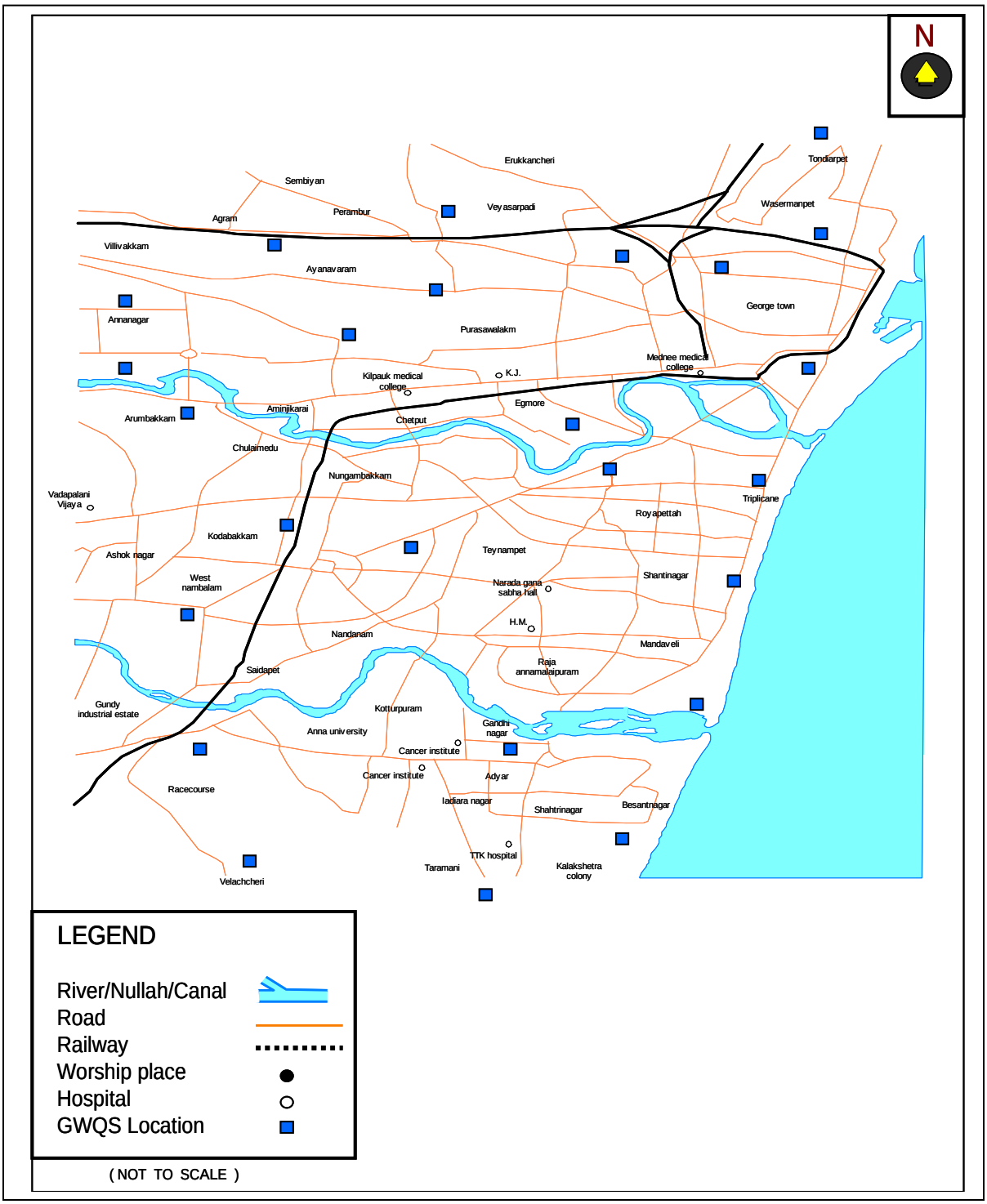


Figure 13: Map of Chennai Metropolitan City

are seen along the Adayar River bed outside Chennai, but no exposures are observed in the city. Sandstones, shales and clays represent the Gondwana sediments. The shales and clays are highly consolidated. The Gondwana shales are exposed in Adayar River near Ramavaram. The Tertiary sandstones are reddish brown to grayish white and white in colors friable and mottled. The occurrence of Tertiaries in Chennai is not well demarcated. The Recent alluvium covers the

major part of the city, but for the localized crystalline pockets in south Chennai in Gandhi Mandapam-Saidapeta Railway station area. The alluvium consists of sand, silts and clays. The thickness of alluvium varies from place to place and a maximum of 28m is encountered in North Madras near Perambur. Kilpauk water works area has 24 m thick alluvium. Groundwater in Chennai city occurs in all the geological formations viz. the Archaean crystallines, Gondwanas, Tertiaries and Alluvium and is developed by means of ring wells, dug wells, filter points, bore wells and tube wells. The average water levels are around 5 m. The Adayar river alluvium is 10 to 20 m in thickness and the occurrence of granular zones at depth varies from place to place. Cooum alluvium varies from 10 to 28 m in thickness and is more granular in Kilpauk-Perambur areas. Beach ridges and sand dunes in Tiruvanmiyur constitute good freshwater aquifers.

Groundwater and Water supply: The occurrence of groundwater is limited to thin granular zones in the alluvium and weathered and jointed, fractured rocks of crystalline rocks. The Gondwana sandstones and shales are also compact and fractured and contain appreciable amount of water at places. During the year 2003-04, Chennai faced a severe drought condition due to insufficient rainfall in the city. It is a common practice in the city, that like milk, drinking water cans are supplied regularly to the houses on payment of Rs. 2/- per litre. As the groundwater, which is the inherent source, is now contaminating with seawater or with pollutants or depleting with lack of rains, the people are forced to depend on the ozonised drinking water on payment basis. The predominant source of water supply to Chennai metropolitan city is surface water, i.e. run off during monsoon periods, stored in tanks and then treated and supplied. This is augmented by groundwater and also additional supply of water from Krishna River through Telugu Ganga Project. The flow in these rivers is seasonal and mostly due to northeast monsoon during the months of October, November and December. Chennai Metropolitan Water Supply and Sewerage Board (also called METRO WATER) engaged in the water supply and maintenance of distribution system in Chennai city. The surface water Reservoirs in Red Hills, Poondi, Chambarambakkam and Cholavaram tanks are the main source of water supply. There are number of groundwater well fields at Minjur, Tamarapakkam, Panjetty, Poondi, Kannigaiper and the Koratalaiyar flood plains in Chengai-MGR district tapping the groundwater in the Recent alluvium and supplementing the surface waters, in providing drinking water to the people of Chennai. Besides the well fields, water is also drawn from shallow wells with in the city boundary, much of it by hand pumps. There are about 35 municipal wells inside Chennai city, which are pumped directly into the overhead tanks, which are not connected to public water supply system. A notable feature in the city is that a shallow water table is available in most parts of the city with a depth of about 8 to 10 m. The area North east of the city was taken up for extensive hydro-geological studies and identified a buried channel, which should have been the course of Palar River thousands of years back. In this course, the well fields were identified extending a stretch of about 50 km length and 5 km average, which is suitable for extraction of groundwater. The aquifer is in general 30 m depth and water-bearing stratum is around 10 m depth. The water supply system maintained by Metro Water is presently drawing about 348 mld from both surface water and groundwater systems in years of normal rainfall. The surface run-off from Kortralaiyar, Nagari and Nandi rivers are collected and stored in three interconnected reservoirs namely, Poondi, Cholavaram and Redhills. Runoff from river Arani is also connected in these reservoirs by means of diversion constructed on the river, which is routed through Kortralaiyar. Another source of drinking water is the supply of Krishna river water to Chennai in

the Telugu Ganga Project. The amount of water 141.6 MCM of water will run from Srisailam reservoir with a stretch of 372 km of canals.

Sewarage & wastewater generation: Chennai is the first urban area of the State to have an under ground sewerage system. The system consisted of a network of gravity mains, force mains and pumping stations serving the different drainage areas into which the city was divided. The sewage collected from each area was pumped from one pumping station to other by relay and conveyed to Kasimedu north of harbour from where it was disposed into sea. As the city grew, the system of relay was found unsuitable and modified to zonalised system, covered in six zones of the city, with its own treatment plant. The Chennai city is divided into six zones for establishing the Sewage Treatment Plants as detailed below:

Zone	Location	Capacity (mld)	Irrigated area (ha)
I	Kodungaiyur	80	198
II	Kodungaiyur	80	--
III	Koyembedu	35	42
IV	Nesapakkam	23	8
V	Perungudi(Pallikaranai)	45	28
VI	Villivakkam	5	--
Total		268	

Due to inadequacy of the system, the sewage water overflows from pumping stations and join the Cooum, Buckingham canal and Adayar rivers. The Cooum and Adayar rivers also receive partially treated effluents from the treatment plants. Zone I serves the northwest of the city and is bounded by the Bay of Bengal to the east, the city limits to the north, the Buckingham canal to the west and Pycrofts road to the south. Sewage from this zone is presently diverted to the sea. Zone II is the largest of the 5 systems bounded by Buckingham canal on the east, Anna Salai/Adyar River in the south, Kodungayur to the south. Zone III is crucial to the water quality of Cooum River. The sewage from this zone is presently diverted to Koyambedu. Zone IV is bounded by the city boundary to the west and Adayar to the south, Arcot road to the north and zone III to the east. The sewage is diverted to treatment unit at Nesapakkam. Zone V is bisected by Adayar River with the northern section containing older parts of the city.

Industries: The majority of the industries are located in Guindy Industrial estate, SIDCO Nagar (Ambattur area), Basin Bridge, Korukkupeta, Tondiar Peta, Chromepeta (after Velachari), and Perambur etc. The most pollution causing industries like chemicals, oil refinery, oil storage tanks etc. are located in Northeast Chennai in Basin bridge area, Korukkupeta and Tondiar peta areas. Besides the above, some of the other major industries spread in Chennai are Standard Motors, Ashok Leyland, TVS, TI Cycles, Dunlop Rubber factory, Surgical instruments factory, Manali Refinery complex, Food factories, Beverage factories, wood, paper and paper products, Machinery tool industries, Transport equipments, Electrical machinery industries etc, Madras port is having 23 berths for handling the cargo in Bay of Bengal. The main exports from Madras seaport are hides and skins, ores, tobacco, food grains, cotton piece goods, bone and bone metal, sugar, chemicals, granites etc. The main imports in the port are food grains, iron and steel, fertilizers, paper, chemicals etc. The Chennai city is having Madras Petrochemical Ltd (Oil refinery), which produces petrol, diesel, tar, etc. from the petroleum crude oil. The petroleum

storage tanks of Indian Oil Corporation Ltd., Bharat Petroleum Corporation Ltd., and Hindustan Petroleum Corporation Ltd. Located near IOC Nagar, Tondiar Peta and Korukkupeta areas.

3.7.2 Groundwater Quality Survey in Chennai city

Groundwater samples from the metropolitan city of Chennai were collected each during pre-monsoon (June 2003) and post-monsoon (December 2003) seasons from various abstraction sources at various depths covering extensively populated area, commercial, industrial, agricultural and residential colonies so as to obtain a good aerial and vertical representation The details of sampling locations and source and depth wise distribution are given in Table 12.

Table 12: Description of groundwater sampling locations in Metropolitan City-Chennai

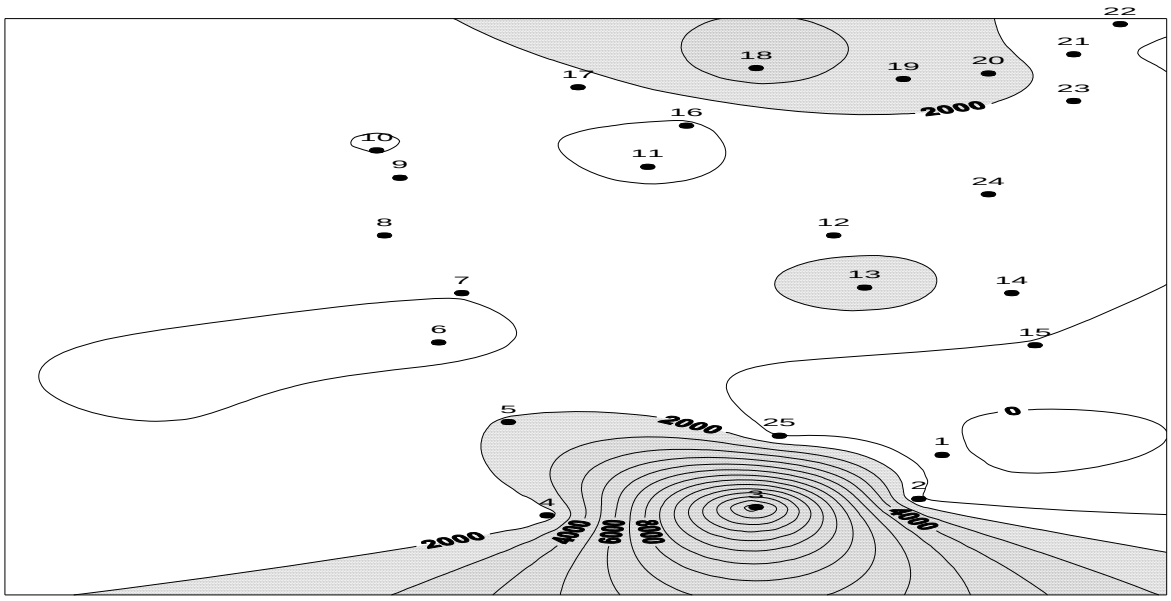
Sl. No.	Location	Identification	Source	Depth, m	Water Use	Land Use/Specific Activity
1	Besant Nagar	Sri. Varasiddi Vinayaka Temple	HP	12	Drinking	Urban
2	Tiruvanniyur	Marudeeswara Temple	HP	15	Drinking	Urban
3	Taramani	New Iyangar Bakery	HP	36	Drinking	Urban
4	Velacheri	Dandeswaran Temple	HP	30	Drinking	Urban
5	Guindy Industrial Estate	Public Hand Pump	HP	33	Drinking	Industrial Area
6	K K Nagar	Vignesh Travels	HP	36	Drinking	Urban
7	Vadapalani	Water Servicing Station	HP	36	Drinking	Urban
8	Koyambedu	Kalyana Mandapam	OW	12	Drinking	Urban
9	Anna Nagar (West)	849, J Block	HP	24	Drinking	Urban
10	Villivakkam	Public Hand Pump	HP	45	Drinking	Industrial Area
11	Ayanavaram	Opp. Sri Balaji Stores	HP	42	Drinking	Urban
12	Egmore	Shishu – The Play School	HP	30	Drinking	Urban
13	Roypet	Central Chennai Corp. Dispensary	HP	48	Drinking	Urban
14	Triplicane	Public Hand Pump	HP	30	Drinking	Urban

15	Santhome	Santhome Church Compound	HP	10	Drinking	Urban
16	Perambur	Public Hand Pump	HP	15	Drinking	Urban
17	Sembiyam	Public Hand Pump	HP	36	Drinking	Urban
18	Erankancheri	Public Hand Pump	HP	42	Drinking	Urban
19	Stanley Nagar	Public Hand Pump	HP	45	Drinking	Petroleum Storage
20	Kurukumpeta	Opp. Indian Oil Corporation	HP	24	Drinking	Petroleum Storage
21	Tondiar Pet	Public Hand Pump	HP	36	Drinking	Urban
22	Toll Gate	Public Hand Pump	HP	42	Drinking	Urban
23	Washerman Pet	Public Hand Pump	HP	33	Drinking	Urban
24	Park Town Area	Public Hand Pump	HP	45	Drinking	Urban
25	IIT Madras Campus	Near Q.No. D1/42	HP	45	Drinking	Urban

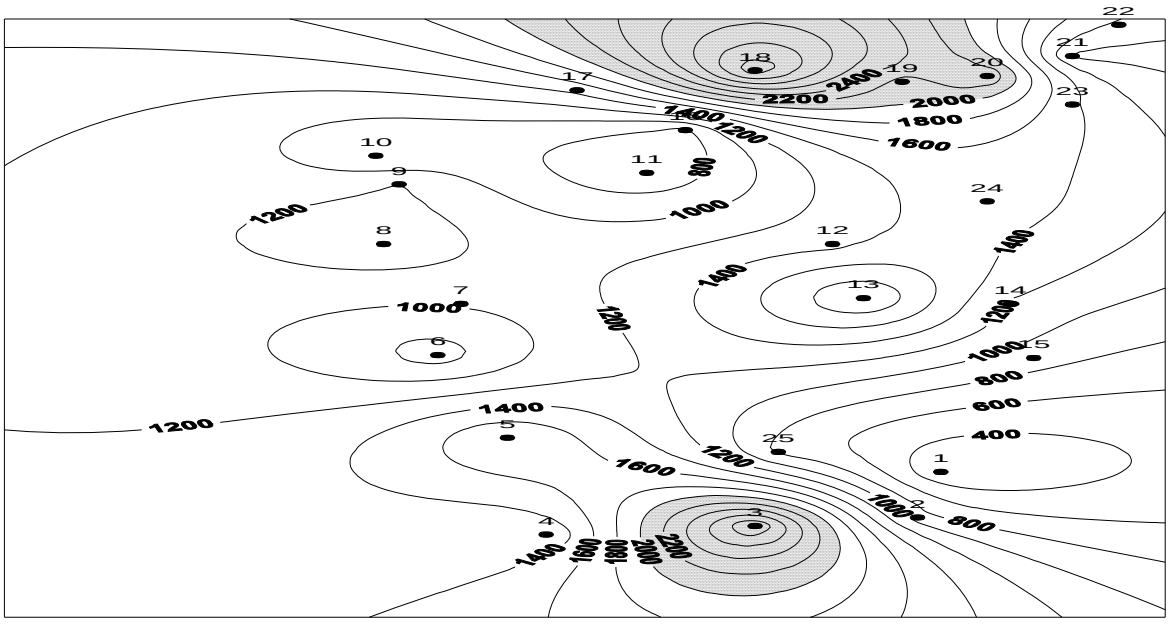
Note: HP - Hand Pump; OW - Open Well

3.7.3 Observations on status of Groundwater Quality in Chennai city

The groundwater quality of the Metropolitan City of Chennai has been assessed to see the suitability of groundwater for domestic applications. The samples collected during pre- and post-monsoon were analyzed for various physico-chemical and bacteriological parameters, heavy metals, pesticides and poly-nuclear aromatic hydrocarbons. The hydro-chemical and bacteriological data was analyzed with reference to BIS and WHO standards and hydro-chemical facies were determined. The quality of the groundwater varies from place to place with the depth of water table. The groundwater quality has indicated higher concentration of electrical conductivity, total dissolved solids, alkalinity, hardness, calcium, magnesium, chloride, sulphate, fluoride, iron, manganese, nickel, lead and cadmium vis-à-vis drinking water quality standards. Pesticides analysis indicated the presence of Aldrin, α-BHC, δ-BHC and Endosulphan at few locations in groundwater of the metropolitan city. The presence of these pesticides in groundwater may be attributed to their use in agricultural activities and for vector control programmes. No Organo-phosphorous pesticides and poly-nuclear aromatic hydrocarbons were detected in any of the groundwater samples of the metropolitan city. The ranges of each parameter along with observations/comments on groundwater quality are presented in Table 6 of Annexure I. An attempt has also been made to show TDS and Nitrate distribution in Chennai Metropolitan city during pre and post Monsoon season (Figure 14 & 15).

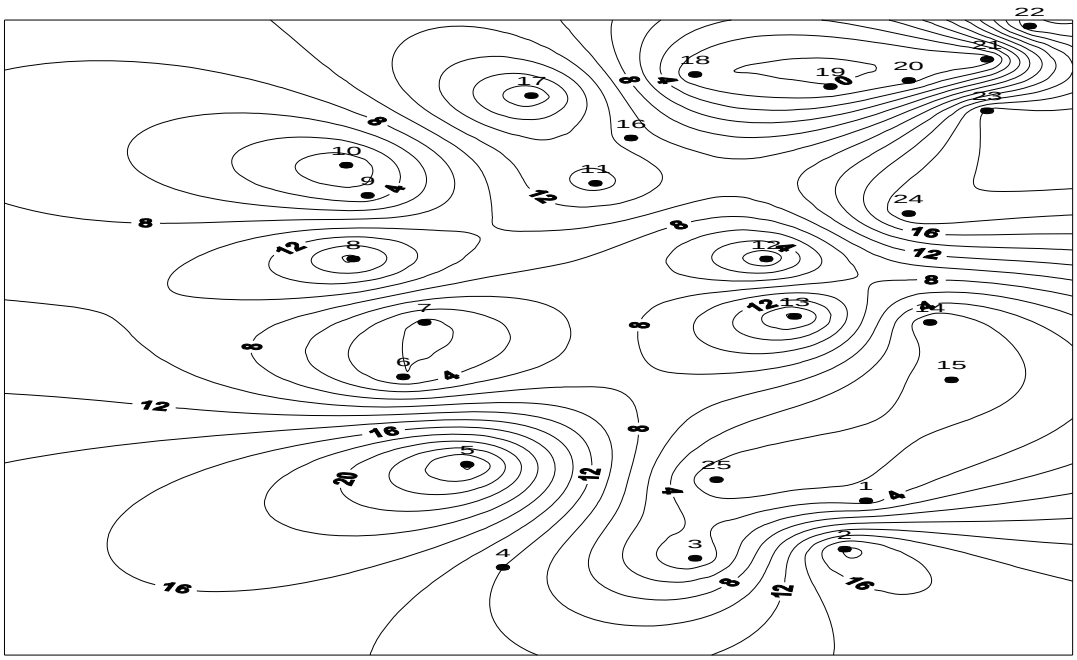


TDS distribution in ground water of
Metropolitan City - Chennai (Pre-monsoon 2003)



TDS distribution in ground water of
Metropolitan City - Chennai (Post-monsoon 2003)

Figure 14: TDS distribution (pre and post monsoon) in Metropolitan city of Chennai



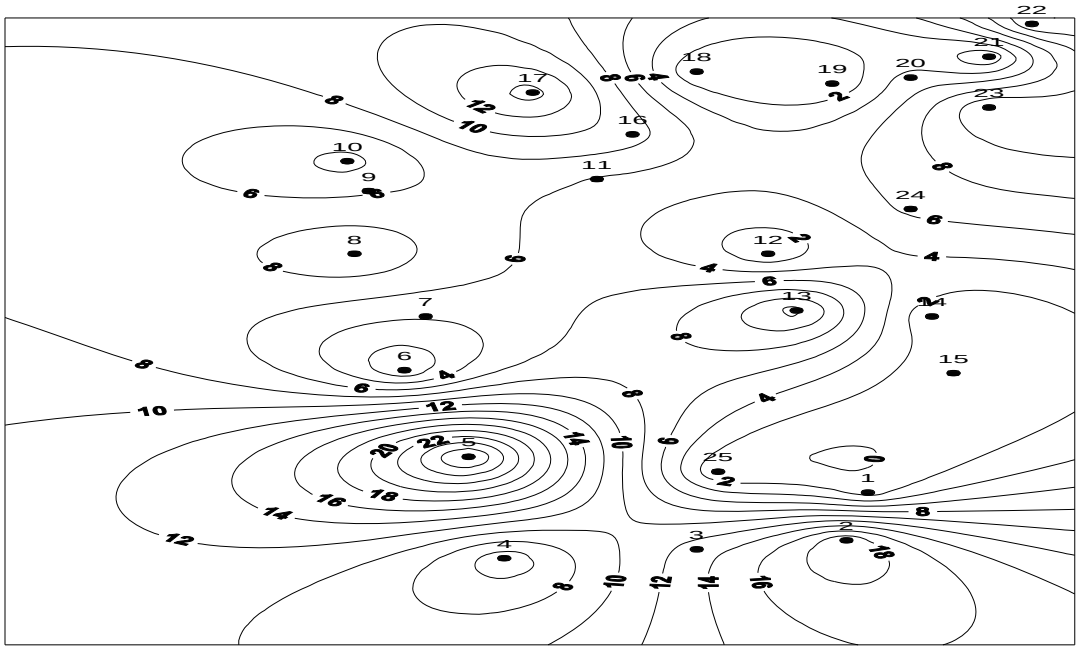


Figure 15: Nitrate distribution (pre and post monsoon) in Metropolitan city of Chennai

3.8 Madurai Metropolitan City

3.8.1 Environmental Profile of Madurai

Topography: Madurai city, which is more than 2500 years old, was once the mighty capital of the ancient Pandya Kingdom. This city has been famous as the seat of Tamil Literature in Southern India and conferences of scholars – Sangams - were held here from remote ages. In one of those gatherings of scholars, Lord Sundareswarar himself is said to have played the part of a poet. The metropolitan city of Madurai is located at $9^{o}58'$ N latitude and $78^{o}10'$ E longitude and occupies an area of about 140 km^2 .The metropolitan city, situated on the banks of the River Vaigai, is the 24^{th} largest town in India (population wise) and third largest in the state of Tamil Nadu after Chennai and Coimbatore. City map of Madurai metropolitan is shown in Figure 16.

Population: The population pressure on the city is ever growing. As per the 2001 census, the population of the metropolitan city of Madurai is 11,94,665.

Climate: Hot and humid, Madurai has the typical climate of the rest of the Deccan plateau. Normally, Sub tropical climate prevails over the city without any sharp variation. The average annual rainfall of the city is 867 mm from four distinct seasons, viz., and South West monsoon, North East Monsoon, Winter Season and Hot Summer Season. The precipitation is uncertain, uneven or unequally distributed. A perceptible change in the pattern of rainfall is noticed, traversing from Western Ghat Region, through Periyakulam, Usilampatti Taluks to Madurai and Melur regions in the east. The temperature rises slowly to maximum in summer months up to May and after which it drops slowly. The mean monthly maximum temperature ranges from 29.2 to 41.8°C and the mean monthly minimum temperature from 13 to 24°C.

Geology: Geologically, the entire Madurai District can be broadly classified into hard rock and sedimentary (alluvial) formations. Hard rocks underlie more than 90% of the district. Generally, hard rock does not contain potential aquifers to store large quantity of water and to transmit to other areas. Alluvial deposits such as sand, silt, stiff clay, gravel etc., are transported sediments by the river are found on either side of Vaigai near Madurai and Vadipatti blocks. These formations are overlying the hard rock as a thin layer. There are six different types of soils in the district, i) Thin red soil, ii) Deep red soil, iii) Red storile soil, iv) Laterite soil, v) Black soil and vi) Red sandy soil. The metropolitan city of Madurai contains red sandy soil. Gneissic type: Groundwater occurs under water table or phreatic conditions in weathered, jointed and fractured formations. The pore space developed in the weathered mantle (disintegrated material) acts as shallow granular aquifers and forms the potential water bearing and yielding zones. Water table is very shallow in canal and tank irrigated regions whereas it is somewhat deeper in other regions. Charnockite type: Groundwater occurs under water table or phreatic conditions but the intensity of weathering, joint, fracture and its development is much less when compared to gneissic formations. As a result, these are not termed, as potential water bearing zones excepting in a region where the intensity of weathering coupled with development of joints and fractures is greater. Sometimes the occurrence of kankar material over charnockite hampers the permeability and well yielding capacity. In alluvial formation, groundwater occurs under water table or semi confined conditions. These formations are highly porous, permeable and develop into potential water bearing zones. Valleyfill sediments groundwater occurs under water table or semi confined

conditions. The Valleyfill sediments are highly porous and permeable and the sandy material facilitates vertical infiltration. There is considerable diversity in the nature of formation even within the short distance. The sedimentary tract of Vaigai alluvium is restricted to either side of the river Vaigai and the thickness of alluvium is estimated to be around 20 m. There is not much variation in the lowest and highest water level conditions over the years in Madurai (North and South), Water requirement for Madurai city is mainly through sub surface (Infiltration Wells) and Vaigai reservoir, which is about 75 km from Madurai.

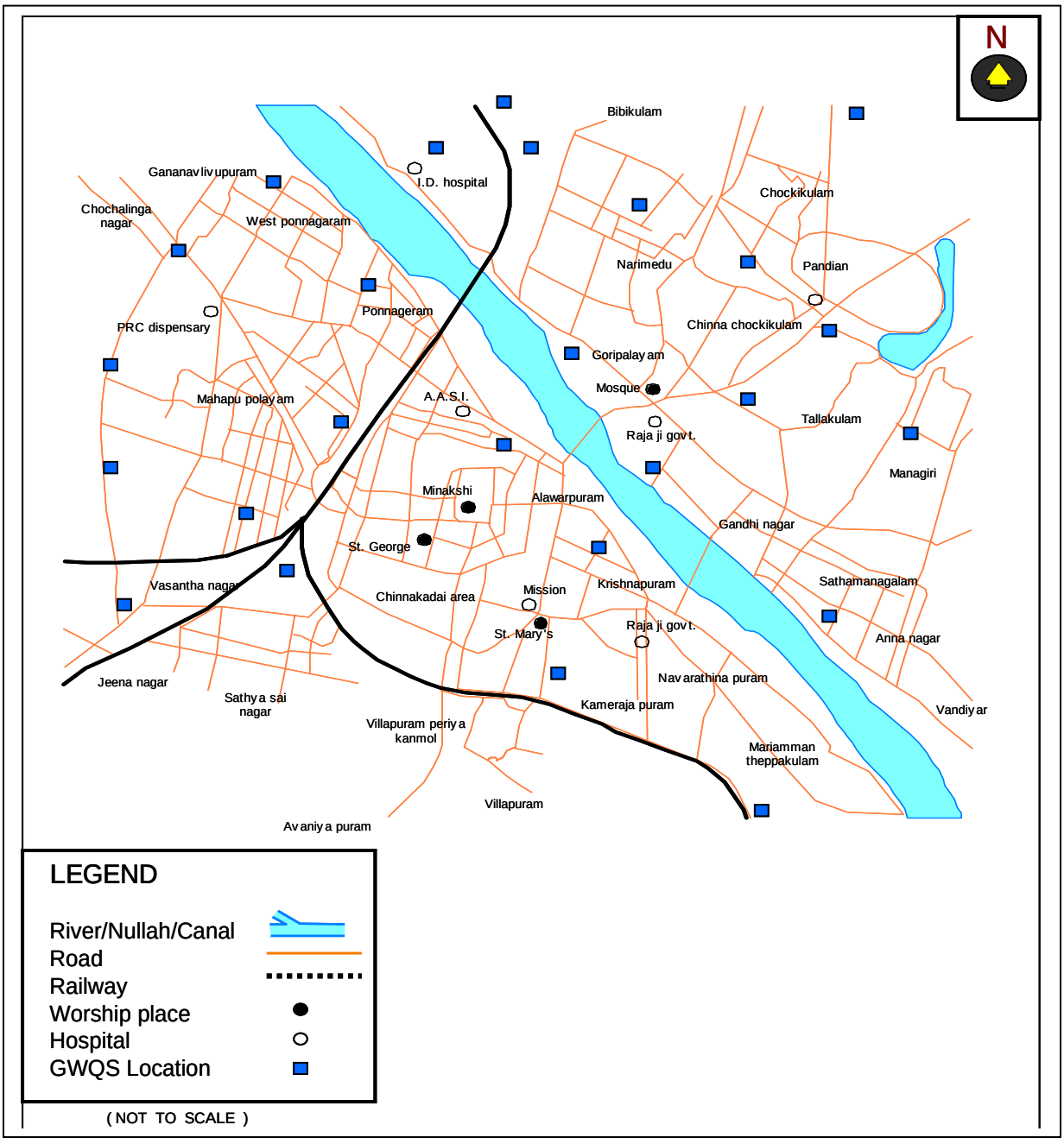


Figure 16: Map of Madurai Metropolitan City

Water resources and Water supply: The flow in the river Vaigai is seasonal and surface flow could be seen only during peak monsoon seasons. Further, vagaries of monsoon directly affect the flow of surface water into the reservoirs, anicuts, lakes etc., and naturally the cultivators have to look for alternative source, viz, groundwater to meet their irrigation requirements. The water supply through sub surface source is 23 mld and from Vaigai reservoir is 68 mld during normal season. But during summer season, the supply is only from Vaigai reservoir and corporation bore wells. The total water supply to the city is about 91 mld through corporation and covers most of the localities within the city area. The corporation area has been divided into 72 wards for water supply distribution.

Wastewater generation: The total municipal corporation wastewater generation in the city is about 80 mld. Only 60% area is covered by underground drainage system. In other areas, people are using septic tanks and soak pits. In some places, the sewage is discharged into open drains either lined or unlined, low lying areas and along the Vaigai riverside without any treatment. Ultimately the wastewater from densely populated areas of both domestic and industries joins at Aveniyapuram and treated by anaerobic system. The treated water is used for growing grasses and other horticultural activities.

Municipal Solid waste: The approximate solid waste generation in Madurai city is about 400 MT/day. The solid waste from house hold and industries in Madurai city is dumped in municipal waste containers located at various places of the city, low lying areas and near the roads, from where it reaches to temporary waste transfer stations at Mattuthavani, Chinna Kanmoi and Sammattipuram. Ultimately, the solid waste is transferred to main sanitary landfill at Aveniyapuram, a place outside the Madurai municipal corporation area. There is no proper system of monitoring the dumping activities.

Industries: The metropolitan city of Madurai is a burgeoning industrial centre with its famous textile mills, & engineering industries. It is estimated that there are approximately 11,000 registered industrial units in the metropolitan city of Madurai, out of which only about 5000 units are functional at present. Most of the Industries are located in Pudur (SIDCO) Industrial Estate, Sellur, Aveniyapuram, Kochadai and Anuppanadi. Textile mills, Dyeing units, Powerlooms, Handlooms, Engineering and Mechanical industries, Electrical and Electronic appliances, Steel rolling mills and small scale industries like Food products, Readymade Garments, Wooden industries, Printing, Moulding industries predominate in the area. There are two petroleum, diesel and kerosene, storages (IOCL and HPCL) existing in Vilangudi and near by Railway station. The other one storage (BPCL) exists in Kappalur, which is located 15 km outside the Madurai city area. The total number of petrol pump of different agencies in the metropolitan city is 36.

3.8.2 Groundwater Survey in Madurai city

Groundwater samples from the metropolitan city of Madurai were collected each during pre-monsoon (June 2003) and post-monsoon (December 2003**)** seasons from various abstraction sources at various depths covering extensively populated area, commercial, industrial, agricultural and residential colonies so as to obtain a good aerial and vertical representation The details of sampling locations and source and depth wise distribution are given in Table 13.

Table 13: Description of groundwater sampling locations in Metropolitan City – Madurai

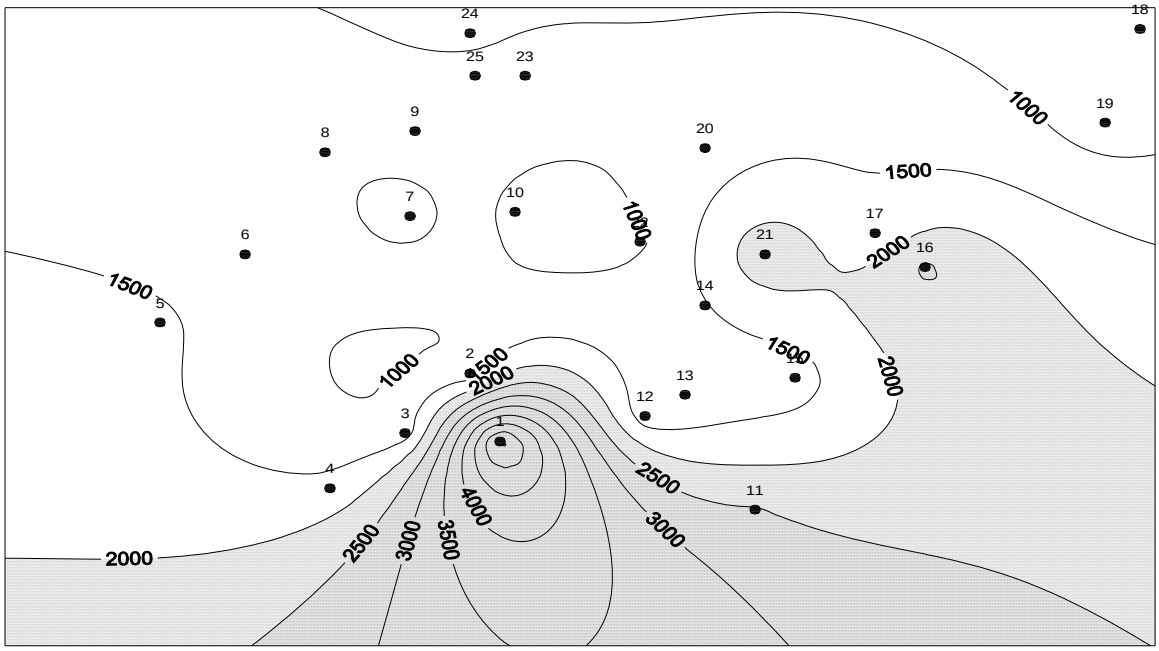
Sl. No.	Location	Identification	Source	Depth, M	Water Use	Land Use/ Specific Activity
1	Aveniyapuram	Tuticorin By-pass Road Mani Cement Works	OW	13	Domestic	Residential/ Landfill site
2	Andalpuram	Below Railway Over Bridge	BW	45	Domestic	Residential/ Waste disposal
3	TVS Nagar	C-31/57, Rajam Road Residence	BW	75	Domestic	Residential
4	Muthupatti	RMS Colony	BW	45	Domestic	Residential
5	Pasumalai	Residence Near Post Office	OW	30	Domestic	Residential
6	Madakulam	Kabali Eswariamman Temple	OW	9	Domestic	Residential
7	Chokkalinga	7th St. near Police Station	BW	45	Domestic	Residential/ Waste disposal
8	Virattipattu	Balaganapathi Temple	BW	45	Domestic	Industrial
9	Pethaniapuram	1st Cross Street	BW	45	Domestic	Residential
10	West Ponnakaram	Opp. Ganapathy Pillai House, Main Road	BW	90	Domestic	Residential/ Petro.storage
11	Anuppanadi	Near TWAD Tank	BW	60	Domestic	Industrial
12	East Madurai	Chinthamani Road, Near Agrochemicals Shop	BW	60	Domestic	Industrial
13	Balarangapuram	Opp. Nageswariamman Temple	BW	90	Domestic	Residential /Waste disposal
14	Alwarpuram	River Side Public BW	BW	45	Domestic	Residential
15	Sathamangalam	Opp. Arvind Eye Hospital	BW	121	Domestic	Residential
16	K.K. Nagar	Opp. Kalaivani Tailors, LIC Colony	BW	60	Domestic	Residential/ Waste disposal
17	Pudur	SIDCO, Ramavarma Nagar 6th St.	BW	45	Domestic	Industrial
18	Jawaharlal Puram	Residence Well	OW	18	Domestic	Residential
19	Kodikulam	Surya Nagar Lime Factory	OW	12	Domestic	Residential

20	Bibikulam	Corporation Toilet BW	BW	90	Domestic	Residential
21	Chinna Chokikulam	OCPM School opp. Police Quarters	BW	60	Domestic	Residential
22	Sellur	Tagore Nagar Tank Bund Side	BW	75	Domestic	Industrial
23	Vilangudi	Residence No. 6/26, IOC Nagar	BW	21	Domestic	Residential/ Petroleum storage
24	Vilangudi	KPS Garden	OW	15	Domestic	Residential/ Petroleum storage
25	Vilangudi	Panchayat Ofiice	OW	15	Domestic	Residential/ Petroleum storage

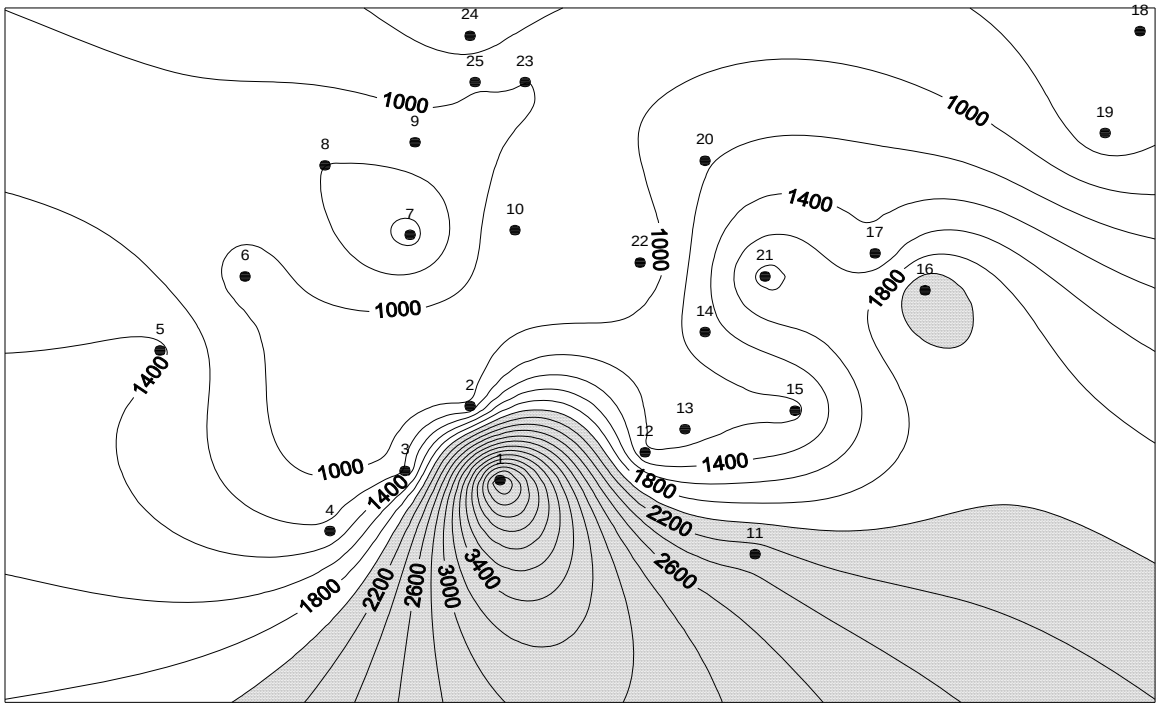
Note: BW - Bore Well; OW - Open Well, TW- Tube well; BW- Bore well

3.8.3 Observations on Groundwater Quality in Madurai city

The groundwater quality of the Metropolitan City of Madurai has been assessed to see the suitability of groundwater for domestic applications. The samples collected during pre- and post-monsoon seasons were analyzed for various physico-chemical and bacteriological parameters, heavy metals, pesticides and poly-aromatic hydrocarbons. The hydro-chemical and bacteriological data was analyzed with reference to BIS and WHO standards and hydro-chemical facies were determined. The quality of the groundwater varies from place to place with the depth of water table. The groundwater quality has indicated higher concentration of electrical conductivity, total dissolved solids, alkalinity, hardness, calcium, magnesium, chloride, sulphate, fluoride, iron, manganese, nickel, lead and cadmium vis-à-vis drinking water quality standards. Pesticides analysis indicated the presence of Aldrin, α-BHC, β-BHC and γ-BHC in groundwater of the metropolitan city. The presence of these pesticides in groundwater may be attributed to their use in agricultural activities and for vector control programmes. No organo-phosphorous pesticides and poly-nuclear aromatic hydrocarbons were detected in any of the groundwater samples of the metropolitan city. The range of each parameter along with observations/comments on groundwater quality is presented in Table 7 of Annexure I. An attempt has also been made to show TDS and Nitrate distribution in Madurai Metropolitan city during pre and post Monsoon season (Figure 17 & 18).

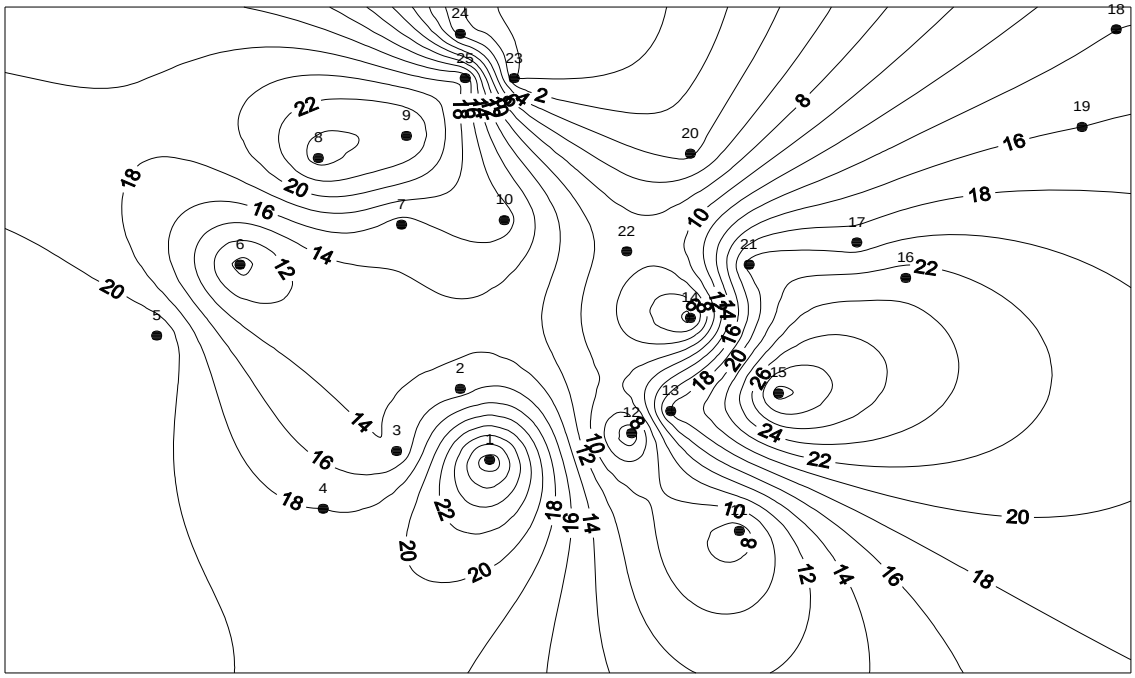


TDS distribution in ground water of Metropolitan City - Madurai (Pre-monsoon 2003)

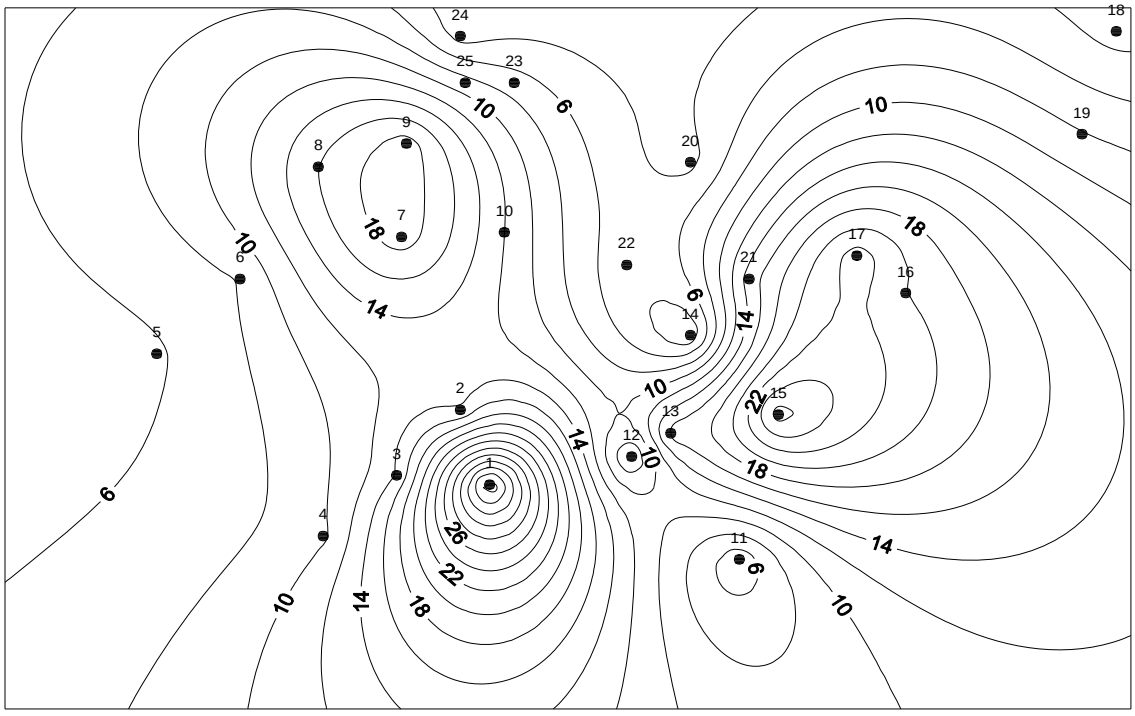


TDS distribution in ground water of Metropolitan City - Madurai (Post-monsoon 2003)

Figure 17: TDS distribution (pre and post monsoon) in Metropolitan city of Madurai



Nitrate distribution in ground water of Metropolitan City - Madurai (Pre-monsoon 2003)



Nitrate distribution in ground water of Metropolitan City - Madurai (Post-monsoon 2003)

Figure 18: Nitrate distribution (pre and post monsoon) in Metropolitan city of Madurai

3.9 Vijaywada Metropolitan City

3.9.1 Environmental Profile of Vijaywada

Topography: The metropolitan city of Vijayawada is one of the important towns of the Andhra Pradesh and is located on the banks of the holy river Krishna. The metropolitan city occupies an area of about 73 km^2 and is located at $16^o31'$ N latitude and $80^o39'$ E longitude. Endowed with a rich variety of soil, the delta area in Krishna District occupied an important place in agricultural production. The Kondapalli hills near Vijayawada and the Jammalavaidurgam hill near Konduru are the two prominent hill ranges around Vijaywada. A city map of Vijaywada metropolitan has been shown in Figure 19.

Population: It is the 34^{th} largest town in India (population wise), and the 3^{rd} largest town in Andhra Pradesh. The population pressure on the city is ever growing. As per 2001 census, the population of metropolitan city Vijayawada is 10,11,152.

Climate: The climate of the City can be classified as tropical with extreme hot summer and cold winter. The normal rainfall of the district is 1028 mm. of which two-third is received during southwest monsoon. The amount of rainfall generally increases from west to east. Of the total rainfall, the southwest monsoon contributes 63% and the northeast monsoon contributes 28%. The southwest monsoon commences from June and end in September and the northeast monsoon period is from October to December. The rainfall in summer is of cyclonic nature with gales. The average maximum and minimum temperatures recorded are 32.3^OC and 23.8°C respectively. The average annual evaporation is 1732 mm. The average relative humidity in the city ranges from 65 to 86% and the lowest humidity of 45% is registered in summer season.

Geology and Soil type: The area has varied lithological formations ranging in age from Archaean crystallines to recent alluvium. Depending upon the occurrence of these rock formations the area can be divided into three lithological provinces. i) The north and western part occupied by crystalline group of rocks comprising of Khondalites, Peninsular gneisses, Dharwars and Proterozoic group of rocks, ii) North-eastern and central part occupied by Sandstones of Gondwana group and iii) Eastern and southern part occupied by River and Coastal Alluvia. There are four types of soils in the area, viz., Black cotton soils (57.6%), Sandy clay loams (22.3%), Red loamy soils (19.4%), and Sandy soils (0.7%). The sandy soils form a fringe along the coast. The black cotton soil is most extensive and occurs in Western part. The sandy clay loams formed along river.

Groundwater: The groundwater occurs under water table to semi-confined conditions in the weathered/fractured zones of Khondalites and sand zones of Alluvium. Its movement is governed by porosity and permeability of the formation. The productivity of the aquifers in Alluvium is directly proportional to the thickness of sand bed and grain size of sand. The tapping of groundwater is being done through filter points and ring wells in Alluvium and open wells/bore wells in Khondalites. The filter points are constructed down to a depth of 10 to 40 m and bore wells to a depth of 40 to 70 m. The yields range from 300 to 1000 lpm for filter points and 100 to 200 lpm for bore wells. Most of the wells are used for domestic purpose due to

urbanization. Ring wells are excavated down to a depth of 3 to 4 m in alluvium and used for domestic purpose.

Waster supply & wastewater generation: The drinking water supply for Vijaywada city is drawn mainly from Krishna River, though groundwater is available in plenty in shallow depths. People are dependent on Krishna River water for drinking due to its sweetness and holiness as well as its freshness. Though River Krishna meets the demands of the people of Vijaywada city, the Municipal Corporation is supplying groundwater as well in some areas of the city, due to the economic constraints in laying pipelines and supplying to far places. Accordingly, the total water supply to the city by Municipal Corporation is 177 mld, out of which 132 mld is drawn from Krishna River and the remaining 45 mld is fulfilled by the groundwater. The City is having a total number of 32 overhead tanks maintained by Vijaywada Municipal Corporation. Prakasam Barrage of length 4,014 feet existing on River Krishna at Vijaywada and meeting all the demands of the delta. Three canals are diverted from Prakasam barrage, namely, Ryves canal, Eluru canal running through middle of the city and Bundar canal flowing parallel to Krishna river in the south of Vijayawada. Besides the mighty River Krishna, another river named Budameru is also passing through the city parallel to Eluru canal. As there is no much flow in this river, it is presently acting as a drain rather than river and finally joining the famous Kolleru Lake in Kaikaluru.

Wastewater generation and treatment: The wastewater produced is around 160 mld. The wastewater is drained by underground draining system in the middle of the city and open draining system in the western side of the city. The major sewage treatment plant (STP) is located at Ajit Singh Nagar in the outskirts of the city and treating nearly 27 million litres per day. Two more sewage treatment plants are under progress at Autonagar and Ramalingeswara nagar. The treated wastewater is used for fodder cultivation in nearby fields and the excess water is let into the Budameru drain or into the downstream of the canals. The major drains in the city are Gundutippa drain, Islampeta drain, and HB drain.

Municipal Solid Waste: The average solid waste generated in the city is 550 tons/day. Vijaywada Municipal Corporation setting an example of generating Wealth from Waste is also using the solid waste properly. The solid waste is being supplied to M/s Excel Industries Pvt. Ltd., Ajitsingh Nagar. The Excel industries is using 150 tons of waste per day by converting the solid waste into manure, called CELRICH, which is a bio-organic soil enricher, thus creating a clean environment to Vijaywada city and a hygienic product to the Plants. M/s Sri uses another 400 tonnes of waste for generating 6 MW power. Ram Energy Systems, which is also adjacent to Excel Industries at Ajit Singh Nagar. The Municipality is also having a Railway dumping yard at Milk project area for waste dumping. Thus, Vijayawada Municipal Corporation has set up an example in utilizing the wastewater and solid waste by proper disposal and utilization.

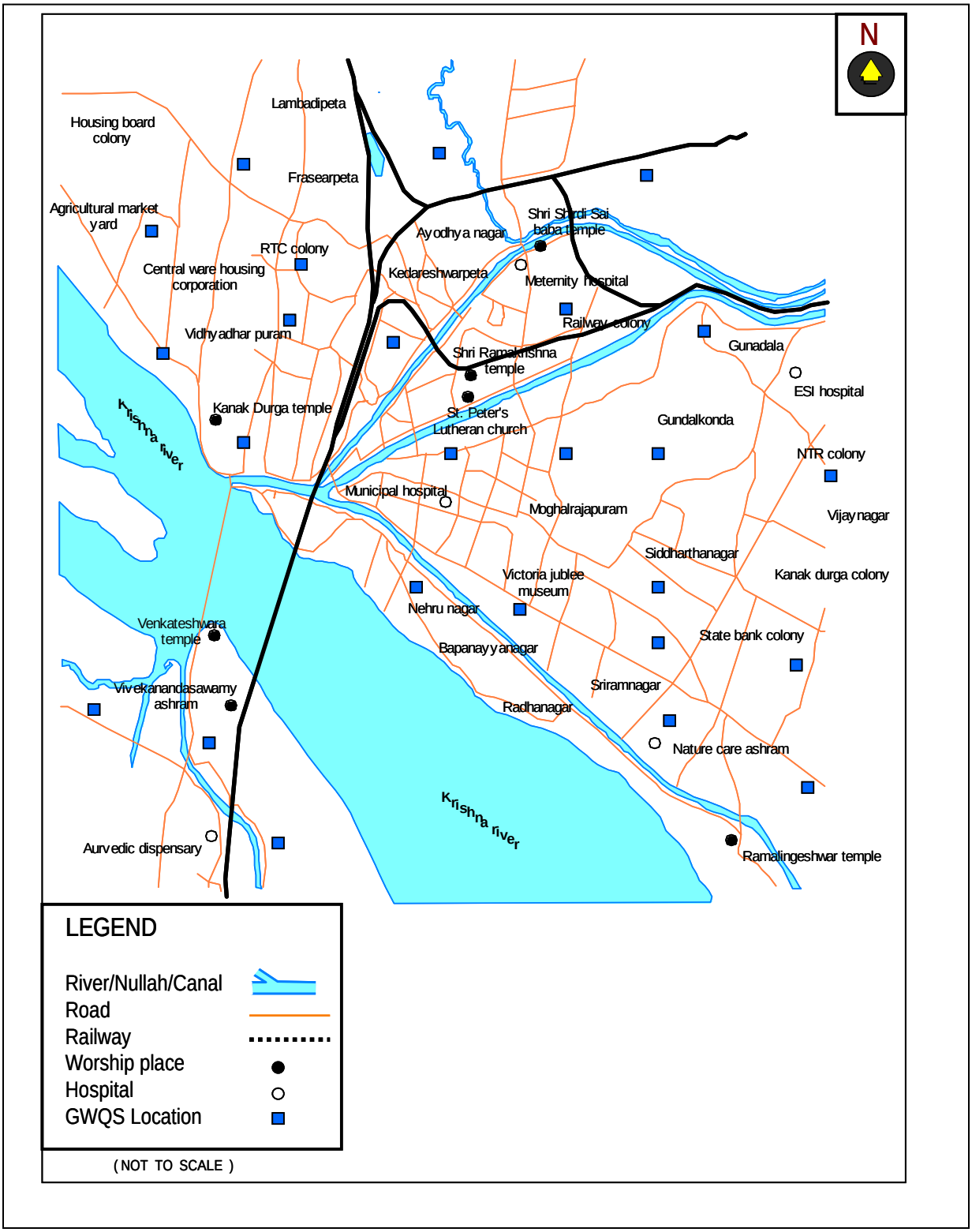


Figure 19: Map of Vijaiwada Metropolitan City

Industries: The metropolitan city of Vijaywada is has number of small and big industries. The most common industries existing in the metropolitan city include rice mills, edible oil,

beverages, tobacco products, cotton textiles, wood and wood products, paper and paper products, leather, rubber, plastic products, motor vehicle spare parts, utensils, scientific instruments, dall and flour mills, chemicals, pharmaceuticals, oil refinery of used motor oils, brawn oil companies, ayurvedic medicines, pickle companies, etc. Most of the industries are located in Industrial estate and Autonagar areas. Milk processing is also a major industry in the city supplying milk in most parts of the district. The NTPC, which is producing thermal electricity, is also just 15 km from Vijayawada city. There are no petroleum storage tanks in the city. The petroleum storage tanks are located at Kondapalli village, which is 25 km away from Vijayawada city. As such, there is no pollution of petroleum leakages in the city area. In the Autonagar area, it is reported that the water is oily, as the automobile servicing units are concentrated in this area and polluting the groundwater with the waste oils.

3.9.2 Groundwater Quality Survey in Vijaywada city

Groundwater samples from the metropolitan city of Vijaywada were collected each during pre-monsoon (June 2003) and post-monsoon (December 2003) seasons from various abstraction sources at various depths covering extensively populated area, commercial, industrial, agricultural and residential colonies so as to obtain a good aerial and vertical representation The details of sampling locations and source and depth wise distribution are given in Table 14.

Table 14: Description of groundwater sampling locations in Metropolitan City - Vijaywada

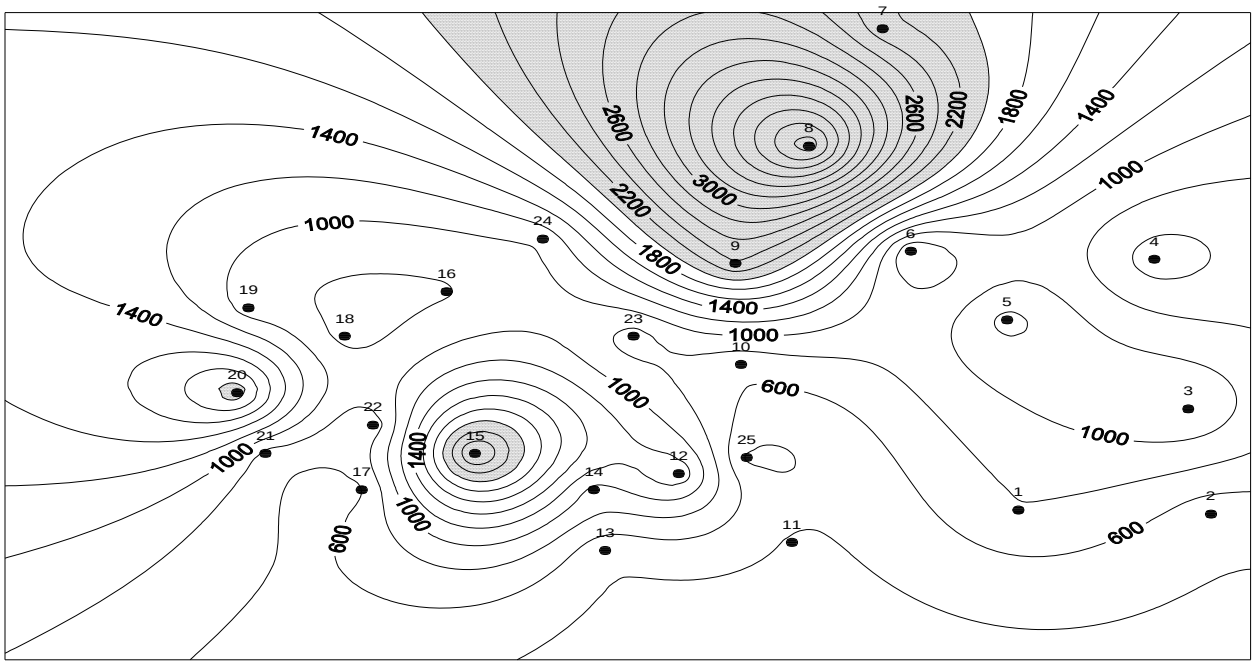
Sl. No.	Location	Identification	Source	Depth, m	Water Use	Land Use/ Specific Activity
1	Benz circle	Opp. Nirmala Convent	HP	36	Drinking	Urban
2	Ashok Nagar Ind. Estate	Opp. Velagapudi Cold Storage	HP	27	Drinking	Industrial Area
3	Auto Nagar	Opp. India Radiators	HP	48	Drinking	Automobile Servicing Area
4	Goldsport Junction	Sri. Lakshmi Rice Store	HP	12	Drinking	Urban
5	Gunadala	Opp. ESI Hospital	HP	10	Drinking	Urban
6	Karmel Nagar	Deepa Nivas	HP	9	Drinking	Agricultural
7	Khandrika	Khandrika Bus Stop Centre	HP	30	Drinking	Urban
8	Payakapuram	Sri. Manasa Fast Foods	HP	21	Drinking	Urban
9	Ajit Singh Nagar	Rajasri Bar and Restaurant	HP	24	Drinking	Urban
10	Satyanarayana Puram	D.No. 23-16-27	OW	5	Drinking	Urban
11	Krishna Lanka	D.No. 41-1/6-2	HP	15	Drinking	Urban
12	Governor Peta	Hotal Paradise	HP	9	Drinking	Urban

13	Krishna Lanka	Opp. Central Bus Stand	HP	27	Drinking	Urban
14	Hanuman Peta	Near Govt. General Hospital	HP	30	Drinking	Urban
15	Kotha Peta	Near St. Ani Public School	HP	18	Drinking	Urban
16	Bheemannavari Peta	Sri. Ganganamma Devi Temple	HP	18	Drinking	Urban
17	Vidhyadhara Puram	Near RTC Workshop	HP	38	Drinking	Urban
18	Jogi Nagar	Near Church	HP	45	Drinking	Urban
19	Urmila Subba Rao Nagar	D.No. 76-17-161	HP	30	Drinking	Urban
20	Bhavanipuram	HIG-H1-70	HP	45	Drinking	Urban
21	Hyderabad Highway	NH-9 & HB Colony Junction	HP	45	Drinking	Urban
22	Vidhyadhara Puram	Anita Apartments	HP	30	Drinking	Urban
23	Ayodya Nagar Junction	Opp. Raghavendra Theatre	HP	7	Drinking	Cement Industry
24	Rajarajeswari Peta	Opp. Habeeb E. Medium School	HP	30	Drinking	Urban
25	Governor Peta	Near Surya Hotal	HP	16	Drinking	Urban

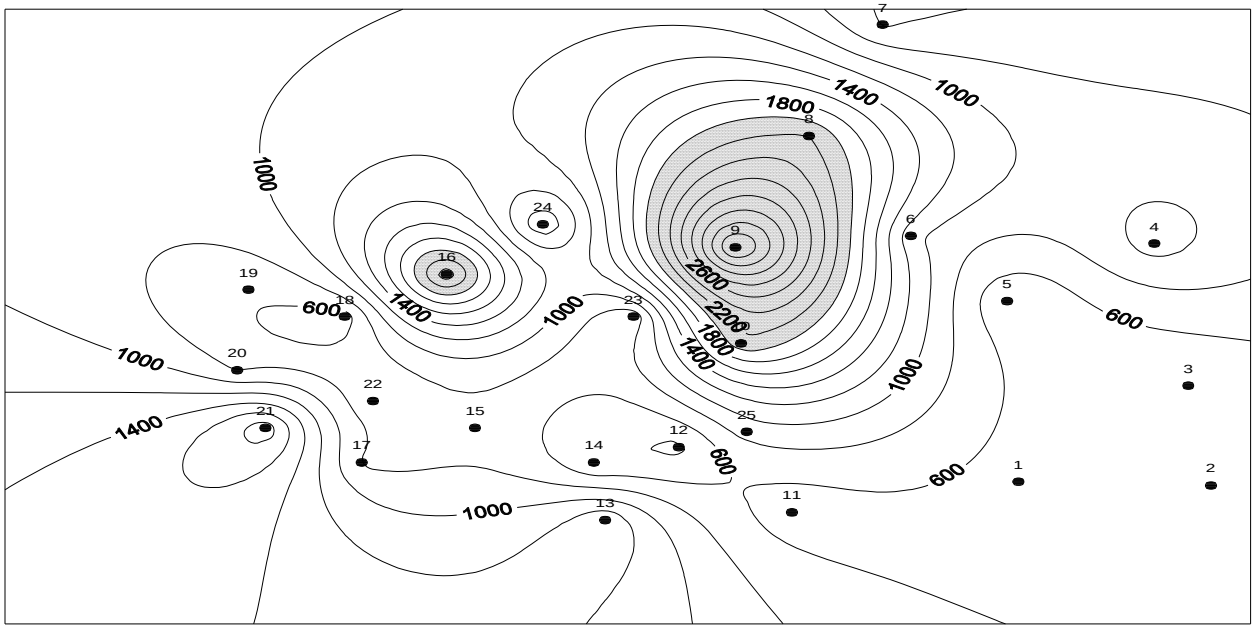
Note: HP – Hand Pump; OW - Open Well; BW- Bore well; TW- Tube well

3.9.3 Observations on status of Groundwater Quality in Vijaywada city

The groundwater quality of the Metropolitan City of Vijaywada has been assessed to see the suitability of groundwater for domestic applications. The samples collected during pre- and post-monsoon seasons were analyzed for various physico-chemical and bacteriological parameters, heavy metals, pesticides and poly-aromatic hydrocarbons. The hydro-chemical and bacteriological data was analyzed with reference to BIS and WHO standards and hydro-chemical facies were determined and water types identified. The quality of the groundwater varies from place to place with the depth of water table. The groundwater quality has indicated higher concentration of electrical conductivity, total dissolved solids, alkalinity, hardness, calcium, chloride, fluoride, iron, manganese, nickel, lead and cadmium vis-à-vis drinking water quality standards. The range of each parameter along with observations/comments on groundwater quality is presented in Table 8 of Annexure I. Pesticides analysis indicated the presence of Aldrin, DDD, DDE, α-BHC, β-BHC, γ-BHC, Endosulphan and Methoxychlor in groundwater of the metropolitan city. The presence of these pesticides in groundwater may be attributed to their use in agricultural activities and for vector control programmes. No organo-phosphorous pesticides and poly-nuclear aromatic hydrocarbons were detected in any of the groundwater samples of the metropolitan city. An attempt has also been made to show TDS and Nitrate distribution in Vijaiwada Metropolitan city during pre and post Monsoon season (Figure 20 & 21).

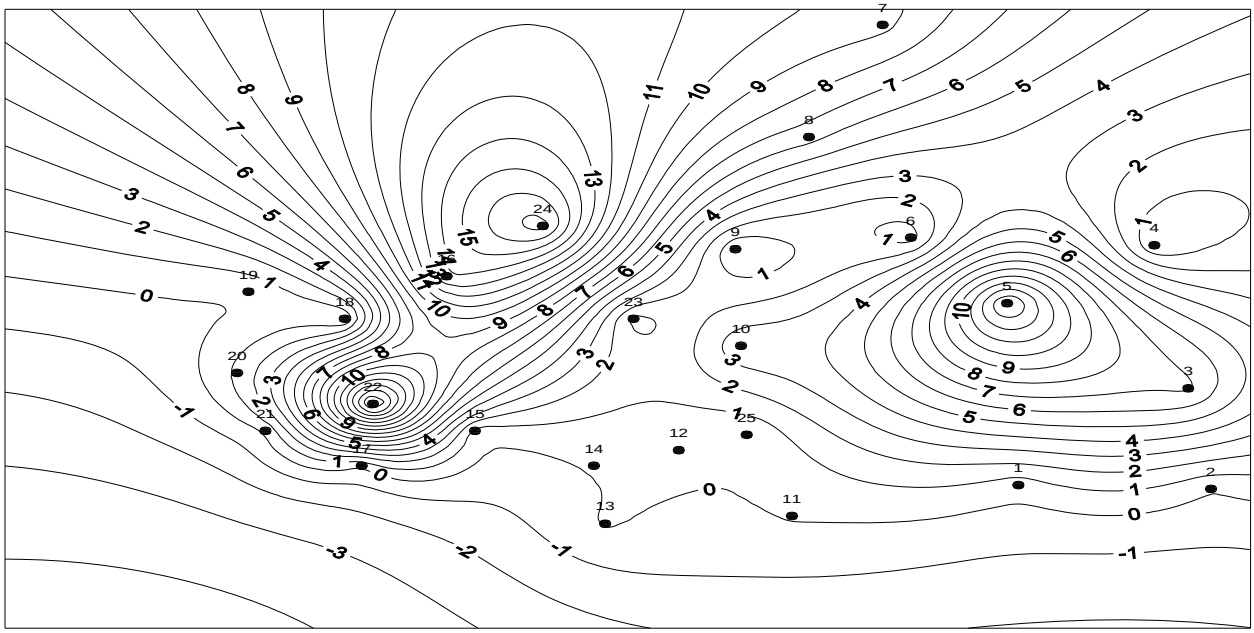


TDS distribution in ground water of Metropolitan City - Vijaywada (Pre-monsoon 2003)

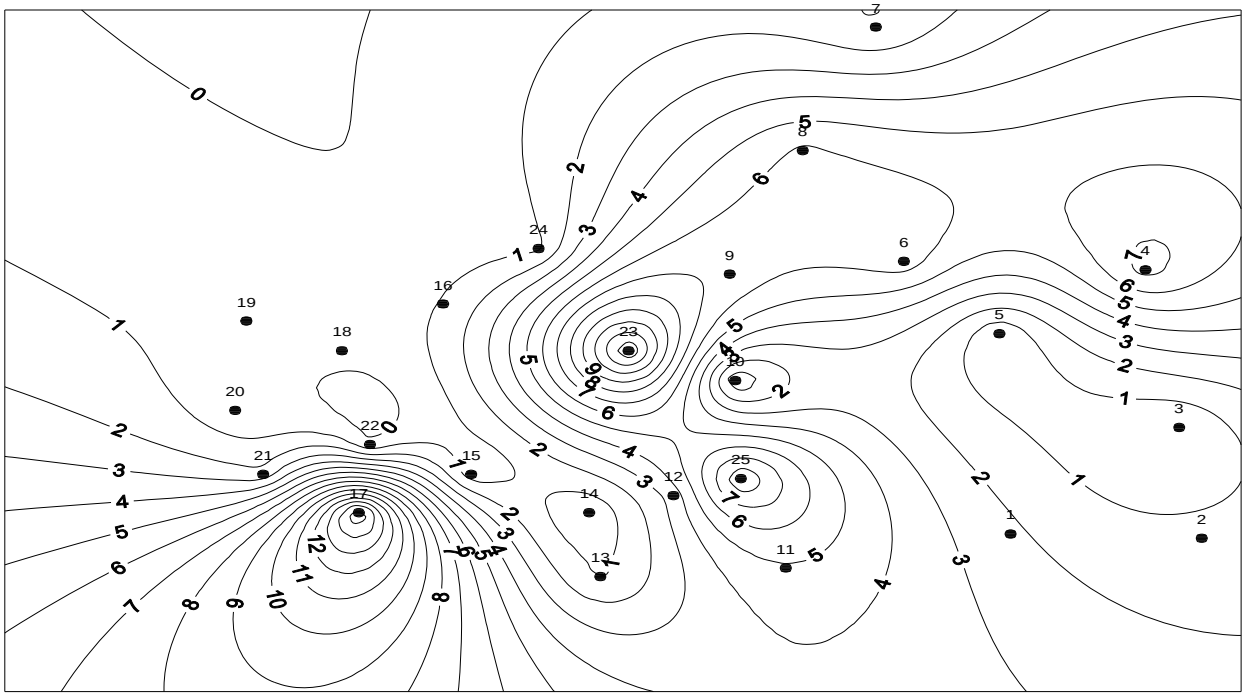


TDS distribution in ground water of Metropolitan City - Vijaywada (Post-monsoon 2003)

Figure 20: TDS distribution (pre and post monsoon) in Metropolitan city of Vijaiwada



Nitrate distribution in ground water of Metropolitan City - Vijaywada (Pre-monsoon 2003)



Nitrate distribution in ground water of Metropolitan City - Vijaywada (Post-monsoon 2003)

Figure 21: Nitrate distribution (pre and post monsoon) in Metropolitan city of Vijaiwada

3.10 Groundwater Quality Compliance/Violation against Drinking Water Standards (DWS) with respect to Critical Parameters

Groundwater quality with respect to critical chemical parameters such as Chloride, Total dissolved solids (TDS), Nitrate-N, Fluoride, Total and Faecal Coliforms and critical heavy (Toxic) metals are presented and summarized. Groundwater quality of these critical parameters, their minimum, maximum ranges are presented in the Figures 22 to 27. Similarly, compliance against drinking water standards of these six parameters are presented in Figure 28 to 33. Groundwater quality with respect to critical heavy metals such as Iron, Chromium, Copper, Manganese and Zinc and their Compliance/violation against drinking water standards in both the seasons are also presented in Figures 34 to 38. The percent compliance exercise includes analysis of total 50 samples in both the seasons at same locations in each metropolitan city. Compliance/

As revealed from the figures (22 to 27), the maximum range of chloride concentration in groundwater is indicating above the 1000 mg/L (Log value) in Chennai Metropolitan city followed by Vijaiwada, Madurai, Coimbatore, and then Agra. Similarly, Total Dissolved Solids indicating very high range (Maximum) in Chennai followed by Vijaiwada, Coimbatore, Madurai and Agra. The Nitrate concentration (log value) revealed that the three metropolitan cities such as Agra, Coimbatore and Meerut indicating above the permissible limit whereas remaining cities such as Lucknow, Ludhiana, Vijaivada, Chennai, and Madurai indicating below the permissible limit. The concentration of Fluoride (Log value) indicated that Agra followed by Vijaivada, Chennai, Madurai and Coimabotore metropolitan cities shown above the permissible limit of drinking water whereas remaining three cities were found within the permissible limit. The Coliform group bacteria did not show any contamination except Lucknow and Meerut Metropolitan cities.

As clear from the Figure 28 that Chloride percent compliance/violation against drinking water standards (BIS/WHO) indicating 18% in Coimbatore city followed by Agra (8%), Chennai (6%), and Lucknow – Vijaiwada (each 4%) whereas Cities like Meerut and Ludhiana did not showed any violation against drinking water standards and indicating chloride concentration within the desirable limit of drinking water standards. As revealed from the Figure 29, the TDS percent Compliance/violation against drinking water standards in eight metropolitan cities indicating highest in Agra (36%) followed by Coimbatore (32%), Chennai (22%), Vijaiwada (18%), and Madurai (10%). The remaining three metropolitan cities (Meerut, Lucknow, Ludhiana) did not indicate any violation with respect to total dissolved solids. Figure 30 revealed that Nitrate violation against drinking water standards only in three metropolitan cities. Agra showed highest (54%), followed by Coimbatore (28%), and then Meerut (14%). The remaining five metros did not indicate any violation. The Fluoride percent compliance/violation against drinking water standards clearly indicated (Figure 31) that Agra is having highest (34%), followed by Chennai (14%), then Madurai and Vijaiwada (each 8%)and then Coimbatore and Meerut (each 4%) while Lucknow and Ludhiana did not show any percent violations. Figure 32 clearly indicates that there is no violation of Total Coliform against drinking water standards except Lucknow (20%), Agra (8%), and Meerut, Chennai (each 2%) while remaining four cities did not indicate any violation. Similarly, Figure 33 indicates that percent violation of Faecal Coliform against drinking water standards only in two Metropolitan cities i.e. Lucknow (28%) and Agra (6%).

Percent compliance against drinking water standards with respect to heavy metals were presented in Figures 34 to 38. It is revealed from the Figure 34 that Iron (Fe) indicates compliance/violations in almost seven metros except Ludhiana. The highest violation was found in Agra (74%) followed by Chennai (32%), Meerut (30%), Vijaiwada (12%), Lucknow (10%), Madurai (4%) and Coimbatore (2%). Percent compliance violation of Copper indicated in Figure 35 indicated Copper concentrations within the permissible limit of drinking water standards in all eight cities. Chromium indicated (Figure 36) compliance/violation in Coimbatore city (4%), while remaining seven cities indicated permissible limit. The Manganese compliance/violation, as revealed from the Figure 37 indicated that out of seven cities attempted, five were violated. The highest violation was found in Chennai Metropolitan (42%) followed by Madurai (16%), Vijaiwada (12%), Agra and Lucknow (each 10%), and Meerut (8%). As clear from the Figure 40, Zinc did not show any violation in any of the Metropolitan city.

Figure 22: Groundwater Quality – Chloride on log scale (Min.-Max. & Average) in Eight Metropolitan cities

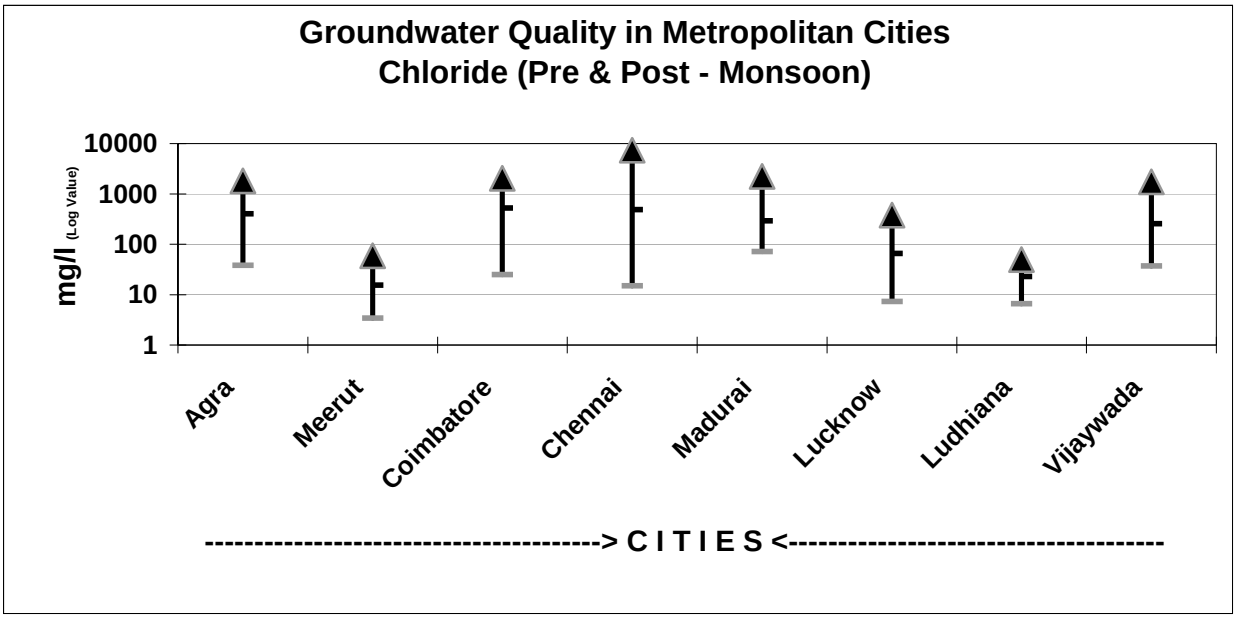


Figure 23: Groundwater Quality – TDS on log scale (Min.-Max. & Average) in Eight Metropolitan cities

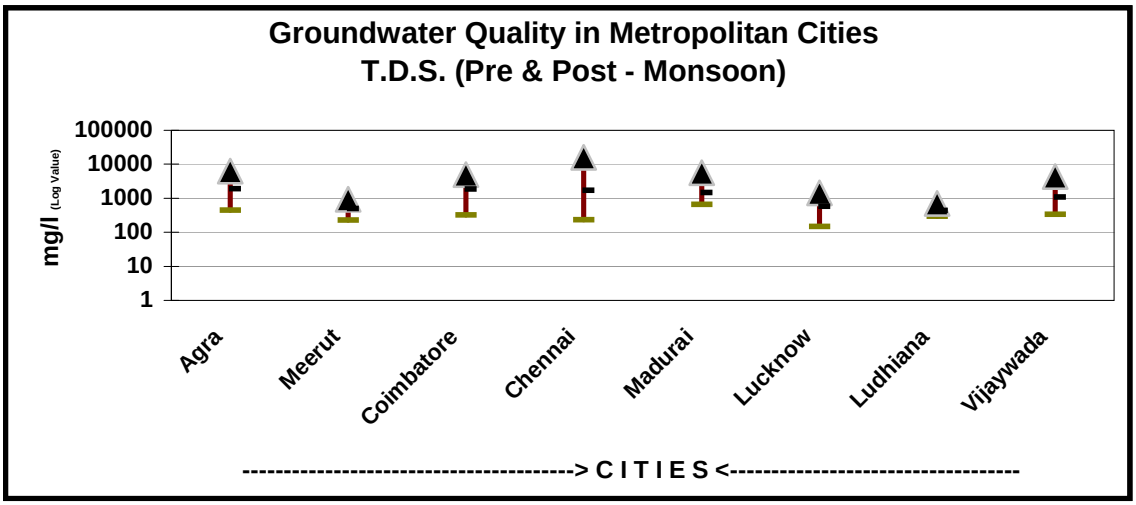


Figure 24: Groundwater Quality – Nitrate on log scale (Min.-Max. & Average) in Eight Metropolitan cities

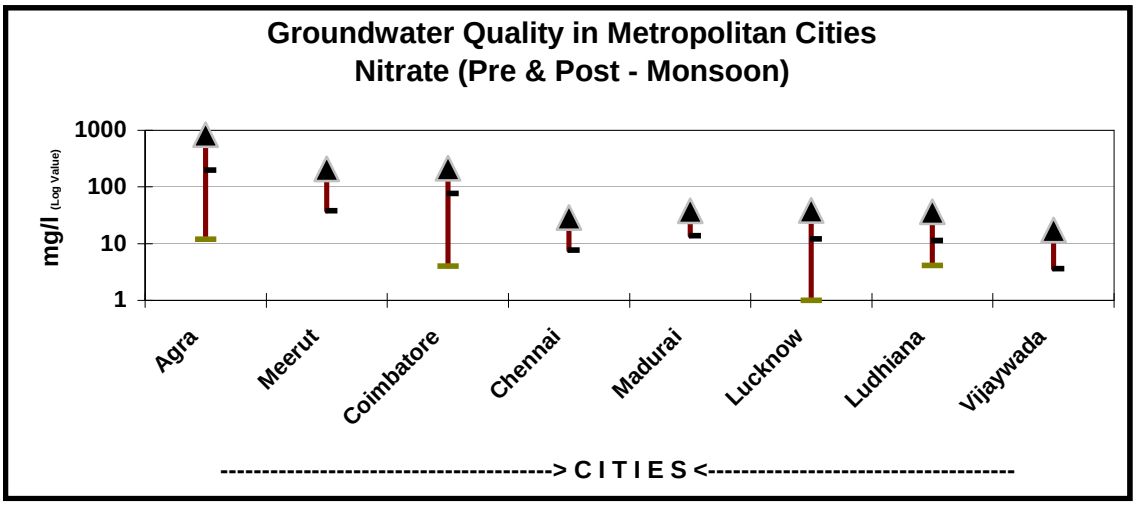


Figure 25: Groundwater Quality – Fluoride on log scale (Min.-Max. & Average) in Eight Metropolitan cities

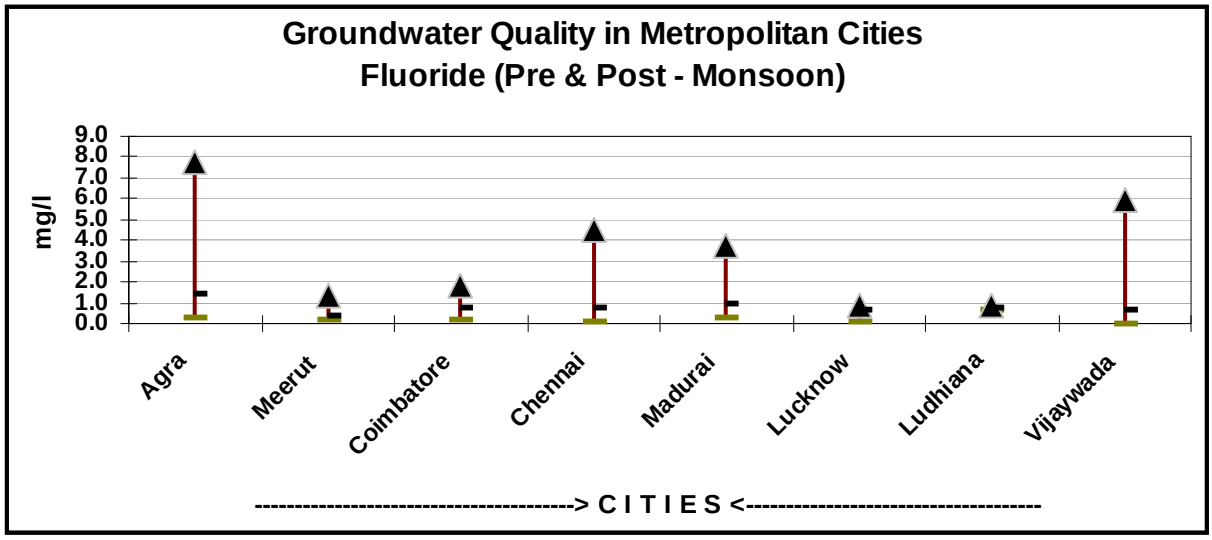


Figure 26: Groundwater Quality – Total Coliform on log scale (Min.-Max. & Average) in Eight Metropolitan cities

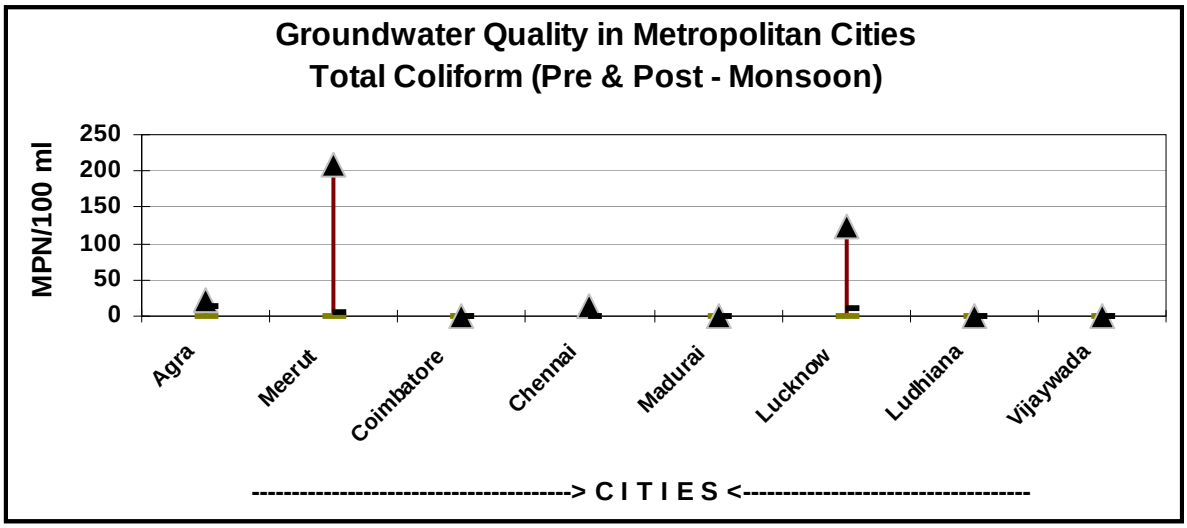


Figure 27: Groundwater Quality – Faecal Coliform on log scale (Min.-Max. & Average) in Eight Metropolitan cities

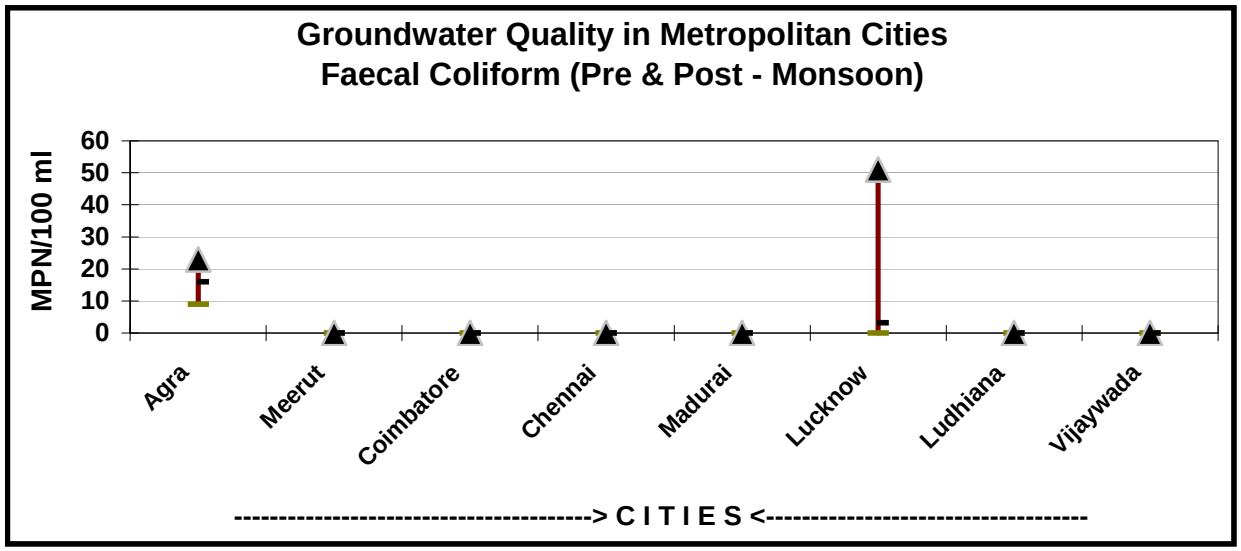


Figure 28: Percentage of samples complying Drinking Water Standards (DWS-IS:10500) in Eight Metropolitan cities

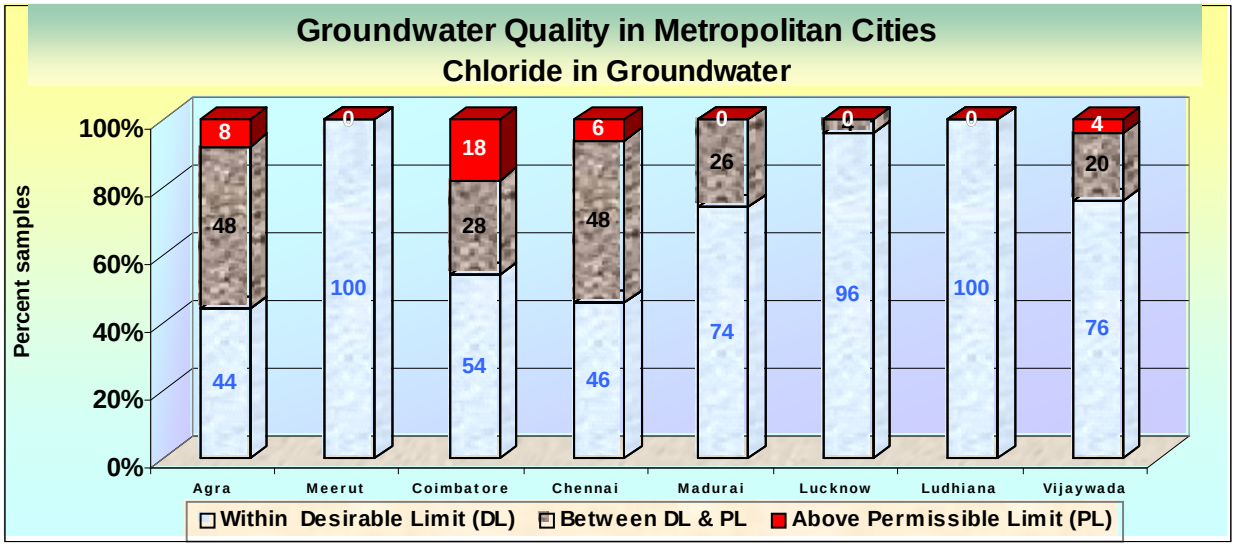


Figure 29: Percentage of samples complying Drinking Water Standards (DWS-IS:10500) in Eight Metropolitan cities

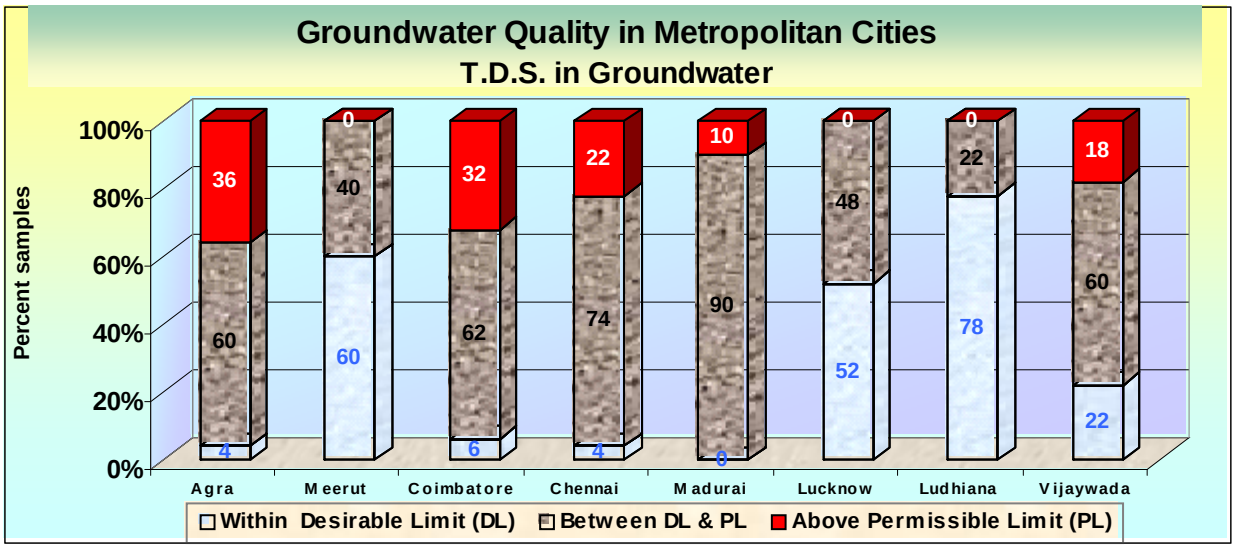


Figure 30: Percentage of samples complying Drinking Water Standards (DWS-IS:10500) in Eight Metropolitan cities

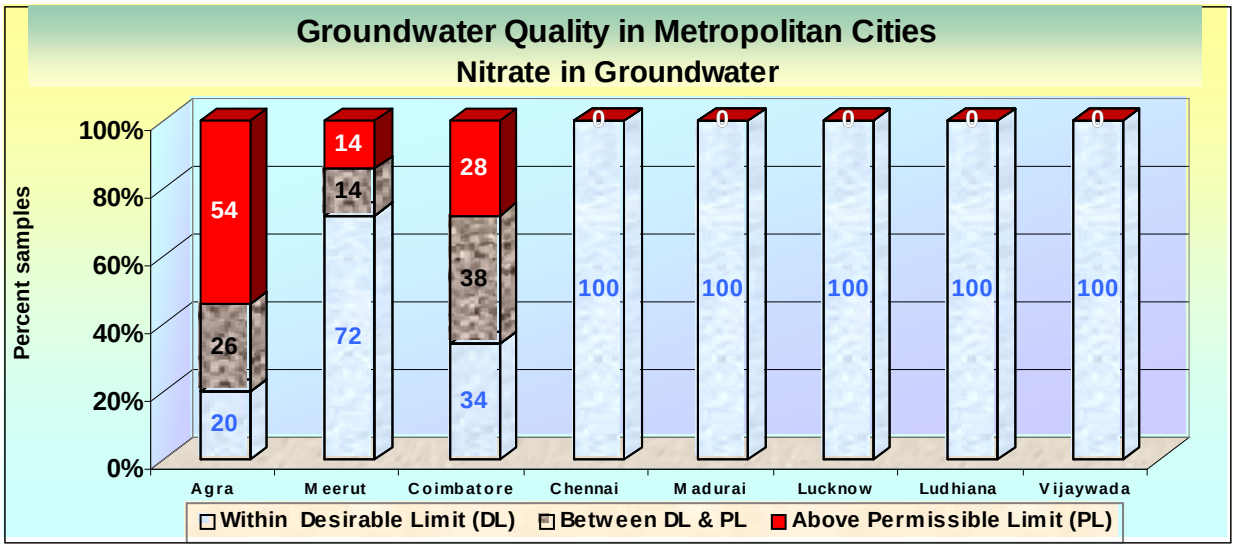


Figure 31: Percentage of samples complying Drinking Water Standards (DWS-IS:10500) in Eight Metropolitan cities

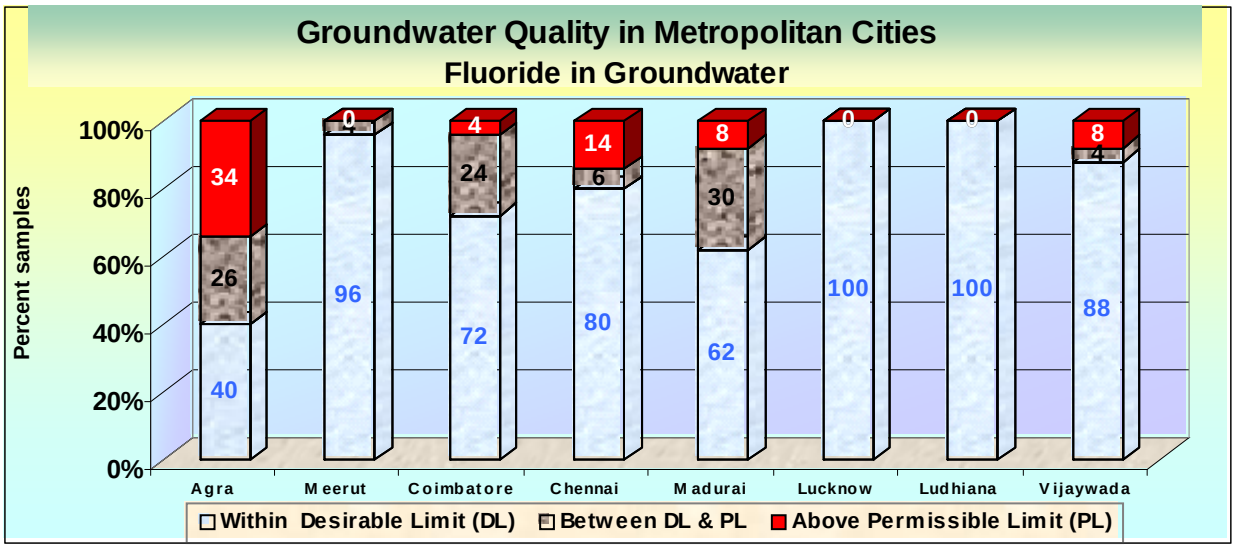


Figure 32: Percentage of samples complying Drinking Water Standards (DWS-IS:10500) in Eight Metropolitan cities

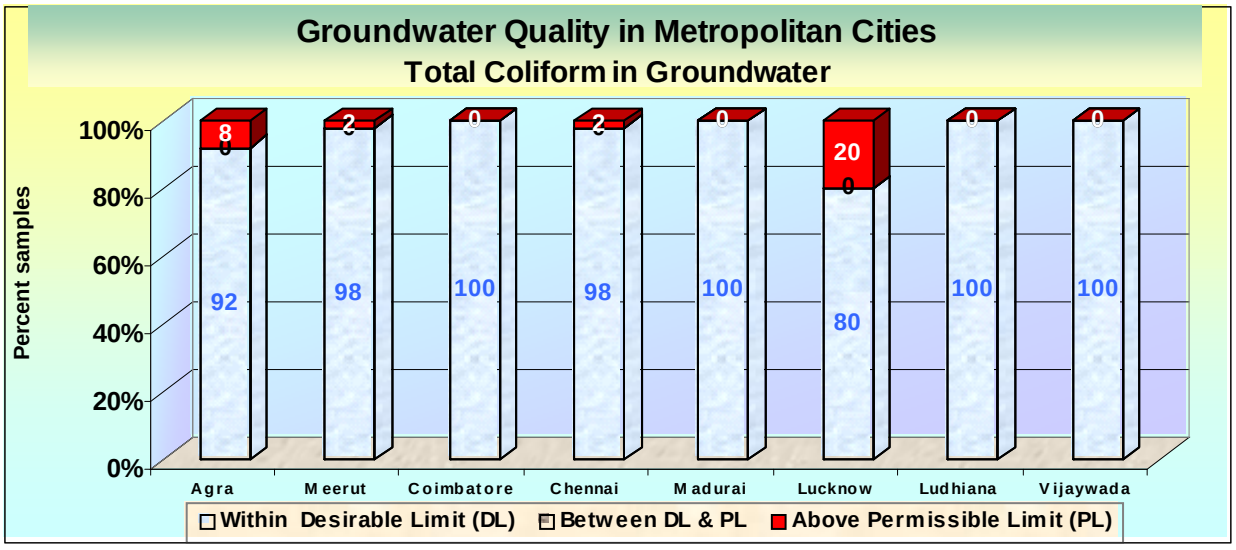


Figure 33: Percentage of samples complying Drinking Water Standards (DWS-IS:10500) in Eight Metropolitan cities

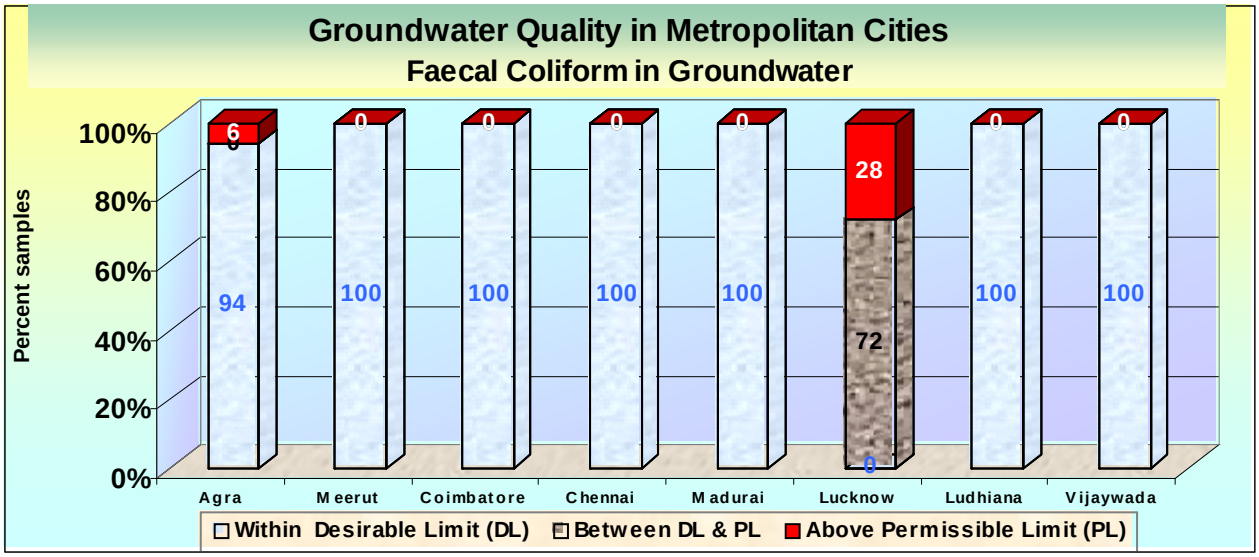


Figure 34: Percentage of samples complying Drinking Water Standards (DWS-IS:10500) in Eight Metropolitan cities

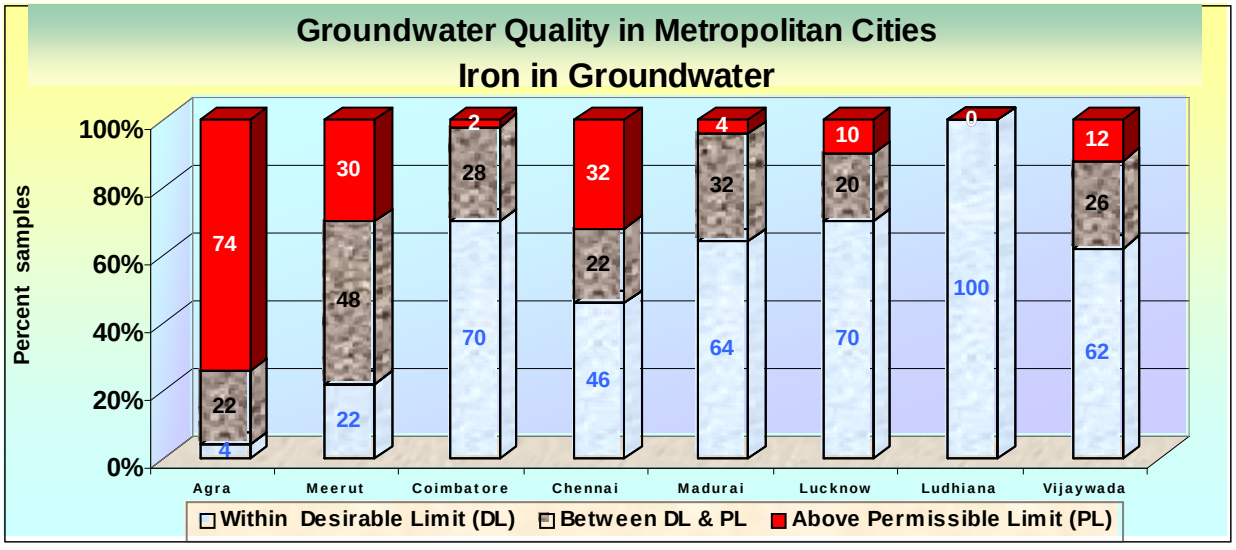


Figure 35: Percentage of samples complying Drinking Water Standards (DWS-IS:10500) in Eight Metropolitan cities

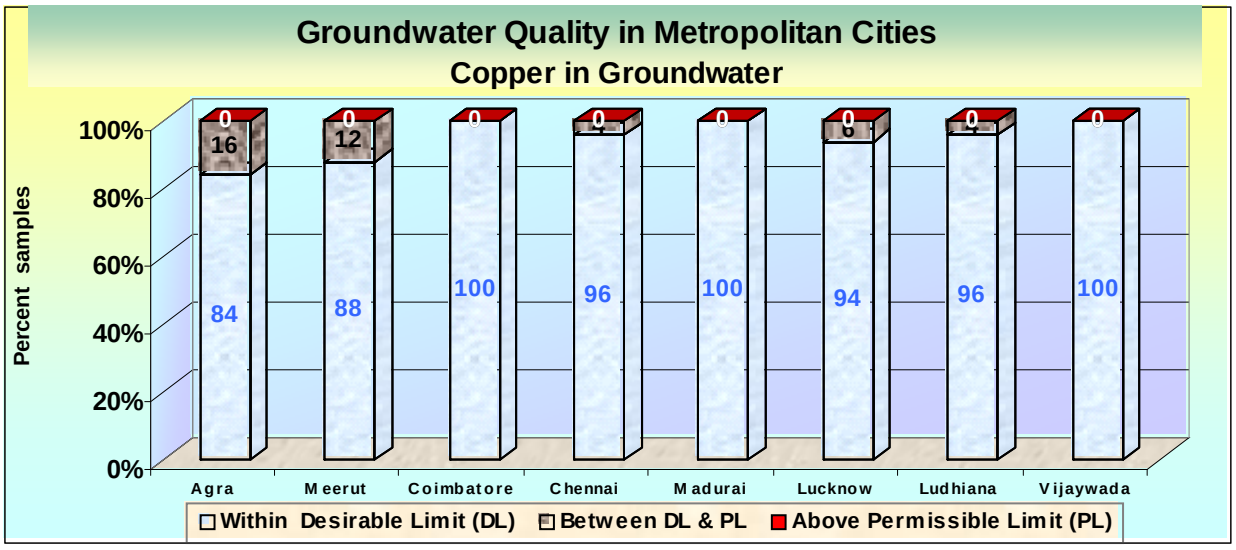


Figure 36: Percentage of samples complying Drinking Water Standards (DWS-IS:10500) in Eight Metropolitan cities

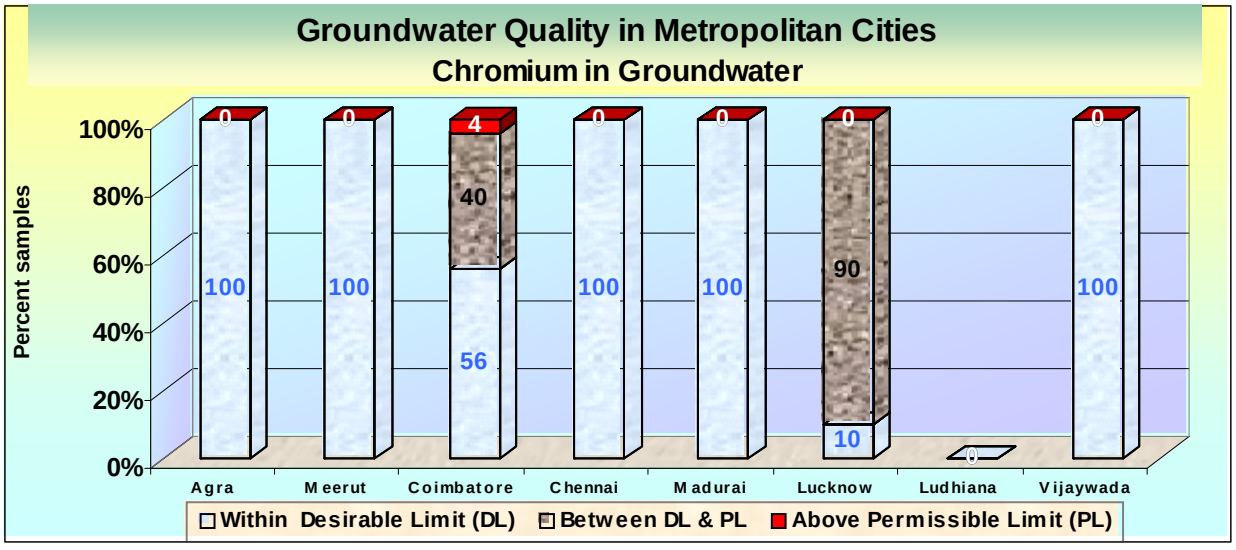


Figure 37: Percentage of samples complying Drinking Water Standards (DWS-IS:10500) in Eight Metropolitan cities

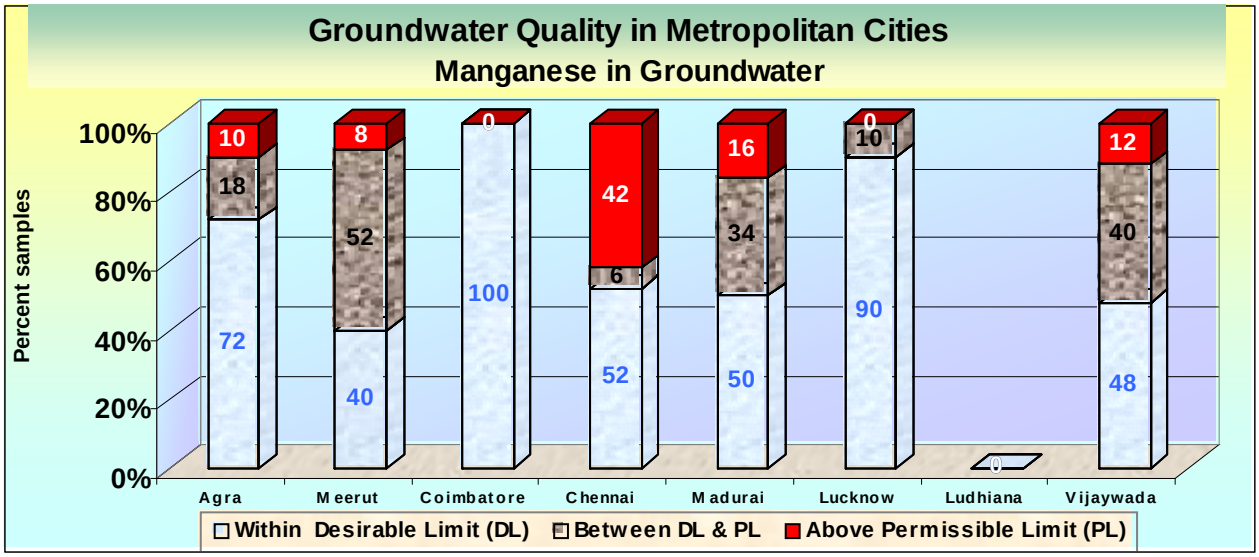
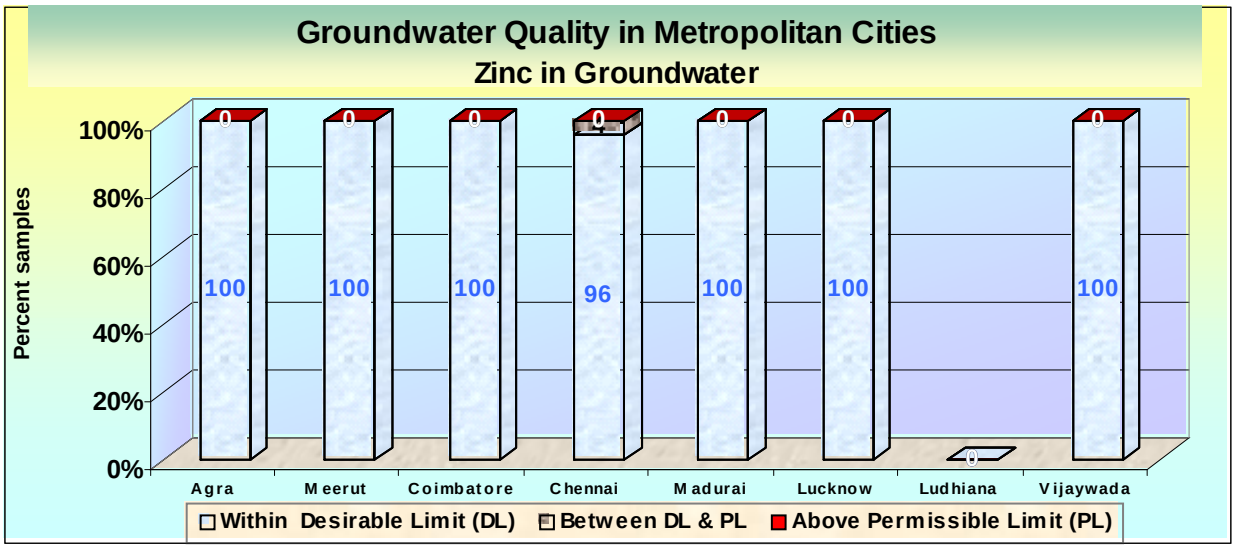


Figure 38: Percentage of samples complying Drinking Water Standards (DWS-IS:10500) in Eight Metropolitan cities



3.11 A summary of the Groundwater quality problems in eight metropolitan cities is given in Table 15.

Table15: Groundwater Quality problems in Metropolitan cities

Sl. No.	Name of the Metro city	Major Anthropogenic and Industrial Activities	Groundwater Quality Problem*
1.	Agra, U.P.	Un-collected domestic sewage (about 200 mld) either on open land or flowing through drains to receiving system. The municipal solid waste generation is about 654 T/D. The industrial activity includes Textiles, Hosiery items, Woolen, Jute, Footwear, Leather, Metal processing, Machinery parts, Marble, Food processing, Foundries and Handicrafts etc. Besides this Petroleum storages (IOCL, HPCL and BPCL) existing in the city.	High concentration of nitrate, fluoride, total hardness, chloride, TDS, calcium, Sulphate, potassium, magnesium, conductivity and Coliform organisms, whereas concentration of micro-pollutants such as toxic (heavy) metals Fe, Mn, and Cu were exceeding the permissible limit for drinking water during pre and post-monsoon seasons and also pesticides such as α-BHC, Endosulphan and Methoxychlor were detected in some of the samples.
2.	Chennai, T.N.	Un-collected domestic sewage (about 268 mld) either on open land or flowing through drains to receiving system. The municipal solid waste generation is more than 3873 T/D. The industrial activity includes Hides & Skins, Tobacco, food grains, Iron and steels, Fertilizers, Paper, Chemicals, Sugar, Bone metals and Granites etc. Besides this Petroleum storages (IOCL, HPCL and BPCL) existing in the city.	High concentration of chloride, TDS, conductivity, Bicarbonate alkalinity, Sulphate, fluoride, calcium (pre-monsoon), total hardness and sodium, whereas concentration of micro-pollutants such as heavy metals Fe and Mn, were exceeding the permissible limit during both the seasons and also pesticides such as Aldrin, α-BHC, δ-BHC and Endosulphan were also detected in some of the samples.
3.	Coimbatore, T.N.	Un-collected domestic sewage (about 140 mld) either on open land or flowing through drains to receiving system. The municipal solid waste generation is about 800 T/D. The industrial activity includes Textile, Foundries, Motor Pumps, Water tanks, Steel furniture's, Electric and Electrical appliances, Automobile components, Washing machines, Wet grinders, General Engineering industries, Food processing units and Printing machineries etc. Besides this Petroleum storages (IOCL, HPCL and BPCL) existing in the city.	High concentration of TDS, chloride, Sulphate, nitrate, fluoride, calcium and total hardness, whereas the concentration of micro-pollutants such as heavy metals Fe and Cr are exceeding permissible limit for drinking purposes and also pesticides such as α-BHC only was detected in some of the samples.

Sl. No.	Name of the Metro city	Major Anthropogenic and Industrial Activities	Groundwater Quality Problem*
4	Madurai, T.N.	Un-collected domestic sewage (about 80 mld) either on open land or flowing through drains to receiving system. The municipal solid waste generation is more than 459 T/D. The industrial activity includes Textile, mills, Dyeing units, Power looms, Handlooms, Engineering and Mechanical Industries, Steel Rolling mills, Small Scale industries like Food products, Readymade Garments, Wooden industries, Printing, Molding industries etc. Besides this Petroleum storages (IOCL, HPCL and BPCL) existing in the city.	High electrical conductivity, TDS, chloride, Bicarbonate alkalinity, Sulphate and fluoride whereas concentration of micro-pollutants such as heavy metals Cr and Fe at few locations were exceeding the permissible limit during both the seasons and also pesticides such as Aldrin, α-BHC, β-BHC, γ-BHC and δ-BHC were detected in some of the samples.
5.	Meerut, U.P.	Un-collected domestic sewage (about 35 mld) either on open land or flowing through drains to receiving system. The municipal solid waste generation is about 490 T/D. The industrial activity includes Distillery, SSI units such as sports goods, chemicals, food processing, surgical goods, engineering works, petrochemicals, rubber, plastic, leather goods, flour mills and readymade garments Besides this, three petroleum storages (IOCL, HPCL and BPCL) existing in the city.	High concentration of TDS, nitrate, fluoride and alkalinity whereas the concentration of micro-pollutants such as heavy metals Fe and Mn are exceeding permissible limit for drinking purposes and pesticides such as α-BHC only was detected in some of the samples.
6.	Lucknow, U.P.	Un-collected domestic sewage either on open land or flowing through drains to receiving system. The municipal solid waste generation is more than 475 T/D. The industrial activity includes Chemical, Petroleum storage, Pesticides, Electronic Manufacturing Units, and Breweries etc. Besides this, Petroleum storages (IOCL, HPCL and BPCL) existing in the city.	High TDS, conductivity, Potassium, Magnesium, Alkalinity, Total Hardness and Total Coliform.
7.	Ludhiana, Panjab	Un-collected domestic sewage either on open land or flowing through drains to receiving system. The municipal solid waste generation is more than 734 T/D. The industrial activity includes Woolen, Dye, Electroplating, Bicycle, and Textile etc. Besides this Petroleum storages (IOCL, HPCL and BPCL) existing in the city.	High electrical conductivity and high concentration of Potassium, Magnesium was detected in some of the samples.

Sl. No.	Name of the Metro city	Major Anthropogenic and Industrial Activities	Groundwater Quality Problem*
8.	Vijaiwada, A.P.	Un-collected domestic sewage (about 160 mld) either on open land or flowing through drains to receiving system. The municipal solid waste generation is about 550 T/D. The industrial activity includes Rice mills, Edible Oils, Beverages, Tobacco, Cotton, Paper, Food Processing, Utensils, Drugs, and Pharmaceuticals, Oil refineries, Motor Vehicle Parts, Wood and wood products, Ayurvedic medicines, Leather products, Rubber Products, Thermal Power plants and Milk and Milk Product processing etc. Besides this Petroleum storages (IOCL, HPCL and BPCL) existing in the city.	High electrical conductivity, TDS, Chloride, Bicarbonate alkalinity, Total Hardness, Potassium, Calcium, Magnesium and fluoride whereas concentration of micro-pollutants such as toxic (heavy) metals Fe, and Mn, were exceeding the permissible limit during both the seasons and also pesticides such as Aldrin, DDE, DDD, α-BHC, β-BHC, γ-BHC, Methoxychlor and Endosulphan were detected in some of the samples.

*=Sampling of Groundwater for Pre & Post Monsoon seasons during 2002-2004

Continued

CHAPTER IV

FINDINGS: PROBLEM AREAS

4.1 Problem Areas Identified by CPCB

Central Pollution Control Board has identified 24 problem areas in the country where industrial and anthropogenic activities are concentrating & cause rigorous environmental degradation. These problem areas are presented in Table 16.

Table 16: Problem Areas Identified by CPCB

Sl. No.	Problem area identified by CPCB	State
1.	Durgapur	West Bengal
2.	Howrah	West Bengal
3.	Dhanbad	Jharkhand
4.	Angul Talcher	Orissa
5.	Singrauli	Uttar Pradesh (U.P.)
6.	Vishakapatnam	Andhra Pradesh (A.P.)
7.	Bolaram-Patancheru	Andhra Pradesh (A.P.)
8.	Bhadravathi	Karnataka
9.	Greater Cochin	Kerala
10.	Manali	Tamilnadu (T.N.)
11.	North Arcot	Tamilnadu (T.N.)
12.	Ankleshwar	Gujarat
13.	Vapi	Gujarat
14.	Chembur	Maharashtra
15.	Tarapur	Maharashtra
16.	Digboi	Assam
17.	Parwanoo	Himachal Pradesh (H.P.)
18.	Kala-Amb	Himachal Pradesh (H.P.)
19.	Mandi Gobindgarh	Punjab
20.	Nagda-Ratlam	Madhya Pradesh (M.P.)
21.	Korba	Chattisgarh
22.	Chembur	Maharashtra
23.	Pali-Jodhpur	Rajasthan
24.	Drain Basin Area, Najafgarh	Delhi

Looking to the diversity of groundwater resources in India and limited resources available for water quality monitoring it is not possible to monitor all the groundwater aquifers of the country. However, the information on groundwater quality is becoming more and more important due to gradual degradation of groundwater quality in certain pockets of the country. Hence with limited resources CPCB has carried out groundwater quality survey at limited locations in order to detect the nature and magnitude of the groundwater quality problems.

The major anthropogenic and industrial activities & groundwater quality issues of these problem areas are described in the following paras.

4.2 Durgapur Problem area

4.2.1 Environmental Profile of Durgapur area

General feature: The Asansol-Durgapur region is an integral part of the Damodar river valley resource region and is one of the most important urban industrial zones of Eastern India located in West Bengal.

Climate: The climate of the area is humid and tropical. It is characterized by a hot and dry summer from March to May, the rainy season was from June to September and a cool pleasant winter from October to February.

Water Resources: Four main rivers form the water resource in the Durgapur region: Ganga, Damodar, Barakar and Ajoy and their tributaries cover the entire district of Bardhaman. The Damodar is the major river in the area with a total length of 70 km flowing along the southern boundary of Asanasol - Durgapur Development Authority (ADDA). The town draws its present water supply both from tube wells and the river Damodar. The raw water from the river was provided complete conventional treatment and tube well water was disinfected before distribution to the consumers through public stand-posts as well as individual household connections. A small fraction of the population was not covered with piped water supply and they depend upon groundwater drawn through hand pumps, tube-wells and open dug wells. Of the total drinking water supplied which was approx. 182 MGD, the four industries namely, Durgapur Steel Plant (DSP), Durgapur Projects Ltd. (DPL), Durgapur Thermal Power Station (DTPS) and Hindustan Fertilizer Corporation Ltd (HFCL) consume the maximum water supplied both for industrial and their townships while a smaller component is supplied to the non-industrial population within the Durgapur Municipal Corporation. The river water in Damodar along the entire stretch is found Colonies of individual industries are fully sewered and well maintained. The present system of domestic waste disposal in other areas consist of septic tanks / sanitary latrines. Treated and untreated effluents and sullage drain into Tamla nala, which ultimately joins river Damodar.

Geology: Durgapur area in Bardhaman district of West Bengal is overlain by a thin alluvial cover and forms a transition zone between hard rock and flat gently sloping alluvial terrain. The alluvial area stretches eastwards beyond Durgapur to the rest of the district. The thickness of alluvial cover in the Durgapur area increases in the eastward direction. The master slope of the district is from west to east and southeast with the land having the highest altitude at the extreme western corner of approx. 150m msl to about 10m near Kalna at the eastern border of the district. Laterite and red soil in the western part of the district and Vindhyan and Gangetic alluvium in rest of the area observed. The district remarkably presents the entire geological succession from Archaean to recent. The western part of the district comprising the Raniganj coalfield is underlain by the Gondwana sedimentary rocks and contains valuable coal deposits. Exploration for ground water in Durgapur area has revealed the presence of sediments, which are co-relatable with the Raniganj coalfield rocks. By paleonological findings the age of the rocks are now fixed as Middle Triassic to Jurassic, against Miocene as thought earlier. The sedimentary framework is suggested to be mainly continental, with a marine transgression during Oligocene-Miocene times. The exploration has further proved the ground water worthiness of the eastern fringe of

Durgapur area. The central part and eastern part of the district are underlain by alluvial formations.

Industries: The following main polluting industries are identified in the area (Table 17):

Table 17: Units under observation in the problem area - Durgapur

Sl No.	Industry name with address
1.	Alloy Steels Plant, Durgapur-8, Burdwan
2.	Durgapur Steel Plant, Durgapur-15, Burdwan
3.	Durgapur Chemicals Ltd., Durgapur-15, Burdwan
4.	East India Pharmaceutical Works Pvt. Ltd. Durgapur-15, Burdwan
5.	IISCO Burnpur Works, Burnpur, Burdwan
6.	Durgapur Projects Ltd. Durgapur-1, Burdwan
7.	DTPS., DVC; Durgapur - 7, Burdwan
8.	Hundusthan Fertilizer Corp. Ltd., Durgapur-12, Burdwan
9.	Exodus Knitwear Pvt. Ltd., Dwarika, Bankura
10.	Mejia Power Station, Durlavpur, Bankura
11.	Dishergarh Power Supply Co. Ltd., Shibpur Power Station, Jamuriahat
12.	Dishergarh Power Supply Co. Ltd., Chinakuri Power Station, P.O. Sundarchak, Buardwan
13.	Santaldih Power Station, Santaldihi, Purulia
14.	Bhajudi Coal Washery, Purulia
15.	Dishergarh Power Supply Co. Ltd., Sitarampur
16.	Sharda Fertilizer, Bankura
17.	Ahmedpur Sugar Mill
18.	Bengal Paper Mill
19.	IISCO, Kulti
20.	Philips Carbon Black
21.	Durgapur Cement
22.	Damodar Cement (Madhukunda)
23.	CLW, Asansol
24.	Purulia Cement
25.	Durgapur Steel Plant (Township)
26.	Bakreswar Thermal Power Project

Source: WBPCB, Annual Report 2000-2001

Besides the above, the region accommodates about 200 other types of industries include major establishments producing base metal, coal, gas, urea, inorganic heavy chemicals, ceramics, batteries, heavy engineering, machinery etc.

Main Environmental Issues: The prime environmental concerns in the region are large-scale mining activities (collieries of the region produce about 95% of the total coal output of West Bengal) in the area and the pollution caused to river Damodar due to discharge of mining/industrial & domestic wastewater.

4.2.2 Ground Water Quality Survey

The sampling stations were chosen so that the probable impacts of the prevailing industrial activities could be reflected. The information pertaining to the depths of these wells were in some cases got from the local public who have been residing in the area for a long period. The area was surveyed earlier in 1994 for groundwater quality. This was second round of survey, in which the same sampling locations as follows were retained (Table 18):

Table 18: CPCB groundwater locations in Durgapur

Sl No.	Location	Approx. depth (m)	Type	Current use
1.	Mayabazar	25-30	Tubewell	Drinking & domestic purposes
2.	Ashisnagar	25-30	Tubewell	-do-
3.	Sagarbhanga	15-20	Dugwell	-do-
4.	Ganatantra Colony	15-20	Dugwell	-do-
5.	Palasdiha	15-20	Dugwell	-do-

4.2.3 Observations and Findings on status of GWQ in Durgapur problem area

The GW data generated at the above mentioned five stations were analysed and have been critically examined vis-à-vis the BIS drinking water standards, as per CPCB's general WQ criteria for raw waters used for organized community water supplies (surface and ground water) along with the data generated in the 1994 round and presented in **Table 1 of Annexure II.** However, the salient observations that can be concluded from Table 1are given below:

i) The groundwater quality of the two tube well located at Ashishnagar and Mayabazar stand out prominently of having exceeded the stipulated norms for parameters in both the rounds that were conducted both in 1994 and in 2001-2002.

ii) Bacterial contamination was observed at all the five stations and this is a serious observation since the observation was found in both – dug well and tube wells.

iii) Fluoride levels were found quite low in most of the samples taken, about 65% of the samples in 2001-2002 reported values less than 0.5mg/l. Fluoride values were only reported in 1999-2000 and the values ranged from 0.18 to 0.45 mg/l in all the locations i.e. Piala, Bhiringi, Banscopa, Deshbandhunagar and Durgapur Barrage.

iv) The values of heavy metals were less than the stipulated values except for iron at the dugwell at Palasdiha.

v) The reported values of DDT were the most prominent compared to all the other pesticide parameter.

4.3 Haora Problem Area

4.3.1 Environmental Profile of Haorah Area

General features & Topography: It has an area of only 1360 km i.e. barely 1.56 percent of the entire state. This district has the distinction of having *no* forest area and lies between the latitude $22^0$22'10" N & $22^0$46'55" N and longitudes $88^0$22'10" E and $87^0$50'45" E respectively. As per the last census the district has the highest population density compared to the other districts of the state excluding Kolkata. Haorah city has an area of 51.74 km and has the highest population figures i.e. 9,50,435 within this district with a population density of 18,369 persons / km. Out of the 33 towns of this district, the highly populated core is the urban agglomeration, Howrah, has a municipal corporation with a population of 9.46 lakhs. Howrah is also the 2nd most populous city after Kolkata in the state of West Bengal. A quick glance at the population figures shows that there was a steady rise in the population over a decade (Table 19).

Table 19: Population statistics for district Howrah

Year	Population in lakhs	Population density persons/sq km
2001	**51.74**	**18,369**
1991	37.29	2543
1981	29.66	2022
1971	24.17	1640
1961	20.38	1383
1951	16.11	1093
1941	14.9	1011
1931	10.98	746
1921	9.97	677
1911	9.43	640

The district is strategically located between the River Rupnarayan in the west and the river Hugli in the east besides being criss-crossed by minor tributaries of these two rivers besides the River Damodar.

Climate: The climate of this region is typically humid by virtue of its geographical location and receives over 1500 mm rainfall annually. The climate related data is provided below. The Haora (note the new name) district registered an average annual rainfall ranging between 1650 mm to 1900 mm and is one of the major flood affected regions of the state. The annual mean temperature have been observed to be 18^0C and 31^0C for winter and summer respectively. The relative humidity exceeds 75%.

Geology & Soil: The alluvial soils are the dominant soil type and occur in the alluvial flat in the Gangetic plain in several districts including Haora. The soils have been reported to be rich in calcium, free calcium carbonate occurs either in surface soils or down the profiles and have low to medium level of organic matter and medium level of available phosphate and potash. The Bengal basin constitutes two-third of the state and is occupied by the thick pile of unconsolidated sediments laid down by the Ganga-Brahmaputra system. These unconsolidated sediments are

made up of clay, silt, sand and gravel of Quaternary age overlying Mio-Pliocene sediments. Movement of groundwater in this hydro-geological unit is controlled by the primary porosities of the sediments. Groundwater occurs here both, under water table and confined conditions. Clay beds generally act as confining layers in part of Haora, However in major parts of Haora, Groundwater occurs under both water table and semi confined condition at different levels under the same vertical column.

Ground water: In some pockets of the coastal tracts of Hoara lying in the active delta of the Ganga Bhagirathi river system, groundwater occurs under a characteristic hydro-chemical situation in which a fresh water group of aquifers, occur within the depth span of 120-300 metres sandwiched between saline aquifers. The top saline water bearing aquifers are separated generally from the underlying fresh water group of aquifers by a 20 m thick impermeable clay layer. The fresh water group of aquifers occur here under confined condition. On basis of yield potentialities these porous formation in Haora come under the area of prolific groundwater resource having yield prospects exceeding 150 m^3/hr, where the aquifers are thick and regionally extensive. Howrah district is the smallest district of West Bengal. Forming a part of the Indo-Gangetic Deltaic Plain, the district is underlain by Quaternary alluvium deposited as flood plain deposits by the south flowing rivers Ganga, Damodar and Rupnarayan.

Pollution sources: The industrial activities in this area is concentrated mostly on both the sides of the R. Hugli however the major industrial areas fall in the districts Haora, Hugli, north and south 24 Parganas. Haora has been characteristically referred to as a highly air polluting area mainly due to the metallurgical related activities (forgings and foundry units) which emit enormous emissions and lack of proper air pollution control devices aggravate the prevailing environment. Out of the total 328 foundries most of them have already erected pollution control system. Many of these industries also generate hazardous wastes. Considering sector-wise the pre-dominant categories were:

a) Metal and metallurgical units which constituted 39.2%
b) Chemical units which constituted 15.8%
c) Battery manufacturing units which constituted 13.7%

Haora area generates about 17% of the total hazardous wastes generated in WB. Based on certain factors, it is estimated that the total landfill capacity to dispose about 11,312 TPA.

In view of the above the environmental issues of the problem area Haora can be classified into water polluting and air polluting types and the salient issues pertaining to these two main categories are presented below.

a. Water polluting sources:

- Non-existence of proper sewage collection and treatment system from the city;
- No proper collection treatment and disposal of the waste water discharged from the Haora railway station;
- Non existence of proper treatment of industrial effluents resulting from the chemical processing industries including paint industries.

b. Air polluting sources:

- Use of coal as fuel for domestic purpose;
- Air pollution emissions from foundries, re-rolling mills and forging units;
- Emission from coal fired steam boilers;
- Emissions from paint industries;
- Emissions from the coal fired glass and ceramic kilns.

Deposition of air pollution on land also contribute to importantr source of groundwater pollution

Regarding status of groundwater explorations, this state is endowed with groundwater and thus there are no grey or black blocks (i.e. stage of GW development exceeding 65%). The aquifers in the Haora region are of mainly of confined type. Estimates of the groundwater reserves in the district showed that good scope exists for further development of the groundwater resources in all the blocks of the district.

4.3.2 Groundwater Quality Survey

The sampling stations were chosen so that the probable impacts of the prevailing industrial activities could be reflected. The Haora region as described in an earlier section is a densely developed area, particularly with respect to innumerable forging & foundry units, electro-plating units and other small industries using coal or diesel as fuel. Besides these there is also a solid waste dumping site. The information pertaining to the depths of these wells were in some cases got from the local public who have been residing in the area for a long period. The area was survey earlier in 1994 for groundwater quality. This was second round of survey, in which the same sampling locations as follows were retained (Table 20):

Table 20: Details of Groundwater Survey in Haora

Sl No.	Location	Approx. depth(m)	Type	Current use
6.	Tikiapara	25-30	Tubewell	Drinking & domestic purposes
7.	St. Thomas School	25-30	Tubewell	-Do-
8.	Sanpur	15-20	Tubewell	-Do-
9.	Dasnagar	15-20	Dugwell	-Do-
10.	Kadamtalla	15-20	Tubewell	-Do-

4.3.3 Observations on the Status of Groundwater Quality (GWQ) in Haora

The Groundwater data generated at the above mentioned five stations were analyzed and have been critically examined vis-à-vis the BIS drinking water standards, as per CPCBs general Water Quality criteria for raw waters used for organized community water supplies (surface and ground water) along with the data generated in the 1994 round and presented in **Table 2 of Annexure II.** However, the salient observations that can be concluded from Table 2 are given below:

i) The groundwater quality of the dug well located at Dasnagar and the tube well at St Thomas School stand out prominently in both the rounds of having exceeded the stipulated norms for parameters that were conducted both in 1994 and in 2001-2002.

ii) *Bacterial contamination was observed at all the five stations and this is a serious observation since the observation was found in both – dug wells and tube wells.*

iii) *Barring the sampling location at Tikiapara (tube well) the values for the parameters namely chloride, hardness, total dissolved solids, conductivity and alkalinity were very high for the other locations.*

iv) Fluoride levels were low in most of the samples taken, about 60% of the samples in 2001-2002 reported values less than 0.6mg/L. Amta Town, Bally, Goalpata, Howrah Town, Jagatballavpur, Kalinagar, Uluberia were also observed to be less than 0.6 mg/L

v) The values of heavy metals were less than the stipulated values at all locations except for iron and manganese. These two parameters were found critical particularly at the locations Dasnagar where the values ranged between 0.3-1.15 mg/l and at St Thomas School where it ranged between 0.42-1.05 mg/l for iron. Regarding manganese the values exceeded 0.6 mg/l at the above two stations besides at Sanpur.

vi) The reported values of DDT (particularly in the pre-monsoon round where values exceeded 0.2 ug/l) were the most prominent compared to all the other pesticide parameters barring at location Tikiapara. As agriculture area is almost nil in the areas where the sampling locations were located one can perhaps conclude the usage of DDT was possibly being used as an anti-malaria practice.

4.4 Dhanbad Problem area

4.4.1 Environmental Profile of Dhanbad Area

General features & Topography: Dhanbad district is located in the Eastern part of India, from 85^0 45' E longitudes to 86^0 30' E longitudes and from 23^0 32' N latitude to 24^0 5' N latitudes. It is situated on the lower steps of Chota Nagpur plateau at an altitude of 750' above MSL. With the extension of railway communication and enlarged coal-mining activities, the population of Dhanbad has been gradually increasing. The Dhanbad town is spread over an area of 23.39 sq. kms. It comprises of the following villages: Hirapur, Dhaiya, Saraidhela, Barmasia, Manaitand, Bhuda, Duhatand, Panderpalha and Bishnupur. Dhanbad is the only district in the Jharkhand state where participation in the non-agricultural sector is more than that in the agricultural sector. It is obviously due to availability of the coal resources has prompted extensive mining activity. Less than 8% of the district population is employed in the agricultural sector. Out of the total 0.713 million acres of land in the district, it is estimated that barely. 22.10% of the land is under agriculture.

Climate: The district census handbook records the maximum temperature as 46.5^0C and minimum temperature as 6^0 C**.**

Drainage: Damodar is the important river in the state as well as in the region. It is the source of water supply. It also, supplies sand for stowing purpose to the collieries. The DVC has prepared an overall development plan for the entire river Damodar Valley. Due to hilly characteristics, the

river is not navigable. Jamania Nadi is the major tributary, meeting Damodar nearly Two km west of Telmucho Bridge. It is fed by a number of hilly streams and seasonal nalas. Jamunia Nadi is also not navigable. Rivers of the region have the usual characteristics of hill streams. Following the natural slope of the region, all the rivers in the region have an easterly or south - easterly course. Katri Nadi dissects the Jharia Coal Field North-South through a number of tributaries, such as Khudiya Nadi, Bans Jhor, Kamari Jhor etc. meeting Katri at different levels. By constructing weirs on Katri at 2-3 places, it is used for water supply e.g. water supply to Railway Colony, Katras. Kaso Jhor is another tributary of Damodar flowing N-S and merging into the Damodar west of Bhowra touching Dhanbad, Jamadoba, Jorapokhar, Bhowra on its way. It is a seasonal nala. Domohani Nadi marks the boundary of Sindri NAC. It flows from North to East merging into Damodar River near Chasnala. There are many seasonal nalas in the region and there are a number of ponds/tanks scattered throughout the region. It is obviously due to availability of the coal resource, which has prompted extensive mining activity.

Damodar River (Wells and Tube wells in the catchments): River Damodar is main source of water supply. The intake works have been located at Jamadoba with capacity to draw 40 MLD of water for use in Dhanbad - Jharia coalfields areas.

Geology: Geologically, the major feature is the great coal basin of this region with intervening areas of crystalline rocks. The ancient rock types of Dharwar and post Dharwars period form the basement rock over which the Lower-Gondwana group of sedimentary strata consisting of coal seams and patches of sandstone are formed. The region is important for its large reserves of Lower-Gondwana coal distributed in these fields, the Jharia and Chandrapura Coalfields and the Barakar series, which extends into the Raniganj Coalfield in West Bengal. The main axis of the Jharia Coalfield basin runs West- North - West-East-South-East and is petering gently towards West and can be seen by the dips of the Raniganj strata along the Jamunia River. This line of axis is neither straight nor curved in simple manner, but is it corrugated due to the forces probably coming from east to west. Though hardly a dozen minerals of economic importance occur in the region, it is one of the premier areas of India so far as the coal is concerned. The Jharia Coalfield reserves are estimated upto 12815 Million tones upto a depth of 600 metres out of which 5640 MTs have been estimated as of prime cooking coal variety, according to a BCCL report on estimates of coal reserves.

Soil Type: Alluvial soil is found along riverbed, which is used for agriculture. It is found in small patches especially in Baliapur and Topchanchi blocks. Sandy soil is also found in the riverbeds, which are the characteristics of granite rocks and sandstones. It is used for stowing and building purposes. Coarse gritty soil is predominant in coal basin. This type of soil mixed with big fragment of rocks is formed from the weathering of pegmatites, quartz and conglomeratic sandstones. Laterite or Kankar is found in the foot of hills while red soil is found further ahead. Some cultivation is practiced on red soil. Cultivable soils are found mainly in the south-eastern part of the region, near Sindri and north to north western part of the region in Gobindpur blocks.

Minining & industrialization: In studying the economy of the region, it has to be borne in mind that this region is one of the largest depositories of best coal reserves in our country, meeting the demands of various large-scale industries. It even serves the railways. In the nation's interest, the

coal mining activity is largely nationalized. The region's economy is basically guided by the employment in the activity of coal mining. This has influenced the location of many coal-oriented industries, such as fertilizers, washeries, coke plants, ceramic industry, pottery works, steel industries, lead and zinc smelting and numerous other engineering industries.

The Dhanbad-Jharia coalfields are one single largest depository of coal. Ever since the mining activity began in the region, the economic profile has shown an upward trend. This has influenced the location of many coal oriented industries, such as, steel plants, fertilizer plants, cement plants, chemical factories, etc., which use coal as a fuel. Apart from these large-scale industries, numerous other industries have come up. These includes:

i) Ancillary industries of above large scale industries which use their products/by-product;
ii) Ancillary industries to supply manufactured processed raw materials;
iii) Ancillary industries to serve for servicing and repairing of machines, tools, equipment;
iv) Ancillary industries for fabrication, molding, casting etc.;
v) Transport industries, which include automobile servicing, repairing, bodybuilding, tyre re-treading, and manufacturing of auto spare parts.

The reflexes of the mining activity on the environment are of great concern. The serious pollution problems of atmosphere, water and land degradation have resulted from the mining activities for nearly the last two centuries, since the mining activity began here.

Some of the important large and medium scale units in the region are:

i) Bokaro Steel Plant, Bokaro
ii) Fertilizer Corporation of India, Sindri
iii) Bihar State Super-Phosphate Factory, Sindri
iv) A.C.C. Ltd., Sindri'
v) Hindustan Metals and Forging Ltd., Bhuli
vi) The Bararee Coke Co. Ltd., Kusunda
vii) Hindustan General Electrical Ltd.
viii) Allied Industries (P) Ltd, Amaghata
ix) Jharia Fire-bricks and Potteries Works, Jharia

Most of the small scale / ancillary units are located in nearby areas such as large / medium scale units and / or major urban areas. There has been industrial development along with the (i) The G.T. Road (ii) Barwada - Dhanbad NH by Pass, (iii) Gobindpur-Dhanbad NH-32 (iv) Dhanbad-Jharia-Sindri Road and (v) Dhanbad-Karkend-Katras Road. The major types of small scale/ancillary industries are:

i) Manufacturing of non-metallic mineral products;
ii) Manufacture / Repairs of mechanical tools/machinery;
iii) Manufacture of metal products;
iv) Automobile repairs and coach building works;
v) Manufacture of food products;
vi) Wood works;

vii) Textile;
viii) Manufacture of steel furniture and steel fabrication jobs;
ix) Printing Press;
x) Ceramic pottery.

The major environmental problems created in the wake of mining activities may be categorized as follows:

- Problem of land subsidence;
- Problem of land degradation;
- Depletion of ground water table;
- Groundwater pollution.

The coal washeries, hard coal 'bhattis' and burning of coal to manufacture coke emit enormous smoke. These industries and mining activities contribute to air pollution to the atmosphere increasing levels of particulate matter and gaseous pollutants like nitrogen oxides, sulphur dioxides, carbon monoxide, and hydrocarbons. These air pollutants apart from polluting the air also deposit on land and leach out in the groundwater and pollute them.

4.4.2 Groundwater Quality Survey

The sampling stations were chosen so that the probable impacts of the prevailing industrial activities could be reflected. The Dhanbad region as described in an earlier section is not a very densely populated area. However, the entire mining and its related activities attract manpower as a source for livelihood. The sampling locations selected are presented in Table 21.

Table 21: CPCB's Groundwater Survey locations

Sl. No.	Locations in 2001-2002	Approx. depth (m)	Location in 1994	Approx. depth (m)	Current use
1.	Bartand Bus stand (TW)	100-120	Puja Cinema Deep (TW)	300	Drinking & domestic purposes
2.	Court More (TW)	-do-	I.T.O. Deep (TW)	300	-Do-
3.	Opposite CRFI (TW)	-do-	Golf Ground (DW)	20	-Do-
4.	Opposite ISM (TW)	-do-	Jharia (DW)	20	-Do-
5.	Rangatnd (TW)	-do-	Jain Bhawan School Deep (TW)	300	-Do-
6.	Govindpur (TW)	-do-			-Do-

Note: Tubewell /dugwell -TW/DW

4.4.3 Observation on status of Groundwater Quality in Dhanbad Problem Area:

The Groundwater data generated at the above mentioned six stations were analysed and have been critically examined vis-à-vis the BIS drinking water standards, as per CPCBs general WQ criteria for raw waters used for organized community water supplies (surface and ground water) along with data generated in the 1994 round and presented in **Table 3 of Annexure II.**

4.5 Angul Talcher Problem Area

4.5.1 Environmental Profile of Angul Talcher (Orissa) Area

General Features & Topography: Angul-Talcher area is one of the major industrial zones in the state of Orissa. The availability of coals in Talcher coalfields and high flow in the river Brahmani are the prime factors for rapid growth of industrial activities in this area. The area is recognised as one of the 24 problem areas identified by Central Pollution Control Board, Delhi in respect of industrial pollution hazard. The area is fast emerging as a big source of coal and thermal power in the country. The study area includes Angul, Banarpal, Talcher and Kaniha blocks of Angul & Talcher subdivisions of Angul district. Angul-Talcher area lies between 20^0 37' to 21^0 10' N latitudes and 84^0 53' to 85^0 28'E longitudes. Angul is situated at an average height of 139 meters above mean sea level and at a distance of 160 Km. from the State capital, Bhubaneswar. National Highway – 42 (Cuttack-Sambalpur) is passing through Angul. Talcher was the terminus of a branch railway line from the east coast line constructed in 1923. Now it has been further extended to Sambalpur. Angul and Talcher Tehsils has been experiencing steady increase in population. As per 2001 Census reports, the district has a population density of 179 persons per sq. Km. and the total population of Angul and Talcher Tehsil is 704221.

The satellite picture of the study area reveals the central area is flat with slightly undulating topography, some scattered hillocks, forest blocks and rocky outcrops. The major part of the area forms the plains of river Brahmani and its tributaries like Singra jhor, Tikira jhor and Nandira jhor.

Geology: The Brahmani valley portion exposes mainly granites and its variants and gneiss with occasional hillocks of Khandolites, while the remaining part from west of Murhi and north of Angul upto the western end of the district is characterised by considerably flat country underlain by sedimentary rocks of Gondawana group having large deposits of coal (Talcher Coal Fields).

Drainage: The western and southern hilly regions form the watershed between rivers Mahanadi and Brahmani. The eastern part of the area slopes towards west and all the rivers and rivulets originating in this area converge into river Brahmani. The eastern hill ranges divide the catchments of river Brahmani and river Ramiala (a tributary of river Brahmani).

There are two large water reservoirs on the river Brahmani at Rengali and Samal. In the south of the area canals are being used for irrigation purposes. The Rengali multi-purpose project and Rengali Irrigation project (Stage-2) are the major irrigation projects and Aunli irrigation project and Derjang irrigation project are the two medium irrigation projects in the area. Brahmani and its tributaries drain the major portion of the area. The Brahmani River flows in a general SE

direction, broadly parallel to the general strike trends of the prevalent rock formations, but locally guided by major joints and faults. The major tributaries of Brahmani are Tikra jhor, Singhra jhor, Samakoi, Nandira jhor, Gambharia, Nigra, Bade jhor etc. and show a general right angle pattern while joining with the river Brahmani.

Water supply: The industrial area as well as the municipality area draw raw water from the Brahmani River and also depend upon the ground water sources. However, a small fraction of the population is not covered by piped water supply by the municipality, therefore, depend upon the ground water drawn through hand pumps, tube wells, and dug wells. The Angul and Talcher Municipalities and townships of FCI, TTPS, NALCO, MCL, TSTPP consume approximately 19.3 mld water, and are being met from Brahmani River and to some extent from ground water sources, and discharge approximately 16.4 mld of wastewater into the Brahmani river basin. Similarly, the major industries of the area consume roughly 368 mld of raw water from Brahmani and Tikira river and discharge 152 mld of waste water to Kisinda Jhor, Nandira river and Deojhar nallah which ultimately join Brahmani river. 42.5 mld of mine drainage water from the coalmines in the area also discharged into Brahmani river basin.

Climate: The area experiences tropical monsoon climate with three distinct seasons in a year viz. summer, rainy and winter. The summer season extends from March to May, rainy season from June to September and winter season from November to February.

Rainfall is the principal source of ground water recharge in the district. Other sources of recharge are seepage from canals and return-flow from applied irrigation water. The base flow in Brahmani and Mahanadi rivers is regenerated ground water resource and part of it is utilised for lift irrigation and surface irrigation.

Agriculture: Angul-Talcher area has 70% of agricultural lands. Using of fertilizers and pesticides in agricultural lands to get better yield is a common practice. Due to such practice, residues of the fertilisers and pesticides find their way to the surface water through surface run-off and to ground water through percolation depending upon the soil permeability thus increasing the possibilities of contamination of ground water source with respect to nitrate, phosphate, and pesticides.

Groundwater: The geological set up of the area governs occurrence and movement of ground water in the district. The major part of the Angul district is underlain by hard crystalline rocks and is devoid of any primary porosity and hence when weathered and fractured, secondary porosity is developed. Depending on the aquifer systems and their parameters in different lithounits, the hydro-geological condition of the district can be broadly grouped into consolidated, semi-consolidated and unconsolidated formations. Consolidated formation includes Granite, Granite gneiss, Khandolite, Channockite, Quartzite, Phyllitis, Mica schist etc. Weathered and semi weathered Granite gneisses form moderately potential aquifers. Groundwater occurs under water table conditions in the weathered residuum and in semi confined to confined condition in fractured rocks at deeper depths. The thickness of the weathered residuum varies from 5 to 20 m that forms repository of groundwater at shallow depths. Ground water from this zone is developed through dug wells. The depth of dug wells varied from 4.50 to 13.95 m. In Khandolites, groundwater occurs under pheretic condition in

weathered zone while in semi-confined to confined condition in deeper fracture zones. The average depth of the wells is around 10 to 11 m. The average depth to water level during pre-monsoon is around 7 to 8 m. while in post-monsoon it ranges from 3 to 6 m. Khandolites are restricted to higher elevation forming hills and groundwater potential is limited. Whereas, Channockite occurs as instruive bodies and covers limited area. It is highly compact and less susceptible to weathering, so not considered as good aquifer.

Mining: The extensive Talcher Coal Fields and Mahanadi Coal Field Limited are located in this region. The general slope of the area is from west to east and from north to south. The Talcher Coal Fields have a vast coal bearing area of about 1813 sq. km. The mining activities started during 1921. The total reserve of coal in this area has been estimated to be 25485.18 million tonne out of which 2548.5 million tonne is superior grade coal and rest 22936.68 million tonne is power grade coal. Mines operating in this area are presented in Table 22.

Table 22: Mines operating in Angul-Talcher area

Sl. No.	Name of Mine	Type of mining	Category
1.	Jagannath colliery	Open cast	Large
2.	Bharatpur OCP	Open cast	Large
3.	Balanda colliery	Open cast	Large
4.	Ananta OCP	Open cast	Large
5.	Lingaraj OCP	Open cast	Large
6.	Kalinga OCP	Open cast	Large
7.	Hingula	Open cast	Large
8.	Talcher colliery	Under ground	Large
9.	Nandira colliery	Under ground	Large
10.	Deulbera colliery	Under ground	Large
11.	Handidhua colliery	Under ground	Large

Industries: Development of industries takes place in this area due to availability of resources like coal reserves, surface water from Brahmani river and infrastructure facilities. The prominent industries of the area are:

i) Talcher Thermal Power Station, Talcher
ii) Fertilisers Corporation India, Talcher
iii) Orichem Limited, Talcher
iv) Heavy water project, Talcher
v) National Aluminium Company, Angul
a) Captive power plant
b) Smelter plant
vi) Talcher Super Thermal Power Plant, Kaniha

Besides these, there are few medium and small scale industries operating in the industrial estate of the Angul-Talcher area as well as within Angul-Talcher area.

Based on the recharge and draft, the stage of ground water development in an area is the percentage ratio of annual net draft to annual utilizable ground water resource for irrigation. The level of ground water development in different blocks is not uniform and varies from 4.76 % in Talcher to 19.98% in Banarpal block. The overall stage of ground water development in Angul-Talcher area is 12.12 % that indicates that there is no restriction for further exploitation of ground water resource.

4.5.2 Groundwater Quality Survey

The sampling stations were chosen so that the probable impacts of the prevailing industrial activities could be reflected. The Angul -Talcher region as described in an earlier section is not a very densely populated area, however, the entire mining and its related activities attract manpower as a source for livelihood. The sampling locations are presented in Table 23.

Table 23: Ground water Survey locations in Angul-Talcher Area

Sl. No.	Location	Type	Approx. Depth (m)	Current use
1	Bonda	Dug well	3.05-10.97	Drinking and domestic purposes
2	Bonda	Tube well	61.5	-do-
3	Kulad	Dug well	2.44-11.58	-do-
4	Kulad	Tube well	54.5	-do-
5	Tulsipal	Dug well	3.3-12	-do-
6	Tulsipal	Tube well	61.08	-do-
7	Kandsar	Dug well	0.914-9.144	-do-
8	Balaramprasad	Dug well	3.66-7.62	-do-
9	Chhelia	Dug well	0.305-12.8	-do-
10	Angul	Tube well	60.8	-do-
11	Kaniha	Dug well	0.609-14.02	-do-
12	Kaniha	Tube well	60	-do-
13	Deranga	Tube well	60	-do-
14	Talcher	Tube well	56.6	-do-
15	Godibandha	Dug well	0.914-12.19	-do-
16	South Balanda	Tube well	80.6	-do-
17	Handidhua chhak	Tube well	64.4	-do-
18	Baghamara	Tube well	64.4	-do-
19	FCI	Tube well	63	-do-
20	Gurujanguli	Dug well	2.133-9.144	-do-
21	Gotmara	Dug well	3.962-9.144	-do-
22	Gotmara	Tube well	60.60	-do-
23	Banarpal	Dug well	4.572-8.53	-do-

4.5.3 Observation on the Status of Groundwater of Angul-Talcher area

To assess the ground water quality status of the area, ground water samples were collected from the selected dug wells and tube wells of the following villages in the months of September-2001, January -2002 and May-2002. Information pertaining to the depth of the wells was obtained from Rural Water Supply and Sanitation, Angul and is presented in Table 24. The samples were critically analysed with respect to BIS standard.

Table 24: Ground water sampling areas

Block	Village	Justification for site selection
Banarpal	Banarpal	Situated at approximately equal distance from NALCO & TTPS.
	Kandsar	Situate in close proximity of NALCO smelter.
	Kulad	Situated in close proximity of NALCO smelter and Kisinda jhor. The jhor is an industrial effluent carrying drain passing near by.
	Tulsipal	Situated near to NALCO smelter and also a vast agricultural land.
	Gotmara	Situated near NALCO, CPP
	Balaram prasad	Situated close proximity to NALCO, CPP
	Bonda	Situated in close proximity of NALCO ash pond and a vast agricultural land.
Angul	Derjang	Baseline ground water quality data.
	Angul	Base line ground water quality data.
Talcher	South Balanda	Coal mining area
	Handidhua	Coal mining area
	Talcher	Situated in close proximity of mining area and industrial area.
	Gurujanguli	Situated near Nandira jhor, an industrial effluent carrying drain.
	Godibandha	Situated little away from mining area and industrial area.
	Baghamara	Situated near ORICHEM solid waste dumping site.
Kaniha	Kaniha	Situated close proximity to TSTPP, Kaniha.
	Chhelia	Base line ground water quality data.
	Kaniha	Situated near TSTPP ash pond.
	Deranga	Situated near to TSTPP ash pond and also a vast agricultural land.

From the physico-chemical analysis of the ground water sample of the study area, it is observed that no definite correlation exist with the wastewater quality generates in the area. Presence of fluoride in the wastewater of NALCO smelter unit is a matter of concern. It is difficult to come to a conclusion for high concentration of fluoride at Bonda and Tulsipal due to discharge of fluoride bearing wastewater of NALCO smelter as high fluoride concentration was also observed at far away locations from smelter unit. The salient observations and conclusions from data given in **Table 4 of Annexure II** are given below:

- In the monsoon, pH varies within 8.06-9.09 whereas in the pre-monsoon season, pH exhibits the range 6.1-8.3. High values of pH (>8.5) in monsoon season are observed at Banarpal, Bonda, Handidhua and Baghamara villages.
- The dug wells and tube wells in Tulsipal, Kulad, Kandsar, Angul and tube well of Gotamara exhibit very high TDS values i.e., within the range 977-1960 mg/l.
- The water class in all places except South Balanda are in the moderately hard to very hard category as classified by Sawyer and Mc Carty. In South Balanda, the ground water is soft (<75 mg/l), while ground water in Banarpal, Bonda, Balaramprasad, Deranga, Godibandha, Talcher Handidhua chhak, Baghamara, FCI, Guruianguli villages are of moderately hard to hard category. Where as the ground water in Gotamara village, Angul, Chellia and Tulsipal area are of very hard category and also exceeds the limit (300 mg/l) laid down for drinking water quality criteria.
- Ground water of Bonda, Tulsipal and Balaramprasad area exhibit very high sodium content in monsoon period (i.e. 250-310 mg/l).
- Very high values of chloride (>250 mg/l) and sulfate are observed in hard waters of FCI, Kandsar, Angul and Tulsipal villages
- During monsoon, the dug wells of Kulad, Kandsar, Godibandha, Chhelia, and Gurunjaguli exhibit very high values of nitrate, however, reduces to the drinking water limit in pre-monsoon period.
- Fluoride concentration was observed to be above the standard limit (1.5 mg/l) at Tulsipal villages (2.5 mg/l) in the month of September and January. However this value decreases below the standard limit in the month of May (0.7 mg/l)
- Heavy metals like Co, Ni, Pb, Cu, Zn, Cd are observed to be within the standard limit prescribed for drinking water. Total chromium and mercury are not detected in any case. Iron, however, is found in some cases above the standard limit (0.3 mg/l).
- Bacterial population was observed at all the dug wells. Excepting the tube wells of Kanhia, South Balanda, Baghamara, Deudokote village, all other tube wells are observed highly contaminated (coliform bacteria should be absent in drinking water source). However, during the month of January, bacterial population has been significantly reduced in all the dug wells except in Kulad and Gatamara village.
- Presence of residues of organochlorine pesticides in the ground water samples were observed in the selected sampling locations close to agricultural lands.
- Water table depths of dug wells in Kandsar, Chhelia, Kaniha, Godibandha villages observed to be within the range 0.3-0.914 m whereas that of the dug wells in Bonda, Kulad, Balramprasad, Gurujanguli and Banarpal villages are within the range 2.44 – 4.572m.

4.6 Singrauli Problem Area

4.6.1 Environmental Profile of Singrauli (U.P.) Area

General features & Topography: Singrauli problem area, as far as identified industries are concerned, lies in the state of Uttar Pradesh. On the east, the area has its boundaries with the Bihar State, while it shares its southern border with M.P.State. The area comprises a part of erstwhile district of Mirzapur in south east of Uttar Pradesh. It encompasses a vast geographical area extending from Obra in the north to Anpara in dist. Sonebhadra and further south to Bina collieries. On geographical consideration, the area lies between 20^0 10' – 24^0 30' North latitude

and 82^0 47' – 83^0 15' East longitude. Although the area is characterized by an uneven topography, the average altitude in the area is 270-280 m. above msl, however it ranges between 262 m to 474 m above MSL. The area witnesses a semiarid climate with annual rainfall ranging between 760-1300 mm. The area is characterized by proven natural resources of coal, limestone and building stone. Predominantly hard-rock topography and limited water resources in the area have ultimately resulted into the situation wherein 40 percent of the total geographical area lies under forest cover, while only 20-30% of the total area is under cultivation.

From the water resource point of view, the area has river Sone as a major surface water body on the northern fringe. Besides, there are five medium sized streams namely Belan, Karnasa, Chandraprabha, Rihand and Kanhar, which, swell considerably during the rainy season and shrink to near insignificant flow during summer. These streams are mainly flowing in NE -SW direction. For raw water requirement, the area more or less depends on Rihand reservoir across river Renu, or on river Son and its subsidiaries besides tapping sub-surface water resources.

Geology & Groundwater: The area is largely covered by hard rock formations belonging to Vindhyan and Precambrian groups, which have comparatively low groundwater potential in general. The groundwater utilisation and development in the district is rather poor. Groundwater in alluvial area generally occurs under unconfined and semi confined conditions. In deeper aquifers groundwater occurs under highly confined conditions. From point of view of groundwater occurrences, the lithological units within the area are broadly classified into five groups, comprising - Granites - Gneisses; Phyllites- Shales; Limestones; Quartizite – Sandstone and alluvium. Groundwater occurs in the pore spaces of the unconfined alluvial / weathered (in hard rock terrain) material. The near surface sediments comprise fine to medium sands with inter-layered pockets of clayey material. This top un-confined aquifer supports large number of dug wells and other shallow groundwater structures. In hard rock formations like granites, phyllites and quartzites etc. groundwater occurrence is limited to weathered zones and plains of foliation or weak fracture zones. The depth to water table ranges from 2 to 24 m. On the whole, these formations have moderate to low groundwater potential with an exception in case of quartizites and sandstone, which occasionally form good aquifers (unconfined) in the area and rank next to alluvial formations, in terms of groundwater potential. In general, the depth of water table ranges between 4 and 6 m. below ground level (bgl). Rainfall is the main source of groundwater recharge, apart from seepage from the surface water bodies. The general hydraulic gradient prevailing in the area is towards River Sone or locally towards the subsidiary surface water bodies. More or less, the flow of groundwater is in conformity to the surface topography.

4.6.2 Sources of pollution in Singrauli Area

As a point source of groundwater pollution in Singrauli problem area, cement industries, stone crushers and thermal power plants are insignificant, however during the coal mining operation in Coal Mining units, the uptake of formation water laden with coal slurry and other metallic and non-metallic proportions, is liable to disturb the aquatic ecosystem of the surrounding areas if enough precautions towards treatment of the effluent and reclamation activities are not taken. Discharge of effluent from aluminum industries, and chemical industries act as a potential source of pollution of sub-surface water on account of mercury, fluoride, titanium, iron, aluminum and pesticides. Besides, the problem associated with disposal of red mud , mercury sludge and such

other refuse also carry a significant potential of surface and groundwater pollution. One important factor worth mentioning is the presence of Rihand reservoir, a fresh water resource for the entire area, which has of- late become a waste disposal site. Besides ensuring the availability, almost stagnant water body of the reservoir, with very high hydraulic gradient, pose a major threat in significantly increasing the salinity of the top soil as well as groundwater in semi confined, unconfined and parched aquifer conditions. In the areas where critical safe balance between draft and recharge is not maintained (groundwater mining), chances of reservoir water contaminating the nearby groundwater cannot be ruled out.

Industrial activity: Groundwater quality monitoring in Singrauli area has been of particular significance in view of large number of industries with significant potential for surface as well as groundwater pollution. The major activities which have been responsible for declaring the area as Problem area has been as following:

- Inter- State situation of the area with its border with M.P. and Bihar States
- Rihand reservoir being a major source of freshwater for the entire area and hence the preservation of its water quality being of immense significance
- Existence of large number of industries with significant potential of water pollution.
- Public complaints of pollution in the area.

The main industrial activities and major environmental issues are presented in Table 25 of the area are as follows:

Table 25 Major industries in Singrauli Area

Sl. no.	Name of Industry	Major environmental issue(s)
1.	HINDALCO Industries, Renukoot	Air and water pollution due to fluoride and disposal of red mud
2.	Kanoria Chemical Industries, Renukoot	Water pollution due to pesticides, chlorine and mercury in wastewater and sludge
3.	Hi-Tech Carbon, Renukoot	Air dispersion of carbon ;oil & grease in wastewater
4.	Northern Coal Fields Ltd., Site, Bina	Mine water discharge, oil & grease from workshop, Air pollution
5.	Northern Coal Fields Ltd., Site , Kakri	-same as above-
6.	Northern Coal Fields Ltd., Site , Khadia	-same as above-
7.	Northern Coal Fields Ltd., Site : Dudhichua	-same as above-
8.	Rihand Super Thermal Power Plant (NTPC)	Air Pollution;Ash Pond Overflow
9.	Renusagar Power Co. Anpara (Captive unit for HINDALCO)	Air pollution;Disposal of fly –ash
10.	U.P.State Cement Corporation, Churk	- Currently closed-

11.	U.P.State Cement Corporation, Dala	- Currently closed
12.	U.P.State Electricity Corporation, Obra	Air Pollution;Ash Pond Overflow
13.	Anpara Thermal Power Station	Air Pollution;Ash Pond Overflow
14.	Singrauli Super Thermal Power Plant	Air Pollution Ash Pond Overflow
15.	Stone Crushers – cluster of appx 150 nos.	Air Pollution

4.6.3 Groundwater Quality Survey

For the purpose of groundwater survey already developed structures were used for sampling. Care was taken to select representative location and to record the impact on shallow level groundwater table. Wherever it was not feasible due to field constraints, samples from middle level groundwater table were collected. The specific information on survey locations summarized in Table 26. In order to establish a trend of groundwater quality with reference to previous studies by CPCB, the survey of station were kept mostly analogous to previous studies. Moreover, attempts to co-relate groundwater quality data with reference to monitoring stations of Central Ground Water Board (CGWB) were also made. As noted, there are three CGWB locations, although do not exactly match with the CPCB locations yet, in general represent the area in terms of the ground-setting and sources of pollution. These three locations are close to CPCB stations located at Renusagar (SG4), Anpara (SG5) and Bina (SG6).

Table 26: Groundwater Survey Locations

Sl. No.	Stn code	Station name	Metre Bgl	Type	Significance of location
01	SG1	Downstream of fly- ash pond of Obra Thermal Power Plant, Obra	10	Sump-well	Impact of ash pond overflow and seepage from ash pond of Obra Thermal Power Plant
02	SG2	Premises of Rotary Health Centre, Near Radha Krishna Temple, Renukoot	12	Hand pump	Impact of Red-Mud disposal and Fly Ash Pond of M/s HINDALCO Renukoot and effluent of M/s Hi-Tech Carbon, Renukoot
03	SG3	Sheo Park Bazar, near HINDALCO gate , Renukoot	15	Hand pump	Impact of effluent from M/s HINDALCO Renukoot and M/s Kanoria Chemical Indus., Renukoot
04	SG4	Renusagar Intermediate College, Renusagar, Anpara	15	Open-Well	Impact of over flow and seepage from ash-pond of M/s Renusagar Power Company,
05	SG5	Type-IV Flats, Anpara Thermal Power Plant Township Anpara	12	Hand pump	Impact of over flow and seepage from ash-pond of M/s Anpara T.P. Plant
06	SG6	Behind Bina Stadium Varanasi-Shaktinagar highway Bina	15	Hand pump	Impact of Coal Mining Operations

At all these location the groundwater is predominantly used for drinking purposes

4.6.4 Observation on status of Groundwater Quality in Singrauli Area

The groundwater quality observation was compared with reference to BIS- specifications (IS: 10500; 1991) for drinking water quality. The Groundwater quality in the area has been generally observed to be alkaline and with moderate concentration of fluoride and colour. With regard to location specific status, the quality observed at Obra has shown alkalinity, total hardness, boron and calcium exceeding the norms. Presence of total and faecal coliform has also been noted. At Renukoot high content of colour, alkalinity, TDS, and boron have been observed. At the other location in Renukoot high content of fluoride, colour, total and faecal coliform have been observed. At Renusagar and at Anpara groundwater has high to very high content of fluoride. Moreover the high content of chloride, sulphate, nitrate and colour at Anpara has also been a significant observation. The presence of total and faecal coliform observed very high at Renusagar are however absent at Anpara. At Bina apart from high colour content and coliform (total as well as faecal) the groundwater is of reasonably good quality.

Heavy Metals:

Mercury and iron have been the only predominant metals in the area. While iron has been observed with high to very high concentration at almost all the locations with its highest concentration (10.2 mg/l) observed at Anpara mercury too has been reported from all the locations except at Renukoot. Highest concentration of mercury (0.004 mg/l) has been reported from Renukoot) followed by Renusagar (code SG4), Bina Obra and Anpara All the other heavy metals have been found within prescribed norms.

Pesticides:

Lindane (γ-BHC), DDT and eldrine have been the predominant pesticides observed. Among all, lindane has been reported at 4 out of 6 locations and its highest concentration (277 ng/l) is recorded at Renukoot followed by Anpara Renukoot and Bina .DDT has been recorded at 2 locations viz.: Obra and at Bina the former location reported highest concentration of 216.2 ng/l. Eldrine was recorded only at Bina.

Seasonal variation

There has been a distinct observation in post-monsoon / winter phase of monitoring, as compared to monitoring in pre-monsoon phase. The groundwater quality has deteriorated in post-monsoon and winter phases of monitoring characterized by higher content of fluoride, colour, alkalinity, coliform and heavy metals, whereas, the trend shown by boron has been generally negative with its concentration generally observed to decrease in the corresponding period. Location specific trend in post monsoon / winter phase monitoring are summarized below:

- At Obra conductivity, alkalinity, TDS, chloride, fluoride, hardness, sulphate, coliform and all the cations have shown significant increase.
- At Renukoot appreciable increase in colour, TDS, sulphate, has been observed. The other location at Renukoot (SG3) has registered significant increase in conductivity, chloride, hardness, all the cations and coliform.

- The location at Renusagar has registered appreciable rise in sulphate, phosphate, boron, all the cations and coliform;
- Seasonal variations at Anpara and at Bina have been more pronounced. In particular, alkalinity, TDS, sulphate and boron have been observed with increased concentration at all the locations. An specific observation with bacteriological parameter (coliform) has been that, while at Anpara they are absent, at Bina their increase has been observed
- Except for Aldrin, which was recorded in the winter phase of monitoring at Bina, all the other pesticides were observed only in the pre-monsoon phase and were absent in winter and post –monsoon phases.

Groundwater Quality - *correlated with previous studies*

Apart from the current study (2001-02), CPCB has undertaken two more phases of survey in 1994 and 1996. The average quality of groundwater in the current study as compared to previous studies has brought out following salient observations:

Physico-Chemical and bacteriological parameters

a. While pH has remained almost unchanged, the concentrations of boron, colour and sulphate have registered a significant decreasing trend. Nitrate concentration has increased at almost all the locations. Sodium Adsorption Ratio (SAR) in general has registered decrease at all the locations.
b. Other parameters have shown a different trend which are location specific;
c. At Obra while SAR, concentration of fluoride, chloride, boron, coliform, colour, alkalinity and phosphate have reduced, there has been a moderate increase in sulphate, conductivity and hardness;
d. At Renukoot while SAR, concentration of fluoride, coliform have reduced, the concentration of sulphate has registered increase;
e. At other location in Renukoot (Code SG_3) itself the fluoride content has increased while SAR, colour, alkalinity and conductivity have registered a sharp decline.
f. At Renusagar there has been increment in coliform, alkalinity, sulphate, nitrate and TDS while phosphate and boron have decreased.
g. At Anpara and at Bina the water quality changes have been quite significant while alkalinity, nitrate, boron, chloride and sulphate have registered a sharp increase and boron exhibiting sharp decline the concentration of fluoride is different. It has increased at Anpara while at Bina reduced concentration has been observed.

Heavy Metals and Pesticides

A significant decreasing trend of all the heavy metals and pesticides at all the locations in general have been observed, except iron and lead which have shown increasing trend at respectively Renukat, Renusagar & Bina.

4.7 Vishakhapatanam Problem Area

4.7.1 Environmental Profile of Vishakhapatnam Area

General Features & Topography: Vishakhapatnam is situated at latitude 17°-42' North and longitude 83°-20' East. The main city area stretches North to South and is a spoon shaped basin surrounded by hills on three sides with a narrow Eastern Zone protruding into the Bay of Bengal. The Western side with a group of small hills joins the plains of the city, which is surrounded by the Adivivaram Hill range on the north and the Yerada Hill range on the South. The fresh water of Magadrigadda River and the seawater from the salt creeks forms the tidal swamp in the plains. The Lavender Canal receives the municipal sewage of the Vishakhapatnam. The area of Vishakhapatnam Urban agglomeration is about 93.44 square km. The land use pattern of Vishakhapatnam metropolitan region showed that 66% of the total area was accounted by agricultural activities, hills and forest cover of the total area while the Steel Plant and other industries occupied about 7% of total area available.

Climate: The monthly mean temperature at Vishakapatnam was in the range of 23.3°C to 31.7°C. In the city the humidity percentage was high with low range of variability. The highest humidity of 75-100% range was observed during July-September, whereas the lowest was experienced during November and December and ranged between 50-75%. Vishakapatnam gets rainfall from the Southwest monsoon in the period between Octobers to November; the average rainfall recorded being 1016 mm.

Water supply & population: The water supply to Vishakapatnam was 110 mld while the per capita domestic consumption was 50 litre per day. The industries consume about two thirds of water supply of entire city. The city is one of the fastest developing cities in the country with rapid industrialization and quick growth of commercial activities. The port area is one of the busiest in the country, which is fully developed with adequate infrastructure to take care of all to handle increased cargo traffic. Due to availability of all basic amenities the city has grown into a vast industrial city with having the country's first coast based steel plant. The Eastern Naval Command was established in the year 1942 with Vishakapatnam as it's Headquarters. Due to its constrained geographical location the city's infrastructure is overloaded and the problem is further stressed due to growing population. As per the last census the population was 13 lakhs (2001census). The water demand for the region was being met from Megadrigadda Dam, groundwater (recharged by streams) besides natural streams make water supply adequate.

Wastewater discharge: A channel originating from the west side receives industrial waste discharges of Hindustan Zinc Limited, Coromandal Fertilisers, Hindustan Petroleum Corporation Limited and A.P. Petrochemicals Limited. The municipal sewage of the Vishakapatnam also meets the water channel through Lavender Canal. The water channel confluences backwater channel and finally to Bay of Bengal in the Eastern direction after meeting

4.7.2 Sources of groundwater contamination

Major polluting industries which Hindustan Polymers, Hindustan Zinc, Coromandal Fertilisers, Hindustan Petroleum Corporation, Vishakapatnam Steel Plant, A.P. Petrochemicals Limited and

Bharat Heavy Plants and vessels Limited are located in Vishakapatnam City and are discharging treated and untreated industrial effluents and domestic sewage into the Bay of Bengal through the Lavender Canal. The industries exploit the Magadrigadda reservoir over flow as a channel to let out their effluents without treatment.

4.7.3 Groundwater quality survey locations

At Vishakapatnam, seven ground water survey stations were selected to study the quality of water in respect of 35 parameters. The sampling stations were identical to those chosen in the year 1994. The samples were analyzed at the regional office of Andhra Pradesh State Pollution Control Board, at Vishakapatnam. Survey stations are presented in Table 27.

Table 27: Survey of Groundwater stations at Vishakapatnam

Sl. No.	Name of the station	Location details	Type of well	Present use
1.	G1. MVP Colony	Inside little Angels Convent	Bore well	Drinking, Garden, Domestic use
2.	G2. IDA, Marripalem	Opp. To Industrial Estate	-do-	Domestic
3.	G3. RR Venkatapuram	Next to Hindustan Polymers Ltd.	-do-	Drinking
4.	G4. Shielanagar	Inside the house No MIG A-8	Open & round	Domestic
5.	G5. Mindi (Early well is closed)	Near bus terminal house No. 2-9-7	-do-	Washing cloths
6.	G6. Pedaghantyada	Near Aruna Theatre	Open & square	Domestic
7.	G7. R.K. Puram	St. Joseph's School	Bore well	-do-

4.7.4 Observation on the Status of Groundwater in Vishakhapatnam

a) **MVP Colony.** Bore well water used for drinking and domestic use. This place is residential area and away from industrial belt. In groundwater the average concentration of the pollutants was as follows: Nickel 120µg /lit, Iron 10µg/lit, Cromium 315µg/lit, Cobalt 15µg/lit, Total Hardness was 365 mg/l, Fluoride was within the limit, Phosphate was nil, TDS was 838 mg/l, Sulphate was 56 mg/l, Total Coliform found very high i.e., 1600/100 ml.

b) **TDA Marripalem.** This station is near to the industrial estate Marripalem, where numerous small units are located, and many of the units are closed In groundwater the average concentration of the pollutants was as follows: Nickel 145 µg /lit, Lead 15µg /lit, Chromium 345 µg /lit, Cobalt 15µg /lit, Total Coliform found low 9 per 100 ml. Total Hardness was found 415 µg/lit, Phosphate was nil , Sulphate was found 42µg/lit, TDS was found high i.e. 987 µg/lit, Fluoride, Chloride and Nitrate were found within the limit.

c) **R.R. Venkatapuram**. This place located near M/s Hindustan Polymers Ltd., to ascertain GW contamination. In groundwater the average concentration of the pollutants was as follows: Nickel 165 µg/lit, Iron 100µg/lit, Lead 50µg/lit, Chromium 15g/lit, Cobalt 50 µg/lit. Total Coliform was nil, Fluorides, Chlorides and Nitrates were within the limit, Phosphates was not traceable, Total Hardness was 200 mg/l,TDS was 849 mg/l.

d) **Shiela Nagar**. This is one of the residential colonies falling in between the main industrial belt and M/s Hindstan Polymers. In groundwater the average concentration of the pollutants was as follows: Nickel 215 µg/lit, Iron 5µg/lit, Cobalt 10µ g/lit, Total Coliform was 1600/100ml, Total Hardness was 276 mg/l, Fluoride exceeded the limit i.e. 2.07 mg/l, Chloride, 185 mg/l, Nitrate 12.3 mg/l, TDS was 2078 mg/l.

e) **Mindi**. This village located in the middle of industrial belt and already identified as highly polluted and this was selected to know the impact of pollution. In groundwater the average concentration of the pollutants were as follows: Nickel 7061 µg/lit, Zinc 200 µ g/lit, Iron 75 µ g/lit, Cobalt 80 µ g/lit, T.coliform was 1600/100 ml, Total Hardness was very high i.e, 2705 mg/l, TDS also high i.e., 7061 mg/l. Fluoride and Chloride are within the limits, Phosphate was not traceable. Nitrates was 14 mg/l, Sulphate high i.e., 2338 mg/l. This monitoring location was found highly polluted.

f) **Peda Chantyada.** This place located on the other side of the industrial belt. In groundwater the average concentration of the pollutants was as follows: Nickel 270 µg/lit, Iron 95 µg/lit, Cobalt 30 µg/lit, Total Coliform 1600/100 ml, Total Hardness was 5565mg/l, TDS was found 1277 mg/l, Fluoride, Chloride and Nitrate were within the limit.

g) **R.K. Puram .** This station was also located on the hillside of the industrial belt and to serve the purpose of the base line station. In groundwater the average concentration of the pollutants were as follows: Nickel 265 µg/lit, Iron 35 µg/lit, and Total Coliform was 1600/100 ml, Total Hardness was 456 mg/l. Fluoride and Nitrate were within the limit, Total dissolved solids was 1105 mg/l, Phosphate was nil.

Heavy metals, pesticides, Physio-chemical and T.Coliform, F.Coliform parameters were analyzed. Three rounds of analysis results with Min. , Max. , And Average has been presented in **Table 5 a), 5 b), 5 c) and 5 d) of Annexure-II and in Table 6 a), 6 b), 6 c) of Annexure-II, Sampling data for September 2001, February, 2002 and October, 2002 has been presented.**

Major Findings

1. Mindi area is highly polluted area, followed by Peda Chantyada.
2. The R.K. Puram also indicated that the groundwater was polluted.
3. Presence of T. Coliform at most of the locations indicates that sewage was polluting the groundwater.
4. Heavy metal presence was minimum in all stations.
5. TDS exceeded the limit in all the groundwater monitoring points. Phosphate was not traceable.

4.8 Bollaram-Patancheru Problem Area

4.8.1 Environmental Profile of Bollaram-Patancheru (A.P.) Area

General Features & Topography: The Bollaram-Patancheru area extends from North latitude 17°-32 to 17°-39 with aerial extent of 70 sq km. Physcically, the Patancheru area is constituted of low hills and hillocks in the south western part and low ground extending from the south of Hyderabad - Mumbai National highway to the north of highway upto the confluence of the Nakkavagu with the Manjira river, the latter is a tributary of Godavari river. Patancheru is a township of Medak District located at a distance of 35 km from Hyderabad. The township covers an area of 17 sq. km with an estimated population 50,000 (1993). The entire area forms small part of the Godavari main valley but exclusively remains entrapped in the micro-valley of Nakkavagu-China Vagu, Pamla Vagu and Pedda Vagu (are some of the minor tributaries of the Naggavagu) and is controlled by the NE-SW and N-S lineaments, thus making it a relief channel with sharp assorted micro alluvial body. Besides the surface streams a number of irrigation tanks are also present. These tanks are also utilised for meeting domestic needs. The total area under irrigation using tank water is estimated to be 69480 ha and the lift irrigation from canals and streams account for 2373 ha. Hydro-geologically the area can be classified as hard rocks comprising the archeans and Deccan trap soft rock comprising of alluvium and laterites groundwater occurs under water table and in semi-confirmed conditions. Presently the development of groundwater potential is 10% in ayacut area and 62% in non-ayacut area. In general dug wells in this area are of low capacity, which tap only upper aquifers. The depth of the wells varies from 8 to 20 m and the average yield range between 40 to 160 kld. Full recuperation is attended in 4 to 8 hrs. For alluvium formation 12 to 16 hrs for laterite formation land and 15 to 40 hrs in hard rock areas required. The Andhra Pradesh Industrial Infrastructural Corporation (APIICC) developed in five phases from the year 1973 onwards. At present about 307 units are located at Patencheru and majority of them (about 276) are operating from APIIC area. The entire Patancheru industrial area is provided with all the necessary infrastructural facilities except the much needed sewer system. There are two natural watercourses in the area and normally for most part of the year, they are dry with no fresh water flowing into them. Bollaram is a village in Jinnaram, a mandal of Medak District and is located at about 28 km away from Hyderabad. The industrial area has approximately 65 units of medium and small-scale units involved in bulk drug / pharmaceutical production. Due to groundwater contamination at present, water requirement was met though tankers. There are no natural watercourses in the area. The aerial distance between Patancheru and Bollaram is about 3.0 KM. This area lies in a tropical savannah type zone climatically. The average ambient temperatures vary from 40°C in summer to about 22°C in winter and get about 800 mm of average rainfall annually. The humidity ranged from 54.9% to 74.4% with an annual mean of 65.2%. The annual potential evaporation was 1935 mm.

4.8.2 Sources of groundwater contamination

The industries located at Bollaram-Patancheru fall into broad categories as follows: leather, slaughterhouse, manufacturing / formulating pesticides and bulk drugs. The treated / untreated effluent was being discharged outside the industrial premise onto the roads over the nearby drain, which ultimately ends up either as a pool of waste water or join the natural water course of

Manjira River through its tributaries. At present there are two common effluent treatment plants (CETP) in this area. The tankers bring industrial effluents to the CETP where treated effluent let into drains. These CETPs are not complying with the pollution control standards for TDS and colour. All the natural watercourses namely Chinna Vagu, Pamla Vagu, Pedda Vagu and Nakka Vagu receive and carry the industrial wastewater, which is highly polluting by nature. This area does not have a sewage treatment system. The unsatisfactory industrial and municipal sewage disposal practices can pollute the groundwater in the region.

4.8.3 Groundwater Quality Survey

At Patancheru and Bollaram area, seven-groundwater quality monitoring stations identical to those monitored in 1994, the GW was analyzed for required parameters. The details of monitoring stations are presented in Table 28.

Table 28: Groundwater monitoring stations at Patancheru and Bollaram

Sl No.	Name of the station	Location details	Type of well	Present use
1.	Lakdaram	Next to the Sarpanch House	Bore well	Domestic use
2.	Khardanoor	Opp. to Shri. Narsimhlu House	-do-	Domestic use incl. Drinking
3.	Inole	Near the entrance of the village	-do-	-do-
4.	Kistareddypet	Opp. to the big irrigation tank	-do-	Domestic use
5.	Isakabhavi	Inside the primary School	-do-	Domestic use incl. Drinking
6.	Bachupalli	Near the entrance of the village	-do-	-do-
7.	Bollaram	Near the Cinema Theatre	-do-	-do-

Central Pollution Control Board, South Zone Office carried out groundwater Survey in the month of September 2001, January 2002 and October 2002 and the samples were handed over to Andhra Pradesh Pollution Control Board Lab at Hyderabad for analysis. The base line station was selected from the Khardanoor village and impact stations are selected at Lakdaram village for Patancheru area and Kistareddypet village for Bollaram area. All the seven-groundwater source were selected from the villages and all the wells are bore wells. The groundwater at all these villages was being used either for drinking or for domestic needs by the villages.

4.8.4 Observation on Status of Groundwater Quality in Patancheru and Bollaram

a) **Lakdaram:** This monitoring point was one of the severely affected villages monitoring station. Piped water supply existed in this region. Total dissolved solids were reported greater

than 1500 mg/l Total Hardness was reported average was 1020 mg/l. Fluoride was reported to be within the limit. T. Coliform and F. Coliform were nil.

b) **Khardanoor (Bore well):** This village is on upstream side of Patancheru on Nakkagu. TDS average was 780 mg/.lit & Total Hardness was 440 mg/l. Fluoride was within the stipulated limit of drinking water. Lead and Chromium were found in microgram level. Mercury Chromium was not traceable. T. Coliform and Fecal Coliform were not reported.

c) **Inole Bore well:** This village is also one of the affected villages in the area down streamside of Patancheru on Nakkavagu. The TDS average was 620 mg/l. Fluoride was 0.9 mg/l. Chromium and Lead were found in microgram level concentration. Mercury, Arsenic and Calcium were not traceable, T. Coliform and F. Coliform were not reported.

d) **Kistareddy peta Bore well:** This village registered many complaints of water pollution against the Chemical units located at Bollaram**.** The TDS average was 1520 mg/l , Total Hardness 2000 mg/l. Nitrates 24 mg/l, Fluoride 1.2 mg/l , Chromium, Lead were present in microgram level.

e) **Bollaram:** This village is located at the core of Bollaram industrial area. The TDS concentration average was 1870 mg/l and Total Hardness was 730 mg/l. Fluoride was 1.1 mg/l and within the drinking water limit. Chromium and Lead were found in microgram level. Mercury, Arsenic and Cadmium were nil. T.Coliform and F.Coliform were present.

f) **Bachupally:** This village is at the periphery of Bollaram Industrial. The TDS concentration average was found 690 mg/l and Total Hardness 600 mg/l. Fluoride 1.0 mg/l. Chromium and Lead were found in microgram level. T. Coliform and F.Coliform were present.

g) **Isakabavi Bore Well:** This village is adjacent to the Patancheru Industrial Area. The TDS average was found 905 mg/l and Total Hardness 330 mg/l. Fluoride was 1 mg/l. Lead & Chromium were in microgram level. Mercury. Arsenic and Cadmium were nil. T. Coliform & F.Coliform were nil.

Lakdaram, Kistareddy peta, Bollaram, Isakabavi were highly polluted area. Khardnoor, Inole Bachupally stations were moderately polluted. Heavy metals, pesticides, Physio-chemical and T.Coliform, F.Coliform parameters were analyzed. Two rounds of analysis results with Min. , Max. , And Average has been presented in **Table 7 a), 7 b), 7 c) of Annexure-II. Sampling data includes for the months of September 2001, February, 2002.**

Major Findings

1. Bollaram-Patencheru study area deepens mainly on groundwater.

2. CETPs are not meeting the treated effluent standards.

3. TDS, Total Hardness, Sulphate and Heavy metals were reported high at all monitoring stations and at some T. Coliform & F. Coliform were reported.

4.9 Bhadrawathi Problem Areas

4.9.1 Environmental Profile of Bhadravathi (Karnataka) Areas

The town is located on the bank of River Bhadra. An important river of the state is the river Tunga, which also flows through this region. Two rivers confluences and form the Tunga-Bhadra at Kudli, which is 15 km north of Bhadravathi. Geologically, this area is predominated by ancient rock Dharwar Schist interspersed with much younger granites and gneisses. The climate of the region is semi arid. The rainfall of the area ranges between from 391 mm to 1025 mm with a average rainfall of 680 mm. The humidity ranged from 42% to 92%. The soil is mostly red-loamy. The minerals available in the area are fine quarzite and limestone in nearby surroundings. Bhadravathi Town has two local authorities i) Town Municipal Council covers old town covering an area about 22.4 sq km and; ii) The notified area covering an area of about 17.55 sq. km. The population as per 1991 census has been reported around 1.5 lakh. The two major industries in this region are namely

- M/s Mysore Paper Mills Ltd.,
- M/s Visveshwararayya Iron and Steel Ltd.,

The Bhadaravathi reservoir spread over an area of approx. 9.5 sq. km provides water for agriculture. The various crops grown in this area are paddy, sugarcane and areca nut.

4.9.2 Sources of pollution

Groundwater contamination can arise from treated effluent discharged into the river from the two major industries viz. M/s Mysore Paper Mills Ltd., and M/s Viveshwarayya Iron and Steel Ltd.. The other major source of pollution is the untreated municipal sewage of the town getting dumped into the river Bhadra. Agricultural practices (chemicals) may also contribute to GW contamination.

4.9.3 Ground water quality survey

To assess the ground water quality and to compare previous rounds GW samples collected were analyzed for three stations (the same as was for the previous monitoring done in the year 1994). The sampling locations are presented in Table 29.

Table 29: Groundwater survey locations

Sl.No.	Name of Groundwater sampling point	Source of water	Mode of use
1.	Amirjan Colony	Bore well	Domestic
2.	Babballi	"	"
3.	Machenahalli	"	"

Samples were collected from the above monitoring points in the months of September 2001, January 2002 and May 2002.

4.9.4 Observation on the Status of Groundwater Quality in Bhadravathi

a) Bhadravathi groundwater was being used mainly for domestic purpose and agriculture purposes.

b) Groundwater samples reported high TDS, Total Hardness and Chloride content indicating that the groundwater was unfit for potable water.

c) Presence of T. Coliform and F.Coliform in the samples indicates that groundwater was being polluted by the town's sewage.

d) Seasonal variation was observed the groundwater quality.

Physio-chemical and T. Coliform, F. Coliform parameters were analyzed. Three rounds of analysis results with Min. , Max. , And Average has been presented in **Table 8 a), 8 b), & 8 c) of Annexure-II; Sampling data for September 2001, January 2002 and May 2002 has been presented in Table 9 a), 9 b), & 9 c) respectively of Annexure-II.**

4.10 Kochi or Cochin Problem Area

4.10.1 Environmental Profile of Cochin (new name Kochi-Kerala) Area

Cochin has one of the world's best natural harbors and is one of the important ports in East-West travel routes. The city has a naval base and is serves as the central distribution of goods. Ernakulam District where the city is located has been declared 100% literate.

General Features & Topography: Cochin region falls within the low land and mid land region. The low land that forms the western portion of the region comprises of backwater and lagoons. The mid land lying east of the low land has a natural drainage. As a whole the land slopes down from east to west. The Periyar is the major river in the region that enters through the northern region. Chitraputzhe is another river found in the area too. The soil is sandy loam or sandy type and is also highly acidic in nature. Paddy, rubber, coconut, pepper etc. are crops of this area. In the city area, it is reported that about 12.6% land is under agricultural use, 23.4% under water sheet and remaining 64% was developed land. Due to the backwater these low-lying are have many small and large islands. The Willington Island was formed by the reclamation of the soil dredged from the backwater to organize the major boat events, which is popular among the tourists. Cochin City and the surroundings suburbs are located in the proximity of the Arabian Sea. The co-ordinates of the region is latitude 9°-58' North and longitude 76°-14' East with the altitude almost to the sea level and to 10 meter mean sea level at some places. Cochin is also the industrial and commercial capital of the state. The study area comprises of about 187 km2 of which the city area is about 95 km.

Population: This City area has a population of 13 lakhs with a population density of 59 persons per hectare during 1991-2001 Census. The city is one of the major tourist spots in Kerala.

Water Supply: The piped water supply is limited to the corporation area only while the other areas are mainly dependent on groundwater. Organized sewerage system does not extend beyond the corporation limit. Most of the houses have individual soak pit and septic tanks. The city is one of the major tourist spots in Kerala. The water supply is limited to the corporation area while the other areas the people are mainly depending on groundwater. The rivers do not contribute to water supply though they serve as recipient bodies of industrial effluent. Both industries and agricultural activities are dependent on groundwater.

Industrialization: The industrialization began with the establishment of M/s FACT in 1947. As the area is well connected both by road and rail, it has attracted the establishment of several industries. There are several major industries, medium and small-scale industries spread through out the study area. Kalamassery industrial estates, Eloor-Alwaye belt, Amlalamugal region accounts for the major industrial establishments in the region. Cochin is now known by its relatively new name - Kochi. It is an important city of the state of Kerala, and is also named as "Queen of the Arabian Sea".

Climate: The Cochin area experiences two monsoons, first from the June to August monsoons providing heavy rains, while the second from September to November. The annual average rainfall was about 3100 mm. During the summer months the city experiences temperature ranging between 22.4°C to 32.5°C, while for rainy season and winter the temperature ranged between 22.3 to 29.7°C and 21.8°C to 31.4°C respectively. Relative humidity ranged between 81% and 87% for the months from June to October; while for other months it was around 72% mean wind speed based on 30 years average ranged from 6.7 to 10.9 km/hour.

4.10.2 Source of groundwater contamination

As mentioned earlier the industrialization in this area began with the establishment of M/s FACT in 1947. As the area is well connected by road and rail this offered several advantages for setting up of industrial units. There are 11 large scale-industries and 8 medium units are presented in Table 30.

Table 30: List of large and medium industries in Cochin

	Large scale industries			**Medium scale industries**
1.	M/s FACT- Petrochemical Division		1.	M/s Kainady Tanneries Pvt. Ltd.
2.	M/s FACT-Udyoga- Mandal Division		2.	M/s Cochin Laethers (P) Ltd.
3.	M/s FACT – Ammonia Plant Division		3.	M/s Sree Sakthi Papers Mills Ltd
4.	M/s Indian Rare Earths		4.	M/s Periyar Chemicals Ltd.
5.	M/s Travancore Cochin Chemicals		5.	M/s Indo-German CArbon (P) Ltd.
6.	M/s Binani Zinc Ltd.		6.	M/s Merchem Ltd.
7.	M/s Cochin Minerals and Rituals		7.	M/s Vithoga Chemicals (P) Ltd.
8.	M/s Indian Aluminum Company		8.	M/s Arjuna Aromation
9.	M/s Hindustan Insecticides Ltd.			
10.	M/s Carborandum Universal			
11.	M/s Travancore Chemicals Manufacturing Co.			

Around 20 small-scale industries are also located in this area. The Kalamassery Industrial Estate, Eloor-Alwaye belt - Ambalamugal region account for major industrial establishments. Industries treated and untreated effluents are being discharged into river and on land. There has been concern of seawater intrusion in t he western part of the city. About 24% of the area is covered by water that is directly or indirectly connected with the sea through canals and backwater. Many islands, in and around the city are thickly populated and they transport their materials through boats. Due to this the canals in the corporation area have become polluted. Sewage was being let out directly into river / lagoons without treatment. In the study area groundwater, mainly the open well, dug wells are main sources of drinking water. As this region receives more than 300 cms of annual rainfall, the groundwater gets recharged every year. Due to shallow water table there is a high risk to groundwater contamination by any polluting source. Land availability being limited human settlements readily build near industries. Many of the wells in the vicinity of these industries have been reported unfit for drinking.

4.10.3 Groundwater Quality Survey

Central Pollution Control Board, South Zone Office carried out groundwater sampling at 7 stations for the period in September, 2001, January, 2002 and May, 2002. The Groundwater samples analyzed at the Kerala State Pollution Control Board Laboratory for the parameters heavy metals, pesticides, T. Coliform, F. Coliform, physio-chemical parameters. The details of Groundwater locations are presented in Table 31.

Table 31: Groundwater Quality Survey Locations

Sl. No.	Name of Groundwater (GW) station	Depth	Type of well	Present use
1.	Bramhapuram (new) (GW1)	25 feet	Dug well	Irrigation
2.	Eloor (new) (GW2)	20 feet	Dug well	-do-
3.	Cochin Export processing Zone (new) (GW3)	20 feet	-do-	-
4.	Kalamassery (new) (GW4)	15 feet	-do-	Drinking
5.	Ambalamugal (new) (GW5)	10 feet	-do-	Drinking /irrigation
6.	Mattancherry (old) (GW6)	10 feet	-do	Domestic
7.	Edayar (new) (GW7)	15 feet	Dug well	-do-

4.10.4 Observations on Status of Groundwater Quality of Cochin

a) **Bramhapuram:** The station located in year 1994 was shifted to a nearby dug well. Dug well groundwater was used for irrigation purpose. This station is located in a low-lying area and near to M/s FACT industry. The GW results for the various parameters are as follows: pH is acidic; cyanide and phospahte were not traceable. Fluoride was within the limit. TDS was slightly high, T. Coliform, 2160 /100 ml. and F. Coliform 2000 /100 ml present, heavy metal Zinc 384 µg/l. Cadmium µg /lit, Iron 243, Manganese 111 µg /lit, Pesticides was traceable.

b) **Eloor:** The previous location in 1984 was shifted to the adjacent house well. The site was observed most polluted on the other side of the driver Periyar. Many large industries are located.

M/s FACT, M/s Indian Rare Earth, M/s Hindustan Insecticides etc. are among them. This well water was being used for irrigation. The GW results for the various parameters were as follows: pH was acidic pH 5.5 to 6.0; cyanide and phosphate were not traceable; sulphate content was found high in the May 2002 sample i.e., 66 mg/l. Total Coliform and Fecal coliform were present. Fluoride content was within the limit. Heavy metals were present in Zinc 106 μg/l, Iron 224 mg/l., Manganese 111 μg/lit in the month of May 2002. Pesticides are not traceable.

c) **Cochin Export Processing Zone (CEPZ) (Dug well):** The CEPZ was established a few years back and is situated near to Kakkanad. At most of the rounds this station water sample pH was acidic, TDS and Fluoride was within the limit. Cyanide and Phosphate are not traceable. Total Hardness between 14 mg/l to 232 mg/l. T. Coliform & F.Coliform were present in the water sample. Heavy metals zinc, cadmium, iron and manganese were present in microgram level pesticides were not present in groundwater samples groundwater sample was polluted by total hardness, heavy metals and T. Coliform and F. Coliform.

d) **Kalamassery:** The dug well is located near Kalamassery industrial estate. This is one of the oldest industrial estates in Kerala. Many medium and small-scale industries are located here. This well water was used for drinking purpose groundwater pH was acidic, total hardness was low ranged between 6 mg/l to 30 mg/l; fluoride was within limit, phosphate, cyanide were not traceable. T. Coliform and F. Coliform were present and pesticides were not traceable. Heavy metal was high in the month of May 2002 i.e., Nickel 18 μg/l, zinc 22 μg /lit, lead 66 μ/lit, cadmium 531 μ/lit, copper 110 μg/l, iron 525 μ g/l and manganese, 102 mg/l respectively.

e) **Ambalamughal:** This area is located at a high altitude. M/s Cochin Refinery, M/s FACT Cochin Division, M/s HOC Ltd. etc are located near this sampling station, dug well water used for drinking purpose. The groundwater pH was acidic. Total hardness ranged between 24 mg/l to 30 mg/l, fluoride was within the limit, cyanide and phosphate were not traceable, nitrate nitrogen was 11 mg/l, T. Coliform, Feacal Coliform were present in the groundwater. Pesticides were not traceable. Heavy metals were present Nickel 11.13 μg /lit, Zinc 1.42 mg/l, Lead 117 μg/l, Cadmium 61 μg/l, Copper 166 μ g/l, Iron 196 μg/l, Manganese 106 μ g/l was observed.

f) **Mattanchery:** Groundwater collected in the same well (earlier monitoring in the year 1994). This is community dug well. This is one of the oldest areas in Cochin City. The population is highest in this region and many people share water from the same wells. The station is also close to sea to check seawater intrusion. Most of the time the groundwater ph was acidic. Total hardness was 310 mg/l in the May month 2002 sample. Fluoride was within the limit. Phosphate and cyanide are not traceable. T. Coliform, F. Coliform was significant. Pesticides were not traceable. Heavy metals zinc, iron, manganese are present in μ g level (microgram).

g) **Edayar** Sampling points is open dug well. The groundwater is used for drinking as well as irrigation. This station is located near river Periyar. Many large and medium industries situated in this area. Among them the important ones are M/s Binani Zinc Ltd., M/s Periyar Chemicals etc. The groundwater samples pH mostly acidic. Total hardness was 365 mg/l. Fluoride value was within the limit. Phosphate and cyanide were not traceable. TDS was 570 mg/l, T. Coliform and F. Coliform found nil. Pesticides were not traceable. Heavy metals, Zinc, Lead, Copper, Iron, and Manganese were found in μg level (microgram).

Greater Cochin study area, rivers and drains are polluted by industries. Most of the groundwater was reported as acidic. This may be due to industrial pollution / or soil nature. Heavy metals, T. Coliforms, F. Coliform were present in the most of the groundwater samples. Most of the wells are surrounded by industries are reported to be unfit for drinking. Physio-chemical, T. Coliform, F. Coliform and Heavy metal Pesticide were analysed. Three rounds results with Min. , Max. , And Average has been presented in **Table 10 to 13 of Annexure-II. Sampling result of September 2001 and May 2002 has been presented in these tables.**

4.11 Manali Problem Area

4.11.1 Environmental Profile of Manali (TN) Areas

General Features & Topography: Chengalpet District in Tamil Nadu has a geographical extent of 7863 sq. KM with a shoreline of 142 KM. This district lies between latitudes 12° 14' - 45" North and 13° 31' North and longitudes 79° 15' East and 80° 20' East. The eastern boundary of the district is marked by the Bay of Bengal on the North by the state of Andhra Paradesh on the south by Cuddalore District (TN) and the on the west by Vellore District. Manali study area is located in the northern part of the district and is spread over area of 800 hectares consisting of Manali, Manali New Town and villages like Sadayankuppam, Elanthancheri, Andarkuppamanf, Kanniyampet.

Rainfall: Manali area receives rainfall from both monsoons (South-West monsoon & North-East monsoon) the normal annual rainfall was 1211mm. The temperature of the district ranged between 25 °C & 40 °C.

Geology: The hydro-geologiccal condition in Chengalpet district can be studied for three units namely the fissured crystalline rocks. The semi consolidated sediments and the unconsolidated alluvia hard rocks occupy almost half of the district area. Generally, the aquifers of these formations are heterogeneous in nature. These rocks possess negligible primary porosity but are rendered porous and permeable with development of secondary openings by fracturing weathering and their inter connections. Groundwater in these formations occurs under water table conditions. The alluvia of the District are of two types and fluvial. The marin type occupies the coastal region. The fluvial type of alluvia was found to occur along the river courses of the rivers. The area under study falls in the former type namely coastal alluvium. In the alluvial formation, groundwater occurs under water table and confined conditions. The depths of dug wells ranges from 4.50 to 12.00 meters below ground level and the depth to water level lies within 6 meter. The study area does not have prominent aquifers; some shallow irrigation wells and a few domestic wells are the common groundwater structures in this area. The Buckingham Canal flows through this area. As no rivers flow in this area, groundwater serves as the major source of water supply.

4.11.2 Source of groundwater contamination

Several industrial units mainly dealing with chemicals, fertilizers and petrochemicals are located in the Manali industrial area and are listed below:

a) M/sTamil Nadu Petro- products Limited
b) M/s EID Parry (Compund) Fertiliser Ltd.
c) M/s Madras Fertilisers Ltd.
d) M/s Ennur Foundry Ltd.
e) M/s Celtepetrol chemiacls Ltd., (Pharmaceutical plant)
f) M/s Chennai Petroleum Corporation Ltd.
g) M/s Ennore Thermal Power Plant
h) M/s North Chennai Thermal Power Plants
i) M/s Indian Organic Chemicals Ltd.

The water required for these industries was being supplied from the groundwater from the nearby Minjur and Thamarapakkam well fields. Some of these industries are using their treated water too. These industries are discharging their treated / untreated effluent into drains or the Buckingham Canal. Being in close proximity to the sea these factories is contaminating the groundwater by seepage besides there is a problem of salt-water intrusion.

4.11.3 Observations on the Status of Groundwater Quality in Manali

Central Pollution Control Board, South Zonal Office, Bangalore carried out groundwater quality monitoring. In Manali area at six locations were spread over the industrial estate, residential area, and agriculture area. The stations names are as follows:

- Bore-well near councilor house Rajendraprasad Street, Manali (**M1)**
- T. Gurusamy house new town, bore-well, Manali (**M2)**
- Dugwell near Manigandam house, Vinayagar Koil, Kannayammanpettai, Manali (**M3)**
- Hand pump at Veeran House, Maryyamman Koil Street, Elandanur, Manali. (**M4)**
- Dug well at Gangaimmman Koil, Sadayankuppam. (**M5)**
- Bore-well at Subramaniyan House II Cross, Jothinagar, Thiruvottiyur, Manali. (**M6)**

The GW samples were collected for the months September 2001, January 2002, and June 2002. Physio-chemical, T. Coliform, F. Coliform and heavy metal pesticides were analyzed. Three rounds of analysis results with Min. , Max. , And Average has been presented in **Table 14 to 22 of Annexure-II.**

Major Findings

- In Manali area, groundwater is the main source of water supply.

- Groundwater was being used as a source for drinking water, domestic use, industry and agricultural purposes.

- Except for the locations T. Gurusamy house new town bore well, Manigandan house, Vinayagam Koil, and Kanniyammanpettai, Manali the TDS was more than 2000mg/l.

- At all the locations fluoride was within the limit of drinking water i.e. less than 1mg/l.

- For the hand pumps at Veeran House, Mariyamman Koil street and Elenthanur the total hardness was high i.e. 1320

- The cyanide content was low.

- Chloride content was within the limit, except for the dug well at Gangaimman Koil Sadayamkuppam where it was reported as 1395mg/l.

- Nitrite content was within the limit in all groundwater locations.

- Heavy metals Cu,Cd, Mn, Pb and total chromium content was low except for the hand pump at Veeran house, Mariyamman Koil Street, Elandanur, Manali.

- Total Coliform & Fecal Coliform contamination was observed.

4.12 North Arcot Problem Area

4.12.1 Environmental Profile of Vellore District (North Arcot, TN) Area

General Features & Topography: The District has a total geographical area of 5887 sq. km. It lies between latitudes 12^{o} 15' North and 13 ^{o} 15' north and longitudes 78^{o} 200 East and 79 ^{o} 55' East. The Western part of the district has a hilly terrain with undulating topography comprising of a few hill ranges. While eastern part is a gently undulating with isolated hillocks of which the highest elevation was 1339 m above sea level.

Drainage: The district is drained by the major river Palar and its tributaries namely the Goddar, the Malattar and the Poiney. The Palar River rises near Nandhidug in Karnataka and enters into Vellore District near Vaniayambadi. The Palar river flow is seasonal with water flowing mainly in the monsoon season.

Climate: Vellore District has a tropical climate. The temperatures ranged between 20 ^{o}C to 35 ^{o}C. The district receives rainfall from both, the Southwest and Northeast monsoons. The average annual rainfall is about 971 mm.

Geology: Geologically, the district is covered by crystalline rocks of Archaean age comprising of charnokites, granites, genesis, quartersites etc. Alluvium occurring in the district is of fluviatile origin and restricted to the course of rivers and major streams. The alluvium consists of gravel, fine, coarse sand clay. Groundwater occurs under water table conditions in the weathered and jointed rocks of the crystalline basement. Water levels range between 2 to 29 m in crystalline rocks and 2 to 8 m cartulary deposits depending on topography. The groundwater extraction points are mostly in the form of open dug-wells of diameters ranging between 6m to 10m, these wells vary in yields. There are several groundwater extraction points in the river Palar bed in the form of infiltration wells and galleries and water from these structures is supplied to the major regions located along the river course including a few industries too. In some of the areas bore wells supply water for drinking and industrial use. The Palar river and tributaries are

seasonal rivers. Water flows only during the rainy seasons while throughout the year there is barely any flow, the district, therefore, relies mostly on rain water and groundwater.

4.12.2 Sources of groundwater contamination

The groundwater is mainly tapped to meet agricultural demand followed by industrial and domestic sectors. The domestic sector mainly depends on water from Palar River Bed. The industries depend on both on the bore well water and Riverbed infiltration well water. Groundwater pollution is widely perceived in the district. The major sources are the effluents from the industrial units especially tanneries, which are engaged in the processing of raw leather. Disposal of urban sewage indiscriminately also can cause groundwater pollution. The non-point sources of pollution are from fertilizers and pesticides applied in the agricultural fields. The dyeing units and other water-based industries located in Vellore District also contribute to Groundwater pollution.

In Ranipet industrial unit M/s Tamilnadu Chromate Industry manufactures chromium compounds, which are being used in tanneries. The chromium bearing hazardous waste (approximately I lakh ton) was being dumped in the factory premises; the industry has been shut down and has not been operating for quite some time. The chromium leaching from the hazardous waste dump cannot be ruled out as the GW samples (yellowish - green colour) collected have reported the presence of chromium

4.12.3 Groundwater quality survey

Fourteen groundwater-monitoring stations were selected in Vellore District. The monitoring stations were selected in the industrial estate, residential area, (domestic), Agriculture Area (agriculture use). The details of the network are shown in the Table 32. The monitoring stations were selected in Ranipet, Kudiyatham, Peranampet, Chinna Thammacheruvu, Periyavarikkam, Venkata samutharam, Solur and Vaniyampadi respectively. The Groundwater samples were collected in the months September 2001, January 2002 and May 2002.

Table 32: Groundwater survey Locations in North Arcot (Vellore)

Station Code	Name of Station	Approx. depth	Type of well	Present use
1	Ranipet library opposite	7 mtrs	Dug well	Domestic use
2	TCL Annanagar, SIPCOT, Ranipet	60 feet	Hand pump	Domestic use
3	Jayavel House, Embroidu Nagar, Ranipet	30 feet	Dug well	Domestic use
4	Well at Chitran Vazram Factory, Mardhangal, Ambur Road, Ranipet	40 feet	Dug well	Domestic use
5	Munisamy house well, Mahaveer Nagar, Gudiyatham	-	Well	Domestic use

6	Near Sumangali Cinema Tent, Pernampet	60 feet	Dug well	Domestic use
7	Maswood and ETO Company Pernampet	100 feet	Bore well	Domestic use
8	Annamalai Chettiyar Dug well, Chinathamancheruvu	60 feet	Dug well	Domestic use
9	A.R. Kumara Naidu Well, Ambur Road, Periyavarikam	50 feet	Dug well	Domestic use
10	Panchayat Dug well, Periyavarakkam	-	Dug well	Domestic use
11	Hand pump at Venkatasamudram near Micro wave tower	150 feet	Hand pump	Domestic use
12	Rajarathnam open well at Solur	35 feet	Open well	Domestic use
13	Hand pump Kamarajapuram, Kacheri Road, Vaniambadi	-	Hand pump	Domestic use
14	Dug well at Gudiyatham Road, Vaniyambadi	40 feet	Dug well	Domestic use

4.12.4 Observation on Status of Groundwater Quality in North Arcot

1. Since the district's water supply is monsoon dependent, the groundwater is hence the main source of water supply to meet the needs of the various uses. The major River Palar and its tributaries have seasonal flow only.

2. Groundwater was being tapped for use by the tanneries, dyeing units besides domestic and agriculture purposes.

3. In Ranipet, M/s Tamil Nadu Chromate (now closed down) had been dumping its chromium bearing hazardous waste within their premises, chromium leaching has been suspected and GW samples also indicate the same.

4. It was observed that salt content i.e., TDS was very high in most of the monitoring points in Vellore District compared to locations at Ranipet opposite library, A.R. Kumar Naidu Well Periyavarikkam, Panchayat dugwell Periavarikkam. The high salt content may be due to tannerry discharges.

5. Fluoride content was normal in all the monitoring points not exceeding 1 mg/l.

6. Calcium, magnesium and chloride ions were reported to be slightly high at most of the monitoring points.

7. The NO_2-N & NO_3-N was reported high at most locations and ranged between 3.64 to 68 mg/l.

8. Cyanide & phosphate content in all groundwater points were below norms.

9. It was reported that for the sample collected in January 2002 the TDS and the total hardness were comparatively low compared to those belonging to September 2001 and May 2002 samples.

10. Heavy metals content particularly total chromium near M/s Tamil Nadu Chromat industries VG2 & VG3 and VG10 were very high ranged between 0.018 mg/l and 2.3 mg/l.

11. Coliform and F. Coliform content in groundwater samples were high however the location VG10 Panchayat dug well Periavaraikkam the values were low.

The groundwater samples were collected for the months September 2001, January 2002, and May 2002. Physio-chemical, T. Coliform, F. Coliform and heavy metal pesticides were analyzed. Three rounds of analysis results and Min. , Max. , And Average has been presented in **Table 23 to 30 of Annexure-II.**

4.13 Ankleshwar Problem Areas

4.13.1 Environmental Profile of Ankaleshwar (Gujarat) Area

Industrialization: The Ankleshwar industrial area was developed by GIDC in Bharuch district in the year 1980. It accommodates about 1500 units engaged in various manufacturing products like dye and dye intermediates, pharmaceuticals pesticides, pulp and paper, textile, plastic, packaging, organic and inorganic chemicals and engineering. The industrial has several industries operating within it they are: nearly 425 chemical units, 150 textiles besides 600 other industrial units. The Ankleshwar Industries Association has provided a common effluent treatment plant (CETP) of 1.2 MLD capacities. The Common Effluent Treatment Plant (CETP) was being jointly operated by 220 member industries and caters to the treatment of effluent wastes generated from the industries (mainly small-scale units). The treated wastewater from CETP and industries was being discharged into an earthen drain named as Amalakhadi, which finally meets the estuarine area of river Narmada. Even though, all the common facilities are available in the estate for better environment, there are many industries, which are generating hazardous wastes, which are being disposed scientifically. It has been reported that hazardous wastes was being disposed indiscriminately along the highway by some of the industrial units surreptitiously. This practice may be one of the potential sources for possible groundwater contamination. There was a Secured Land Fill Site (SLFS) having 305 member industries only.

4.13.2 Ground Water Quality Survey

To study the groundwater quality and possible cause of pollution, GW samples were collected from bore wells at various locations for four rounds to ascertain seasonal impacts. The first round

of sampling was completed in the month of December (Winter of 2001), the second round was completed in the month of March (Pre monsoon of 2002), third round during August – September (Monsoon of 2002) and fourth round in January (Winter of 2003). The details of the CPCB's groundwater (GW) survey locations are given in Table 33. A location map of Problem Areas of Ankaleshwar has been presented in **Figure 1 of Annexure II.**

Table 33: Groundwater Quality Survey in Ankaleshwar

Sl. No.	Station code	GW Station Name	Approx. Depth (m)	Type of Well	Present use
01	AK – 01	CETP GIDC Ankleshwar	26 m	Bore Well	Gardening and Washing
02	AK –02	Piraman School	30 m	Bore well with Hand pump	Washing and Bathing
03	AK – 03	Bharuch Naka	40 m	Bore Well	Washing and Construction work

4.13.3 Observation on Status of Groundwater Quality in Ankleshwar

The physico-chemical properties of groundwater in the problem area were studied in four rounds of sampling by measuring the following parameters viz. pH, total dissolved solids (TDS), conductivity, total hardness (TH), calcium, magnesium, alkalinity, chloride, sulphate (SO_4), phosphate (PO_4), nitrate, fluoride, and sodium, Total Coliform (TC) and Feceal Coliform (FC) were measured for studying the microbiological characteristics of the groundwater. Four rounds of analysis results for physico-chemical characteristics has been presented in **Table 31) a) of Annexure-II.** The salient observations are given below:

1. The measured pH values during first and second rounds of sampling were well within the stipulated limit of 6.5 – 8.5.
2. The measured values of TDS in the groundwater were in the range of 1148 mg/l and 5270 mg/l. Results indicated significant contamination by the surface pollutants. The values exceeded limits of 500 mg/l at all stations during the four rounds of sampling.
3. The measured total hardness varied between 111 mg/l and 2033 mg/l, whereas, alkalinity was in the range between 20 mg/l and 980 mg/l. The reason for high total hardness and alkalinity in the groundwater may be attributed to the percolation of haphazardly discharged industrial pollutants.
4. The measured Chloride ranged between 330 mg/l and as high as 2428 mg/l. The chloride concentrations were not within the limit of 250 mg/l. The high values indicated the possibility of seawater intrusion in the groundwater.
5. The sulphate varied between 26 mg/l and as high as 965 mg/l. Higher values were encountered at Bharuch Naka, which exceeded the limit of 250 mg/l.

6. Nitrate varied between BDL and 73 mg/l. In general values were within the limit of 45 mg/l except some values measured at Piramal School. The conductivity ranged between 2020µmhos/cm and 7600 µmhos/cm, indicating inorganic soluble contamination from surface.
7. The measured values of fluoride were within the limit of 1.0 mg/l.
8. The counts of TC and FC were higher at Bharuch Naka, which indicated the possibility of sewage contamination in the groundwater.
9. The calcium varied between 21 mg/l and as high as 1396 mg/l, whereas, magnesium varied from 14 mg/l to 637 mg/l.
10. The values of phosphate varied between BDL and 0. 65 mg/l.

Heavy Metals

The heavy metals like chromium, lead, zinc, cadmium, nickel, iron, copper and manganese were measured in groundwater of Ankaleshwar. The analytical results of four rounds are presented towards end of the report. Four rounds of analysis results for heavy metals have been presented in **Table 31) b) of Annexure-II.** The salient features are given below:

a) The measured values of chromium have ranged between BDL and 0.161 mg/l and lead between 0.06 mg/l and BDl. The measured values of Chromium and lead in the first round exceeded the limit of 0.05.

b) The measured values of Mn were within the limit of 0.1 mg/l except at Piramal School and Bharuch Naka. The measured Zn, Cd and Cu were either within the limit or BDL.

Groundwater quality graphs for physico-chemical parameters have been presented in **Fig. 2) a), b), c), and d) of Annexure-II** along with variations in different rounds.

4.14 Vapi Problem Area

4.14.1 Environmental Profile of Vapi (Gujarat) Area

Industrialization: This area was identified as one of the problem areas in the state of Gujarat due to the establishment of the Gujarat Industrial Development Corporation (GIDC), which was developed in 1967 covering some 1140 hectares of land at Vapi. This is one of the biggest industrial estates in the country accommodating about 1800 industrial units, ranging from dye and dye intermediates, pulp and paper, pharmaceuticals, pesticides, engineering, plastic, textiles, food processing etc. At present around 1400 industrial units are in operation, out of which 700 are chemical units. Besides contamination from these chemical units the environmental problems of the area are: highly populated, poor drainage system, poor sanitation, huge movement of transport. On-going construction activities and unplanned growth of the town are also major causes of environmental problems in the area. River Damanganga was the main source of water to Vapi town and Vapi Industrial area. Ground water was also being used for drinking purposes. The total consumption of water was around 50 MLD with 35 MLD being taken up by the industrial units and remaining for domestic use.

The installation of a Common Effluent Treatment Plant (CETP) and Common Secured Land Fill site in Vapi industrial estate handles the industrial effluent and the solid waste generated by these industries. Lately a common incineration facility has been installed in the estate for incineration of hazardous wastes. Despite all the infra-structural facilities installed to improve the environmental quality there are yet some industries are not complying with the stipulated practices. It has been reported that hazardous wastes were being disposed off haphazardly along the highway by some of them, such practices may be a potential source for possible groundwater contamination.

4.14.2 Sources of Pollution/Wastewater discharge

The estimated total discharge of wastewater was around 45 MLD of which 30 MLD was from the industrial units and the remaining from domestic discharge. The overflow of wastewater in the GIDC was observed in the Bil khadi, which ultimately merges with River Kolak. The treated effluent of CETP was being discharged into river Damanganga.

4.14.3 Groundwater Quality Survey

To study the groundwater quality and possible cause of pollution, GW samples were collected from bore wells at various locations for four rounds to ascertain seasonal impacts. The first round of sampling was completed in the month of December (Winter of 2001), the second round was completed in the month of March (Pre monsoon of 2002), third round during August–September (Monsoon of 2002) and fourth round in January (Winter of 2003). The details of the CPCB's Groundwater network are presented in Table 34.

Table 34: Groundwater Quality Survey in Vapi (Gujarat)

Sl. No.	Station Code	Station Name	Approximate depth (m)	Type of Well	Present Use
01.	VP-01	IOC godown and near Vapi railway station	21m	Hand Pump	Drinking Washing and Bathing
02.	VP-02	Rajhans complex, Charwad road	30m	Bore well	Drinking Washing and Bathing

4.14.4 Observation on Status of Groundwater Quality in Vapi Area

The physico-chemical properties of groundwater in the problem area were studied in four rounds of sampling by measuring the following parameters viz. pH, total dissolved solids (TDS), conductivity, total hardness (TH), calcium, magnesium, alkalinity, chloride, sulphate (SO_4), phosphate (PO_4), nitrate, fluoride, and sodium, Total Coliform (TC) and Feceal Coliform (FC) were reported for studying the microbiological characteristics of the groundwater. The physico-chemical characteristics of groundwater in Vapi area have been presented in **Table 32) a) of Annexure-II.** The salient observations are given below:

i. The reported pH values during first and second rounds of sampling were well within the limit of 6.5 – 8.5.

ii. The reported values of TDS in the groundwater were exceeding the limit 500mg/l at both the stations, which indicated contamination by the surface pollutants.

iii. The reported total hardness varied between 88 mg/l and 894 mg/l, Alkalinity varied between 189 mg/l and 616 mg/l . The reason for high alkalinity in the groundwater could be due to the percolation of alkaline surface pollutants.

iv. The reported Chloride ranged between 132 mg/l and 428 mg/l. The values near IOC godown were within the limit of 250 mg/l, however, at Charwad road they were exceeded the stipulated limit.

v. The reported values of Sulphate were within the limit of 200 mg/l at both the stations, which were in the range of 49 mg/l and 100 mg/l.

vi. All the reported values of nitrate were well within the limit of 45 mg/l except one value of 70 mg/l, which was reported during monsoon round near IOC godown.

vii. The conductivity ranged between 940 µmhos/cm and 1940 µmhos/cm, indicated contamination from surface pollutants.

viii The reported values of fluoride were in the range of 0.27 mg/l to 1.12 mg/l. Some values were exceeded the limit at Charwad road. This indicated unsuitability of groundwater for drinking purpose.

ix The counts of TC and FC were below detectable limit except IOC godown during the first round of monitoring. The TC and FC were found high at station IOC godown; during first and third round this may be attributed to unhygienic conditions in the vicinity of the sampling area of hand pump. Sewage contamination in the groundwater cannot be ruled out.

x The calcium varied between 15 mg/l and 112 mg/l whereas, magnesium varied from11mg/l to 150 mg/l.

xi The values of phosphate near IOC godown varied between BDL and 3.98 mg/l, at Charwad road between BDL and 0.05 mg/l during the study period.

Heavy Metals

The heavy metal like chromium, lead, zinc, cadmium, nickel, iron, copper and manganese were reported in groundwater of Vapi. The heavy metal characteristics of groundwater in Vapi area have been presented in **Table 32) b) of Annexure-II.** The salient features are given below:

a) The reported values of chromium have ranged between BDL and 0.793 mg/l and lead between 0.062 mg/l and BDl. Values exceeded their limits during first round, whereas they were within limit during other rounds of sampling.

b) The values of Manganese (Mn) were within the limit of 0.1 mg/l, except at IOC Godown during third and fourth rounds of sampling.
c) The reported values of Zn, Cd and Cu at both the sampling locations during four rounds of sampling were within the limit or else were BDL.

4.15 Chembur Problem Area

4.15.1 Environmental Profile of Chembur (Mumbai, Maharashtra) Area

General Features: Chembur is an important suburban area of Greater Bombay with population around 17.5 lacs spread over an area of 20 sq. Km and is located on the western side of the Thane creek. This area was identified as problem area in 1990 as this industrial area was having several large and medium scale industries. Nine big industries were identified being responsible environmental degradation. The effluent being generated nearly 42,702 m^3/day. For assessing the ground water quality and possible cause of pollution and groundwater samples were collected from bore well / dug wells in the area for analysis.

The Greater Bombay Municipal Corporation drawn mainly from river was providing the main source for water supply to the residents and industries. Some of the industries like M/s. Hindustan Petroleum Corporation Limited (HPCL) and M/s. Rashtriya Chemicals and Fertilizers (RCF) are buying Municipal Wastewater to fulfill their water requirement and after treat the wastewater to meet their process requirements. The treated effluent of the industries was being discharged into the Thane creek.

4.15.2 Groundwater Quality Survey

To study the groundwater quality and possible cause of pollution, Groundwater samples were collected from bore wells at various locations for four rounds to ascertain seasonal impacts. The first round of sampling was completed in the month of December (Winter of 2001), the second round was completed in the month of March (Pre monsoon of 2002), third round during August-September (Monsoon of 2002) and fourth round in January (Winter of 2003). The details of the CPCB's groundwater (GW) network are presented in Table 35. The location map of problem area has been presented in **Figure 3 of Annexure II.**

Table 35: Groundwater Quality Survey in Chembur, Mumbai (Maharashtra)

Sl. No.	Station code	Station Name	Approx depth (m)	Type of Well	Present use
01	CH- 01	Pepsico India Ltd.	23 m	Bore pump	Gardening
02	CH-02	Ambadapada Village	10 m	Open Well	Washing and Bathing
03	CH-03	BPCL	17 m	Bore well	Gardening
04	CH-04	Acharya Samridhi Apartment	10 m	Open Well	Washing and Bathing
05	CH-05	Meryland Apartment	20 m	Bore well	Washing bathing and Gardening
06	CH-06	Vadvali village	33 m	Bore well	Washing and Bathing

4.15.3 Observation on Status of Groundwater Quality in Chembur

The physico-chemical properties of groundwater in the problem area were studied in four rounds of sampling by measuring the following parameters viz. pH, total dissolved solids (TDS), conductivity, total hardness (TH), calcium, magnesium, alkalinity, chloride, sulphate (SO_4), phosphate (PO_4), nitrate, fluoride, and sodium, Total Coliform (TC) and Feceal Coliform (FC) were reported for studying the microbiological characteristics of the groundwater. Physico-chemical characteristics of groundwater in Vapi area has also been presented in **Figure 4) a), b), c) and d) of Annexure-II.** The salient observations are given below:

- The reported pH values during first and second rounds of sampling were well within the limit of 6.5 – 8.5;

- The reported values of TDS in the groundwater were in the range of 252 mg/l and 1346 mg/l. Results indicate contamination by the surface pollutants;

- The reported total hardness varied between 53 mg/l and 329 mg/l, Alkalinity varied between 102 mg/l and 970 mg/l. The reason for high alkalinity in the Ground water may be due to the percolation of alkaline surface pollutants;

- The reported Chloride ranged between 23 mg/l and 320 mg/l. The values at Ambadapada dug well were exceeding the limit of 250 mg/l, however, at other locations they were within the limit;

- The reported values of Sulphate varied between 18 mg/l and 239 mg/l. Higher values were encountered in the first round of sampling;

- All the reported values of nitrate were well within the limit of 45 mg/l except one value, which was reported during monsoon, round at Ambadapada dug well;

- The conductivity ranged between 310 µmhos/cm and 1780 µmhos/cm, indicating contamination from surface pollutants;

- The reported values of fluoride were within the limit of 1.0 mg/l;

- The counts of TC and FC were very high at open dug well during summer. There is a possibility of sewage contamination in the groundwater;

- The calcium varied between 8.0 mg/l and 93 mg/l whereas, magnesium varied from 4 mg/l to 32 mg/l;

- The values of phosphate varied between BDL and 0.64 mg/l.

Heavy Metals

The heavy metal like chromium, lead, zinc, cadmium, nickel, iron, copper and manganese were reported in groundwater of Chembur. The heavy metal characteristics of groundwater in

Chembur area have also been presented in **Table 33 of Annexure-II.** The salient features of four rounds are presented below:

a) The reported values of chromium ranged between BDL and 0.343 mg/l and lead between 0.089 mg/l and BDl. The reported values of Chromium at Meriland Apartment during fourth round and the reported value of Lead at Achariya Apartment during first round were higher than the limit of 0.05 mg/l;

b) The some values of Mn were higher than the limit of 0.1 mg/l at Ambadapada, near BPCL, Meriland Apartment and Acharya Apartment during fourth rounds of sampling;

c) The reported values of Zn, Cd and Cu at locations during four rounds of sampling were either within the limit or BDL.

4.16 Tarapur Problem Area

4.16.1 Environmental Profile of Tarapur (Maharashtra) Area

Industrialization: The Maharashtra Industrial Development Corporation (MIDC), located in Boisar developed Tarapur industrial area, Taluka of Thane district, on Mumbai-Ahmedabad Railway route; it is about 5k m away from the Arabian Sea. This industrial estate is one of the largest industrial estates in Maharashtra spread over 1130 hectares and accommodates around 1100 industrial units of different categories like chemicals, textiles engineering plastic, packing etc. There are about 390 chemical units, which have been identified as one of the major sources of environmental pollution.

The main source of water supply was the river Surya and the water requirement for the industries alone nearly 79,200 m^3/day. The total wastewater generation was 67,000 m^3/day, out of which industrial wastewater generated nearly 25,000m^3/day. Currently the MIDC was collecting industrial effluent through under ground pipelines in three different sumps, which finally discharge, into one sump. The wastewater from this sump was being discharged into the Arabian Sea about 5 km away at Navapur through a closed pipeline. The Tarapur Industrial Management Association (TIMA) has installed a Common Effluent Treatment Plant (CETP) of capacity 1000 m^3/day for assessing the Groundwater quality and possible cause of pollution samples were collected from Bore well / Dug well.

4.16.2 Groundwater Quality Survey

To study the groundwater quality and possible cause of pollution, GW samples were collected from bore wells at various locations for four rounds to ascertain seasonal impacts. The first round of sampling was completed in the month of December (Winter of 2001), the second round was completed in the month of March (Pre monsoon of 2002), third round during August–September (Monsoon of 2002) and fourth round in January (Winter of 2003). The details of the CPCB's groundwater (GW) network are presented in Table 36. The location map of problem area has been presented in **Figure 5 of Annexure II.**

Table 36: Groundwater Quality Survey in Tarapur (Maharashtra)

Sl. No.	Station code	Station Name	Approx. depth (m)	Type of Well	Present use
01	TP- 01	Chandrika Nagar	23 m	Bore pump	Construction, Washing and Bathing
02	TP-02	Dhodipada	25 m	Hand pump	Drinking, Washing and Bathing
03	TP-03	Bhairam chikuwadi (opp. Special Steel)	10 m	Open well	Agriculture
04	TP-04	Ospada, Saravali village	25 m	Hand pump	Drinking, Washing and Bathing
05	TP-05	Kolwade Village	33 m	Bore well	Washing bathing and Gardening
06	TP-06	Kumbhavali Village (Gajanan Nagar)	33 m	Bore well	Gardening, Washing and Bathing
07	TP-07	Pasthal village	17 m	Bore well	Construction work

4.16.3 Observation on Status of Groundwater Quality

The physico-chemical properties of groundwater in the problem area were studied in four rounds of sampling by measuring the following parameters viz. pH, total dissolved solids (TDS), conductivity, total hardness (TH), calcium, magnesium, alkalinity, chloride, sulphate (SO_4), phosphate (PO_4), nitrate, fluoride, and sodium, Total Coliform (TC) and Faecal Coliform (FC) were reported for studying the microbiological characteristics of the groundwater. Physico-chemical characteristics of groundwater in Tarapur Problem area has been presented in **Figure 6) a), b), c) and d) of Annexure-II** and physico-chemical characteristics of groundwater in Tarapur Problem area has also been presented in **Table 34 of Annexure-II.** The salient observations are given below:

- The reported pH values during first and second rounds of sampling were well within the stipulated limit of 6.5 – 8.5;

- The reported values of TDS in the groundwater ranged between 208 mg/l and 1740-mg/l. Results indicated contamination by surface pollutants. The values exceeded limits of 500 mg/l at all stations during the four rounds of sampling except at station Kumbhavali village;

- The reported total hardness varied between 51 mg/l and 1011 mg/l, alkalinity ranged between 127 mg/l and 432 mg/l. The reason for high alkalinity in the groundwater could be due to the percolation of surface pollutants;

- The reported chloride ranged between 16 mg/l and as high as 346 mg/l. The chloride concentrations were within the limit of 250 mg/l, except at MIDC center and Pasthal Village.

The reported values were 346 mg/l and 271 mg/l respectively. These high values indicated possibility of seawater intrusion into the groundwater regime;

- The Sulphate varied between 1 mg/l and 294 mg/l. Higher values were encountered at Pasthal Village and MIDC center whereas other values were within the limit of 250 mg/l;

- Reported values of nitrate varied between 0.79 mg/l and 75 mg/l. In general values were within the limit of 45 mg/l except some values. The conductivity ranged between 260μmhos/cm and 1740 μmhos/cm, indicating inorganic soluble contamination from surface;

- The reported values of fluoride were within the limit of 1.0 mg/l;

- The counts of TC and FC were very high, possibility of sewage contamination in the groundwater cannot be ruled out;

- The Calcium concentration varied between 11 mg/l and 624 mg/l, Magnesium concentration varied between 5 mg/l to 225 mg/l;

- The values of phosphate varied between BDL and 0. 28 mg/l;

Heavy Metals

The heavy metal like chromium, lead, zinc, cadmium, nickel, iron, copper and manganese were reported in groundwater of Chembur. A heavy metal characteristic of groundwater in Tarapur Problem area has also been presented in **Table 35 of Annexure-II.** The salient observations are given below:

1. The reported values of chromium ranged between BDL and 0.107 mg/l and lead between 0.042 mg/l and BDl. All values were within their limits except chromium at Kambavali Village during the second round;

2. The reported values of Mn were within the limit of 0.1 mg/l except at Chandrica nagar during the second round and at MIDC during the fourth round;

3. The reported values for Zn, Cd and Cu during the four rounds of sampling were either within the limit or BDL.

4.17 Digboi Problem Area

4.17.1 Environmental Profile of Digboi Area

General Features & Topography: Digboi is a small town in Tinsukia district of Assam and is located between the latitude $27^0$20' N to $27^0$35' N and longitude $95^0$35' E to $95^0$40' E. and appears in the Survey of India's toposheet No. 83 M/11. The area is famous for Digboi Refinery, which is the oldest working refinery in the world. Digboi is well connected by road and rail to the rest of the country. The refinery as well as Digboi Township occupies part of the Digboi hill of Naga-

Patkai range. Digboi hill forms low to moderate height structural hill and extend through wide valley from SW to NE direction. Digboi has an average elevation of 148 m above MSL with an uneven topography having a several of hills/hillocks. The Burhi-Dihing River in the south and Dibru River in the north, both flow at distances of 8 to 10 km from Digboi and form the major drainage system in the area. Both the rivers are part of the Brahmaputra river system. Digboi River, a small tributary, carries the runoff water of Digboi area to he Burhi-Dihing River. A number of drains viz. Missionpara Nala, Digboi Nala and Borbil Nala discharge into the Digboi River. Besides the above the area also has a few natural water reservoirs in swampy lands and other low-lying lands surrounded by hillocks.

Industries: Digboi was declared as one of the problem areas in the country for the following reasons:

a) Digboi Refinery, one of the oldest working refinery in the world, was commissioned in the year 1901 has been operating ever since. The acid tar pond within the premise was the main reason behind declaring Digboi as a problem area. Besides the above, the industry effluent and emissions from the industry cause environmental problems;
b) Digboi Refinery is discharging the effluents into the nearby Missionpara and Digboi drains which can pollute the surface and sub-surface water in the area. Spillage of acid tar during heavy rains into surroundings could contaminate not only the soil but also the groundwater;
c) Emissions, including fugitive emissions, may pollute the area;
d) There is no centralized sewerage system in Digboi. The entire sewage is going into the drains that may also contribute to surface water and groundwater contamination.

Climate: The area experiences a hot sub-tropical humid climate. The annual normal rainfall is around 2900 mm. Rainfall is caused by SW monsoon from April-May to November. Maximum rainfall was recorded during July and August. Temperature varied from 50^0C in winter to 38^0C in summer. Winter rainfall is occasional. Relative Humidity (RH) is very high for a major part of the year as the mean monthly RH being was in the range of 81-89% throughout the year. Wind in the area is gentle to moderate, the average wind speed is about 6.8 km/hr (hourly average) with an average calm condition of about 50% (EIA 1998).

Geology: Hydro geological condition in an area is controlled by the geomorphological condition. In case of Digboi, the position of structural hill divides the hydro geological depositional environment into two domains and as such, the northern part of Digboi comprise of un-consolidated sediments from North and NNE direction. In the sourthern part of the hydro geological domain depositional situation is not similar with northern part (CGWB, 2001). The area is inferred to act as recharge area but lithological criteria emphasizes run-off conditions only (CGWB 1993). Depth of water table varies from 1 m to 7 m bgl during lean period with an average of 2 to 4 m. Well hydrograph monitored by CGWB at Digboi situated in teriary with a very thin vaneer of alluviam formation that indicates thigh infiltration character of underlying formation. The lighologs of bore holes at Borbil and Digboi up to a depth of 90 m and 71 m respectively.

Groundwater flow: follows the surface topography of the area and is towards NW in Northa nd S to SW in south of Digboi. Ground water flow gradient is calculated as 1.956 k/km in NW and 1.174-2.93 m/km in SSW directions (CGWB 2001). The average horizontal flow was in the

order of 1.40 X 10^{-2} cm/sec (12.096 m/day) whereas the vertical flow of groundwater was calculated as of 1.04 X 10-2 cm/sec (9.02 m/day) during a study conducted by CGWB in 1993 in the surrounding of acid tar pond of Digboi Refinery and categorized the area as low permeable zone (CGWB 1993).

Soil: The soil of the study area is acidic in nature with pH 4.8 to 6.5 in most of the places. The texture of the soil is mostly sandy clay loam in nature. The soil is rich in common metals such as Sodium, Potassium, Calcium, Mangesium, Iron, Zinc and Magnesium (EIA 1998).

4.17.2 Groundwater Quality Survey

Following groundwater quality survey locations were selected. While selecting the stations, priority was given to those locations from where water is being used by large number of population for drinking and other domestic purposes. Sampling locations at Missionpara, Borbil and Kalibari were fixed to know whether there is any drastic change in the quality of the groundwater in the area by pollutant-seepage from the acid tar pond in the refinery. The samples of groundwater collected for analyses are shown along with their nature in Table 37.

Table 37: Name and nature of groundwater quality monitoring stations in Digboi

Station code	Station name	Type of well	Approx. Depth (m)	Present use
016	Hawkinspara	Shallow tube well	20-25	Drinking and other domestic used
017	Kalibari	Dug well	15	-do-
018	Missionpara	Dug well	15	-do-
019	Golai	Shallow tube well	25	-do-
020	Borbil	Shallow tube well	25	-do-

4.17.3 Observations on Status of Groundwater Quality in Digboi

a) Physico-chemical parameters

It is found that in most of the cases the pH value ranged between from 6.5 to 8.5, which is acceptable for good drinking water. pH value of 6.0 to 6.2 were recorded in the water samples of Golai and Missionpara respectively during January 2002 sampling. In other time of the year the pH was within the limit. In Hawkinspara pH of 9.2 was recorded in January 2002 sampling which indicated high alkaline water in that period. But in the other two rounds of sampling, the pH was within acceptable limit. Physico-chemical characteristics of groundwater in Digboi Problem area have also been presented in **Table 36 of Annexure-II.** The salient results are below:

i. The turbidity value ranged from a minimum of 1.11 NTU at Hawkinspara to a maximum of 219 at Borbil NTU as on May 2002;

ii. Conductivity (value ranged between 179 to 411 umhos/cm at 25^0C) showed good ground water;

iii. The total hardness of water varied from a minimum of 8.0 ppm at Hawkinspara to a maximum of 200 ppm at Missionpara;

iv. Calcium concentration was found below detectable limit at Borbil in January 2002 sampling. Calcium concentration was found maximum at Missionpara in January 2002 and was reported as 140.0 ppm;

v. Total alkalinity ranged between from 8.0 to 208 ppm;

vi. Chloride concentration varied between 4.0 to 63 ppm;

vii. TDS values ranged between 130 to 504 ppm. At Kalibari the TDS was maximum at 504 ppm in January 2002;

viii. The concentration of fluoride was below detectable limit during monsoon but during January 2002, the maximum fluoride concentration of 0.20 ppm was found at Borbil;

ix. A study on ground water quality in Digboi was done by CGWB, NE Region, Guwahati in 2001 in a study entitled ` Feasibility report on assessment on Ground water potential for construction of deep tube wells in Digboi Refinery area'. The groundwater quality analysis result and the ground water quality interpretation, as done by CGWB, are given below.

Heavy Metals

The ground water samples were analyzed for heavy metals contents viz.. Cu, Zn, Cr, Cd, Mn, Pb and Fe. The heavy metal characteristic of groundwater in Digboi Problem area has also been presented in **Table 37 of Annexure-II.** The analysis result has shown in the Table 37 and reproduced below:

i. The concentration of Cu ranged between 0.01 ppm to 0.28 ppm. Maximum concentration of Cu (0.28 ppm) was recorded at Hawkinspara during May 2002;

ii. Maximum concentration of Zn i.e. 3.28 ppm was recorded at Kalibari in January 2002 sampling;

iii. The concentration of Cr was measured 0.02 ppm at Kalibari, Hawkinspara and Missionpara. During January 2002 sampling, Cr wa not detected at any of the stations;

iv. During January 2002, Ni was found only at Golai where the concentrations measured was 0.07 ppm and that was the maximum-recorded concentration of Ni in the area. Ni was not detected at any of the other stations;

v. Cd was not detected in January 2002, but during May 2002, the highest Cd concentration (0.07 ppm) was recorded at Borbil;

vi. Mn concentration ranged between 0.06 to 10.13 ppm. The highest concentration of Mn was found to be 10.13 ppm at Missionpara in January 2002. The concentration of Mn was also high at Kalibari, where it was recorded as 9.24 ppm;

vii. Pb concentration varied between 0.03 ppm to 0.14 ppm;

viii. Highest concentration of Fe was recorded at 3.14 ppm at Borbil in May 2002 while it was lowest at Hwkinspara in September 2001 and was recorded at 0.19 ppm.

It was observed from the chemical analyses that the groundwater quality was good. Fe and Mn in groundwater are significantly high in Digboi. Other heavy metals were found to be within stipulated limits. Effluents from Digboi refinery need to be analyzed for finding the concentration of heavy metals. The refinery authority started reclaiming the acid tar in the acid tar pond in 1998 but it was observed that only 15 to 20% of the pond has been reclaimed so far.

4.18 Summary of the Findings on Groundwater Quality in Problem Areas

The study revealed that the development of industrialization and urbanization play an important role in water resources both in terms of quantity and quality led to tapping alternate water resources. Thus groundwater (GW) came to play a major role in supplementing man's water needs and hence this crisis led to sinking of wells. This activity reached critical levels when extraction of GW far exceeded the replenishable extent due to indiscriminate sinking of wells. These unregulated activities brought to attention cases of saline intrusion, groundwater contamination and to some extent subsidence. The Table 38 below summarizes the major industrial activities of the problem areas.

This is in continuation to the previous GW survey conducted in 1994 for the 22 problem areas that were identified (Table 39). The current study in problem areas summarized groundwater problem in different problem areas in Table 40. In our current study two new problem areas have been covered namely Ankleshwar (Gujrat) and Tarapur in Maharashtra.

Table 38: Major industrial activities in the problem areas

Sl. No.	Location	Major industrial activities
1.	Dhanbad (Bihar)	Coking plants, coal washeries, Chemicals, Cement, Explosive factory and ancillary units
2.	Digboi (Assam)	Oil Refinery
3.	Durgapur (West Bengal)	Chemicals, cement, power plants, coal fields
4.	Howrah (West Bengal)	Foundries, electroplating & other mechanical Engg. Units
5.	Bollaram Patncheru (AP)	Pesticide, Pharmaceuticals
6.	Greater Cochin (Kerala)	Fertilizer, Pesticides, Chemicals, Chloro-alkali

7.	North Arcot (TN)	Tanneries, dyeing units
8.	Bhadravathi (Karnataka)	Viveshwaraya Steel Ltd., Mysore Paper Mills Ltd.
9.	Ratlam Nagda (M.P.)	Distillery Dye (intermediates) Pharmaceutical (intermediates)
10.	Vapi (Gujarat)	Dyes, Pesticides, Paper & Pulp mills, organic and inorganic chemicals
11.	Chembur, Mumbai (Maharashtra)	Refineries, Fertilizer & Petrochemical, Thermal Power Plant
12.	Korba (M.P.)	Thermal Power Plants, Ancillary units, Aluminum industries, Mining
13.	Singrauli (U.P.)	Thermal Power Plants, Aluminum plants, organic chemicals industries and other subsidiary units with carbon plants, caustic soda and pesticides
14.	Mandi Gobindgarh (Punjab)	Wooden Chemicals, Electroplating units and other steel metals units
15.	Visakapatnam (AP)	Steel plant, medium and small scale units
16.	Manali (TN)	Petroleum products, fertilizers, pharmaceuticals, power plant
17.	Parwanoo (HP)	Ancillary, general industries, fruit processing, pesticides
18.	Kala Amb (HP)	Paper Mills
19.	Pali (Rajasthan)	Textile, dyes
20.	Jodhpur (Rajasthan)	Textile, steel, Engineering foundry, Chemicals, minerals dye plastic, oil, pulses and rubber
21.	Najafgarh Drain Basin Area (Delhi)	Insecticides, Caustic soda, Vanaspati, electroplating and treated and Un-treated sewage etc.
22.	Angul Talcher (Orrissa)	Thermal Power station, Fertilizers, Chemicals, Mining activities and Aluminum
23.	Tarapur (Maharashtra)	Chemicals and textiles
24.	Ankleshwar (Gujarat)	Dyes, chemicals, textile units

Table 39: Ground Water Quality in problem Areas (1994)

Sl. No.	Area	Industrial Activities	Ground Water Quality Problem*
1.	Dhanbad (Bihar)	Fertilizers, Chemicals, Coke plants, Cement explosive factory and Ancillary units	Low pH, whereas NO_3, Al, Ca, TDS, TH, Fe, Mn, Cr, Zn, Cu, Hg & Cd, and also Pesticides exceeded standards
2.	Digboi (Assam)	Oil Refinery	Fe and Mn exceeded standards
3.	Durgapur (West Bengal)	Coal fields, Power Plants, Cement Plants and Chemical units	Heavy metals except Cu exceeded standards. Hg was also reported as high as 9.5 mg/l. Phenolic compounds & CN were in traces. Total pesticides levels have exceeded standards
4	Howrah (West Bengal)	Foundries, Electroplating & other Mechanical Engineering units	Heavy metals viz. Pb, Cd, Cr, Fe & Mn were very high. EC, TH, Cl, TDS were some time very high Pesticides were also on high side CN & Phenolic compounds in traces.

Sl. No.	Area	Industrial Activities	Ground Water Quality Problem*
5.	Bolaram-Patancheru (AP)	Pesticides, Pharmaceuticals	Phosphates, Hg, As, Cd, Fe, Mn & Pb TDS, TH, Ca exceeded standards, Pesticides were also found to be present.
6.	Greater Cochin (Kerala)	Fertilizer, Pesticides, Chemicals, Chlor – alkali	Predominantly acidic. The presence of coliform of faecal origin was high.
7.	North Arcot (Tamilnadu)	Tanneries, Dying units	Zn, Cu, Cr, Fe & Mn, total coliform exceeded standards at several locations.
8.	Bhadravathi (Karnataka)	Steel Plants, Paper Mills	Zn, Fe & Mn , Pesticides like Aldrin, Dieldrin, Lindane & DDT Pathogenic organisms reported to be high.
9.	Ratlam-Nagda (MP)	Distillery , Dye (intermediates) Pharmaceutical (intermediates)	Colour, TDS, TH, Hg, Pb were on higher side , considerable amounts of Pesticides were also reported. Fecal Coliform were also present particularly at Nagda
10.	Vapi (Gujarat)	Dyes, Pesticides, Paper & Pulp mills, organic & inorganic chemicals	Phenolic compounds, Cyanide & heavy metals were present within limit as per drinking standards.
11.	Chembur (Maharashtra)	Petroleum, Refineries, Fertilizer & Petrochemical, Thermal Power Plant.	TDS, Alkativity, TH were higher, Heavy metals, Pesticides, phenolic compounds were present in concentrations, but not very significant. Coliform were on higher side.
12.	Korba (MP)	Thermal Power Plants, Ancillary Units, Alluminium industries, Mining	The presence of Cd, Fe, Cr & Cu has exceeded standards, Pesticides were also present. Coliform, F, TDS, CN, B & phenolic compounds also exceeded the standards.
13.	Singrauli (UP)	Thermal Power Plants, Alluminium Plant, Organic chemicals industries, Carbon Black plant, Caustic soda & pesticides.	Fe, Cr & Cu were present in predominance, Presence of high Aldrine, Dieldrin & Lindane levels were also observed. Beside this F, Ca, Mg, B, Coliform, Phenols exceeded standards
14.	Mandi Gobindgarh (Punjab)	Wooden, Chemicals, Electroplating units and other Steel metals units.	Pb, Cu, Cd exceeded standards, Phenolic compounds & Cyanide was also present on higher side.
15.	Parwanoo (HP)	Ancillary , general industries, Fruit proceeding plant, pesticides.	Presence of Cd, Pb, Fe, Mn were observed on higher side. Traces of pesticides were also present. Phenolic exceeded standards.
16.	Kala-Amb (HP)	Paper Mills	Phenolic compounds exceeded standards; Heavy metals like Cd, Pb & Mn and also pesticides are above limits
17.	Pali (Rajasthan)	Textile, dyeing units	Colour, Lead, Zinc Fluoride TDS, Cl, Sn were in concentrates exceeding standards.
18.	Jodhpur (Rajasthan)	Textile, Steel, Engineering foundry, Chemicals, minerals	Colour, Heavy metals such as Fe, Cr, Mn NO_3 Na, TDS exceeded standards

Sl. No.	Area	Industrial Activities	Ground Water Quality Problem*
		dye plastic, oil, pulses and rubber.	
19.	Drain Basin Area, Najafgarh (Delhi)	Insecticides, Caustic Soda, Vanaspati, Electroplating etc.	EC, TDS Coliform, F, NO_3, Fe & Cr both exceeded the drinking water standards.
20.	Angul- Talcher (Orissa)	Thermal Power station, Fertilizers, chemicals, Mining activities & aluminum	Cr, Fe, Cd, Pb, F and NO_3 were found in concentrates level exceeding standards
21.	Manali (TN)	Thermal Power Station, Fertilizer, Petroleum Refining	High microbial contamination have been reported, Nitrates, Fluoride have exceeded standards
22.	Vishakhapatnam (Andhra Pradesh)	Zinc Smelting, Fertilizer, Petroleum Refining	Heavy Metal, Fluoride and Nitrates exceeded standards

* With reference to BIS standards for drinking water; Source: Central Pollution Control Board

Table 40: Ground Water Quality in Problem Areas (2002-2004)

Sl. No.	Area	Industrial Activities	Ground Water Quality Problem*
1.	Angul-Talcher (Orissa)	Thermal Power station, Fertilizers, chemicals, Mining activities & aluminum	Fe, F and NO_3 were found in higher level and exceeding standards. Very high values of TDS, TH, Cl, TC & FC were observed at all locations. Pesticides were detected
2.	Ankleshwar (Gujarat)	Dyes, chemicals, textile units	TDS, Cl, SO_4, Pb, Cr and Pathogenic organisms were reported to be high
3.	Bolaram-Patancheru (A.P.)	Pesticides, Pharmaceuticals	Fe, Mn & TDS, TH, Cl, SO_4 exceeded standard, Bacterial (Pathogenic) contamination were also found
4.	Bhadravathi (Karnataka)	Steel Plants, Paper Mills	High TDS, TH, Cl, and Pathogenic contamination observed.
5.	Chembur, Bombay (Maharashtra)	Petroleum, Refineries, Fertilizer & Petroche-mical, Thermal Power Plant.	TDS, Cl, SO_4, TH were higher, Heavy metals such as Cr, Pb, & Mn, were excee-ding limit. Coliform were on higher side
6.	Dhanbad (Bihar)	Fertilizers, Chemicals, Coke plants, Cement explosive factory and Ancillary units	Low pH, whereas NO_3, Ca, TDS, TH, Fe, Mn, & Hg on higher side. Also Pesticides were detected in many of the sample
7.	Digboi (Assam)	Oil Refinery	Fe and Mn exceeded standards
8.	Durgapur (West Bengal)	Coal fields, Power Plants, Cement Plants and Chemical units	Heavy metals except Fe were within the stipulated standards. SO_4 and NO_3 higher at some locations. Bacterial contamination on higher side. Pesticides such as DDT were the most prominent compared to other pesticides
9.	Greater Cochin	Fertilizer, Pesticides,	Predominantly acidic. High content of

Sl. No.	Area	Industrial Activities	Ground Water Quality Problem*
	(Kerala)	Chemicals, Chlor –alkali	metals such as Zn, Ni, Pb, Cu, Fe and Mn, Faecal contamination reported.
10.	Howrah (West Bengal)	Foundries, Electroplating & other Mechanical Engineering units	Heavy metals viz. Fe & Mn were high. EC, TH, Cl, TDS were also very high. Pesticides such as DDT on higher side. Bacterial contaminations such as TC & FC are observed on all locations.
11.	Manali (Tamilnadu)	Thermal Power Station, Fertilizer, Petroleum Refining	High microbial contamination has been reported. Nitrates, Fluoride, Chloride, Sulphate, TDS, TH have exceeded standards, Cyanide in traces, Cu, Cd, Mn, Zn, were high
12.	North Arcot (Tamilnadu)	Tanneries, Dying units	Cd, Cu, Cr, Fe & Mn, and Fecal & Total Coliform exceeded standards at several locations. SO_4 , Cl, TDS, NO_3 were high.
13.	Singrauli (U.P.)	Thermal Power Plants, Alluminium Plant, Organic chemicals industries, Carbon Black plant, Caustic soda & pesticides.	Fe & Hg were present in predominance, Presence of high Aldrine, Dieldrin & Lindane levels were also observed. Beside this F, TH, SO_4 , Ca, Mg, TDS, Cl, and Coliform, were exceeded standards.
14.	Tarapur, (Maharashtra)	Chemicals, textiles, Engineering, Plastic, & Packing	TDS, Cl, SO_4 and Cr were present in high concentration. TC and FC were reported very high
15.	Vapi (Gujarat)	Dyes, Pesticides, Paper & Pulp mills, organic & inorganic chemicals	TDS, CL, were high and heavy metals such as Cr, Pb, were exceeding the limit as per drinking standards.
16.	Vishakhapatnam, A.P.	Zinc Smelting, Fertilizer, Petroleum Refining	Heavy Metal such as Ni, Cr, Co, TC, F, TH, TDS were exceeded standards

* Information gathered during 2002-2004

Limitations

The current report has attempted to provide a broad survey of the Groundwater quality status of the Problem Area. However, there are some inherent limitations needs to keep in mind while reviewing the individual reports. Some limitations are given below:

As mentioned earlier CPCB does not maintain a routine Groundwater quality monitoring network in these areas, hence drawing conclusions and attributing reasons for quality fluctuations may need further monitoring, however the current exercise has generated a database that shall be useful in the near future. The individual Groundwater (GW) network (on an average approx. 5 to 6 sampling stations per problem area) may not be exhaustive enough to represent the total area of influence. Only sixteen problem areas have been covered in this report.

Contamination due to Geogenic sources:

Central Pollution Control Board (CPCB), Central Ground Water Board (CGWB) and other institutions/agencies such as Jadhavpur University have conducted the studies in groundwater pollution due to toxic substances. The groundwater contamination occurred due to geogenic activity in groundwater. There are few main pollutants found in the groundwater. These are i) Arsenic (As) ii) Fluoride (F) and iii) Iron.

Arsenic Contamination:

Way back in 1980, the Government was aware that eight districts of West Bengal and two districts of Chattisgarh are severely affected with arsenic contamination in Ground water. Later on, in 2002 the arsenic contamination was reported in Bhojpur and Patna districts of Bihar. Mostly, the above studies were carried out by UNICEF & Jadhavpur University of West Bengal. The further investigations carried out during 2003-2004 and found that Groundwater of Bhojpur, Buxar, Paschimi Champaran, Purba Champaran, Sitamarchi, Madhubani, Supaul, Araria, Kishanganj Purnea & Katihar Districts of Bihar is contaminated with Arsenic, above the permissible limit. During 2004, the Sahibganj district of Jharkhand State also found Arsenic contaminated Groundwater. Some Districts (Two) of Assam also found Arsenic contamination in Groundwater. The results of above investigations supports the earlier theory of areas near the Gangatic plains and the Padma-Meghna-Brahmputra basin, where arsenic is present naturally due to the geological activities of there Rivers and have deposited arsenic sediments across these basins. The groundwater arsenic contamination in Ballia district (UP) during 2003 was discovered and groundwater arsenic contamination and consequent suffering of people were apprehended arsenic problem in Uttar Pradesh. The Arsenic contamination in Groundwater was found in 3 blocks, 8 GPs and 25 villages of Ballia district. The survey discovered that 307 villagers and registered 53 patients with arsenical skin lesions. During further investigations in U.P., Arsenic contamination in many more blocks, villages from Ballia district and other two new districts Gazipur and Benaras were reported. Based on the studies, it was reported that Chain Chapra is one of the severe arsenic contaminated villages and people are suffering severely from arsenic toxicity. Incidents occurred due to geogenic sources of Arsenic contamination are presented in **Table 41.**

Fluoride Contamination:

The contamination of groundwater due to Fluoride in various parts of the country is also established. The Central Ground Water Board and Central Pollution Control Board are monitoring the groundwater quality. Fluoride Pollution in Ground Water in various states is summarized in **Table 42.**

Table 41: Incidents Occurred due to Geogenic sources and Districts/Villages affected by Arsenic Contamination

Sl. No.	Incidents found in the year	Names of the districts /Villages	State
1.	1980	Maldah, Murshidabad, Nadia, North 24 Parganas, South 24 Parganas, Bardaman, Howrah, Hooghly, Kolkata	West Bengal
2.	1999	Two districts of Chhatisgarh–Rajnandgaon and Durg.	Chhatisgarh
3.	2002	Bhojpur Districts of Bihar	Bihar
4.	2003-2004	Fourteen districts of Bihar-Paschimi Champaran, Purba Champaran, Sitamarhi Supaul, Aroria, Kishanganj, Purnia, Katihar, Patna, Bhojpur, Buxar, Saran (Chapra) Vaishali, Madhubani and Sahibganj Distt. of Jharkhand	Bihar & Jharkhand
5.	2003-2004	Eleven districts of Uttar Pradesh Pilibhit, Lakhimpur Baharaich, Shravasti Balrampur, Siddarthnagar, Maharajganj, Kushinagar, Ballia, Unnao, Lucknow.	Uttar Pradesh
6.	2004	Dhimaji, Karimganj	Assam

Table 42: Number of districts affected by groundwater pollution due to contamination of Fluorides in various states of India

Sl. No.	States	Number of districts having incidence of fluoride problem
1.	Andhra Pradesh	10
2.	Assam	3
3.	Bihar and Jharkhand	9
4.	Gujarat	15
6.	Haryana	5
7.	Karnataka	7
8.	Madhya Pradesh and Chhattisgarh	9
9.	Maharashtra	4
10.	Rajasthan	7
11.	Tamilnadu	9
12.	Uttar Pradesh	5
13.	West Bengal	3
14.	Kerela	1
15.	Orissa	4
	Total Districts	**91**

Contamination of groundwater due to anthropogenic and geogenic sources:

The Central Ground Water Board has carried out studies regarding contamination of ground water due to inorganic substances, chemicals and heavy metals in various parts of the country. State-wise details of contamination of ground water due to various contaminants found in some areas of various districts are given in the **Table 43.**

Table 43: Statewise Details of Contamination of Ground Water in Some Areas of the Districts Due to Various Contaminants

Sl No	State	Iron	Fluoride	Nitrate	Arsenic
1.	Andhra Pradesh	-	Prakasam, Nellore Anantpur, Nalgonda, Rangareddy, Adilabad	Vishakhapatnam, East Godavari, Krishna, Prakasam Nellore, Chittoor, Anantpur, Cuddapah, Kurnool, Mehboobnagar, Rangareddy, Medak, Adilabad, Nalgonda, Khammam	-
2.	Assam	Northern Bank of Brahmaputra	-	-	Dhimaji, Karimganj,
3.	Bihar	Champaran, Muzaffarpur, Gaya, Munger, Deioghar, Madhubani, Patna, Palamau, Nalanda, Nawada, Banka	Giridigh, Jamui, Dhanbad	Palamau, Gaya, Patna, Nalanda, Nawada, Bhagalpur, Sahebgunj, Banka	Bhojpur, Paschimi Champaran, Purba Champaran, Sitamarhi Supaul, Aroria, Kishanganj, Purnia, Katihar, Patna, Bhojpur, Buxar, Saran (Chapra) Vaishali, Madhubani
4.	Chattisgarh	-	-	-	Rajnandgaon, Durg.
5.	Gujarat	-	Kachch, Surendra Nagar, Rajkot, Ahmedabad Mehsana, Banaskantha, Sabarkantha, Panchmahal, Kheda	-	-
6.	Haryana	-	Rohtak, Jind, Hissar, Bhiwani, Mahendragarh, Faridabad	Ambala, Sonepat, Jind, Gurgaon, Faridabad, Hissar, Sirsa, Karnal, Kurukshetra, Rohtak, Bhiwani, Mahendragarh	-
7.	Himachal Pradesh	-	-	Kulu, Solan, Una	-
8.	Karnataka	-	Tumkur, Kolar, Bangalore, Gulbarga Bellary, Raichur	-	-
9.	Kerala	-	Palghat	-	-
10.	Jharkhand	-	-	-	Sahibganj
11.	Madhya Pradesh	-	Bhind Morena, Guna, Jhabua, Chhindwara, Seoni, Mandla, Raipur, Vidisha	Sehore	-
12.	Maharashtra	-	Bhandara, Chandrapur, Nanded, Aurangabad	Thane, Jalna, Beed, Nanded, Latur, Osmanabd, Solapur, Satara, Sangli, Kolhapur, Dhule, Jalgaon, Aurangabad, Ahmednagar, Pune, Buldhana, Amravati, Akola, Nagpur, Wardha, Bhandara, Chandrapur, Gadchiroli	-
13.	Orissa	Parts of coastal Orissa	Bolangir	-	-

Sl No	State	Iron	Fluoride	Nitrate	Arsenic
14.	Punjab	-	Ludhiana, Faridkot, Bhatinda, Sangrur, jalandhar, Amritsar	Patiala, Faridkot, Firozpur, Sangrur, Bhatinda	-
15.	Rajasthan	Bikaner, Alwar, Dungarpur	Barmer, Bikaner, Ganganagar, Jalore, Nagaur, Pali, Sirohi	Jaipur, Churu, Ganganagar, Bikaner, Jalore, Barmer, Bundi, Swai Madhopur	-
16.	Tamil Nadu	-	Dharmapuri, Salem North Arcot-Ambedkar, Villipuram-Padayatchi, Muthuramalingam, Tiruchirapalli, Pudukottai	Coimbatore, Periyar, Salem	-
17.	Tripura	Dharmnagar, Kauleshaher, Khowai, Ambasa, Amapur and parts of Agartala valley	-	-	-
18.	Uttar Pradesh	-	Bulandshahar, Aligarh, Agra, Unnao, Rae-Bareli	Orai, Jhansi, Lalitpur, Faizabad, Sultanpur, Maharajganj, Gorakhpur, Deoria	Pilibhit, Lakhimpur Baharaich , Shravasti Balrampur, Siddarthnagar, Maharajganj , Kushinagar, Ballia, Unnao, Lucknow
19.	West Bengal	Midnapore, Howrah, Hoogly, Bankura	Birbhum	Uttar Dinajpur, Malda, Birbhum, lNadia, Midnapore, Howrah, Murshidabad, Purulia	Kolkata, Malda, South 24-Paraganas, North 24-Paraganas Nadia, Hoogly Murshidbad, Bradhaman, Howrah
20.	NCT of Delhi	-	-	Shahdara, & Mehrauli Blocks	-

Continued

CHAPTER V

CONCLUSIONS AND RECOMMENDATIONS

A) Metro-cities

- The groundwater quality problems are mainly due to i) contamination by geogenic and man-made sources; and ii) sea water intrusion due to over-abstraction of groundwater along the coasts.
- The geogenic contamination can be attributed to over-abstraction causing lowering of water table and disturbing the contaminated geological structures.
- The man-made contamination is mainly due to large-scale urbanisation, industrialisation and agricultural activities.
- Groundwater quality is being increasing threatened by agricultural, urban & industrial wastes, which leach or are injected into underlying aquifers.
- In many cases, the abstraction of excessive quantities of groundwater has resulted in the drying up of wells, salt-water intrusion & drying up of rivers that receives their flows in dry seasons from groundwater.
- With fast urban growth and increasing standard of living the waste generation has steeply increased in India, especially in large urban centres. Due to paucity of resources the local authorities, who are responsible for waste management are not able to adequately address the problem.
- This has resulted in a large amount of wastes, both solid and liquid, not being collected, treated or disposed properly. The un-collected wastes are largely accumulated in the city areas, percolate or leach in the ground and pollute the groundwater.
- The fast industrial growth also results in generation of large quantity of wastes (solid, liquid and gaseous). Many times these wastes also do not get collected, treated and disposed. They also have the same fate as domestic wastes in the city.
- A large number of industrial activities are taking place in urban areas, especially in congested, populated areas. The wastes generated by industrial activities in urban areas get mixed with domestic wastes and pollute the groundwater.
- The groundwater is only source of drinking in many urban centres of the country. Thus, a large urban population is at risk of consuming polluted water.
- Realising the importance of the pollution of groundwater in urban areas, CPCB has initiated groundwater quality survey in urban areas. In the first phase metro-cities were taken. Similar study was also carried out in problem areas (industrial pockets).
- The results available for the 8 metro-cities and 22 Problem Areas indicate that groundwater problems are of diverse nature. The major problem is urban areas are related to increasing salinity, nitrate, coliform (indicators of pathogen), fluoride and in some cases micro-pollutants.
- The quality of groundwater with respect to bacteriological parameters in some of the pockets of metropolitan cities showed bacterial contamination at few locations during pre-monsoon season. This can be attributed to in-adequate collection of sewage, garbage leading to accumulation of wastewater and garbage, inadequate maintenance of hand pumps, improper sanitation and unhygienic conditions around the structures and in the

city limit may be responsible for bacterial contamination at few locations during the pre-monsoon season.

- In some of the metro-cities like Agra and Meerut, the salinity is increasing at a fast rate. This can be attributed to percolation of accumulated salts in intense irrigated areas and industrial activities.
- With respect to physico-chemical properties of the samples collected, it is either conforming to desirable or permissible limits. The quality of ground water from a few shallow tube wells has been impaired in some of the areas. However, the deep bore/tube wells have not yet been affected.
- Groundwater quality with respect to critical chemical parameters such as Chloride, Total dissolved solids (TDS), Nitrate-N, Fluoride, Total and Faecal Coliforms and heavy metals are summarized. Groundwater quality with respect to critical metals such as Iron, Chromium, Copper, Manganese and Zinc and their compliance/violations against drinking water standards in both the seasons. The percent compliance/violation exercise includes analysis of total 50 samples in both the seasons at same locations in each metropolitan city.
- It is revealed that concentration Chloride in groundwater is indicating above the 1000 mg/L (Log value) in Chennai Metropolitan city followed by Vijaiwada, Madurai, Coimbatore, and then Agra. Similarly, Total Dissolved Solids also indicating very high range (Maximum) in Chennai followed by Vijaiwada, Coimbatore, Madurai and Agra.
- The Nitrate concentration (log value) revealed that the three metropolitan cities such as Agra, Coimbatore and Meerut indicating above the permissible limit whereas remaining cities such as Lucknow, Ludhiana, Vijaivada, Chennai, and Madurai indicating below the permissible limit.
- The concentration of Fluoride (Log value) indicated that Agra followed by Vijaivada, Chennai, Madurai and Coimabotore metropolitan cities shown above the permissible limit of drinking water whereas remaining three cities were found within the permissible limit.
- The Coliform group bacteria did not show any contamination except Lucknow and Meerut Metropolitan cities.
- The results revealed that Chloride percent compliance/violation against drinking water standards (BIS/WHO) indicating 18% in Coimbatore city followed by Agra (8%), Chennai (6%), and Lucknow – Vijaiwada (each 4%) whereas Cities like Meerut and Ludhiana did not showed any violation against drinking water standards and indicating chloride concentration within the desirable limit of drinking water standards.
- It is concluded that the TDS percent compliance/violation against drinking water standards in eight metropolitan cities indicating highest in Agra (36%) followed by Coimbatore (32%), Chennai (22%), Vijaiwada (18%), and Madurai (10%). The remaining three metropolitan cities (Meerut, Lucknow, Ludhiana) did not indicate any violation with respect to total dissolved solids.
- It is also revealed that the Nitrate compliance/violation against drinking water standards only in three metropolitan cities. Agra showed highest (54%), followed by Coimbatore (28%), and then Meerut (14%). The remaining five metros did not indicate any violation.
- Fluoride percent compliance/violation against drinking water standards clearly indicated that Agra is having highest (34%), followed by Chennai (14%), then Madurai and

Vijaiwada (each 8%)and then Coimbatore and Meerut (each 4%) while Lucknow and Ludhiana did not show any percent violations.

- Total Coliform indicates that there is no violation against drinking water standards except Lucknow (20%), Agra (8%), and Meerut, Chennai (each 2%) while remaining four cities did not indicate any violation.
- Similarly, Faecal Coliform indicates that percent violation against drinking water standards only in two Metropolitan cities i.e. Lucknow (28%) and Agra (6%).
- Percent compliance/violations against drinking water standards with respect to heavy metals revealed that the Iron (Fe) indicates violations in almost seven metros except Ludhiana. The highest violation was found in Agra (74%) followed by Chennai (32%), Meerut (30%), Vijaiwada (12%), Lucknow (10%), Madurai (4%) and Coimbatore (2%).
- Percent compliance/violation of Copper indicated only in Chennai Metropolitan city (96%), while remaining seven cities indicated Copper concentrations within the permissible limit of drinking water standards.
- Chromium Showed violation only in Coimbatore city (4%), while remaining seven cities indicated permissible limit.
- The Manganese compliance/violations, as revealed from the results, that out of seven cities attempted, five were violated. The highest violation was found in Chennai Metropolitan (42%) followed by Madurai (16%), Vijaiwada (12%), Agra and Lucknow (each 10%), and Meerut (8%).
- As clear from the results, Zinc did not show any violation in any of the Metropolitan city.
- Pesticides analysis indicated the presence of α-BHC, β-BHC, γ-BHC Endosulphan and methoxychlor in ground water of the metropolitan city but their content was well within the permissible limits of World Health Organization (WHO) for drinking water. Pesticide analysis indicated the presence of Aldrin, α-BHC, δ-BHC DDD, DDE, β-BHC and Endosulphan at few locations in ground waters of the Southern metropolitan city. The presence of these pesticides in ground water may be attributed due to their use in agricultural activities and for vector control programmes. The pesticide applied on surface might have traveled through soil strata under the influence of hydraulic gradient and become source of contamination in ground water.
- In order to minimize over-abstraction and deterioration of ground water quality all the ground water extraction structures should be registered and regulated.
- The water obtained from all the ground water structures should be tested before use to ensure suitability of the quality for human consumption. The ground water abstraction sources and their surroundings should be properly maintained to ensure hygienic conditions and no sewage or polluted water should be allowed to percolate directly to ground water aquifer.
- Possibilities of construction of artificial recharge structures should be explored to augment the ground water recharge.
- The hand pumps, which have been identified as having suspected water quality should be painted red to indicate and warn the public that the water drawn from the source is not fit for human consumption.
- The de-fluoridation treatment (domestic level) should be undertaken if the water is having high fluoride. Treatment option for nitrate should be undertaken in ground water drawn from sources exceeding the permissible limit of 100 mg/L.

- The ground water drawn from hand pumps should be properly chlorinated to eradicate the presence of bacterial contamination.
- The untreated sewage and sewerage flowing in various open drains are one of the causes of ground water quality deterioration. Proper under ground sewerage system must be laid in all inhabited areas and the untreated sewage and industrial wastes should not be allowed to flow in open drains.
- A regular monitoring of Groundwater quality should be done in the areas where water was found contaminated in metropolitan cities. Proper collection & treatment of wastewater and proper collection & disposal of municipal solid waste should be done. Industrial activities specially, polluting industry should be prohibited in residential areas. No stagnation of wastewater should be allowed to avoid percolation of contaminants in groundwater.
- Disposal of hazardous waste or biomedical waste should be prohibited in the city limit to avoid any leaching process in to the groundwater or to provide engineered landfill, if it is within the city limit. Three major contaminants were observed in the metro-cities i.e. Chlorides, Nitrates & Coliform bacteria. Wherever such contaminants were observed, the water should be used especially for drinking only after de-contaminating.
- Among the metro-cities, Agra was found most polluted followed by Meerut, Lucknow, Vishakhapatanam, Vijaywada, Chennai, Coimbatore.
- It is suggested that some low cost and easy to implement techniques may be provided to the consumers for removing hardness, total dissolved solids arsenic, fluoride, coliform and chloride in water where the value exceeds the permissible limit of drinking water.

B) Problem Areas

1) **Durgapur**

- As mentioned earlier the depths of the two tube wells at Ashishnagar and Mayabazar could not be ascertained except from the local public residing nearby. The groundwater quality particularly the bacterial contamination demands that the issue needs to be brought to the attention of the municipality;
- The bacterial contamination in the dug wells implies that the prevailing activities in the vicinity of the wells have unsanitary conditions for there is seepage from the underground septic tanks. The local peoples of the area need to be forewarned and directed to improve the sanitary conditions of the area;
- Except for DDT there was barely any significant change in the heavy metal concentrations and the pesticides concentration in the CPCB two rounds of survey. DDT could most probably be used as a disinfectant against malaria and also as seepage from agricultural activities. The local authority overseeing municipal work need to be apprised of this observation;
- Low fluoride concentrations in both the rounds of survey conducted by CPCB is a matter of concern particularly when the lower limit stipulated by BIS was 0.6 mg/l. The PHED / municipality need to study the cause and suggest necessary measures;
- The economics of executing the GW project was also a limiting factor in choosing the size of the survey network. Hence, GW network of five stations for the Durgapur problem may not be adequate to entirely project the prevailing GW quality of the area.

- There is a need make an update of the quantum pollutional load generated from various sources of pollution in the Durgapur problem area, since there has been a significant change in the industrial landscape over the past decade. This inventorisation shall assist in ascertaining whether fluctuations in GW quality could be co-related with the prevailing industrial or commercial activities;
- Status of Action Plan of **Durgapur Problem Areas** to be reviewed with regard to control of pollution so that the impact on groundwater can be minimized.

2) Haora

- The bacterial contamination to both the tubewells and the dug well located in Dasnagar, implies that the prevailing activities in the vicinity of the wells have unsanitary conditions for there is seepage from the underground septic tanks. The locals of the area need to be forewarned and directed to improve the sanitary conditions of the area.
- The incidence of DDT in the GW samples taken by CPCB could be attributed to the anti - malaria practices of the regions as there is barely any agricultural activity in the near vicinity. The local authority overseeing municipal work needs to be apprised of this observation.
- Low fluoride concentrations in both the rounds conducted by CPCB is a matter of concern particularly when the lower limit stipulated by BIS was 0.6 mg/l. The PHED / municipality need to study the cause and suggest necessary measures;
- Status of Action Plan of **Haora Problem Areas** to be reviewed with regard to control of pollution so that the impact on groundwater can be minimized.

3) Dhanbad

- As mentioned earlier the depths of the tube wells at the different were could not be ascertained except from the local public residing nearby. The groundwater quality particularly the bacterial contamination demands that the issue needs to be brought to the attention of the municipality;
- The bacterial contamination to the dug wells implies that the prevailing activities in the vicinity of the wells have unsanitary conditions for there is seepage from the underground septic tanks. The locals of the area need to be forewarned and directed to improve the sanitary conditions of the area;
- Low fluoride concentrations in both the rounds conducted by CPCB is a matter of concern particularly when the lower limit stipulated by BIS was 0.6 mg/l. The PHED / municipality need to study the cause and suggest necessary measures;
- Status of Action Plan of **Dhanbad Problem Areas** to be reviewed with regard to control of pollution so that the impact on groundwater can be minimized.

4) Angul-Talcher

- Bacteriological analysis reveals that most of the dug wells are contaminated with coliform bacteria that may be due to the improper sanitation around the dug wells. During

monsoon period high values of coliform content are found in the tube wells of Tulsipal, Talcher, Handidhua Chhak, FCI and Gotamara villages, which may be attributed to improper drainage of wastewater;

- The Municipality and the local people should be informed about this observation; Impact of residues of pesticides and fertilisers are observed at the selected sampling stations in the agricultural belts of the study area;
- To derive a definite correlation, further study on uptake of fertilisers by the plants, quantity of residues remains, annual consumption of fertilisers and pesticides in the agricultural land and use of pesticides in other purposes are necessary; Though from the study it appears that impact on quality of ground water does not seem to be apparent, but on recharge of ground water, depletion of ground water level due to alteration of physiography might be a future concern due to mining activities;
- Status of Action Plan of **Angul Talcher Problem Areas** to be reviewed with regard to control of pollution so that the impact on groundwater can be minimized.

5) Singrauli

- The highly fragile hydro-geological setting in the areas close to the Rihand reservoir must be given due attention in fast changing land-use pattern in the area either for industrial expansion or for disposal of industrial refuse / effluents;
- Groundwater extraction in areas bordering close to Rihand reservoir should be strictly regulated to eliminate chances of promoting reservoir water infiltrating through reservoir bed which in all probabilities must be rich in metals and thus magnify the concentration of heavy metal in nearby groundwater bearing zones;
- Similarly, the practice of encroaching the reservoir for disposal of ash / augmentation of ash-pond capacity and other similar purposes should be strictly prohibited. This has direct relation with the possible percolation of heavy metals into the reservoir as well as in the increased risk of structural failure in ash dykes;
- Low cost sanitation facilities should be promoted and the system for collection and treatment of sewage must be given due attention. Municipal solid waste must also be disposed judiciously. This is of particular significance in terms of bacteriological contamination and high nitrate concentration observed in groundwater;
- The practice of disposing the untreated / partly treated effluent into the Rihand reservoir should be strictly prohibited. Strict enforcement to check by-pass of untreated effluent by the industries must be ensured. Efforts must be made to re-use the effluent after proper treatment. This should be taken-up in order to reduce stress on groundwater resources and ensure conservation of reservoir water;
- Conventional treatment for the effluent generated from coal yard, boiler blow down cooling tower blow -down, ash pond overflow should be properly ensured at all the power plants to minimize the adverse effect on account of heavy metals, boron and other related constituents;
- In-plant measures adopted by industries with significant potential of water pollution should be regularly operated. The effluent treatment plant at M/s Kanoria Chemicals, M/s HINDALCO Industries and M/s Hi-Tech Carbon should be further upgraded to reduce the chances of pesticide, chlorine, mercury, fluoride, iron, and oil-grease. These measures

must include judicious disposal of mercury sludge, spent cathode linings trapping oil and grease from the effluents;

- The existing capacity of ash ponds and structural strength of ash dykes in power plants and other industries should be regularly reviewed so as to provide sufficient disposal sites and minimize the chance of ash over flow;
- All the industries in the area must carryout regular monitoring of groundwater at appropriately locations decided in consultation with CPCB / UPPCB. The data generated must be made available to CPCB / UPPCB;
- Concerted measures should be adopted for plantation of resistant plants in filled up ash ponds. It is recommended that plantation of alfalfa, cotton and tobacco plant in red mud ponds and its admixtures can significantly reduce the concentration of fluoride and its derivatives. Encouraging results have been recorded especially in case of filled-up fly-ash ponds where plant species like Acacia nilotica (Babool), Leucina leucocephella (Subabool), Pongamia pinnata (Kanji) etc.;
- Status of Action Plan of **Singrauli Problem Areas** to be reviewed with regard to control of pollution so that the impact on groundwater can be minimized.

6) Vishakhapatnam

- Vishakapatnam Municipality should treat their sewage before discharging into any water bodies;
- All industries need to comply with the stipulated water and air emission standards;
- The A.P. State Pollution Control Board needs to monitor groundwater to ascertain GW contamination and take necessary actions;
- Indiscriminate groundwater tapping needs to be restricted;
- Industries should be encouraged to adopt clean technology and encourage reuse / recycle of materials where ever possible;
- Establishment of new industries to be restricted following zoning Patterns of land use;
- Effluent discharged into Megadrigadda Channel to be checked by AP Pollution Control Board;
- Status of Action Plan of **Vishakhapatnam Problem Areas** to be reviewed with regard to control of pollution so that the impact on groundwater can be minimized.

7) Bollaram-Patancheru

- In Bollaram-Patencheru industrial area all major and medium industries should have their provisions to treat their own effluents to comply with stipulated limits, else they should be restrained from operating;
- Small-scale industries to be encouraged avail of the CETP facilities. All CETPs should meet treated water effluent limits;
- The Andhra Pradesh Pollution Control Board may monitor the groundwater periodically;
- Tapping groundwater may be restricted;
- New industries may be restricted to establish in this area;
- In this industrial estate industries to be encouraged to recycle their effluent fully or partially and follow clean technology;

- Status of Action Plan of **Bollaram-Patancheru Problem Areas** to be reviewed with regard to control of pollution so that the impact on groundwater can be minimized.

8) Bhadravathi

- The two major units viz. M/s Visveshwaryya Iron and Steel Ltd. and M/s Mysore Paper Mills to ensure that stipulated norms for effluent discharge was being complied with besides they should restrain from discharging effluent into the river;
- Bhadravathi City Municipality needs to provide a sewage treatment plant;
- The Karnataka State Pollution Control Board may periodically analyze GW water quality of the region;
- Status of Action Plan of **Bhadravathi Problem Areas** to be reviewed with regard to control of pollution so that the impact on groundwater can be minimized.

9) Greater Cochin (Kochi)

- The Kerala State Pollution Control Board may be monitor the groundwater periodically;
- All defaulting industries to be directed to comply with stipulated effluent norms else face closure by the SPCB;
- Establishing new industries may be discouraged or restricted;
- Alternate drinking water provisions need to be explored to groundwater-affected areas;
- 100% sewage treatment by Municipal Corporation needs to be enforced;
- Recycling and clean technology may be insisted / encouraged in all industries;
- Status of Action Plan of **Greater Cochin Problem Areas** to be reviewed with regard to control of pollution so that the impact on groundwater can be minimized.

10) Manali

- M/s Ennur Thermal Power Station should refrain from releasing fly ash slurry into the sea. (Bay of Bengal).
- M/s Ennur Foundry requires to install air pollution control system and re-use their treated effluent.
- Measures need to be taken to restrain industries from disposing effluent into the Buckingham canal.
- Groundwater needs to be monitored periodically to maintain a database and ascertain deterioration in groundwater quality of the region;
- The industries located in Manali area need to be encouraged to recycle treated wastewater;
- Status of Action Plan of **Manali Problem Areas** to be reviewed with regard to control of pollution so that the impact on groundwater can be minimized.

11) North Arcot

- All tanneries, dyeing units should have treatment plant facilities. CETP & individual treatment plants need to explore reuse of the treated water. Presently, sludge generated

was thrown into the riverbeds or on land. Sludge should be segregated and kept within a in a closed area similar to the provisions for storing hazardous wastes.

- The tannery units need to explore how best to decontaminate the chromium contaminated leather shavings are presently being thrown about indiscriminately;
- The T.N. Pollution Control Board to consider ways in disposing the chromium hazardous waste left behind by M/s Tamilnadu Chromate hazardous waste;
- Periodically GW samples need be taken to generate a database on the GW quality to ascertain deterioration, if any;
- Status of Action Plan of **North Arcot Problem Areas** to be reviewed with regard to control of pollution so that the impact on groundwater can be minimized.

12) Ankleshwar

- In the problem area Ankaleshwar, the groundwater quality was poor as indicated by the measured parameters. The reasons of contamination may be attributed to the indiscriminate discharge of industrial effluent and hazardous industrial solid wastes on the surface soil, which was percolating and infiltrating down into the water table;
- The samples were having high TDS, FC, TC, total hardness, sulphate and nitrate;
- Groundwater quality can be improved by restraining indiscriminate discharge of industrial effluent and hazardous solid waste on the surface;
- Status of Action Plan of **Ankaleshwar Problem Areas** to be reviewed with regard to control of pollution so that the impact on groundwater can be minimized.

13) Vapi

- In Problem area Vapi Groundwater quality was contaminated as indicated by the reported parameters.
- The reasons for contamination may be attributed to the indiscriminate discharge of industrial effluent and hazardous industrial solid waste on the surface soil, which perhaps percolated and contaminated the GW.
- The samples indicated colour and had high, TDS, FC, TC, Chlorides, Alkalinity, total hardness, Sulphate, Nitrate values and GW was not potable.
- Ground water quality can be improved by preventing indiscriminate discharge of industrial effluent and hazardous solid waste on the surface;
- Status of Action Plan of **Vapi Problem Areas** to be reviewed with regard to control of pollution so that the impact on groundwater can be minimized.

14) Chembur

- In the Problem area of Chembur, Groundwater quality is poor as indicated by reported Parameters. The reasons of contamination may be attributed to the indiscriminate discharge of industrial effluent and hazardous industrial solid waste on the surface soil, which was percolating down and could contaminate the GW;
- The samples indicated colour and had high, TDS, FC, TC, Chlorides, Alkalinity, total hardness, Sulphate, Nitrate values and GW was not potable;

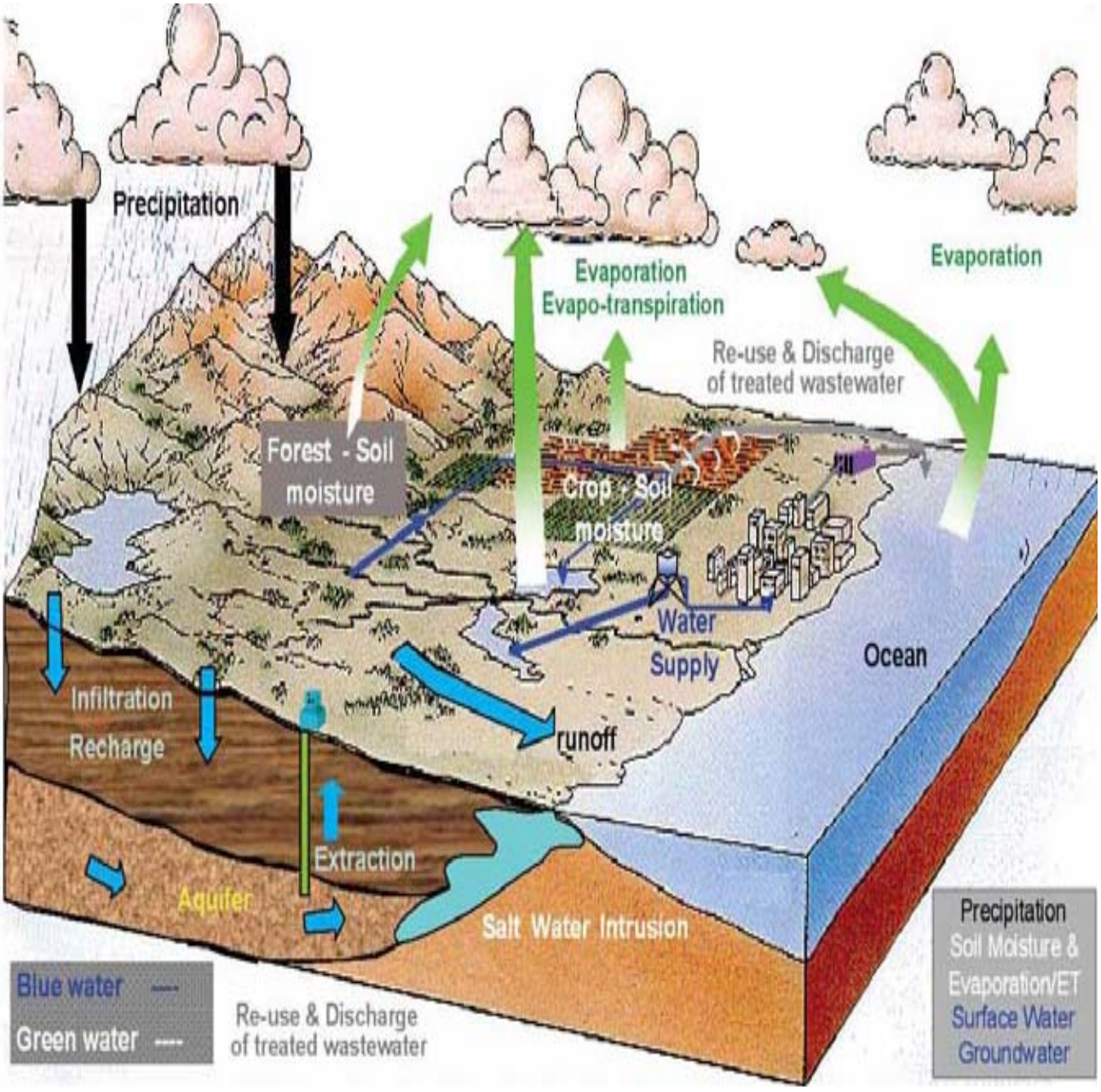
- Ground water quality can be improved by preventing indiscriminate discharge of industrial effluent and solid waste;
- Status of Action Plan of **Chembur Problem Areas** to be reviewed with regard to control of pollution so that the impact on groundwater can be minimized.

15) Tarapur

- In the problem area of Tarapur, the groundwater quality is poor as indicated by reported parameters. It may be noted that groundwater does not account for a major source of groundwater. The reasons of contamination may be attributed to the indiscriminate discharge of industrial effluent and hazardous industrial solid waste on the surface soil, which is percolating and infiltrating down into the water table;
- The concentrations of the pollutants at the dug well were found higher than those of tube wells;
- High values of TDS, FC, TC, total hardness, Sulphate and Nitrate were reported;
- Groundwater contamination can check by restraining indiscriminate discharge of industrial effluent and dumping of hazardous solid waste on the surface;
- Status of Action Plan of **Tarapur Problem Areas** to be reviewed with regard to control of pollution so that the impact on groundwater can be minimized.

16) Digboi

- It was observed from the chemical analyses that the groundwater quality was good;
- Fe and Mn in groundwater are significantly high in Digboi. From available data it can be concluded that Fe occurred naturally and may not be due to industrial pollution;
- Other heavy metals were found to be within stipulated limits;
- Effluents from Digboi refinery need to be analysed for finding the concentration of heavy metals;
- The refinery authority started reclaiming the acid tar in the acid tar pond in 1998 but it was observed that only 15 to 20% of the pond has been reclaimed so far. The industry may be asked to carry out the reclamation work at a faster rate;
- Construction of a sewage treatment plant would be desirable for the Digboi Township;
- Status of Action Plan of Digboi Problem Areas to be reviewed with regard to control of pollution so that the impact on groundwater can be minimized.



Water Cycle: Picture reproduced from UN-World Water Development Report 2006 Report 2-Water a shared responsibility

Continued

ANNEXURE I

ANNEXURE I: Groundwater Quality Observation and Percent Violation of Samples Collected in METROPOLITAN CITIES OF INDIA

Table1: Groundwater quality Observation and % sample violation with respect to drinking water standards in Agra Metropolitan city

	Parameters (All are in mg/L except pH)	Range- (Pre-Monsoon)	Range (Post-Monsoon)	Stds. BIS/ WHO Guideline	% Sample violation (DL-PL, Analysis of 50 samples)	Observations
1.	pH value	6.76-7.6	6.59-7.81	6.5-8.5	None	• The pH values are well within the limit of various uses
2.	Total Hardness (as $CaCO_3$)	132-2484	115-2450	300-600	40% within the DL while 30% crosses the DL but are well within the PL and 30% crosses PL.	• The ranges in both the monitoring rounds indicate that total hardness values are being exceeded w.r.t the stipulated standard at some location(s); • For both the monitoring rounds the HP monitored at Khandari, Sultanpura, Rakabganj, Namner, Bundu Katra, Baluganj, Tajganj and Balkeshwar were exceeded the PL.
3.	Chloride (as Cl)	50-1815	38-1795	250 -1000	44% falls within DL, while 48 % exceeds the DL but are within the PL. 8% crosses PL	• The values at all locations for both the rounds were within the stipulated standards; • The HP at Sultanpura & Namner exceeded the permissible limit recommended by BIS/ WHO.
4.	Total dissolved solids	474 - 6246	449 – 5920	500-2000	36% exceeding maxmum Permissible limit while 60% crosses DL but within PL & 4% within DL	• The ranges in both the monitoring rounds indicate that total dissolved solids are being exceeded w.r..t the stipulated standard at some location(s); • For both the monitoring rounds the HP monitored at Khandari, Sultanpura, Namner, Bundu Katra, Rakabganj exceeded the PL of 2000mg/l.
5.	Calcium (as Ca)	30-453	28-461	75-200	40% falls within the DL (BIS) & 40% crosses the DL but are within the PL, while 20% crosses the PL	• The ranges in both the monitoring rounds indicate that calcium values are being exceeded w.r.t. the stipulated standard at some location(s); • For both the monitoring rounds the HP monitored at Khandari, Sultanpura, Namner exceeded the max. PL
6.	Sulphate (as SO_4)	35-1475	30-1275	200 - 400	40% fall within the DL while 20% exceeds DL but are within the PL. 40% crosses the PL	• The ranges in both the round indicated that the values are exceeded the stipulated standard at some locations; • For both the monitoring rounds the HP monitored at Khandari, Shahganj, Sultanpura, Rakab-ganj, Namner, Bundu Katra, Baluganj, Ratanpura, Tajganj and Balkeshwar were exceeded the max. PL

	Parameters (All are in mg/L except pH)	Range- (Pre- Monsoon)	Range (Post- Monsoon)	Stds. BIS/ WHO Guideline	% Sample violation (DL-PL, Analysis of 50 samples)	Observations
7.	Nitrate (as NO_3 N)	12-702	12-832	45-100	54% exceeds the PL of 100 mg/l. 20% samples shows NO_3^- content < DL while 26% samples crosses the DL but within the PL	• The ranges in both the round indicated that the values are exceeded the stipulated standard at some locations; • For both the monitoring rounds the HP monitored at Khandari, Shahganj, Sultanpura, Idgah colony, Rakab-ganj, Namner, Bundu Katra, Gandhi nagar, Mantola, Chilgarh, Baluganj, Ratanpura, Tajganj and Balkeshwar were exceeded the maximum PL.
8.	Fluoride (as F)	0.46 – 7.8	0.32-3.7	1.0-1.5	26% exceeds the DL but are within the PL and 34% crosses the PL during pre-monsoon. While 40% are within the DL	• The ranges in both the round indicated that the values are exceeded the stipulated standard at some locations; • For both the monitoring rounds the HP monitored at Sikandra, Khandari, Lohamandi, Shahganj, Sultanpura, Idgah Colony, Rajamandi, Nai ki mandi, Namner, Gandhi Nagar, Maithan, Mantola, Naulakha, Ratanpura, Itma-Ud-Daulla were exceeded the maximum PL.
9.	Sodium (as Na)	56-1196	48-1192	200 (No limit in BIS/WHO)	The high sodium value in the metro may be attributed to base action phenome-non.	• In both the monitoring rounds the values of sodium content was found very high. Ground water with such high sodium is not sutiable for irrigation purpose due to sodium sensitivity of crops.
10.	Potassium (as K)	1.3-65.0	1.1-54.0	No limit in BIS/WHO	The high K value in the metro may be attributed to base action phenomenon.	• In both the monitoring rounds the values of potassium exceeded the 10 mg/l of EEC standard at, Sultanpura, Idgah Colony, Nai ki mandi, Bundu Katra, Mantola, Chilgarh, Baluganj, Belanganj, Industrial Estate and Itma-Ud-Daulla. • The main sources of potassium in ground water include rainwater, weathering of potash, silicate minerals, use of potash fertilizers and use of surface water for irrigation. • The BIS has not included K in drinking water standards. How-ever the EEC has prescribed guideline level of 10 mg/l potassium during pre-monsoon.
11.	Magnesium (as Mg)	4-348	10-316	30 - 100 (BIS standard)	40% falls within the DL (BIS) & 40% crosses the DL but are within the PL, while 20% crosses the PL	• The ranges in both the monitoring rounds indicate that Magnesium values are being exceeded the Stipulated standard at some location(s); • For both the monitoring rounds the HP monitored at Khandari, Sultanpura, Namner exceeded the max. PL

	Parameters (All are in mg/L except pH)	Range- (Pre-Monsoon)	Range (Post-Monsoon)	Stds. BIS/ WHO Guideline	% Sample violation (DL-PL, Analysis of 50 samples)	Observations
12.	Phosphate (as PO_4)	0.01-0.18	0.01-0.11	No limit in BIS/WHO	The values are usually low in groundwater samples.	• Phophorus is essential plant nutrient and is extensively used in fertilizers. Phosphate gets adsorbed or fixed as aluminum or iron phosphate in acidic soils or as calcium phosphate in alkaline or nutral soils, as a result the concentration of phosph-ate is usually low but various chemical processes in soil strata may induce the mobility of phosphate in subsoil & GW.
13.	Conducti-vity (as EC) µS/cm	740-9760	702-9250	No limit in BIS (1000 µS/cm irrigation standard)	Almost all the sample having conductivity value above 1000 µS/cm during both the seasons.	• There was no seasonal variation at almost all the locations. However, the value of conductivity exceeded the irrigation standards at most of the locations. • For both the monitoring rounds the HP monitored at Khandari, Shahganj, Sultanpura, Idgah colony, Rakabganj, Namner, Bundu katra, Mantola, Chilgarh, Baluganj, Naulakha, Ratanpura, Tajganj, Industrial estate, Balkeshwar and Itma-ud-daulla exceeded the PL.
14.	Faecal Coliform MPN/100ml	09-23	Nil	Should be nil	6% crosses PL while 92% within DL	• Some bacterial contamination at few locations during PM season. Three samples exceeded the DL i.e. Nil. However, during post-monsoon season no sample has indicated any sign of bacterial contamination; • The pre-monsoon showed bacterial contamination (9 & 23 MPN/100 ml) at Nai Ki Mandi, Naulakha and Tajganj; • Inadequate maintenance of hand pump, improper sanitation and unhygienic conditions around the structure may be responsible for bacterial contamination during the pre-monsoon season.
15.	Total Coliform MPN/100ml	03-23	Nil	5% samples Should not be >10 in 100ml sample.	6% exceeded the PL	• Some bacterial contamination at few locations during Pre-monsoon season. four samples exceeded the PL i.e. 10 MPN/100ml. However, during post-monsoon season no sample has indicated any sign of bacterial contamination; • The pre-monsoon showed bacterial contamination (23 MPN/100 ml) at Nai Ki Mandi, Naulakha, Tajganj and Industrial estate; In-adequate maintenance of hand pump, improper sanitation and unhygienic conditions around the structure may be responsible for bacterial contamination during the pre-monsoon season.

	Parameters (All are in mg/L except pH)	Range- (Pre-Monsoon)	Range (Post-Monsoon)	Stds. BIS/ WHO Guideline	% Sample violation (DL-PL, Analysis of 50 samples)	Observations
16.	Alkalinity (as HCO_3) mg/l	153-455	144-434	200-600	68% and 40% during pre and post-monsoon seasons respectively crosses the DL, but well within the PL	• There was no seasonal variation at almost all the locations. However, the value of alkalinity exceeded the desirable limit in 68% and 40% during pre and post-monsoon seasons respectively. • For both the monitoring rounds the HP monitored at Sikandra, Khandari, Lohamandi, Sultanpura, Idgah Colony, New Agra Colony, Rajamandi, Rakabganj, Namner, Bundu Katra, Dayalbagh, Mantola, Chilgarh, Baluganj, Naulakha, Ratanpura, Tajganj, Industrial Estate, Balkeshwar and Itma-Ud-Daulla are exceed the DL for drinking purpose..
17.	Boron as B mg/l	0.01-0.68	0.01-0.86	1.0-5.0	All the samples indicate that the ground water is safe for irrigation purpose only.	• All the samples are well within the desirable limit.

	Heavy Metals (µg/l)	Range (Pre-Monsoon)	Range (Post-Monsoon)	Stds. BIS/WHO Guideline	**% Sample violation (DL-PL, analysis of 50 samples)**	Observations
1.	Iron (as Fe)	446-9000	176-5262	300-1000	72% and 84% crosses PL during pre and post monsoon respectively. However, overall scenario (50 samples) showed 74% crosses PL while 22% between DL & PL and only 4% <DL	• It is evident from the results that none of the sample fall within the DL during pre-monsoon season and only 28% samples fall within the permissible limit (PL); • In both the rounds of monitoring high concentration of iron observed in most of the samples and violating drinking water standards.
2.	Lead (as Pb)	33-270	24-186	50- No relaxation	68% and 44% crosses the PL during pre and post monsoon seasons respectively.	• It is evident from the results only 40% and 56% of samples fall within the PL during pre and post monsoon seasons respectively; • In both the rounds of monitoring, a high (<50 µg/l} concentration of lead observed in 13 locations and violating the drinking water standards.

	Heavy Metals (µg/l)	Range (Pre-Monsoon)	Range (Post-Monsoon)	Stds. BIS/WHO Guideline	**% Sample violation (DL-PL, analysis of 50 samples)**	Observations
3.	Manganese (as Mn)	15-445	7-519	100-300	Only 10% crosses the PL during pre and post monsoon seasons.	• It is evident from the results 72% fall within the PL during pre and post monsoon seasons; • In both the rounds of monitoring, a high (<300 µg/l} concentration of Mn observed at Sultanpura and Industrial estate during pre-monsoon and Sultanpura, Namner and Industrial estate during post-monsoon and violating the drinkingwater standards.
4.	Copper (as Cu)	8-235	9-117	50-1500	Only 16% exceeds the DL during pre and post monsoon seasons.	• It is evident from the results 84% fall below the DL during pre and post monsoon seasons; • In both the rounds of monitoring, a high (<50 µg/l} concentration of Cu observed at Shah ganj, Sultanpura, New agra colony, Raja mandi and Industrial estate during pre and post monsoon seasons.
5.	Cadmium (as Cd)	5-28	3-24	10- No relaxation.	40% and 24% crosses the PL during pre and post monsoon seasons respectively.	• 60% of the samples are found within the PL during Pre-monsoon and 70% are fall within the PL during post monsoon seasons; • In both the rounds of monitoring, a high (<10 µg/l} concentration of Cd was observed at Khandari, Shah ganj, Sultanpura, Idgah Colony, Rakabganj, Namner, Bundu Katra, Bauganj, Tajganj, Balkeshwar during pre and post monsoon seasons.
6.	Chromium (as Cr)	6-35	7-43	50- No relaxation	All the samples fall well within the DL of drinking water	• All the samples fall well within the DL of drinking water;
7.	Nickel (as Ni)	17-144	16-124	20 (as guideline value of WHO)	96% crosses the WHO limit during pre and post monsoon seasons.	• In almost all the samples, the WHO guideline value of Ni crosses the drinking water limit; • In both the rounds of monitoring, a high (20-40 µg/l) concentration of Ni was observed at 16 locations during pre and post monsoon seasons.
8.	Zinc (as Zn)	24-2442	22-2232	5000-15000	All the samples were found within the desirable limit prescribed by BIS (1991) and WHO (1996).	• The concentration of Zn in groundwater samples is within the stipulated standards.

	Pesticides (µg/l)	Range (Pre-Monsoon)	Range (Post-Monsoon)	Standards BIS/WHO Guideline	% Sample violation	Observations
Organo-chlorinated pesticides						
1.	Aldrin	NT	NT	0.03 (WHO guideline)	-	-
2.	∝-BHC (µg/l)	0.02-1.15	0.03-0.86	1.0 (WHO guideline)	All the samples are well within the WHO limit except one.	• The concentration of ∝-BHC were detected in eight samples but well within the WHO limit except at Mantola i.e. 1.15 µg/l
3.	Endosul-phan (µg/l)	0.1-1.03	0.15-1.06	No guideline	Out of 25 samples, 14 samples were detected endosulphan concentration.	• The concentration of Endosulphan were detected in fourteen samples may be harmful for the drinking purpose.
4.	Methoxy-chlor (µg/l)	0.33-0.58	0.37-0.67	20 (WHO guideline)	All the samples are well within the WHO limit.	• The concentration of Methoxychlor was detected in two samples but well within the WHO guideline value.
5.	DDT (µg/l)	NT	NT	2.0 (WHO guideline)	The DDT concentration were not detected in all the samples.	• The concentrations of DDT were not detected in any of the groundwater samples.
6.	∝-HCH (µg/l)	NT	NT	No guideline	No samples found ∝-HCH concentrations	• The concentrations of ∝-HCH were not detected in any of the groundwater samples.
OrganaPhosphorous pesticides						
7.	Malathion (µg/l)	NT	NT	-	-	• No samples traceable for Melathion.
8.	Methyl parathion (µg/l)	NT	NT	-	-	• No samples traceable for Methyl parathion.
9.	Chlorpyri-phos (µg/l)	NT	NT	-	-	• No samples traceable for Chloropyriphos.

Note: Range of Standards (BIS) indicated Desirable to Permissible limit while WHO guideline considered wherever BIS standards not prescribed. The abbreviation indicated above as 'DL' = Desirable Limit; 'PL' = Permissible Limit; 'HP = Hand pump; 'TW' = Tube well, NT=Not Traceable

Table2: Groundwater quality Observation and % sample violation with respect to drinking water standards in Meerut Metropolitan city

	Parame-ters (All are in mg/L)	Range (Pre-Monsoon)	Range (Post-Monsoon)	Stds. BIS/ WHO	% Sample Compliance/ violation	Observations
1.	pH value	6.7-7.4	6.65-7.57	6.5-8.5	None	➢ The pH values of all the samples are well within the limits prescribed by BIS and WHO,
2.	Total Hardness (as $CaCO_3$)	98-239	86-236	300-600	None	➢ The ranges in both the monitoring rounds indicate that total hardness values are within the stipulated standard at all the locations; ➢ All the samples are found well within the DL in both the seasons.
3.	Chloride (as Cl)	3.7-59	3.4-57	250 -1000	No sample in the study area crosses the DL.	➢ The values at all locations for both the rounds were within the stipulated standards.
4.	Total dissolved solids	249-926	230-864	500-2000	60% were found within the DL while 40% were found above the DL but within the PL.	➢ The ranges in both the monitoring rounds indicate that total dissolved solids are within the PL for drinking water standards; ➢ For both the monitoring rounds the HP/TW monitored, 40% were found above the DL but within the PL.
5.	Calcium (asCa)	23-58	22-67	75-200	None	➢ The ranges in both the monitoring rounds indicate that calcium values are within the stipulated standard at all the locations.
6.	Sulphate as (SO_4	10-150	9-140	200 -400	None	➢ The ranges in both the round indicated that the sulphate values are within the stipulated standard at all the locations.
7.	Nitrate (asNO_3)	0.44-209	0.2-168	45-100	72% samples shows less than DL while 18% crosses the DL and 14% crosses the PL.	➢ The ranges in both the round indicated that the values are exceeded the stipulated standard at some locations; ➢ For both the monitoring rounds the higher level of nitrate monitored at Thapar Nagar, Muftiyan, Bharampuri and Islamabad were exceeded the maximum PL.
8.	Fluoride (as F)	0.2-1.2	0.2-1.3	1.0-1.5	4%Sample Crosses the PL while 96% within the DL	➢ The ranges in both the round indicated that the Fluoride values are well within the stipulated standard except at one location i.e. Sports Complex during both the seasons
9.	Sodium (as Na)	22-128	21-130	200 (WHO limit)	None	➢ In both the monitoring rounds the values of sodium content was found well within the WHO standard for irrigation purpose; ➢ All the samples are well within the stipulated standards.
10.	Potassium (as K)	5.1-174	4.8-170	Not Prescribed	None	➢ In both the monitoring rounds the values of potassium are exceeded the limits of 10 mg/l of EEC standard at the place named Muftiyan. The main sources of potassium in ground water include rainwater, weathering of potash, silicate minerals, use of potash fertilizers and use of surface water for irrigation.

	Parame-ters (All are in mg/L)	Range (Pre-Monsoon)	Range (Post-Monsoon)	Stds. BIS/ WHO	% Sample Compliance/ violation	Observations
11.	Magnesium (as Mg)	8.3-25	8-23	30 - 100 (BIS std.)	None	➢ The ranges in both the monitoring rounds indicate that Magnesium values are well within the stipulated standard at all the locations.
12.	Phosphate (as PO_4)	0.02-1.39	0.03-2.04	Not Prescribed	None	➢ The concentration of Phosphate is low in both the rounds of monitoring except at ➢ one location named Muftiyan; ➢ The values are usually low in groundwater samples. However, the concentration exceeds 1 mg/l at Muftiyan
13.	Conducti-vity (as EC) (µS/cm)	389-1447	360-1350	1000 µSimens/cm (irrigation standard)	20% samples having conductivity values above 1000 µSimens/cm during both the seasons	• The maximum conductivity value of 1447 and 1350 µS/cm were observed at Muftiyan during pre and post-monsoon seasons respectively. • For both the monitoring rounds the HP monitored at Muftiyan exceed the PL for irrigation.
14.	Faecal Coliform MPN/100ml	Nil	Nil	Should be nil	None	• All the samples found Faecal Coliform are well within the stipulated standards for drinking purposes.
15.	Total Coliform MPN/100ml	9-210	Nil-4	5% samples Should not be >10 in 100ml sample	2% sample crosses standard	• All the samples found Total Coliform are well within the stipulated standards for drinking purposes except few location.
16.	Alkalinity (as HCO_3)	151-344	148-340	200-600	More than 50% of the samples fall within the DL & 50% crosses the DL but are within the PL.	• The value of alkalinity exceeded the desirable limit in 50% samples during pre and post-monsoon seasons respectively. • For both the monitoring rounds the HP/TW monitored, no sample crosses the PL for drinking purposes.
17.	Boron (as B)	0.09-0.73	0.08-0.73	1.0-5.0	None However 100% samples fall within the DL	• All the samples are well within the desirable limit of drinking water.

	Heavy Metals (All values are in µg/L)	Range (Pre-monsoon)	Range (Post-Monsoon)	Stds. BIS/ WHO	% Sample violation	Observations
1.	Iron (as Fe)	112-3543	22-3205	300-1000	30% samples crosses the PL 22% samples fall within the DL	• It is evident from the results that 22% samples fall within the DL and 30% samples crosses the permissible limit (PL) While 48% between DL-PL

	Heavy Metals (All values are in µg/L)	Range (Pre-monsoon)	Range (Post-Monsoon)	Stds. BIS/ WHO	% Sample violation	Observations
						• In both the rounds of monitoring, high concentration of iron was observed in some of the samples and violating drinking water standards.
2.	Manganese (as Mn)	13-523	8-362	100-300	40% samples well within the DL and 52% crosses the DL but within the PL, while 8% crosses the PL during pre and post monsoon seasons.	• It is revealed that the 92% samples fall within the PL during pre and post monsoon seasons; while 8% above the permissible limit; • In both the rounds of monitoring, a high (376, 523 µg/l} concentration of Mn was observed at Kankar Khera and Vijay Nagar during pre and post-monsoon seasons and violating the drinking water standards.
3.	Copper (as Cu)	7-307	3-243	50-1500	88% fall below the DL & remaining 12% crosses the DL but are within the PL during pre and post monsoon seasons.	• It is evident from the results 88% fall below the DL during pre and post monsoon seasons; • In both the rounds of monitoring, a high (68, 186, and 307 µg/l} concentration of Cu was observed at Bharampuri, Vijay Nagar and Sports Complex respectively during pre-monsoon and a high concentration (97, 213 and 243 µg/l) was observed at Gurudwara, Sports Complex and Bharampuri respectively during post monsoon seasons.
4.	Chromium (as Cr)	2-11	1-18	50- No relaxation	None	• All the samples fall well within the DL of drinking water.
5.	Zinc (as Zn)	32-2619	2-1084	5000-15000	None	• The concentration of Zn in groundwater samples is within the stipulated standards. • All the samples were found within the desirable limit prescribed by BIS (1991) and WHO (1996).

	Pesticides	Range (Pre-monsoon)	Range (Post-Monsoon)	Stds. BIS/WHO	% Sample violation	Observations
Organo-chlorinated pesticides						
1.	Aldrin	NT	NT	0.03 (WHO guideline)	-	• No aldrin concentration was found in groundwater samples of metro city.
2.	∝-BHC	0.06-0.23	0.08-0.7	0.01 (WHO guideline)	None	• All the samples are well exceeding
3.	Endosulphan	NT	NT	No guideline	-	• No endosulphan concentration was found in groundwater samples of metro city.

	Pesticides	Range (Pre-monsoon)	Range (Post-Monsoon)	Stds. BIS/WHO	% Sample violation	Observations
4.	Methoxychlor	NT	NT	30 (WHO guideline)	-	• No methoxychlor concentration was found in groundwater samples of metro city.
5.	DDT	NT	NT	1.0 (WHO guideline)	-	• No DDT concentration was found in groundwater samples of metro city.
6.	∝-HCH	NT	NT	No guideline	-	• No ∝-HCH concentration was found in groundwater samples of metro city.
OrganaPhosphorous pesticides						
7.	Malathion	NT	NT	-	-	• No samples traceable for Melathion.
8.	Methyl parathion	NT	NT	-	-	• No samples traceable for Methyl parathion.
9.	Chloropyriphos	NT	NT	-	-	• No samples traceable for Chloropyriphos.

Note: The abbreviation indicated above as 'DL' = Desirable Limit; 'PL' = Permissible Limit; 'HP = Hand pump; 'TW' = Tube well

NT=Not Traceable

Table 3: Groundwater quality Observation and % Sample Compliance/violation with respect to drinking water standards in Lucknow Metropolitan city

Sl. No.	Parameters (all values are in mg/L)	Range- (Pre-monsoon)	Range (Post-Monsoon)	Stds. BIS/ WHO	% Sample compliance/violation	Observations
1	pH value	7.8-8.3	7.4-8.1	6.5-8.5	None	• The pH values are well within the limit of various uses
2	Total Hardness (as $CaCO_3$)	140-760	120-612	300-600	**97% within the DL while 3% crosses the DL but are well within the PL.**	• The ranges in both the monitoring rounds indicate that total hardness values are being exceeded w.r.t the stipulated standard at some location(s); • For both the monitoring rounds the HP monitored at Asharfabad, Shadatganj, Gomti Nagar& Rastogi ghat.were exceeded the PL.
3	Chloride (as Cl)	11-380	7.3-268	250 -1000	None, However 4% exceeds DL & 96% within DL	• The values at all locations for both the rounds were within the stipulated standards; • The HP at Rastogi Nagar during pre monsoon exceeded the permissible limit recommended by BIS/ WHO.
4	Total dissolved solids	336 - 1452	149 – 1259	500-2000	None, However 48% exceed the DL while 52% within the DL	• The ranges in both the monitoring rounds indicate that total dissolved solids are being exceeded w.r..t the stipulated standard at some location(s); • For both the monitoring rounds the HP monitored at Imambara,Charbag,, Darulshafa & Rastogi ghat exceeded the PL of 2000mg/l.
5	Calcium (as Ca)	14.4-67.3	21.0-96.18	75-200	None	• The ranges in both the monitoring rounds indicate that calcium values are being exceeded w.r.t. the stipulated standard at some location(s); • For both the monitoring rounds the HP monitored does not exceeded the max. PL
6	Sulphate (as SO_4)	6.2-76.2	5.84-98.3	200 - 400	None	• The ranges in both the round indicated that the values are not exceeded the stipulated standard . • For both the monitoring rounds the HP monitored does not were exceeded the max. PL
7	Nitrate (as NO_3)	1.0-38.2	0.25-16.0	45-100	None	• The ranges in both the round indicated that the value does not exceed the stipulated standard.
8	Fluoride (as F)	0.70 – 0.94	0.10-0.92	1.0-1.5	None	The ranges in both the round indicated that the values within in the stipulated standard.

Sl. No.	Paramet-ers (all values are in mg/L)	Range- (Pre-monsoon)	Range (Post-Monsoon)	Stds. BIS/ WHO	% Sample compliance/violation	Observations
9	Sodium (as Na)	15.5-200	16.9-92.4	200 (No limit in BIS/WHO)	None	• In both the monitoring rounds the values of sodium content was within the PL & DL
10	Potassium (as K)	3.9-21.0	4.25-12.8	No limit in BIS/WHO	The BIS has not included K in drinking water standards. However the EEC has prescribed guideline level of 10mg/l potassium during premonsoon.	• In both the monitoring rounds the values of potassium does nor exceeded the 10 mg/l of EEC standard.
11	Magnesium (as Mg)	23.0-108.0	22-100	30 - 100 (BIS standard)	40% falls within the DL (BIS) & 40% crosses the DL but are within the PL, while 20% crosses the PL	• The ranges in both the monitoring rounds indicate that Magnesium values are being exceeded the Stipulated standard at some location(s); • For both the monitoring rounds the HP monitored at Imambara, Gomti Nagar, Indira NagarCharbag, & Rasto Ghat exceeded the max. PL
12	Phosphate (as PO_4)	0.38-2.7	0.30-1.5	No limit in BIS/WHO	None	• Phophorous is essential plant nutrient and is extensively used in fertilizers. Phosphate gets adsorbed or fixed as aluminum or iron phosphate in acidic soils or as calcium phosphate in alkaline or nutral soils, as a result the concentration of phosphate is usually low but various chemical processes in soil strata may induce the mobility of phosphate in subsoil and groundwater.
13	Conducti-vity (as EC) µS/cm	250-1968	405-1910	1000 µS/cm (irrigation standard)	Almost all the sample having conductivity value below 1000 µS/cm during both the seasons but 20 % remain > PL and 80 % within the DL.	• There was no seasonal variation at almost all the locations. However, the value of conductivity exceeded the irrigation standards at most of the locations. • For both the monitoring rounds the HP monitored at Imambara, Gomti Nagar, Indira Nagar,, Charbagh, Darulshafa& Rstogi Ghat exceeded the PL.
14	Faecal Coliform MPN/100ml	<2-40	<2-51	Should be nil		• Some bacterial contamination at few locations during PM season. Three samples (Amenabad & HP alomg the river Gomti exceeded the DL i.e. Nil. However, during post-monsoon season no sample has indicated any sign of bacterial contamination; • The pre-monsoon showed bacterial contamination (2 & 40 MPN/100 ml) at Amenabad & HP along the River Gomti; whereas during post monsoon it was <2 to 51 • Iinadequate maintenance of hand pump, improper sanitation and

Sl. No.	Paramet-ers (all values are in mg/L)	Range- (Pre-monsoon)	Range (Post-Monsoon)	Stds. BIS/ WHO	% Sample compliance/violation	Observations
						unhygienic conditions around the structure may be responsible for bacterial contamination during the pre-monsoon season and Post monsson. • The river water itself containing average of 175000 MPN/100 ml which may get percolate into the ground water sources along the River Gomti,
15	Total Coliform MPN/100ml	<2-40	<2-125	5% samples Should not be >10 in 100ml sample.	15% exceeded the PL.	• Some bacterial contamination at few locations during PM season. Three samples (Amenabad & HP along the river Gomti exceeded the DL i.e. Nil. However, during post-monsoon season no sample has indicated any sign of bacterial contamination; • The pre-monsoon showed bacterial contamination (2 & 100 MPN/100 ml) at Amenabad & HP along the River Gomti; whereas during post monsoon it was <2 to 125 • Iinadequate maintenance of hand pump, improper sanitation and unhygienic conditions around the structure may be responsible for bacterial contamination during the pre-monsoon season and Post monsoon. The river water itself containing average of 175000 MPN/100 ml which may get percolate into the ground water sources along the River Gomti.
16	Alkalinity (as HCO_3)	310-600	190-523	200-600	None	• There was no seasonal variation at almost all the locations. All the values were within the permissible & Desirable limits.
17	Boron as B	ND	ND	1.0-5.0	All the samples indicate that the ground water is safe for irrigation purpose only.	• All the samples are well within the desirable limit.

	Heavy Metals (µg/L)	Range (Pre-monsoon)	Range (Post-Monsoon)	Stds. BIS/WHO (mg/L)	% Sample compliance/ violation	Observations
1	Iron as Fe	0.11-3.60	0.02-0.10	0.3-1.0	14% and 0% crosses PL during pre and post monsoon respectively.	• It is evident from the results that none of the sample fall within the DL during pre-monsoon season and only 14% and 0% samples fall crosses the permissible limit (PL)in pre monsoon & post monsoon respectively • In both the rounds of monitoring high concentration of iron observed in most of the samples during pre monsoon and violating permissible limits of drinking water standards.
2	Manganese as Mn	ND – 0.09	ND-0.08	0.1-0.3	Only 1% crosses the PL during pre and post monsoon seasons.	• It is evident from the results 1% fall more then the PL during pre and post monsoon seasons;
3	Copper as Cu	0.01-0.04	ND – 0.04	5 - 25	Nil	• It is evident from the all the results falls well below the permissible limits during pre and post monsoon seasons;
4	Chromium (as Cr)	ND – 0.03	ND	0.05 No relaxation	Nil	• All the samples fall well within the PL of drinking water;
5	Zinc (as Zn)	0.07 - 0.98	0.01-0.84	5-15	Nil	• The concentration of Zn in groundwater samples is within the stipulated standards.

	Pesticides (µg/l)	Range (Pre-Monsoon)	Range (Post-Monsoon)	Stds. BIS	% Sample violation	Observations
	Organochlorinated pesticides					
10.	Aldrin	ND	ND	0.03 (WHO guideline)	All the samples are well within the WHO limit except one.-	• The concentrations of Aldrin were not detected in any of the groundwater samples.
11.	∝-BHC	ND	ND	1.0 (WHO guideline)	All the samples are well within the WHO limit except one.	• The concentrations of BHEC were not detected in any of the groundwater samples.
12.	Endosul-phan	ND	ND	No guideline	All the samples are well within the WHO limit except one.	• The concentrations of Endosulphan were not detected in any of the groundwater samples.
13.	DDT	ND	ND	2.0 (WHO guideline)	All the samples are well within the WHO limit except one.	• The concentrations of DDT were not detected in any of the groundwater samples.

Note: The abbreviation indicated above as 'DL' = Desirable Limit; 'PL' = Permissible Limit; EEC is = European Union Standard, 'HP = Hand pump; 'TW' = Tube well

Table 4: Groundwater quality Observation and % Sample Compliance/violation with respect to drinking water standards in Ludhiana Metropolitan city

Sl. No.	Parameters (All values are in mg/L)	Range- (Pre-monsoon)	Range (Post-Monsoon)	Stds. BIS/ WHO	% Sample compliance/violation	Observations
1	pH value	7.1-7.6	7.2-7.6	6.5-8.5	None	• The pH values are well within the limit of various uses
2	Total Hardness ($asCaCO_3$)	148-296	144-288	300-600	None	• The Total Hardness values are well within the limit of various uses
3	Chloride (as Cl)	12-65	11.5 - 63	250 -1000	None	• The Chloride values are well within the limit of various uses
4	Total dissolved solids	322 -498	331 – 523	500-2000	None	• The Total Dissolved Solids values are well within the limit of various uses
5	Calcium (as Ca)	28.9-54	30.5-52.4	75-200	None	• The Calcium values are well within the limit of various uses
6	Sulphate (as SO_4)	16.8-60.5	14.1-55.1	200 - 400	None	• The Sulphate values are well within the limit of various uses
7	Nitrate (as NO_3)	4.27-30.6	4.10-28.21	45-100	None	• The Nitrate values are well within the limit of various uses
8	Fluoride (as F)	0.71– 0.92	0.70-0.86	1.0-1.5	None	• The Fluoride values are well within the limit of various uses
9	Sodium (as Na)	29.5-78	35-81	200 (No limit in BIS/WHO)	None	• The Sodium values are well within the limit of various uses
10	Potassium (as K)	2.5-15	3.1-17.3	No limit in BIS/WHO	EEC has prescribed guideline level of 10 mg/l potassium during pre-monsoon.	• In both the monitoring rounds the values of potassium exceeded the 10 mg/l of EEC standard at Kidwai Nagae, Sardar Nagar, Bhai R.S.Nagar, Shahi Mod. • The main sources of potassium in ground water include rainwater, weathering of potash, silicate minerals, use of potash fertilizers and use of surface water for irrigation.
11	Magnesium (as Mg)	19.0-32.5	19.8-33.4	30 - 100 (BIS standard)	None	• The ranges in both the monitoring rounds indicate that Magnesium values are within the Stipulated standard at all the location(s); • For both the monitoring rounds the HP monitored atGuru R.D.Park Chowk,Fatehgarh, Sabzimandi, K.M.Singh, Langer Hall Daba and Model Town Mkt and Shahi Mhd. Exceeded the max. PL

Sl. No.	Parameters (All values are in mg/L)	Range- (Pre-monsoon)	Range (Post-Monsoon)	Stds. BIS/ WHO	% Sample compliance/violation	Observations
12	Phosphate (as PO_4)	0.43-3.3	0.38-2.11	No limit in BIS/WHO	None	• Phosphorous is essential plant nutrient and is extensively used in fertilizers. Phosphate gets adsorbed or fixed as aluminum or iron phosphate in acidic soils or as calcium phosphate in alkaline or nutral soils, as a result the concentration of phosphate is usually low but various chemical processes in soil strata may induce the mobility of phosphate in subsoil and groundwater.
13	Conductivity (as EC) µS/cm	439-1164	450-1178	1000 µS/cm (irrigation standard)	Almost all the sample having conductivity value below 1000 µS/cm during both the seasons but 4 % remain > PL and 96 % within the DL.	• There was no seasonal variation at almost all the locations. However, the value of conductivity exceeded the irrigation standards at most of the locations. • For both the monitoring rounds the HP monitored at Char Acre Colony. 2.5 No. Police Post Bhai R.S. Nagar, Gurudev Nagar,Model Town MktShahi Moh, Kitchlu Nagar Tajpur Road & Humbra Road exceeded the PL.
14	Faecal Coliform MPN/100ml	<2-<2	<2-<2	Should be nil		• All the values are well within the permissible limits.
15	Total Coliform MPN/100ml	<2-4	<2-<2	5% samples Should not be >10 in 100ml sample.	None	• All the values are well within the permissible limits
16	Alkalinity (as HCO_3)	236-372	244-380	200-600	None	• There was no seasonal variation at almost all the locations. However, the value of alkalinity exceeded the permissible limit in 58% and 58% during pre and post-monsoon seasons respectively. • For both the monitoring rounds the HP monitored at MIG Sector 32A, Sherpur, Kailash Nagar, Kidwai Nager , GuruA.D. Park C.Chowk, Industrial Area-A, Narinder Nagar, Janta Nagar, Industrial Area-B, Darresi, Fatehgarh, Sabzimandi, N.Shivpuri, Panjabibagh, Gagan D. Colony, Janta Colony, Sardar Nagar K.M.Singh and Langar Hall Daba. are exceed the PL for drinking purpose whereas all the values well within the desirable limits..
17	Boron as B	ND	ND	1.0-5.0	All the samples indicate that the ground water is safe for irrigation purpose only.	• All the samples are well within the Permissible & desirable limit.

	Heavy Metals (mg/L)	Range (Pre-monsoon)	Range (Post-Monsoon)	Stds. BIS/WHO (µg/L)	% Sample Compliance/ violation	Observations
1	Iron as Fe	0.04-0.13	0.04-0.11	0.3-1.0	0% crosses PL during pre and post monsoon respectively.	• It is evident from the results that none of the sample fall within the PL during pre-monsoon season & post monsoon respectively • In both the rounds of monitoring high concentration of iron observed in most of the samples during pre monsoon and violating permissible limits of drinking water standards.
2	Magnesium as Mn	19-32.5	19.8-33.4	30 -100	Only 21% crosses the PL during pre and post monsoon seasons.	• It is evident from the results 21% fall more then the PL during pre and post monsoon seasons;
3	Copper as Cu	ND-.02	ND – 0.03	5 - 25	Nil	• It is evident from the all the results falls well below the permissible limits during pre and post monsoon seasons;
4	Chromium $^{+}$as Cr	ND – 0.03	ND	0.05 No relaxation	Nil	• All the samples fall well within the PL of drinking water;
5	Zinc as Zn	0.07 -0.98	0.01-0.84	5-15	Nil	• The concentration of Zn in groundwater samples is within the stipulated standards.

	Pesticides (µg/l)	Range (Pre-Monsoon)	Range (Post-Monsoon)	Stds. BIS	% Sample Compliance/ violation	Observations
Organochlorinated pesticides						
6	Aldrin	ND	ND	0.03 (WHO guideline)	All the samples are well within the WHO limit except one.-	• The concentrations of Aldrin were not detected in any of the groundwater samples.
7	∝-BHC	ND	ND	1.0 (WHO guideline)	All the samples are well within the WHO limit except one.	• The concentrations of BHEC were not detected in any of the groundwater samples.
8	Endosul-phan	ND	ND	No guideline	All the samples are well within the WHO limit except one.	• The concentrations of Endosulphan were not detected in any of the groundwater samples.
9	DDT	ND	ND	2.0 (WHO guideline)	All the samples are well within the WHO limit except one.	• The concentrations of DDT were not detected in any of the groundwater samples.

Note: The abbreviation indicated above as 'DL' = Desirable Limit; 'PL' = Permissible Limit; EEC is = European Union Standard, 'HP = Hand pump; 'TW' = Tube well

Table 5: Groundwater quality Observation and % sample violation against drinking water standards in Coimbatore Metropolitan city

	Parame-ters (All values in mg/L)	Range (Pre-monsoon)	Range (Post-Monsoon)	Stds. BIS/ WHO	% Sample Compliance/ violation	Observations
1.	pH value	7.08-7.68	7.25-7.81	6.5-8.5	None	• The pH values of all the samples are well within the limits prescribed by BIS and WHO
2.	Conducti-vity (EC) µS/cm	532-7720	510-6890	1000 µS/cm (irrigation standard)	92% samples having conductivity values above 1000 µSimens/cm during both the seasons.	• The conductivity value exceeded the stipulated standard for irrigation in almost all the locations except at Puliyakulam and Kavumdampalayam; • The maximum conductivity value of 7720 and 6890 µS/cm were observed at Irugur during pre and post-monsoon seasons respectively.
3.	Total dissolved solids	340-4941	326-4410	500-2000	33% were found above the PL and 56% were found above the DL but within the PL and 6% within the DL in both the seasons.	• The ranges in both the monitoring rounds indicate that 32% samples are above the PL for drinking water standards; • The maximum TDS values were observed at Ganapathi, Villankurichi, Singanannur, Ondipudur, Irugur, Souripalayam and Vellalur above the PL during both the seasons.
4.	Chloride (as Cl)	28-2030	25-1878	250 -1000	18% exceed the maximum PL and 28% exceeds the DL but are within the PL and 54% fall within the DL during both the seasons.	• 54% samples in both the rounds are within the DL of 250 mg/l at all locations, 28% are above the DL but are within the PL; • The maximum concentrations (1390, 1010, 2030, 1614 and 1810) of chloride during pre-monsoon were observed at Ondipudur, Irugur (two locations), Souripalayam, Puliyakulam and Vellalur respectively; • The maximum concentrations (1152, 1878, 1399 and 1694) of chloride during post-monsoon were observed at Ondipudur, Irugur, Puliyakulam and Souripalayam respectively.
5.	Alkalinity (as HCO_3)	122-671	142-586	200-600	2% samples exceeded however 90% exceeded the DL while 8% fall within the DL	• The value of alkalinity exceeded the desirable limit in 92% samples during pre and post-monsoon seasons respectively. • The high alkalinity values at few locations may be due to the action of carbonates upon the basic materials in the soil. A high of 671mg/L alkalinity was found at Velandipalayam.
6.	Sulphate (as SO_4)	25-880	21-860	200 -400	30% of samples crosses the permissible limit for drinking water and 50% fall within the desirable	• The ranges in both the rounds indicated that the Sulphate values are exceeding the DL of 200 mg/l in about 20% samples; • The maximum concentrations (800, 420, 450, 475, 880, 875, 450 and 675 mg/l) of Sulphate during pre-monsoon were observed at

	Parame-ters (All values in mg/L)	Range (Pre-monsoon)	Range (Post-Monsoon)	Stds. BIS/ WHO	% Sample Compliance/ violation	Observations
					limit and 20% exceeds the DL but are within the PL.	Ganapathi, Tewelamedu, Villankurichi, Ondipudur, Irugur (two locations), Souripalayam and Vellalur respectively. • The maximum concentrations (645, 410, 860, 760 and 610 mg/l) of Sulphate during post-monsoon were observed at Ganapathi, Villankurichi, Ondipudur, Iruvur (two locations) and Vellalur respectively.
7.	Nitrate (as NO_3)	8.8-212	4-197	45-100	28% samples crosses the PL and 38% samples crosses the DL but are within the PL and 34% Sample within DL during both the seasons.	• The ranges in both the round indicated that the values are exceeded the stipulated standard at some locations; • For both the monitoring rounds the higher level of nitrate monitored at Krishnarayapuram, Villankurichi, Sitra (Kalapatti), Ondipudur and Irugur were exceeded the maximum PL.
8.	Fluoride (as F)	0.21-1.8	0.21-1.75	1.0-1.5	4% crosses the PL during pre and post-monsoon while 72% samples are within the DL and 24% exceeds the DL but are within the PL	• The ranges in both the round indicated that the Fluoride values are exceeded the PL at few locations while 72% samples fall within the DL; • For both the monitoring rounds the higher level of Fluoride monitored at Irugur was exceeding the maximum PL.
9.	Phosphate (as PO_4)	0.04-0.09	0.02-0.06	-	None	• The concentration of Phosphate is low in both the rounds of monitoring during pre and post-monsoon seasons.
10.	Calcium (as Ca)	32-650	29-590	75-200	36% samples exceeds the PL while 44% exceeds the DL and 20 % fall within the DL	• The ranges in both the monitoring rounds indicate that calcium values in 20% samples are within the stipulated standard of Desirable limit while 44% exceeds the desirable standard; • The higher concentration of Calcium at few locations indicates that presence of high inorganic salts (Carbonates, bicarbonates, Chlorides, Sulphates, Nitrates and Phosphates of Ca, Mg, Na, & K) in groundwater.
11.	Magnesium as Mg	12-420	13-345	30-100 (BIS Standard)	22% samples exceed the PL while 64% exceeds the DL but within the PL and 14 % fall within the DL in both the seasons.	• The ranges in both the monitoring rounds indicate that magnesium values in 14% samples are within the stipulated standard of Desirable limit while 64% exceeds the desirable standard but within the Permissible Limit; • The higher concentration of Magnesium at few locations indicates that presence of high inorganic salts (Carbonates, bicarbonates, Chlorides,

	Parame-ters (All values in mg/L)	Range (Pre-monsoon)	Range (Post-Monsoon)	Stds. BIS/ WHO	% Sample Compliance/ violation	Observations
						Sulphates, Nitrates and Phosphates of Ca, Mg, Na, & K) in groundwater.
12.	Total Hardness (as $CaCO_3$)	129-3349	126-2891	300 –600	40% samples exceeds the maximum PL while 40 % exceeds the DL but well within the PL and 20% within the DL.	• The ranges in both the monitoring rounds indicate that total hardness values are exceeding the stipulated standard at all the locations; • In both the rounds of monitoring the hardness value exceeded the PL at few locations during pre and post-monsoon seasons.
13.	Sodium (as Na)	42-1074	41-1024	200 (WHO)	Sodium Content violated WHO but than at some locations	• In both the monitoring rounds the values of sodium content was exceeding the limit for irrigation standards ground water with such high sodium concentrations is not suitable for irrigation purpose due to sodium sensitivity of crops / plants.
14.	Potassium (as K)	3.8-87	3.9-78	- (10-NR)	Potassium Content violated EEC standard at some location	• The BIS has not included K in drinking water standards. However the EEC has prescribed guideline level of 10 mg/l of Potassium during pre-monsoon. The maximum concentration of Potassium was observed at several locations during both the rounds of monitoring and even indicating that water is not fit for irrigation purposes.
15.	Boron (as B)	ND	ND	1.0-5.0	None	• All the samples are not detected Boron content
16.	Faecal Coliform MPN/100ml	Nil	Nil	Should be nil	None	• All the samples found faecal Coliform Contamination
17.	Total Coliform MPN/100ml	Nil	Nil	5% samples Should not be >10 in 100ml sam.	None	All the samples are not with contaminated Faecal Coliform

	Heavy Metals (µg/L)	Range (Pre-monsoon)	Range (Post-Monsoon)	Stds. BIS/WHO	% Sample compliance/ violation	Observations
1	Iron (as Fe)	90-1260	71-980	300-1000	2% samples exceed the PL While 70% within the DL and 28% above the DL but well within the PL.	• It is evident from the results that 70% samples fall within the DL 28% during pre and post-monsoon seasons respectively; • For both the monitoring rounds the high concentration of Fe, observed at Velandipalayam during pre-monsoon season and was exceeding the maximum PL.
2	Manganese (as Mn)	9-59	7-53	100-300	None	• It is found that all the samples are well within the desirable limit for drinking purposes.
3	Copper (as Cu)	1-13	1-11	50-1500	None	• All the samples in metropolitan city of Coimbatore with respect to Cu are well within the desirable limit for drinking purposes.
4	Chromium (as Cr)	10-70	6-55	50- No relaxation	4% samples exceed the PL while 40% crosses DL & 56% within DL.	• It is revealed from the results that 96% samples fall within the PL. In both the rounds of monitoring the concentration of Cr exceeds the PL at Ganapathy (70 and 55 µg/l) and Ondipudur (70 and 54 µg/l) during pre and post-monsoon seasons respectively.
5	Zinc (as Zn)	10-2100	7-1770	5000-15000	None	• All the samples in metropolitan city of Coimbatore with respect to Zn are well within the desirable limit for drinking purposes.

	Pesticides	Range (Pre-monsoon)	Range (Post-Monsoon)	Stds. BIS	% Sample Compliance/ violation	Observations
Organo-chlorinated pesticides (All Values are in µg/L)						
1	Aldrin	NT	NT	0.03 (WHO guideline)	None	• No aldrin concentration was found in groundwater samples of Coimbatore metro city.
2	∝-BHC	NT	NT	0.01 (WHO guideline)	None	• No ∝-BHC concentration was found in groundwater samples of Coimbatore metro city.
3	β-BHC	NT	NT	0.01 (WHO guideline)	None	• No β-BHC concentration was found in groundwater samples of Coimbatore metro city.
4	γ-BHC (µg/l)	NT	NT	0.01 (WHO guideline)	None	• No γ-BHC concentration was found in groundwater samples of Coimbatore metro city.

	Pesticides	Range (Pre-monsoon)	Range (Post-Monsoon)	Stds. BIS	% Sample Compliance/ violation	Observations
5	δ-BHC	0.3-1.1	0.3-0.7	0.01(WHO guideline)	4% sample crosses the WHO limit during both seasons.	• During pre-monsoon season it is observed that δ–BHC concentration was found exceeding the WHO limit which is unfit for drinking purposes at Bharathi Nagar of Coimbatore metropolitan city.
6	Endosulphan	NT	NT	(No guideline)	None	• No endosulphan concentration was found in groundwater samples of Coimbatore metro city.
7	Methoxychlor	NT	NT	30 (WHO guideline)	None	• No Methoxychlor concentration was found in groundwater samples of Coimbatore metro city.
8	DDE	NT	NT	(No guideline)	None	• No DDE concentration was found in groundwater samples of Coimbatore metro city.
9	DDD	NT	NT	(No guideline)	None	• No DDD concentration was found in groundwater samples of Coimbatore metro city.
Organo-phosphorous pesticides (All Values are in µg/L)						
10	Methyl parathion	NT	NT	(No guideline)	None	• No methylparathion concentration was found in groundwater samples of Coimbatore metro city.
11	Ethyl parathion	NT	NT	(No guideline)	None	• No ethylparathion concentration was found in groundwater samples of Coimbatore metro city.
12	Chloropyriphos	NT	NT	(No guideline)	None	• No Chloropyriphos concentration was found in groundwater samples of Coimbatore metro city.
13	Famphur	NT	NT	(No guideline)	None	• No famphur concentration was found in groundwater samples of Coimbatore metro city.
14	Ethion	NT	NT	(No guideline)	None	• No ethion concentration was found in groundwater samples of Coimbatore metro city.
15	Thionazin	NT	NT	(No guideline)	None	• No thionazin concentration was found in groundwater samples of Coimbatore metro city.

	Pesticides	Range (Pre-monsoon)	Range (Post-Monsoon)	Stds. BIS	% Sample Compliance/ violation	Observations
16	Sulfotepp	NT	NT	(No guideline)	None	• No sulfotepp concentration was found in groundwater samples of Coimbatore metro city.
17	Phorate	NT	NT	(No guideline)	None	• No phorate concentration was found in groundwater samples of Coimbatore metro city.
18	Dimethoate	NT	NT	(No guideline)	None	• No dimethonate concentration was found in groundwater samples of Coimbatore metro city.
19	Disolphoton	NT	NT	(No guideline)	None	• No disolphoton concentration was found in groundwater samples of Coimbatore metro city.

Note: The abbreviation indicated above as 'DL' = Desirable Limit; 'PL' = Permissible Limit; 'HP = Hand pump; TW' = Tube well, NT=Not Traceable

Table 6: Groundwater quality Observation and % sample violation with respect to drinking water standards in Chennai Metropolitan city

	Parame-ters (All values are in mg/L)	Range (Pre-monsoon)	Range (Post-Monsoon)	Stds. BIS/ WHO	% Sample Compliance/violation	Observations
1.	pH value	6.3-8.2	6.1-8.1	6.5-8.5	None	• The pH values of all the samples are well within the limits prescribed by BIS and WHO.
2.	Conducti-vity (EC) µS/cm	392-24860	365-5242	1000 µS/cm (irrigation standard)	96% and 92% samples having conductivity values above 1000 µSimens/cm during pre and post-monsoon seasons respectively.	• The conductivity value exceeded the stipulated standard for irrigation in almost all the locations except at Besant Nagar and Ayanavaram; • The maximum conductivity value of 24860 and 5242 µS/cm were observed at Taramani and Erankancheri during pre and post-monsoon seasons respectively.
3.	Total dissolved solids	251-15910	234-3355	500-2000	22% crosses the PL while 74% were found above the DL but within PL during both the seasons;	• The ranges in both the monitoring rounds indicate that 76% samples are above the DL for drinking water standards; • The maximum TDS values (15910 and 3355 mg/l) were observed at Taramani and Erankancheri during pre and post-monsoon seasons respectively; • During both the rounds the TDS values (> 2000 mg/l) were observed at 11 locations.
4.	Chloride (as Cl)	16-7358	15-1022	250 -1000	6% exceeds the PL and 48% exceed the DL but are within the PL while 46% within the DL during both the seasons.	• 94% samples in both the rounds are within the PL of 250 mg/l at all locations, 48% are above the DL but are within the PL; • The maximum concentrations (7358 and 1026 mg/l) of chloride during pre-monsoon were observed at Taramani and Erankancheri respectively; • The maximum concentrations (1022 mg/l) of chloride during post-monsoon was observed at Taramani (location no.3).
5.	Alkalinity (as HCO_3)	134-1025	135-686	200-600	26% exceed the PL in both the seasons and 70% fall above the DL but within the PL. while 4% within the DL	• The value of alkalinity exceeded the desirable limit in 96% samples during both the seasons; • The high alkalinity values at few locations may be due to the action of carbonates upon the basic materials in the soil. A high value of 1025, 686 mg/l alkalinity was found at Taramani and Roypet during pre and post-monsoon seasons respectively.
6.	Sulphate (as SO_4)	25-1850	21-742	200 -400	6% of samples crosses the PL and 80% fall within the DL while 14% exceeds the	• The ranges in both the rounds indicated that the Sulphate values are exceeding the DL of 200 mg/l in about 14% samples;

	Parame-ters (All values are in mg/L)	Range (Pre-monsoon)	Range (Post-Monsoon)	Stds. BIS/ WHO	% Sample Compliance/violation	Observations
					DL but are within the PL during both the seasons.	• The maximum concentrations (1850 and 825 mg/l) of Sulphate during pre-monsoon were observed at Taramani and Irankancheri respectively. • The maximum concentration (742 mg/l) of Sulphate during post-monsoon season was observed at Irankancheri.
7.	Nitrate (as NO_3)	0.1-27	0.1-29	45-100	None	• The ranges in both the round indicated that the values are within the stipulated standard i.e. within the desirable limit of 45 mg/l.
8.	Fluoride (as F)	0.17-4.5	0.11-3.5	1.0-1.5	14% crosses the PL while 80% samples are within the DL and 6% exceed the DL but are within the PL	• The ranges in both the round indicated that the Fluoride values are exceeded the PL at few locations while 80% samples fall within the DL; • For both the monitoring rounds the higher level of Fluoride monitored at Taramani, Villivakkam and Perambur were exceeding the maximum PL.
9.	Phosphate (as PO_4)	0.06-1.38	0.02-1.12	-	None	• The concentration of Phosphate is high (>1 mg/l) at some of the locations in both the rounds of monitoring during pre and post-monsoon seasons.
10.	Calcium (as Ca)	12-229	8.4-196	75-200	4% samples crosses the PL while 52% exceeds the DL and 44 % fall within the DL	• The ranges in both the monitoring rounds indicate that calcium values in 44% samples are within the stipulated standard of Desirable limit while 52% exceeds the desirable standard but within the Permissible Limit; • The higher concentration of Calcium at few locations indicates that presence of high inorganic salts (Carbonates, bicarbonates, Chlorides, Sulphates, Nitrates and Phosphates of Ca, Mg, Na, & K) in groundwater.
11.	Magnesium (as Mg)	1.9-107	3.1-76	30 - 100 (BIS standard)	4% samples crosses the PL during pre-monsoon season while 44% exceeds the DL but are within the PL and 54 % fall within the DL during both the seasons.	• The ranges in both the monitoring rounds indicate that magnesium values in 54% samples are within the stipulated standard of Desirable limit while 44% exceeds the desirable standard but within the Permissible Limit; • The higher concentration of Magnesium (107 mg/l) found at Kurukumpeta.
12.	Total Hardness (as $CaCO_3$)	38-941	34-802	300 –600	16% samples crosses the maximum PL while 38 % exceeds the DL but well within the PL and 46% within the DL during both the seasons.	• The ranges in both the monitoring rounds indicate that total hardness values are exceeding the stipulated standard at some of the locations; • In both the rounds of monitoring the hardness value exceeded the PL at few locations during pre and post-monsoon seasons.

	Parame-ters (All values are in mg/L)	Range (Pre-monsoon)	Range (Post-Monsoon)	Stds. BIS/ WHO	% Sample Compliance/violation	Observations
13.	Sodium (as Na)	37-5500	31-900	200 (No limit by BIS and WHO for drinking purposes)	60% samples exceed the maximum PL while 40% within the DL during both the seasons.	• In both the monitoring rounds the values of sodium content was exceeding the irrigation standard for groundwater. Such high sodium concentrations is not suitable for irrigation purpose due to sodium sensitivity of crops / plants.
14.	Potassium (as K)	2.1-71	1.1-58	Not Prescribed However EEC	72% samples exceed the irrigation standard (EEC) during both the seasons.	• The BIS has not included K in drinking water standards. However the EEC has prescribed guideline level of 10 mg/l of Potassium during pre-monsoon. The maximum concentration of Potassium was observed at several locations during both the rounds of monitoring and even indicating that water is not fit for irrigation purposes.
15.	Boron (as B)	ND	ND	1.0-5.0	None	• All the samples are well within the desirable limit of drinking water.
16.	Faecal Coliform MPN/100ml	Nil	Nil	Should be nil	None	• No Contamination was found for and Faecal Coliform within the stipulated standards for drinking purposes.
17.	Total Coliform MPN/100ml	2-14	Nil	5% samples Should not be >10 in 100ml sample.	4% samples exceeded the prescribed MPN (10 per 100ml sample).	• All the samples found Total Coliform are well within the stipulated standards except one location (Valacheri) for drinking purposes during pre-monsoon season.

	Heavy Metals (µg/L)	Range (Pre-monsoon)	Range (Post-Monsoon)	Stds. BIS/WHO	% Sample violation	Observations
1	Iron (as Fe)	19-16428	13-15556	300-1000	During both the seasons, 32% and 46 % samples exceeded the PL and DL respectively.	• It is evident from the results that 32% and 46% samples exceeded the PL & DL during pre and post-monsoon seasons respectively; • During pre-monsoon season, a high concentration (7605, 9648, & 16428 µg/l) of Fe was observed at Vadapalani, Washermanpet, & K.K. Nagar respectively; while during post- monsoon a high concentration (7200, 9446, & 15556 µg/l) of Fe was observed at Vadapalani, Washermanpet, & K.K. Nagar respectively and was exceeding the maximum PL.

	Heavy Metals (µg/L)	Range (Pre-monsoon)	Range (Post-Monsoon)	Stds. BIS/WHO	% Sample violation	Observations
2	Manganese (as Mn)	4-1414	5-1237	100-300	42% samples crosses the PL during pre and post monsoon seasons, while 6% above the DL but within the PL and 52% within the DL in both seasons	• It is found that 52% samples fall within the DL while 6% samples between the DL and Pl whereas 42 % samples shown very high concentrations of Mn and exceeding the permissible limit for drinking purposes; • The maximum concentrations (1414, 1164, and 1075 µg/l) of Manganese during pre-monsoon were observed at Vadapalani, K.K. Nagar and Kurukumpeta respectively; • The maximum concentrations (1237, 1123, & 956 µg/l) of Manganese were observed on the same locations during post-monsoon season.
3	Copper (as Cu)	2-111	3-97	50-1500	None, However 4% above the DL &96% within the DL	• All the samples in metropolitan city of Chennai with respect to Cu are well within the Permissible limit for drinking purposes only 4% exceeds Desirable limit
4	Chromium (as Cr)	2-27	3-21	50- No relaxation	None	• All the samples in metropolitan city of Chennai with respect to Cr are well within the desirable limit for drinking purposes. • It is obvious from the results that the groundwater of the Chennai metropolitan city does not pose any hazards to humans as the level observed was below detection limit.
5	Zinc (as Zn)	2-7020	5-6999	5000-15000	None	• All the samples in metropolitan city of Chennai with respect to Zn are well within the desirable limit for drinking purposes.

	Pesticides	Range (Pre-monsoon)	Range (Post-Monsoon)	Stds. BIS	% Sample Compliance/violation	Observations
Organo-chlorinated pesticides (All values are in µg/L)						
6	Aldrin	6.67-13.33	4.76-11.34	0.03 (WHO guideline)	20% sample exceeds the WHO limit	• The concentration of Aldrin was found in both the seasons of groundwater samples (20% samples) and exceeding the WHO limit for drinking purposes in Chennai metro city. These locations are Tiruvanniyar (6.67µg/l), Sembiyam (10.5µg/l), Erankancheri (13.33µg/l), Stanley Nagar (12.0µg/l), Kurukumpeta (10.1µg/l) during pre monsoon and Tiruvanniyar (4.76µg/l), Sembiyam (7.67µg/l), Erankancheri (11.34µg/l), Stanley Nagar (9.87µg/l), and Kurukumpeta (8.98µg/l) during post monsoon season.

	Pesticides	Range (Pre-monsoon)	Range (Post-Monsoon)	Stds. BIS	% Sample Compliance/violation	Observations
7	∝-BHC	NT-9.38	NT-7.56	0.01 (WHO guideline)	4% samples exceeding the WHO guideline in both the seasons	• The concentration of ∝-BHC (9.38 & 7.56 µg/l) was found only at Triplicane location during pre and post monsoon season respectively in groundwater samples of Chennai metro city.
8	β-BHC	NT	NT	0.01 (WHO guideline)	None	• No β-BHC concentration was found in groundwater samples of Chennai metro city.
9	γ-BHC	NT	NT	0.01 (WHO guideline)	None	• No γ-BHC concentration was found in groundwater samples of Chennai metro city.
10.	δ-BHC	10.1-31.0	7.76-25.45	0.01(WHO guideline)	8% sample crosses the WHO limit during pre-& post monsoon seasons.	• During pre-monsoon season it is observed that δ–BHC concentration (10.1 & 31.0µg/l) was found exceeding the WHO limit which is unfit for drinking purposes at Tiruvanniyur and Perumbur respectively, while post monsoon season also indicated the concentration of δ–BHC of 7.76 & 25.45 µg/l respectively on the same locations of chennai Metropolitan city.
11.	Endosul-phan	2.5-20.76	NT-17.67	(No guideline)	8% Samples were detected Endosulphen	• The concentration (25.76, 2.5 & 2.5 µg/l such as Besant Nagar, Kurukumpeta, and Tondiyarpet respectively) of Endosulphan was observed at three locations during pre monsoon season & 17.67µg/l at Besant Nagar (one location) during post monsoon seasons in groundwater samples of Chennai metro city.
12.	Methoxy-chlor	NT	NT	30 (WHO guideline)	None	• No Methoxychlor concentration was found in groundwater samples of Chennai metro city.
13.	DDE	NT	NT	(No guideline)	None	• No DDE concentration was found in groundwater samples of Chennai metro city.
14.	DDD (µg/l)	NT-12	NT-12	(No guideline)	4% samples found the traces of DDD	• The DDD concentration (12.0 µg/l) was found in both the seasons at only one location named Park Town Area in groundwater samples of Chennai metro city.
Organo-phosphorous pesticides (All values are in µg/l)						
15.	Methyl parathion	NT	NT	(No guideline)	None	• No methylparathion concentration was found in groundwater samples of Chennai metro city.

	Pesticides	Range (Pre-monsoon)	Range (Post-Monsoon)	Stds. BIS	% Sample Compliance/violation	Observations
16.	Ethyl parathion	NT	NT	(No guideline)	None	• No ethylparathion concentration was found in groundwater samples of Chennai metro city.
17.	Chloropy-riphos	NT	NT	(No guideline)	None	• No Chloropyriphos concentration was found in groundwater samples of Chennai metro city.
18.	Famphur	NT	NT	(No guideline)	None	• No famphur concentration was found in groundwater samples of Chennai metro city.
19.	Ethion	NT	NT	(No guideline)	None	• No ethion concentration was found in groundwater samples of Chennai metro city.
20.	Thionazin	NT	NT	(No guideline)	None	• No thionazin concentration was found in groundwater samples of Chennai metro city.
21.	Sulfotepp	NT	NT	(No guideline)	None	• No sulfotepp concentration was found in groundwater samples of Chennai metro city.
22.	Phorate	NT	NT	(No guideline)	None	• No phorate concentration was found in groundwater samples of Chennai metro city.
23.	Dimethoanate	NT	NT	(No guideline)	None	• No dimethonate concentration was found in groundwater samples of Chennai metro city.
24.	Disolphoton	NT	NT	(No guideline)	None	• No disolphoton concentration was found in groundwater samples of Chennai metro city.

Note: The abbreviation indicated above as 'DL' = Desirable Limit; 'PL' = Permissible Limit; 'HP = Hand pump; TW' = Tube well, NT=Not Traceable

Table 7 : Groundwater quality Observation and % sample compliance/ violation with respect to drinking water standards in Madurai Metropolitan city

	Parame-ters (All values in mg/L)	Range (Pre-monsoon)	Range (Post-Monsoon)	Stds. BIS/ WHO	% Sample Compliance/ violation	Observations
1	pH value	7.0-7.8	7.3-7.8	6.5-8.5	No Guideline in BIS/WHO, However	• The pH values of all the samples well within the stipulated standards
2	Conducti-vity (EC) µS/cm	1170-8880	1040-7670	1000 µS/cm (irrigation standard)	100% samples having conductivity values above 1000 µSimens/cm during seasons	• The conductivity value exceeded the stipulated standard for irrigation in all the locations during pre and post monsoon seasons; • The maximum conductivity value of 8880 and 4030 µS/cm were observed at Aveniyapuram and K. K. Nagar during pre monsoon and 7670 and 3600 at Aveniyapuram and Anuppanadi during post monsoon season respectively.
3	Total dissolved solids (TDS)	749-5683	666-4909	500-2000	10% samples were found above the PL during both the seasons; while 90% values were found above the DL but within the PL during both the seasons.	• The ranges in both the monitoring rounds indicate that 10% samples are above the PL for drinking water standards; • The maximum TDS values (5683 and 2579 mg/l) were observed at Aveniyapuram and K. K. Nagar during pre monsoon and also High values of TDS (4909 and 2304 mg/l) were observed at Aveniyapuram and Anuppanadi during post monsoon respectively; • During both the rounds the TDS values (> 2000 mg/l) were observed at 05 locations.
4	Chloride (as Cl)	86-2220	71-1984	250 -1000	4% exceeds the PL and 22% exceed the DL but are within the PL while 74% within the DL during both the seasons.	• 74% samples in both the rounds are within the DL of 250 mg/l at all locations, and 22% are above the DL but are within the PL while 4% above the PL; • The maximum concentrations (Pre monsoon 2220 and 756 mg/l) and (Post monsoon 1984 and 626 mg/l) of chloride were observed at Aveniyapuram and K. K. Nagar respectively during both the seasons.
5	Alkalinity (as HCO_3)	342-1025	301-946	200-600	50% exceeded the PL in both the seasons and 50% fall above the DL but within the PL. while none of the samples found within the DL during both the seasons.	• The value of alkalinity exceeded the desirable limit in 100% samples during both the seasons; • The high alkalinity values at few locations may be due to the action of carbonates upon the basic materials in the soil. A high value of 1025 and 1000 mg/l alkalinity was found at Chokkalinga and Anuppanadi during pre-monsoon and 946 and 921 was found at Anuppanadi and Chokkalinga during post-monsoon seasons respectively.
6	Sulphate (as SO_4)	14-775	11-621	200 –400	4% of samples cross the permissible limit for drinking	• The ranges in both the rounds indicated that the Sulphate values are

	Parame-ters (All values in mg/L)	Range (Pre-monsoon)	Range (Post-Monsoon)	Stds. BIS/ WHO	% Sample Compliance/ violation	Observations
					water and 94% fall within the desirable limit whereas 2% exceeds the DL but are within the PL during both the seasons.	exceeding the PL of 400 mg/l in 4% samples while 94% fall within the DL of 200 mg/l and in about 2% samples within the DL and PL; • The maximum concentrations (775mg/l) of Sulphate during pre-monsoon was observed at Aveniyapuram location while maximum concentration (621 mg/l) of Sulphate during post-monsoon season was also observed at same location.
7	Nitrate (as NO_3)	0.1-31	2.1-38	45-100	None	• The ranges in both the round indicated that the values are within the stipulated standard i.e. within the desirable limit of 45 mg/l.
8	Fluoride (as F)	0.29-3.7	0.31-3.12	1.0-1.5	8% crosses the PL during pre and post-monsoon while 62% samples are within the DL and 30% exceeds the DL but are within the PL	• The ranges in both the round indicated that the Fluoride values are exceeded the PL at few locations i.e. 8% while 62% samples fall within the DL and 30% exceeds the DL but are within the PL; • For both the monitoring rounds the higher level of Fluoride monitored at TVS Nagar and Alwarpuram were exceeding the maximum PL i.e. 3.7 and 2.6 mg/l respectively in pre monsoon and 3.12 and 2.32 in post monsoon respectively.
9	Phosphate (as PO_4)	0.04-0.89	0.04-0.55	-	None	• The concentration of Phosphate was >1 mg/l at all the locations in both the rounds of monitoring during pre and post-monsoon seasons.
10	Calcium (as Ca)	32-274	27-214	75-200	4% samples exceeds the PL while 70% exceeds the DL and 26% fall within the DL	• The ranges in both the monitoring rounds indicate that calcium values in 26% samples are within the stipulated standard of Desirable limit while 70% exceeds the desirable standard but within the Permissible Limit while 4% exceeds the PL; • The higher concentration of Calcium at few locations indicates that presence of high inorganic salts (Carbonates, bicarbonates, Chlorides, Sulphates, Nitrates and Phosphates of Ca, Mg, Na, & K) in groundwater.
11	Magnesium (as Mg)	15-267	17-187	30 - 100 (BIS standard)	12% samples exceeds the PL during both the season while 72% exceeds the DL but are within the PL and 16 % fall within the DL during both the seasons.	• The ranges in both the monitoring rounds indicate that magnesium values in 16% samples are within the stipulated standard of Desirable limit while 72% exceeds the desirable standard but within the Permissible Limit; • 12% exceeds the permissible limit in both the rounds. The higher concentration of Magnesium (267 and 146 mg/l) was found at Aveniyapuram and Anuppanadi in pre monsoon respectively while 187 and 127 mg/l was found respectively during post monsoon.

	Parame-ters (All values in mg/L)	Range (Pre-monsoon)	Range (Post-Monsoon)	Stds. BIS/ WHO	% Sample Compliance/ violation	Observations
12	Total Hardness (as $CaCO_3$)	235-1782	177-1303	300 –600	32% samples exceeds the maximum PL while 56 % exceeds the DL but well within the PL and 12% within the DL during both the seasons.	• The ranges in both the monitoring rounds indicate that total hardness values (56% samples) are above the stipulated standard of desirable limit at some of the locations while values exceeding (32% samples > permissible limit) exceeded the PL at few locations during pre and post-monsoon seasons; • The max. Concentration of hardness value was found at Aveniyapuram (1782 & 1303 mg/l) during pre and post monsoon respectively.
13	Sodium (as Na)	93-1244	81-1065	200 (No limit by BIS and WHO for drinking purposes)	26% samples exceed the maximum Limit of 200 mg/l during both the seasons.	• In both the monitoring rounds the values of sodium content was exceeding the irrigation standard for groundwater. Such high sodium concentrations is not suitable for irrigation purpose due to sodium sensitivity of crops / plants; • The max. Concentration of Sodium (1244 & 1065 mg/l) was found at Aveniyapuram during pre and post monsoons respectively.
14	Potassium (as K)	2.1-95	2.1-65	- (No limit by BIS and WHO for drinking purposes)	26% samples exceed the irrigation standard (EEC) during both the seasons.	• The BIS has not included K in drinking water standards. However the EEC has prescribed guideline level of 10 mg/l of Potassium during pre-monsoon. The maximum concentration of Potassium was observed at several locations during both the rounds of monitoring and even indicating that water is not fit for irrigation purposes.
15	Boron (as B)	ND	ND	1.0-5.0	None	• All the samples are well within the stipulated standard of drinking water.
16	Faecal Coliform MPN/100 ml	Nil	Nil	Should be nil	None	• All the samples are well within the stipulated standards for drinking purposes.
17	Total Coliform MPN/100 ml	Nil	Nil	5% samples Should not be >10 in 100ml	None	• All the samples are well within the stipulated standards for drinking purposes

	Heavy Metals (µg/L)	Range (Pre-monsoon)	Range (Post-Monsoon)	Stds. BIS/WHO	% Sample Compliance/ violation	Observations
1	Iron (as Fe)	39-1059	37-964	300-1000	4% sample crosses the PL and 32% fall between the DL and PL in both the seasons while 64% within the DL	• It is evident from the results that 32% samples exceeded the DL but within the PL while 64% are within the DL and 4% exceeded the PL only in Pre monsoon; • During pre-monsoon season, a high concentration (1059 & 1056 µg/l) of Fe was observed at East Madurai and Alwarpuram respectively; while during post- monsoon a high concentration (964 & 961µg/l) of Fe was observed on the same locations.
2	Manganese (as Mn)	3-917	2-844	100-300	16% samples exceed the PL during pre and post monsoon seasons, while 34% above the DL but within the PL and 50% within the DL in both seasons	• It is found that 50% samples fall within the DL while 34% samples between the DL and PL whereas 16% samples shown very high concentrations of Mn and exceeding the permissible limit for drinking purposes; • The maximum concentrations (917, 599 and 593 µg/l) of Manganese during pre-monsoon were observed at Madakulam, East Madurai and Alwarpuram respectively; • The maximum concentrations (844, 504 & 498 µg/l) of Manganese were observed on the same locations during post-monsoon season.
3	Copper (as Cu)	3-41	2-33	50-1500	None	• All the samples in metropolitan city of Madurai with respect to Cu are well within the desirable limit for drinking purposes.
4	Chromium (as Cr)	2-20	2-18	50- No relaxation	None	• All the samples in metropolitan city of Madurai with respect to Cr are well within the desirable limit for drinking purposes.
5	Zinc (as Zn)	11-1840	8-1823	5000-15000	None	• All the samples in metropolitan city of Madurai with respect to Zn are well within the desirable limit for drinking purposes.

	Pesticides (µg/L)	Range (Pre-monsoon)	Range (Post-Monsoon)	Stds. BIS/WHO	% Sample violation	Observations
Organo-chlorinated pesticides						
6	Aldrin	NT-2.1	NT-1.71	0.03 (WHO guideline)	4% sample exceeds the WHO limit	• The concentration of Aldrin was found in both the seasons of groundwater samples (4% samples) and exceeding the WHO limit for drinking purposes in Madurai metropolitan city. The location is Muthupatti of Metro city.
7	∝-BHC	NT-0.5	NT-0.3	0.01 (WHO guideline)	8% Samples exeeds the WHO limit	• The concentration of ∝-BHC (0.5 & 0.5 µg/l) was found only at two locations during pre monsoon season and (0.3 and 0.25 µg/l) during post monsoon respectively in groundwater samples of Madurai metropolitan city.
8	β-BHC	NT-1.6	NT-1.42	0.01 (WHO guideline)	4% sample exceeds the WHO limit	• The concentration of β-BHC was found only at Muthupatti location in groundwater samples of Madurai metropolitan city.
9	γ-BHC	NT-2.1	NT-1.62	0.01 (WHO guideline)	8% sample exceeds the WHO limit	• The γ-BHC concentration was found in groundwater samples of Madurai metro city.
10	δ-BHC	NT-2.5	NT-2.16	0.01(WHO guideline)	8% sample crosses the WHO limit during pre-& post monsoon seasons.	• During pre-monsoon season it is observed that δ–BHC concentration (2.1 & 1.5µg/l) was found exceeding the WHO limit and is unfit for drinking purposes at Andalpuram and Muthupatti respectively, while post monsoon season also indicated the concentration of δ–BHC of 1.67 & 1.32 µg/l respectively on the same locations of Madurai Metropolitan city.
11	Endosul-phan	NT	NT	(No guideline)	-	• No Endosulphan concentration was found in groundwater samples of Madurai metro city. •
12	Methoxy-chlor	NT	NT	30 (WHO guideline)	None	• No Methoxychlor concentration was found in groundwater samples of Madurai metro city.
13	DDE	NT	NT	(No guideline)	None	• No DDE concentration was found in groundwater samples of Madurai metro city.
14	DDD	NT	NT	(No guideline)	None	• No DDD concentration was found in groundwater samples of Madurai metro city.
Organo-phosphorous pesticides (All values in µg/l)						
15	Methyl parathion	NT	NT	(No guideline)	None	• No methylparathion concentration was found in groundwater samples of Madurai metro city.
16	Ethyl parathion	NT	NT	(No guideline)	None	• No ethylparathion concentration was found in groundwater samples of Madurai metro city.

	Pesticides (µg/L)	Range (Pre-monsoon)	Range (Post-Monsoon)	Stds. BIS/WHO	% Sample violation	Observations
17	Chloropy-riphos	NT	NT	(No guideline)	None	• No Chloropyriphos concentration was found in groundwater samples of Madurai metro city.
18	Famphur	NT	NT	(No guideline)	None	• No famphur concentration was found in groundwater samples of Madurai metro city.
19	Ethion	NT	NT	(No guideline)	None	• No ethion concentration was found in groundwater samples of Madurai metro city.
20	Thionazin	NT	NT	(No guideline)	None	• No thionazin concentration was found in groundwater samples of Madurai metro city.
21	Sulfotepp	NT	NT	(No guideline)	None	• No sulfotepp concentration was found in groundwater samples of Madurai metro city.
22	Phorate	NT	NT	(No guideline)	None	• No phorate concentration was found in groundwater samples of Madurai metro city.
23	Dimethoan ate	NT	NT	(No guideline)	None	• No dimethonate concentration was found in groundwater samples of Madurai metro city.
24	Disolphoto n	NT	NT	(No guideline)	None	• No disolphoton concentration was found in groundwater samples of Madurai metro city.

Note: The abbreviation indicated above as 'DL' = Desirable Limit; 'PL' = Permissible Limit; EEC is = European Union Standard, 'HP = Hand pump; 'TW' = Tube well, NT=Not Traceable

Table 8 : Groundwater quality Observation and % sample violation with respect to drinking water standards in Vijaiwada Metropolitan city

Sl. No.	Parameters (All values are in mg/L)	Range (Pre-monsoon)	Range (Post-Monsoon)	Stds. BIS/ WHO	% Sample Compliance/ violation	Observations
1	pH value	6.50-7.1	6.7-7.20	6.5-8.5	None	• The pH values of all the samples well within the limits of BIS/WHO
2	Conductivity (EC) µS/cm	570-6810	523-5750	1000 µS/cm (irrigation standard)	62% samples having conductivity values above 1000 µS/cm and 38% within 1000 µS/cm during pre and post-monsoon seasons respectively.	• The conductivity value exceeded the stipulated standard for irrigation in 31 sampling locations (68%) during pre and post monsoon seasons; • The maximum conductivity value of 6810 and 4220 µS/cm were observed during pre monsoon and 5750 and 3980 during post monsoon season respectively at Payakapuram and Kotha peta.
3	Total dissolved solids (TDS)	365-4358	335-3680	500-2000	18% samples above the PL and 60% above the DL but within the PL while 22% below the DL during both the seasons.	• The ranges in both the monitoring rounds indicate that 18% samples are above the PL and 60% above the DL but within the PL for drinking water standards; • The maximum TDS values 4358 and 2701 mg/l) were observed during pre monsoon and 3608 and 2547 mg/l were observed during post monsoon respectively at Payakapuram and Kotha Peta locations; • During both the rounds the TDS values (> 2000 mg/l) were observed at 09 locations.
4	Chloride (as Cl)	45-1740	37-1477	250 -1000	4% exceeds the PL and 20% exceeds the DL but are within the PL while 76% within the DL during both the seasons.	• 76% samples in both the rounds are within the DL of 250 mg/l and 20% are above the DL but are within the PL while 4% above the PL; • The maximum concentrations (Pre monsoon 1740 and 950 mg/l and Post monsoon 1477 and 888 mg/l) of chloride were observed at Payakulam and Kotha Peta respectively during both the seasons.
5	Alkalinity (as HCO_3)	146-842	134-798	200-600	12% exceeded the PL in both the seasons and 78% fall above the DL but within the PL, while 10% samples found within the DL during both the seasons.	• The value of alkalinity exceeded the desirable limit in 78% samples during both the seasons and 12% exceeded in permissible limit; • The high alkalinity values at few locations may be due to the action of carbonates upon the basic materials in the soil. A high value of 842 and 761 mg/l alkalinity was found at Khotha Peta and Bhavanipuram during pre-monsoon and 798 and 675 was found on the same locations during post-monsoon seasons respectively.
6	Sulphate (as SO_4)	7.5-395	5.8-323	200 –400	4% of sample crosses the permissible limit for	• The ranges in both the rounds indicated that the Sulphate values are exceeding the PL of 400 mg/l in 4% samples while 94% fall within the

Sl. No.	Parame-ters (All values are in mg/L)	Range (Pre-monsoon)	Range (Post-Monsoon)	Stds. BIS/ WHO	% Sample Compliance/ violation	Observations
					drinking water and 94% fall within the desirable limit whereas 2% exceeds the DL but are within the PL during both the seasons.	DL of 200 mg/l and in about 2% samples within the DL and PL; • The maximum concentrations (775mg/l) of Sulphate during pre-monsoon was observed at Aveniyapuram location while maximum concentration (621 mg/l) of Sulphate during post-monsoon season was also observed at same location.
7	Nitrate (as NO_3) mg/l	0.1-18	0.1-16	45-100	None	• The ranges in both the round indicated that the values are within the stipulated standard i.e. within the desirable limit of 45 mg/l.
8	Fluoride (as F) mg/l.	0.01-5.9	0.01-4.35	1.0-1.5	8% crosses the PL during pre and post-monsoon while 62% samples are within the DL and 30% exceeds the DL but are within the PL	• The ranges in both the round indicated that the Fluoride values are exceeded the PL at few locations i.e. 8% while 62% samples fall within the DL and 30% exceeds the DL but are within the PL; • For both the monitoring rounds the higher level of Fluoride monitored at TVS Nagar and Alwarpuram were exceeding the maximum PL i.e. 3.7 and 2.6 mg/l respectively in pre monsoon and 3.12 and 2.32 in post monsoon respectively.
9	Phosph-ate (as PO_4) mg/l	0.01-0.57	0.01-0.41	-	None	• The concentration of Phosphate was >1 mg/l at all the locations in both the rounds of monitoring during pre and post-monsoon seasons.
10	Calcium (as Ca) mg/l	25-290	21-281	75-200	4% samples exceeds the PL while 70% exceeds the DL and 26% fall within the DL	• The ranges in both the monitoring rounds indicate that calcium values in 26% samples are within the stipulated standard of Desirable limit while 70% exceeds the desirable standard but within the Permissible Limit while 4% exceeds the PL; • The higher concentration of Calcium at few locations indicates that presence of high inorganic salts (Carbonates, bicarbonates, Chlorides, Sulphates, Nitrates and Phosphates of Ca, Mg, Na, & K) in groundwater.
11	Magne-sium (as Mg) mg/l	13-70	13-65	30 - 100 (BIS standard)	12% samples exceeds the PL during both the season while 72% exceeds the DL but are within the PL and 16 % fall within the DL during both the seasons.	• The ranges in both the monitoring rounds indicate that magnesium values in 16% samples are within the stipulated standard of Desirable limit while 72% exceeds the desirable standard but within the Permissible Limit; • 12% exceeds the permissible limit in both the rounds. The higher concentration of Magnesium (267 and 146 mg/l) was found at Aveniyapuram and Anuppanadi in pre monsoon respectively while 187

Sl. No.	Parame-ters (All values are in mg/L)	Range (Pre-monsoon)	Range (Post-Monsoon)	Stds. BIS/ WHO	% Sample Compliance/ violation	Observations
						and 127 mg/l was found respectively during post monsoon.
12	Total Hardness (as $CaCO_3$) mg/l	132-1011	126-968	300 –600	32% samples exceeds the maximum PL while 56 % exceeds the DL but well within the PL and 12% within the DL during both the seasons.	• The ranges in both the monitoring rounds indicate that total hardness values (56% samples) are above the stipulated standard of desirable limit at some of the locations while values exceeding (32% samples > permissible limit) exceeded the PL at few locations during pre and post-monsoon seasons; • The max. Concentration of hardness value was found at Aveniyapuram (1782 & 1303 mg/l) during pre and post monsoon respectively.
13	Sodium (as Na)	46-1410	41-1210	200 (WHO limit)	26% samples exceed the maximum Limit of 200 mg/l during both the seasons.	• In both the monitoring rounds the values of sodium content was exceeding the standard for groundwater. Such high sodium concentrations is not suitable for irrigation purpose due to sodium sensitivity of crops / plants; • The max. Concentration of Sodium (1410 & 1210 mg/l) was found at Payakapuram during pre and post monsoons respectively.
14	Potassium (as K) mg/l	2.0-52	1.8-38	- (No limit by BIS and WHO for drinking purposes)	26% samples exceed the irrigation standard (EEC) during both the seasons.	• The BIS has not included K in drinking water standards. However the EEC has prescribed guideline level of 10 mg/l of Potassium during pre-monsoon. The maximum concentration of Potassium was observed at several locations during both the rounds of monitoring and even indicating that water is not fit for irrigation purposes.
15	Boron (as B) mg/l	NT	NT	1.0-5.0	None	• All the samples are well within the stipulated standard of drinking water.
16	Faecal Coliform MPN/100ml	Nil	Nil	Should be nil	None	• All the samples are well within the stipulated standards for drinking purposes.
17	Total Coliform MPN/100ml	Nil	Nil	5% samples Should not be >10 in 100ml sample.	None	• All the samples are well within the stipulated standards for drinking purposes

	Heavy Metals (µg/l)	Range (Pre-monsoon)	Range (Post-Monsoon)	Stds. BIS/WHO	% Sample violation	Observations
1	Iron (as Fe)	30-4045	28-3855	300-1000	During pre monsoon season 4% sample exceeds the PL and 32% fall between the DL and PL in both the seasons while 64% within the DL	• It is evident from the results that 32% samples exceeded the DL but within the PL during pre and post-monsoon seasons respectively while 64% are within the DL and 4% exceeded the PL only in Pre monsoon; • During pre-monsoon season, a high concentration (1059 & 1056 µg/l) of Fe was observed at East Madurai and Alwarpuram respectively; while during post- monsoon a high concentration (964 & 961µg/l) of Fe was observed on the same locations.
2	Manganese (asMn)	9-1642	11-1558	100-300	12% samples exceed the PL during pre and post monsoon seasons, while 40% above the DL but within the PL and 48% within the DL in both seasons	• It is found that 48% samples fall within the DL while 48% samples between the DL and PL whereas 12% samples shown very high concentrations of Mn and exceeding the permissible limit for drinking purposes; • The maximum concentrations (917, 599 and 593 µg/l) of Manganese during pre-monsoon were observed at Madakulam, East Madurai and Alwarpuram respectively; • The maximum concentrations (844, 504 & 498 µg/l) of Manganese were observed on the same locations during post-monsoon season.
3	Copper (as Cu)	3-28	4-25	50-1500	None	• All the samples in metropolitan city of Vijaywada with respect to Cu are well within the desirable limit for drinking purposes.
4	Chromium (as Cr)	2-10	3-8	50- No relaxation	None	• All the samples in metropolitan city of Vijaywada with respect to Cr are well within the desirable limit for drinking purposes.
5	Zinc (as Zn)	10-1900	8-1865	5000-15000	None	• All the samples in metropolitan city of Vijaywada with respect to Zn are well within the desirable limit for drinking purposes.

	Pesticides (µg/l)	Range (Pre-monsoon)	Range (Post-Monsoon)	Stds. BIS/WHO	% Sample violation	Observations
Organo-chlorinated pesticides						
6	Aldrin	NT-14	NT-11.4	0.03 (WHO guideline)	4% sample exceeds the WHO limit	• The concentration of Aldrin was found in both the seasons of groundwater samples (4% samples) and exceeding the WHO limit for

	Pesticides (µg/l)	Range (Pre-monsoon)	Range (Post-Monsoon)	Stds. BIS/WHO	% Sample violation	Observations
						drinking purposes in Vijaywada metropolitan city. The location is Muthupatti of Metro city.
7	∝-BHC	NT-15	NT-13.2	1 (WHO guideline)	8% sample crosses the WHO limit during pre-& post monsoon seasons.	• The concentration of ∝-BHC (0.5 & 0.5 µg/l) was found only at two locations during pre monsoon season and (0.3 and 0.25 µg/l) during post monsoon respectively in groundwater samples of Vijaywada metropolitan city.
8	β-BHC	NT-6.3	NT-5.6	1 (WHO guideline)	4% sample exceeds the WHO limit	• The concentration of β-BHC was found only at Muthupatti location in groundwater samples of Vijaywada metropolitan city.
9	γ-BHC	NT-13.9	NT-11.5	1 (WHO guideline)	8% sample exceeds the WHO limit	• No γ-BHC concentration was found in groundwater samples of Vijaywada metro city.
10	δ-BHC	NT	NT	1(WHO guideline)	8% sample crosses the WHO limit during pre-& post monsoon seasons.	• During pre-monsoon season it is observed that δ–BHC concentration (2.1 & 1.5µg/l) was found exceeding the WHO limit and is unfit for drinking purposes at Andalpuram and Muthupatti respectively, while post monsoon season also indicated the concentration of δ–BHC of 1.67 & 1.32 µg/l respectively on the same locations of Vijaywada Metropolitan city.
11	Endosul-phan	NT-9.9	NT-12.2	(No guideline)	-	• No Endosulphan concentration was found in groundwater samples of Vijaywada metro city.
12	Methoxy-chlor	NT-10.0	NT-7.8	30 (WHO guideline)	-	• No Methoxychlor concentration was found in groundwater samples of Vijaywada metro city.
13	DDE	2-10.4	1.3-8.7	(No guideline)	-	• No DDE concentration was found in groundwater samples of Vijaywada metro city.
14	DDD	5.0-13.0	4.6-11.4	(No guideline)	-	• No DDD concentration was found in groundwater samples of Vijaywada metro city.
Organo-phosphorous pesticides						
15	Methyl parathion	NT	NT	(No guideline)	-	• No methylparathion concentration was found in groundwater samples of Vijaywada metro city.
16	Ethyl parathion	NT	NT	(No guideline)	-	• No ethylparathion concentration was found in groundwater samples of Vijaywada metro city.
17	Chloropy-riphos	NT	NT	(No guideline)	-	• No Chloropyriphos concentration was found in groundwater samples of Vijaywada metro city.
18	Famphur	NT	NT	(No	None	• No famphur concentration was found in groundwater samples of

	Pesticides (µg/l)	Range (Pre-monsoon)	Range (Post-Monsoon)	Stds. BIS/WHO	% Sample violation	Observations
				guideline)		Vijaywada metro city.
19	Ethion	NT	NT	(No guideline)	None	• No ethion concentration was found in groundwater samples of Vijaywada metro city.
20	Thionazin	NT	NT	(No guideline)	None	• No thionazin concentration was found in groundwater samples of Vijaywada metro city.
21	Sulfotepp	NT	NT	(No guideline)	None	• No sulfotepp concentration was found in groundwater samples of Vijaywada metro city.
22	Phorate	NT	NT	(No guideline)	None	• No phorate concentration was found in groundwater samples of Vijaywada metro city.
23	Dimethoanate	NT	NT	(No guideline)	None	• No dimethonate concentration was found in groundwater samples of Vijaywada metro city.
24	Disolphoton	NT	NT	(No guideline)	None	• No disolphoton concentration was found in groundwater samples of Vijaywada metro city.

Note: The abbreviation indicated above as 'DL' = Desirable Limit; 'PL' = Permissible Limit; EEC is = European Union Standard, 'HP = Hand pump; 'TW' = Tube well, NT=Not Traceable

Continued

ANNEXURE II

ANNEXURE II: Groundwater Quality Observation and Comments on samples collected in Problem Areas of India

Table 1: Characteristics and Observations/comments on Groundwater Quality in Durgapur Problem Areas

Sl. No.	Parameters (All values one in mg/L except pH)	Range (1994)	Range (2001-02)	Stds. BIS	Observations
1.	pH value	5.3 - 8.3	5.3 - 6.9	6.5-8.5	• pH values have decreased compared to the first round done in 1994; • pH values of <5.5 have been observed at some stations; • low pH values ranged between 5.3 to 6.06 at Ganatantra Colony which is a dugwell in 2001-2002.
2.	Total Hardness (as $CaCO_3$)	66 – 0490	47 - 675	300	• Ranges in both the monitoring rounds indicate that total hardness values are being exceeded w.r..t the stipulated standard at some location(s); • w.r.t. the 2001-2002 round the post monsoon values ranged between 508-712 mg/l which is far higher than the stipulated standard; • For both the monitoring rounds the tube well monitored at Mayabazar and Ashishnagar exceeded 300mg/l.
3.	Chloride	17 – 198	29 –135	250	• The values at all locations for both the rounds were within the stipulated standards; • the well at Sagabhanga & Ganatantra colony reported values<40 mg/l for both the rounds; • at Mayabazar and Ashishnagar (both tubewells) reported higher values which ranged between 60-111 mg/l.
4.	Total dissolved solids	138 – 861	172 -800	500	• The ranges in both the monitoring rounds indicate that total dissolved values are being exceeded w.r..t the stipulated standard at some location(s); • For both the monitoring rounds the tube well monitored at Mayabazar and Ashishnagar exceeded 500mg/l.
5.	Calcium (as Ca)	-	12 - 196	75	• The ranges in both the monitoring rounds indicate that calcium values are being exceeded w.r..t the stipulated standard at some location(s); • 2001-2002 round the post monsoon values ranged between 148-196 mg/l which is far higher than the stipulated standard; • For both the monitoring rounds the tube well monitored at Mayabazar and Ashishnagar exceeded 75 mg/l.
6.	Sulphate (as So4)	1.6 - 335	1.7 – 77	150	• 2001-2002 round the post monsoon values ranged between 508-712 mg/l which is far higher than the stipulated standard;
7.	Nitrate (as No3 –N)	1.84 - 14	6.74 - 74.16	45	• In both the rounds values are within the stipulated standards, however both the monitoring rounds the tube well monitored at Mayabazar and Ashishnagar reported higher values compared to the other three stations.
8.	Fluoride (aS F)	0.1 - 1.2	0.02 – 1.8	0.6-1.2	• As per BIS if the reported value is <0.6mg/l the water should not be rejected for drinking purpose but suitable public health measures need to be taken. A maximum value of 1.5 may be extended if no alternate source of water is available; • In the ranges given alongside for both the rounds of monitoring it shows that though the upper stipulated limit was being met however in almost all the stations fluoride values were< 0.6 mg/l; • Only at Ashishnagar the fluoride values exceeded 1.0 mg/l;
9.	Phenolic compound (as C_6H_5OH)	BDL	Not done	0.001	• No comments given since the parameter was not monitored because the values were below detection limit (BDL) in the first round.

10.	Cyanide mg/L	BDL	BDL	0.05	• No comments given since the parameter was and the values were below detection limit (BDL) in both the rounds.
11.	Sodium	Not done	20 - 113	Not given	• the post monsoon values exceeded the winter and pre-monsoon values; • The values at Mayabazar, Ashishnagar and Palasdiha were higher compared to the other two stations; • The values at Mayabazar ranged between 63-83 gm/l while at Ashishnagar it ranged between 97-113 mg/l.
12.	Magnesium (as mg)	0.1-62	4 – 60	30	• The ranges in both the monitoring rounds indicate that magnesium values are being exceeded w.r..t the stipulated standard at some location(s); • 2001-2002 round the post monsoon values ranged between 31-53 mg/l which is far higher than the stipulated standard; • The tube well monitored at Ashishnagar exceeded 30 mg/l in both the rounds.
13.	Phosphate	0.005 - 0.5	0.01 - 0.04	Not given	• The values were less <.5 mg/L ,no comments given since no BIS stipulated standard given.
14.	Conductivity us/l 25^0C	168 -1222	200 - 1275	Not given	• There was no seasonal variation at the individual stations; • For both the monitoring rounds the tube well monitored at Mayabazar and Ashishnagar exceeded 800 us/l 25^0C.
15.	F.Coliorm (MPN/100ml)				• Bacterial contamination observed in 2nd round as no analysis was done in the 1st round; • the pre-monsoon and winter cycles showed bacterial contamination (16 MPN/100 ml) but 'no growth' was reported in the post-monsoon cycle in 2001-2002 round.
16.	Alkalinity	5 - 675	30 - 378	Not given	• The values were less <100 mg/L , however the values at Mayabazar & Ashishnagar were higher than 200 mg/l for all the three seasons compared to the other three stations; • No further comments could be given since no BIS stipulated standard given.
17.	Total Coliform (MPN/100ml)	-	No growth -16		• Bacterial contamination was observed in both the rounds; • The pre-monsoon and winter cycles showed bacterial contamination (16 MPN/100 ml) but 'no growth' was reported in the post-monsoon cycle in 2001-2002 round. In the 1st round the analysis was done using the cluster forming units method.

	Heavy Metals (mg/L)	**Range (1994)**	**Range (2001-02)**	**Stds. BIS**	**Observations**
1.	Iron	NT - .83	NT – 1.35	0.3	• In winter cycle for 2002-2003 the values were reported as 'not traceable' (NT) at any of the locations. However for the post monsoon barring Palasdiha the values ranged between 0.4-1.3mg/L
2.	Lead	NT -0.1	NT -0.01	0.1	• Values were meeting the stipulated standard
3.	Zinc	NT -1.45	NT – 0.35	5.0	• Values were meeting the stipulated standard
4.	Manganese,	NT -4.09	NT – 0.74	0.1	• Values were meeting the stipulated standard except in the pre-monsoon round where it ranged between 0.12-0..60 ppm with Ashishnagar having the highest values in the 2001-2002 cycle.
5.	Copper	NT -0.01	NT - 0.012	1.0	• Values were meeting the stipulated standard
6.	Cadmium	NT - 0.04	BDL	0.01	• Values were meeting the stipulated standard
7.	Arsenic	Not Done	BDL	0.05	• Values were meeting the stipulated standard
8.	Mercury	NT-0.009	BDL	0.001	• Values were meeting the stipulated standard
9.	Chromium	NT -0.14	BDL	0.05	• Values were meeting the stipulated standard
10.	Nickel	NT- 0.073	Not Done	Not given	• No further comments could be given since no BIS stipulated standard given.

	Pesticides (mg/L)				
1.	Dieldrin	NT - 250	NT - 39.3		Values are low
2.	Lindane	Not Done	NT - 494.1		-do-
3.	Aldrin	NT	NT - 61.2		-do-
4.	DDT	NT - 7308	12.3 - 305		DDT is used both in agriculture and in maintaining sanitation
5.	Endosulphan	NT - 485	NT - 134		Very low values
6.	BHC	NT - 4556	NT - 1904		-do-

Note: Limits in bold print are WHO standards while the rest are BIS 10500- 1991 for drinking water; the first round refers to 1994 and 2nd round refers to 2000-2001

Table 2: Characteristics and Observations/comments on Groundwater Quality in Haora Problem Areas

Sl. No.	Parameters (All values are in mg/L except pH)	Range (1994)	Range (2001-02)	Stds. BIS	Observations
1.	pH value	6.6-7.7	6.6-7.43	6.5-8.5	• No apparent variation in pH in the two rounds.
2.	Total Hardness (as $CaCO_3$)	100-3560	149-1078	300	• The water samples in the both the rounds indicated water is acutely hard ; • All the seasonal rounds in the 2nd round of monitoring also indicated hardness exceeding 500 mg/l, though the location Tikiapara has lower hardness values compared to the other locations.
3.	Chloride	15.6-1301	123-1084	250	• In the 2nd round the water had high chloride values (> 600 mg/l) except for the sampling location at Tikiapara where the values ranged between 123-377 mg/l; • The values were acutely high particularly in Shanpur, St Thomas School and Dasnagar; • A similar observation was found in the 1st round where Tikiapara was found comparatively least saline.
4.	Total dissolved solids	385-2546	238-3327	500	• In the 1st round the values were observed to be very high (> 500 mg/l) particularly St Thomas School and Dasnagar; • In the 2nd round irrespective of season the values were very high (mostly > 1000 mg/l) except at Tikiapara where the pre and post monsoon values exceeded 700 mg/l.
5.	Calcium (as Ca)	78.4-1163	128-619	75	• The values in both the rounds exceeded the available stipulated values by BIS.
6.	Sulphate (as so4)	3.3-29	2-54.8	200	• The sulphates values have not exceeded the BIS limits
7.	Nitrate) N03-N)	<10.8	<1.0	45	▪ In both the rounds the values were within the stipulated standards;
8.	Fluoride (as F)	-	0.33-0.98	1.0-1.5	• As per BIS if the reported value is <0.6mg/l the water should not be rejected for drinking purpose but suitable public health measures need to be taken. A maximum value of 1.5 may be extended if no alternate source of water is available; • In the ranges given alongside for both the rounds of monitoring it shows that though the upper stipulated limit was being met however in almost all the stations fluoride values were hovering around < 0.6 mg/l;

9.	Phenolic compound (as C_6H_5OH)	BDL	Not done	0.001	• No comments given since the parameter was not monitored because the values were below detection limit (BDL) in the first round.
10.	Cyanide	BDL	BDL	0.05	• No comments given since the parameter was monitored and the values were below detection limit (BDL) in both the rounds.
11.	Sodium	Not done	8.2-510	Not given	• The values were very high (exceeding 400 mg/l) in all the stations except at Tikiapara where the values were almost < 100 mg/l. The locations Dasnagar and St Thomas Girls' School exceed 350 mg/l.
12.	Magnesium mg/l	5.2-135	43-109	30	• The ranges in both the monitoring rounds indicate that magnesium values are being exceeded w.r.t the stipulated standard at all the location(s); • The locations at ST Thomas School, Dasnagar and Shanpur the values exceeded 75 mg/l.
13.	Phosphate	<0.7	0.02-0.093	<0.7	• The values were less <0.7 mg/ at all the locations.
14.	Conductivity, us/l 25^0C	210-4060	1230-3790	Not given	• There was barely any seasonal variation at the individual stations; • The conductivity values exceeded 3000 us/l at St Thomas School, Dasnagar and Shanpur where the values ranged between 1000-2500 at the other two stations.
15.	F.Coliform MPN/100ml	-	-		▪ Bacterial contamination was observed in the 2nd round;
16.	Alkalinity	130-888	203-588	Not given	• The values exceeded 300 mg/l in almost all the locations with post monsoon values being less than the pre monsoon values.
17.	Total Coliform MPN/100ml	-	5-16		• Bacterial contamination was observed in both the rounds; • the pre-monsoon , post monsoon and winter rounds showed bacterial contamination . In the 1st round the analysis was done using the cluster forming units method.
	Heavy Metals (All values are in mg/L)	**Range (1994**	**Range (2001-02)**	**Stds. BIS**	**Observations**
18.	Iron ***(Note all values given in ng/l for 1st round for metals)***	0.024-4.8	0.1-1.35	0.3	• The desirable value is 0.3 mg/l and the acceptable value being 5 mg/l as per CPCB's general WQ criteria for raw waters used for organised community water supplies (surface and ground water). • This parameter was found critical particularly at the locations Dasnagar where the values ranged between 0.3-1.15 mg/l and at St Thomas School where it ranged between 0.42-1.05 mg/l.
19.	Lead	0.014 -0.13	<0.03	0.1	• Values were meeting the stipulated standard
20.	Zinc	<5	<0.5	5.0	• Values were meeting the stipulated standard
21.	Manganese	0.012 -1.61	0.34 -1.45	0.1	• All values exceeded the stipulated value in the 2nd round particularly in Dasnagar, St Thomas School and Sanpur where the values exceeded 0.6 mg/l for all the seasons.
22.	Copper	<0.05	Mostly BDL	**1.0**	• Values were meeting the stipulated standard
23.	Cadmium	<0.06	BDL	0.01	• Values were meeting the stipulated standard
24.	Arsenic	-	BDL	0.05	• Values were meeting the stipulated standard
25.	Mercury	0.0002 -0.017	BDL	0.001	• Values were meeting the stipulated standard
26.	Chromium	<0.055	BDL	0.05	• Values were meeting the stipulated standard
27.	Nickel	0.007-0.1	Not traceable	Not given	• no further comments could be given since no BIS stipulated standard given.

	Pesticides (mg/L)				
28.	Dieldrin	<0.67			The desirable value for total pesticides stipulated is 0.001 mg/l and the acceptable value being 0.0025 mg/l as per CPCB's general WQ criteria for raw waters used for organised community water supplies (surface and ground water). Except for DDT which showed significant presence the other parameters almost not detectable. DDT was high in is the pre-monsoon values in all the locations barring Tikiapara. As agriculture area is almost nil in the areas where the sampling locations were located one can perhaps conclude the usage of DDT was possibly being used as an anti-malaria practice.
29.	Lindane	Not Done			
30.	Aldrin	<0.79			
31.	DDT	<9.8			
32.	Endosulphan	0.07-4.8			
33.	BHC	2.5-6.7			

Note: Limits in bold print are WHO stds while the rest are BIS 10500- 1991 for drinking water ; the first round refers to 1994 and 2nd round refers to 2000-2001

Table 3: Characteristics and Observations/comments of Groundwater Quality in Dhanbad Problem Areas

Sl. No.	Parameters (All values one in mg/L)	Range (1994)	Range (2001-02)	Stds. BIS	Observations (In the 2001-2002 two rounds of sampling was - once in Jan'02 and next in May'02)
18.	pH value	5.4-7.3	5.79-7.03	6.5-8.5	▪ For 2nd round - Acidic pH observed ; less than 6.5 at all locations except at Govindpur
19.	Total Hardness (as $CaCO_3$)	127-667	184-750	300	▪ For 2nd round < 300mg/l observed at Opp. CRFI and Opp. ISM.
20.	Chloride	16-660	32-336	250	▪ For 2nd round < 35 mg/l observed only at Opp. CRFI though < 250mg/l at all location. The values ranged between 323-336 mg/l.
21.	Total dissolved solids	304-570	442-1253	500	▪ For the 2nd round all values exceeded 500 mg/l except at Opp CRFI.
22.	Calcium as Ca	140-421	64-176	75	▪ For 2nd round < 75mg/l observed only at Opp. CRFI
23.	Sulphate	69-296	48.7-145.7	150	▪ Meeting norms
24.	Nitrate)	2-121	5.64-65.26	45	▪ For 2nd round the Jan'02 round the values exceeded 45 mg/l at Govindpur else the values were meeting norms
25.	Fluoride (As F)	0.56-0.98	0.19-1.44	1.0-1.5	▪ For 2nd round < 0.6mg/l at Court More and Bar Bus stand
26.	Phenolic compound (as C_6H_5OH)	BDL	Not done	0.001	-
27.	Cyanide	Not done	BDL	0.05	-
28.	Sodium	Not done	37.2-135.2	Not given	▪ For the 2nd round though all the values were observed to be < 75 mg/l (refer to the remarks on chlorides too) the values at Gobindpur ranged between 126-135.2 mg/l
29.	Magnesium	0.09-103	12-69	30	The values for Gobindpur ranged between 40-69 mg/l
30.	Phosphate	0.004-0.62	0.009-0.052	<0.7	-
31.	Conductivity	140-1875	600-1962	Not given	▪ For the 2nd round the values < 1000 us/l only at Opp. CRFI. The values were

	us/l 25^0C				observed to be in the range 1940 - 1962 us/l at Govindpur.
32.	F. Coliform MPN/100ml	Not done	≅16		▪ Bacterial contamination observed.
33.	Alkalinity	124-560	102-268	Not given	▪ For 2nd round the values were less than 170 mg/l except at Govindpur where the values ranged between 255-268 mg/l
34.	Total Coliform MPN/100ml		≅2 to 9		▪ Bacterial contamination observed in both rounds however in the 1st round the analysis was done using the cluster forming units method (CFU).

Note: Limits in bold print are WHO stds while the rest are BIS 10500- 1991 for drinking water; the first round refers to 1994 and 2nd round refers to 2000-2001

Sl No.	Heavy Metals values	Range (1994)	Range (2001-02)	Stds. BIS	Observations
11.	Iron (ppm) ***(Note all values given in ng/l for 1st round for metals)***	0.045-2.87	0.1-7.5	0.3	• The desirable value is 0.3 mg/l and the acceptable value being 5 mg/l as per CPCB's general WQ criteria for raw waters used for organised community water supplies (surface and ground water). • For the 1st round this parameter was found critical particularly at the location Opp ISM in May'02 when values was reported as 7.7 ppm
12.	Lead (ppm)	BDL-0.083	NT	0.1	• Values were meeting the stipulated standard
13.	Zinc (ppm)	0.025-1.37	<1.32	5.0	• Values were meeting the stipulated standard
14.	Manganese (ppm)	0.022-0.43	<0.1	0.1	• Values were meeting the stipulated standard
15.	Copper (ppm)	BDL-0.02	NT	**1.0**	• Values were meeting the stipulated standard
16.	Cadmium (ppm)	BDL-0.09	NT	0.01	• Values were meeting the stipulated standard
17.	Arsenic (ppm)	Not done	<0.016	0.05	• Values were meeting the stipulated standard
18.	Mercury (ppm)	<0.02	<0.015	0.001	• Values were meeting the stipulated standard however detectable values were observed in Jan'02 at Opp ISM, Opp CRFI and at Govindpur.
19.	Chromium (ppm)	<0.1	NT	0.05	• Values were meeting the stipulated standard
20.	Nickel (ppm)	<0.05	NT	Not given	• -
	Pesticides				

	(µg/L)				
7.	Dieldrin	BDL-483	3-64.8		▪ The desirable value for total pesticides stipulated is .001 mg/l and the acceptable value being .0025 mg/l as per CPCB's general WQ criteria for raw waters used for organised community water supplies (surface and ground water). The values are low as can be observed. ▪ For the 1st round the values have been fluctuating randomly in 1994 though the upper limits show significant presence the profile for the 2nd round is also similar w.r.t fluctuation but this round also indicates the presence of pesticides.
8.	Lindane	Not done	2.1-425.4		
9.	Aldrin	BDL-1411	3.6-77.4		
10.	DDT	BDL-7364	20.4-596.2		
11.	Endosulphan	BDL-1110	20.1-243		
12.	BHC	BDL-4744	167-1516.8		

Note: Limits in bold print are WHO stds while the rest are BIS 10500- 1991 for drinking water; the first round refers to 1994 and 2nd round refers to 2000-2001

Table 4: Characteristics and Observations/comments of Groundwater Quality in Angul-Talcher Problem Areas

Sl. No.	**Parameters (mg/L)**	**Range (2001-02)**	**Stds (BIS) IS:10500-1991**	**Observations**
1	PH	6.11-9.05	6.5-8.5	• pH in most of the ground water sources is within the standard limit. • Dug wells of Chhelia and Kaniha villages show low pH i.e. 6.1-6.3 during pre monsoon period. • In monsoon, high pH value (> 8.5) is observed in dug wells of Banarpal, Bonda, Kaniha and Godibandha voillages and in the tube wells of Bonda, Kulad, Kaniha and Dudurkote villages.
2	Total Alkalinity (As $CaCO_3$,)	38-788	Not prescribed	• Very low values of alkalinity are observed in dug wells of south Balanda and Chhelia and tube wells of South Balanda and FCI. • Very high value of alkalinity i.e. 788 mg/l is observed in the tube well of Tulsipal village. • In most of the cases, post monsoon values are higher than the monsoon values.
3	Total dissolved solids,	181-1960	500	• TDS in the ground water sources of Kaniha, Godibandha, Talcher, Handidhua Chhak, South Balanda and Baghamara area are within the standard limit. • Ground water sample in Bonda, Balaramprasad, Chhelia and Derjung villages exhibit moderately high TDS value i.e. within the range 650- 872 mg/l. • TDS is very high (977-1960 mg/l) than the stipulated standard in Tulsipal, Kulad, Kandsar, Angul and Gotmara areas.
4	Conductivity, □S/cm	264-3340	Not prescribed	• The correlation equation, Conductivity = TDS x 0.65 holds good at all station. • Very high conductivity value (i.e. > 2000 □S/cm) is observed in Tulsipal, Kandsar, Angul areas
5	Total hardness (As $CaCO_3$,)	46-652	300	• Total hardness vary within 64-640 mg/l in monsoon period and within 46-652 mg/l in pre-monsoon season. • Total hardness in South Balanda is within 46-68 mg/l, while ground water in Banarpal, Bonda, Balaramprasad, Deranga, Godibandha, Talcher Handidhua chhak, Baghamara, FCI, Guruianguli villages are within 75- 300 mg/l. • Total hardness in the ground water of Gotamara, Angul, Chellia and Tulsipal area exceeds the standard limit.
6	Calcium hardness (as $CaCO_3$,)	13.6-202	75	• Calcium content in the ground water samples of all villages except Angul, Chhelia, Handidhua chhak, South Balanda and FCI show an increasing trend from monsoon to pre-monsoon period. • In Chhelia, calcium content decreases significantly from 144 mg/l in monsoon to 60 mg/l in pre-monsoon. However, a marginal decrease from 64.1 to 40.7 mg/l is observed in Handidhua chhak

				over the months. • In the month of May, the calcium content in tube wells of Bonda and dug wells of Kaniha, Gurujanguli and Gotamara villages exceeds the standard limit. The ground water samples collected from Angul, Chhelia, Gurujanguli and Gotamara villages exhibit calcium content more than 75 mg/l through out the study period.
7	Magnesium	5.36-79.44	Not prescribed	• Magnesium content in all the tube wells except those of Tulsipal, Derjung villages were found to be less than the calcium content.
8	Sodium,	8-310	Not prescribed	• In dug well of Banarpal, Gotamara and Gurujanguli villages, sodium content has increased from monsoon to pre-monsoon period. In all other cases, the sodium content fluctuates marginally.
10	Sulphate,	0.537-162.2	200	• Sulphate content at all placec is l within the standard limit. • Increase in sulphate content from monsoon to pre-monsoon period is much more pronounced in case of tube wells than in dug wells.
11	Phosphate,	0.0-0.95	Not prescribed	• Monsoon values of phosphate in dug wells of Banarpal, Kandsar, Kaniha and tube well of Tulsipal are more than the pre-monsoon values. • In all other cases, post monsoon value is greater than the monsoon value.
12	Nitrate,	ND-150	45	• Nitrate in the dug wells of Kulad, Kandsar, Godibandha, Chhelia, Gurujaguli in monsoon are higher than the stipulated standard.
13	Fluoride,	0.106-2.5	1.0	• Fluoride content in Bonda, Kulad and FCI area are above the prescribed limit. • High fluoride content is observed at Tulsipal (2.5 mg/l) in September and January which, however, reduces to 0.7 mg/l in May. • In most of the places, fluoride content remains fairly constant in the study period.
14	Cyanide,	0-0.02	0.05	• Cyanide content is within the standard limit. • Pre-monsoon values are observed to be less than the post-monsoon and monsoon values.
15	Total coliform, MPN/100 ml	<2- >1100	Absent	• High bacterical population was observed in all the dug wells in monsoon. • Excepting the tube wells of Kanhia, South Balanda, Baghamara, Dudurkote, all other tube wells were contaminated.
16	Fecal coliform, MPN/100 ml	<2- >1100	Absent	• In January the bacterial population has been significantly reduced in all the dug wells except in Kulad and Gatamara village. • Tube wells of Derjang, FCI, Talcher, Handidhua, Angul area also show a decreasing population of coliform bacteria but still does not meet the drinking water quality criteria.
17	Chromium (VI) ,	ND	0.05	▪ Not detected at any place throughout the study period.
18	Mercury	ND	0.001	▪ Not detected at any place throughout the study period.
19	Iron,	0.034-6.27	0.3	• Iron content in most of the sampling locations either remains fairly constant throughout the study period or shows an increasing trend from September-01 to January-02. • In Kulad, Balaramprasad, Kandsar, Kaniha and Baghamara areas, iron content is above the prescribed limit. • High iron value (2.2-6.3) is observed in the tube wells of Derjung, South Balanda, Handidhua chhak.
20	Manganese,	ND-1.582	0.1	• Manganese was found to be slightly greater than 0.1 mg/l in Angul, Chhelia and Derjung area. • Very high Mn content (≥ 1.0 mg/l) are observed in tube wells of Bonda, Talcher, Baghamara and dug well of Gotamara. • In pre monsoon period, Mn content is observed to be either absent or in very low quantity at all

				places and except at tube well of Tulsipal village (0.25 mg/l)
21	Cobalt,	ND-0.017	Not prescribed	• No comments could be given since no BIS standards prescribed.
22	Nickel,	ND-0.072	Not prescribed	• No comments could be given since no BIS standards prescribed.
23	Cadmium,l	ND-0.007	0.01	• Values were within the stipulated standard
24	Copper,	ND-0.052	0.05	• Values were within the stipulated standard
25	Zinc,	0.01-7.63	5.0	• Values greater than the stipulated standard was observed only in Tube well of Kaniha in Jan'02 and May'02.
26	Lead,	0.002-0.103	0.05	• Values were within the stipulated standard
27	Pesticides		Absent	BHC, Lindane, DDT and Endosulfan in the dugwells of Gotmara, Kulad and Tulsipal villages are observed to decrease from monsoon to pre-monsoon period, whereas, in the dug wells of Balaramprasad and Kaniha villages, an increasing trend is observed from September'01 to January'02 and BHC and Lindane were not detected in May'02. DDT and Endosulfan were not detected in the dug wells of Banarpal, Bonda, Balaramprasad and Gotmara villages in May'02. Heptachlor, aldrin and dieldrin fluctuate widely during the study period.
	BHC,	ND-2.4		
	Lindane, □g/l	ND-1.3		
	DDT, □g/l	ND-2.68		
	Endosulfan,	ND-2.6		
	Heptachlor,	ND-7.982		
	Aldrin,	ND-6.588		
	Dieldrin,	ND-0.394		

Table 5 a): Analysis report of groundwater - Vishakapatnam (3 rounds)

Code	PH			Conductivity			Total hardness			Fluoride			Chlorides		
	MIN	MAX	AVG	IN	MAX	AVG	MIN	MAX	AVG	MIN	MAX	AVG	MIN	MAX	AVG
1	7.5	7.59	7.5	118	151	127	310	420	361	0.55	0.99	0.8	15	350	186
2	7.5	7.9	7.57	119	208	169	355	440	388	0.70	1.25	1.06	110	200	158
3	7.9	8.4	8.1	107	151	136	180	220	183	0.89	1.54	1.28	130	226	182
4	7.9	8.51	8.18	177	806	275	100	448	156	1.89	2.51	1.8	150	210	168
5	7.36	7.5	7.4	806	1033	922	2800	2800	2736	0.79	0.90	0.89	130	135	168
6	7.28	7.7	7.52	166	246	210	513	570	548	0.19	1.38	0.66	220	300	251
7	7.42	8.16	7.6	155	320	267	155	326	317	0.52	1.4	0.91	190	256	226

Table 5 b): Analysis report of groundwater - Vishakapatnam (3 rounds)

	Nitrate			Phosphate			Sulphate		
Code	MIN	MAX	AVG	MIN	MAX	AVG	MIN	MAX	AVG
1	13.4	22	16	BDL	BDL	BDL	46	76	63
2	13.1	40.8	22	BDL	BDL	BDL	31.2	53.3	45.7
3	0.3	1.8	1.0	BDL	BDL	BDL	31.2	59.6	49.3
4	6.0	21.2	15.2	BDL	BDL	BDL	23.8	73.9	528
5	6.0	14.7	27	-	-	0.07	1355	2248	2010
6	14.0	43.9	26.9	-	-	0.06	135	2228	854
7	22.8	29.6	25.9	-	-	0.01	65.9	83.3	74.6

Station code: 1 :MVP Colony; 2- TDA Marripalem; 3-.R. Venkatapuram; 4- Shiela Nagar; 5- Mindi; 6-Peda Chantyada; 7- R.K. Puram

Table 5 c): Analysis report of groundwater - Vishakapatnam (3 rounds)

	Sodium			Potassium			Calcium			TDS		
Code	MIN	MAX	AVG	MIN	MAX	AVG	MIN	MAX	AVG	MIN	MAX	AVG
1	75	140	100	35	132	71	20	52	40	791	985	915
2	64	85	73	40	77	57	66	88	73	799	1400	1124
3	87	175	120	47	167	90	16	28	33	723	1015	904
4	97	2200	108	50	234	163	22	28	20	3002	6720	5310
5	105	290	164	52	290	314	500	596	552	5403	6720	6114
6	85	143	108	43	136	80	132	1340	535	1085	1650	1401
7	65	77	71	34	48	41	50	66	55	911	1040	975

Table 5 d): Analysis report of groundwater - Vishaka patnam (3 rounds)

Code	Nickel			Zinc			Copper			Iron			Lead			Chromium			Manganese		
	MIN	MAX	AVG	MIN	MAX	AVG	MIN	MAX	AVG	MIN	MAX	AVG	MIN	MAX	AVG	MIN	MAX	AVG	MIN	MAX	AVG
1	0.0	0.14	0.08	-	0.8	0.8	BDL	BDL	BDL	-	-	0.02	0.01	0.02	0.01	0.07	0.56	0.23	0.06	1.44	
2	0.01	0.12	0.6	-	-	0.02	BDL	BDL	BDL	BDL	BDL	0.01	-	-	0.03	0.16	0.56	0.23	0.05	0.44	0.29
3	0.15	0.18	0.16	-	-	0.18	BDL	BDL	BDL	0.07	0.10	0.8	BDL	BDL	0.05	BDL	BDL	0.01	0.26	0.46	0.36
4	0.19	0.24	0.21	BDL	BDL	0.11	BDL	BDL	BDL	0.01	0.16	0.8	BDL	BDL	BDL	BDL	BDL	BDL	0.08	0.58	0.33
5	0.27	0.29	0.28	0.03	0.3	0.16	-	-	0.01	0.03	0.08	0.6	-	-	-	BDL	BDL	-	0.05	0.62	0.33
6	0.01	0.28	0.27	-	-	0.04	-	-	-	0.03	0.19	0.19	-	-	0.01	-	-	-	0.05	0.39	0.22
7	-	-	0.26	-	-	0.02	-	-	-	-	-	-	0.03	-	-	-	BDL	BDL	-	-	0.92

Station code: 1 :MVP Colony; 2- TDA Marripalem; 3-.R. Venkatapuram; 4- Shiela Nagar; 5- Mindi; 6-Peda Chantyada; 7- R.K. Puram

Table 6 a): STATEMENT OF GROUNDWATER QUALITY AT VISAKHAPATNAM SEPTEMBER 2001

S.No.	Location	Nickel	Zinc	Copper	Iron	Lead	Chromium	Cobalt	Total Coliform	pH	Conductivity	Total Hardness	Fluorides	Chlorides	Nitrates	Phosphates	Sulphates	Sodium	Potassium	Calcium	TDS	Alalinity
1.	MVP Colony	0.14	-	-	0.02	0.02	0.07	0.03	1600	7.59	151	420	0.55	350	13.5	-	46.7	140	132	20	985	640
2.	IDA Marripalem	0.017	-	-	0.00	0.03	0.16	0.03	9.00	7.53	180	440	0.70	200	14.0	-	31.2	85.0	77.0	76	1175	660
3.	RRV Puram	0.18	-	-	0.10	0.05	0.01	0.10	2.0	8.13	150	210	0.89	220	1.00	-	31.2	175	167	16	975	560
4.	Sheela Nagar	0.24	-	-	0.01	-	-	0.10	1600	8.51	177	100	1.89	160	6.00	-	23.8	220	234	12	1155	600
5.	Mindi	0.29	-	-	0.08	-	-	0.16	1600	7.42	1033	2610	0.19	240	602	-	2228	290	290	596	6720	580
6.	Peda Chantyada	0.28	-	-	0.19	-	-	0.06	1600	7.46	166	570	0.20	220	14.0	-	65.2	143	136	1340	1080	460
7.	Jalaripalli Palem		-	-	0.07	-	-	-	1600	7.42	200	490	0.44	300	13.8	-	37.9	141	132	92.0	1300	520

Note : All values are reported in mg/l except pH and Conductivity

Table 6 b) : STATEMENT OF GROUNDWATER QUALITY AT VISAKHAPATNAM FEBRUARY, 2002

S.No.	Locat-ion	Nickel	Zinc	Cop-per	Iron	Lead	Chr-omium	Cobalt	Man-ganese	Cadm-ium	PH	Con-ductivity	Total Hard-ness	Fluor-ides	Chlor-ides	Nitra-tes	Phos-phates	Sulp-hate	Sodi-um	Pota-ssium	Calci-um	TDS	Alalin-ity
1.	MVP Colony	0.10	0.08	BDL	BDL	BDL	0.56	BDL	1.44	BDL	7.55	118	310.00	0.96	175.0	13.4	BDL	66.5	75.0	35.0	52.0	791.0	470
2.	IDA Marripalem	0.12	BDL	BDL	BDL	BDL	0.53	BDL	0.44	BDL	7.31	119	390.00	1.25	165.0	13.1	BDL	52.6	64.5	40.0	88.0	799.0	420
3.	RRV Puram	0.15	BDL	BDL	BDL	BDL	BDL	BDL	0.26	BDL	7.97	107	180.0	1.54	130.0	0.3	BDL	57.3	87.5	47.0	28.0	723.0	670
4.	Sheela Nagar	0.19	BDL	BDL	BDL	BDL	BDL	BDL	0.58	BDL	7.93	448	220.0	2.25	210.0	18.6	BDL	73.9	97.0	55.0	28.0	3002	740
5.	Mindi	0.27	0.39	BDL	0.07	BDL	BDL	BDL	0.62	BDL	7.36	806	2800.0	0.81	130.0	14.7	BDL	2448	97.0	52.0	500.0	5403	900
6.	Peda Ghantyada	0.26	BDL	BDL	BDL	BDL	BDL	BDL	0.39	BDL	7.28	220	560.0	0.55	300.0	22.8	BDL	135.80	85.0	43.0	132.0	1475	420
7.	RK Puram	0.26	BDL	BDL	BDL	BDL	BDL	BDL	0.84	0.03	7.42	135	320.0	1.40	190.0	22.8	BDL	65.90	77.0	34.0	50.0	911	390
8.	Standard	NS	5000	50	300	50	NS	NS	NS	NS	6.5 to 8.5	NS	300	1.0	250	45	NS	200	NS	NS	75		200

Note : All Parameters are given in mg/lt. Expect pH and Conductivity (m/S/M) . NS : Not specified. BDL : Below detectable limit

Table 6 c): STATEMENT OF GROUNDWATER QUALITY AT VISAKHAPATNAM OCTOBER, 2002

S.No.	Location	Nickel	Zinc	Copper	Iron	Lead	Chromium	T. Coliform	Manganese	Cadmium	PH	Conductivity	Total Hardness	Fluorides	Chlorides	Nitrates	Phosphates	Sulphates	Sodium	Potassium	Calcium	TDS	Alkalinity	F.Coliform
1.	MVP Colony	0.00	0.05	BDL	0.00	0.01	BDL	1350	0.06	0.00	7.50	145	355	0.99	15	22	0.01	76.6	84.5	48.0	64.0	970	270	Nil
2.	IDA Marripalem	0.00	0.02	BDL	0.01	BDL	BDL	4970	0.05	BDL	7.90	207	355	1.24	110	41	0.01	53.3	70.0	56.0	66.0	1400	240	Nil
3.	RRV Puram	BDL	0.09	BDL	0.07	BDL	BDL	5260	0.46	0.0	8.40	152	220	1.42	196	1.8	0.01	59.6	98.5	56.0	22.0	1015	430	10
4.	Sheela Nagar	BDL	0.11	BDL	0.16	BDL	BDL	4670	0.08	0.00	8.10	202	150	2.51	150	21.2	0.01	60.9	110.0	50.0	22.0	1350	600	330
5.	Mindi	BDL	0.03	0.01	0.03	BDL	BDL	5780	0.05	BDL	7.50	928	2800	0.79	135	12.4	0.07	1355	105.0	60.0	560.0	6220	200	300
6.	Peda Ghantyada	0.01	0.04	BDL	0.08	0.01	BDL	6940	0.05	BDL	7.70	246	515	1.38	235	44	0.06	201.9	98.0	63.0	134.0	1650	190	90
7.	RK Puram	BDL	0.02	BDL	0.03	BDL	BDL	3350	0.08	BDL	8.10	155	315	0.52	167	29.5	0.01	83.3	65.0	48.0	60.0	1040	240	750
8.	Standard	NS	5	0.05	0.3	0.05	NS	NS	NS	NS	6.5 to 8.5	NS	300	1.0	250	45	NS	200	NS	NS	75	500	200	NS

Note: All Parameters are given in mg/lt. Expect pH and Conductivity (m/S/M) Total Coliform (Coliform colonies per 100 ml) NS: Not specified.
BDL: Below detectable limit.

Table 7) a): Analysis report - Pattancheru & Bollaram , September, 2001

Code.	PH	Conductivity (µs/Cm)	Turbidity(NTU)	TDS mg/l	T- Alkalinity (as Caco3)	TH	Ca mg/l	Mg mg/l	Cl mg/l	SO4 mg/l	Nitrates (As N)	TOC	Fluorides	Lead	Cadmium	Chromium (µ/l)
1.	7.71	2,430	5.0	1500	540	980	280	111	497	200.2	24	12	1.0	BDL	BDL	18
2.	7.43	1,160	6.0	740	400	400	80	48	208	138.8	8.8	9	0.9	BDL	BDL	10
3.	7.85	950	5.0	600	340	185	36	23	75	16.7	3.9	8	0.85	BDL	BDL	15
4.	7.71	2690	8.0	1120	400	800	156	111	565	216.1	24	11	1.2	BDL	BDL	15
5.	7.49	2090	5.0	1340	400	780	152	97	432	128.2	24	10	1.1	BDL	BDL	10
6.	7.53	1100	5.0	700	310	400	80	48	132	66.3	11.7	8	1.0	BDL	BDL	10
7.	8.00	1600	5.0	1070	540	300	64	34	289	65.8	0.39	10	1.0	BDL	BDL	10

Table 7) b): Analysis report - Pattancheru & Bollaram February, 2002

Code	PH	Conductivity (µs/Cm)	Turbidity (NTU)	TDS	T Alk mg/l	TH mg/l	Ca mg/l	Mg mg/l	Cl mg/l	SO4	Nitrates (As N)	TOC	F mg/l	Lead	Cadmium	Chromium (µ/l)
1.	7.12	2380	6.0	1600	520.0	1060	216	126	456	196	16.72	15	1.2	0.03	BDL	BDL
2.	7.60	1190	10.0	820	450.0	480	98	57	210	145	16.0	8	1.0	0.03	BDL	0.01
3.	7.76	780	8.0	640	300.0	175	36	21	63	20	4.072	8	0.9	0.05	BDL	0.01
4.	7.19	2750	8.0	1920	420.0	1200	240	145	727	240	24.0	16	1.3	0.03	BDL	0.01
5.	7.24	1990	6.0	1400	480.0	680	144	78	572	130	14.832	12	1.2	0.03	BDL	0.01
6.	7.39	1000	10.0	680	360.0	510	104	61	160	75	12.428	12	1.1	0.03	BDL	0.01
7.	8.22	970	8.0	740	335.0	360	72	44	146	75	0.58	12	0.9	0.05	BDL	0.01

1: Lakdaram. ; 2: Khardanoor (Bore well); 3: Inole Bore well ; 4: Kistareddy peta Bore well. ; 5: Bollaram. ; 6: Bachupally.; 7 : Isakabavi Bore Well.

Table 7) c): Analysis report of Pattancheru and Bollaram during the month of September, 2001 and February, 2002 (two months min, and & average)

Analysis report of Pattancheru and Bollaram during the month of September, 2001 and February, 2002 – two months min, max & average																							
Sl. No.	**Location code**	**1**			**2**			**3**			**4**			**5**			**6**			**7**		
	Parameters	min.	max.	mean	min	max.	mean	min	max.	mean	min.	max	mean	min.	max.	mean	min.	max	mean	min.	max.	mean
1	pH	7.12	7.71	7.42	7.43	7.60	7.52	7.76	7.85	7.81	7.19	7.71	7.45	7.24	7.49	7.37	7.39	7.53	7.46	8.00	8.22	8.11
2	Conductivity		2430	2405	1160	1190	1175	780	950	865	2690	2750	2720	1990	2090	2040	1000	1100	1050	970	1600	1285
3	TDS	1500	1600	1550	740	820	780	600	640	620	1120	1920	1520	1340	1400	1370	680	700	690	740	1070	950
4	T-HARDNESS, (as Caco3)	980	1060	1020	400	480	440	175	185	180	800	1200	1000	680	780	730	400	510	455	300	360	330
5	CALCIUM, (as Ca)	216	280	248	80	98	89	36	36	36	156	240	198	144	152	148	80	104	92	64	72	68
6	MAGNESIUM (as Mg)	111	126	118.5	48	57	52.5	21	23	22	111	145	128	78	97	87.5	28	61	54.5	34	44	39
7	T-ALKALINITY (as Caco3)	520	540	530	400	450	425	300	340	320	400	420	410	400	480	440	310	360	335	335	540	437.5
8	CHLORIDE,	456	497	476.5	208	210	209	63	75	690	565	727	646	432	572	502	132	160	146	146	289	217.5
9	SULPHATE,	196	200	198	138.8	145	142	16.7	20	18.35	216	240	228	128	130	129	66.3	75	70.7	65.8	75	70.4
10	NITRATE NITROGEN,	16.72	24	20.36	8.88	16	12.44	4.0	4.07	4.034	24	24	24	14.3	24	19.4	11.7	12.4	12.07	0.392	0.580	0.486
11	FLUORIDE,	1	1.2	1.1	0.9	1	0.95	0.85	0.9	0.875	1.2	1.3	1.25	1.1	1.2	1.15	1	1.1	1.05	1	0.9	0.95
12	TOC	12	15	13.5	8	9	8.5	8	8	8	11	16	13.5	10	12	11	8	12	10	10	12	11
13	Turbidity (NTU)	5	6	5.5	6	10	8	5	8	6.5	8	8	8	5	6	5.5	5	10	7.5	5	8	6.5

Note : All values are in mg/l except pH and Conductivity (μS/Cm)

Table 8) a) : ANALYSIS REPORT OF GROUNDWATER - BHADRAVATHI : SEPTEMBER, 2001, JANUARY, 2002 & MAY, 2002

Code	pH			Conductivity			TDS			Chloride			Sulphate		
	Min	Max	Avg.	Min	Max	Avg.	Min	Max	Avg	Min	Max	Avg	Min	Max	Avg.
1.	6.7	7.80	7.13	680	1054	867	433	1060	740	59	250	161	24	94	63
2.	6.8	8.12	7.2	760	980	870	762	846	787	121	142	128	58	64	54
3.	6.7	7.75	7.0	670	910	790	500	582	528	98	142	114	7	80	57

Table 8) b) : ANALYSIS REPORT OF GROUNDWATER - BHADRAVATHI : SEPTEMBER, 2001, JANUARY, 2002 & MAY, 2002

Sl.No.	Nitrate			Sodium (Na)			Phosphate			Fluoride			T. Hardness		
	Min	Max	Avg.	Min	Max	Avg.	Min	Max	Avg.	Min	Max	Avg.	Min	Max	Avg.
1.	0.6	12	4.9	62	84	73	0.002	0.04	0.0	0.11	0.5	0.25	256	887	510
2.	10	12.6	7.5	36	40	28	0.004	0.06	0.03	0.01	0.56	0.28	371	605	450
3.	0.66	1.14	0.9	48	54	51	0.004	0.06	0.028	0.17	0.17	0.17	274	585	397

Table 8) c) : ANALYSIS REPORT OF GROUNDWATER - BHADRAVATHI : SEPTEMBER, 2001, JANUARY, 2002 & MAY, 2002

Sl. No.	C. Hardness			Mg. Hardness			Cyanide			T.Coliform			F.Coliform		
	Min	Max	Avg.	Min	Max	Avg.	Min	Max	Avg.	Min	Max	Avg.	Min	Max	Avg.
1.	186	840	454	47	70	56	ND	ND	ND	86	114	100	34	89	61
2.	286	540	391	24	90	59	ND	ND	ND	67	80	73	3	94	48
3.	196	392	282	16	193	181	0.0	0.03	0.01	15	40	27.0	27	47	37

Note: Station code : 1 - Machanahalli ; 2 - Ameerjanhalli ; 3- Babbahalli

Table 9) a) : ANALYSIS REPORT OF GROUNDWATER - BHADRAVATHI - SEPTEMBER, 2001

Name of Location	PH	Conductivity	TDS	Chloride	Sulphate	Nitrate	Sodium (Na)	Phosphate	Fluoride	T-Hardness	Ca Hardness	Mg. Hardness	Cyanide	Tcoliform /100 ml.	Fcoliform /100 ml.
Machanahalli	6.9	1054	1060	250	24.0	2.24	84	0.002	NA	887	840	47	0.0064	114	89
Ameerjan Colony	6.8	760	846	140	40.8	12.6	36	0.007	NA	605	540	65	Nil	67	94
Baba Halli	6.7	672	500	102	2.01	0.66	54	0.004	NA	585	392	193	0.0309	15	47

Table 9) b) : ANALYSIS REPORT OF GROUNDWATER - BHADRAVATHI - JANUARY, 2002

Name of Location	pH	TDS	Chloride	Sulphate	Nitrate	Sodium (Na)	Phosphate	Fluoride	T Hardness	CaHardness	Mg.Hardness	Cyanide	Tcoliform /100 ml.	F coliform /100 ml.
Machanahalli	6.7	728	174	71	12	62	0.01	0.011	387	336	51	0.0076	86	34
Ameerjan Colony	6.9	762	121	58	ND	40	0.01	0.012	371	347	24	0.0053	80	3
Baba Halli	6.8	504	98	7	1.14	48	0.06	ND	274	258	16	0.017	40	27

Note: All values are in mg/l except pH and Conductivity (μ mhos/cm)

Table 9) c) : GROUNDWATER QUALITY RESULTS - BHADRAVATHI, KARNATAKA - MAY, 2002

Sl .No.	Name of station	PH	Conductivity	TDS	T. Hardness	Ca hardness	Mg Hardness	Chloride	Sulphate	Nitrate Nitrogen (NO3-N)	T. Alkalinity	Fluoride	Cyanide	Phosphate
1.	Ameerjohn Colony	8.12	980	754	376	286	90	142	64	10	192	0.56	0.0	BDL
2.	Bapana Halli	7.75	910	582	332	196	136	142	8.0	1.12	374	0.17	0.0	0.0043
3.	Machanahalli	7.80	680	433	256	186	70	59	94	0.601	282	0.50	0.0	0.043

Note: All values are in mg/L except pH and Conductivity (μ mhos/cm)

Table 10: GROUNDWATER QUALITY RESULTS OF GREATER COCHIN (Kochi or Cochin)

S.No.	Parameters	G1			G2			G3			G4		
		Min	Max	Avg.	Min	Max	Min	Min	Max	Avg.	Min	Max	Avg.
01	PH	6.6	8.0	7.3	5.5	7.15	6.22	5.09	7.0	6.13	4.64	6.7	5.38
02	Conductivity	660	930	783	78	500	243	57	1040	576	40	172	100
03	T. Hardness	192	250	229	34	90	53	14	232	142	6	30	14.6
04	Fluoride	0.05	0.24	0.14	ND	0.15	0.07	0.07	0.28	0.16	ND	0.10	0.06
05	Chloride	88	200	129	18	20	19.3	14	206	120	14	26	20
06	Sodium	42.3	106	78.4	6.9	13.6	9.7	5.6	125	83.5	3.2	19.4	8.8
07	Nitrate	1.1	25	15.3	1.73	4.23	3.36	0.45	4.85	2.23	0.91	2.72	1.65
08	Phosphates	ND	1.61	0.93	ND	ND	ND	ND	ND	ND	ND	0.05	0.01
09	Calcium	52	91.2	67.5	5.6	28	13.9	1.6	40	24	1.6	9.6	4.3
10	Magnesium	5.35	23.3	14.5	3.89	4.8	4.51	2.4	37.9	19.9	0.49	1.44	0.97
11	TDS	356	816	525	60	446	189	120	392	301	32	228	98
12	Cyanide	ND	ND	ND		ND	ND	ND	ND	ND	ND	N D	ND
13	Sulphates	16.4	42.6	27.2	3.53	42.6	16.7	ND	28.3	12.9	ND	3.4	2.13
14	Alkalinity	10	230	127	8	16	12	8	150	92.6	6	10	8
15	F. Coliform	0	2160	747	0.0	16	7	ND	350	167	ND	70	23
16	Total Coliforms	390	2000		10	100	37	50	590	320	ND	600	243
17	Mercury (as Hg)	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND
18	Nickel (as Ni)	ND	ND	ND	ND	3.13	1.03	ND	ND	ND	ND	ND	ND
19	Zinc (as Zn)	ND	384	145	106	250	157	50	605	335	30	130	93
20	Lead (as Pb)	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	12.5	4.2
21	Arsenic (as As)	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND
22	Cadmium (as Cd)	ND	48	16	ND	6	2	ND	43	14.3	ND	ND	ND
23	Copper (as Cu)	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	23	7.7
24	Iron (as Fe)	ND	243	108	ND	224	105	348	700	473	70	197	122
25	Manganese (asMn)	ND	111	44	10	188	73	30	590	307	10	96	45
26	Chromium (as Cr)	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND
27	Aldrin	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND
28	Dieldrin	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND
29	Lindane	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND
30	DDT	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND

Note: All values are in mg/L except pH, Conductivity (Micro mhos/cm) and TC and FC (Colonies/100ml)

Table 10 Contd. : GROUNDWATER QUALITY RESULTS OF GREATER COCHIN (Kochi or Cochin) (Contd/-)

S.No	Parameters	G5			G6			G7		
		Min	Max	Avg.	Min	Max	Avg.	Min	Max	Avg.
01	PH	4.2	5.8	5.13	5.7	6.9	6.13	5.65	5.9	5.78
02	Conductivity	120	129	123	360	950	583	720	990	890
03	T. Hardness	24	36	30	52	310	140	320	396	365
04	Fluoride mg/l	0.06	0.11	0.08	0.05	0.10	0.08	0.24	0.57	0.43
05	Chloride mg/l	20	30	24.7	16	118	51	78	90	84
06	Sodium mg/l	9.9	16.2	12.9	7.3	49	21.6	41.8	69	54.6
07	Nitrate mg/l	0.27	10.8	6.94	2.55	20.1	11.9	0.9	10.2	6.82
08	Phosphates mg/l	ND	ND	ND	ND	ND	ND	ND	ND	ND
09	Calcium mg/l	3	9.6	6.3	11.2	108	45.3	36.8	80	57.6
10	Magnesium mg/l	1.46	5.28	2.89	3.89	9.6	6.44	43.2	73.8	53.6
11	TDS mg/l	100	128	110	170	508	293	470	636	559
12	Cyanide mg/l	ND	ND	ND	ND	ND	ND	ND	ND	ND
13	Sulphates mg/l	ND	9	3.45	24.8	36.3	28.7	30	214	144
14	Alkalinity mg/l	2	16	10.7	4	190	69	6	30	17.3
15	F. Coliform	0.0	160	53	0.0	1600	537	0.0	0.0	0.0
16	Total Coliforms	10	310	130	50	280	163	ND	101	37
17	Mercury mg/l	ND	ND	ND	ND	ND	ND	ND	ND	ND
18	Nickel mg/l	ND	11	3.6	ND	ND	ND	ND	18.6	6.2
19	Zinc mg/l	ND	1427	502	100	302	177	22418	26500	24039
20	Lead mg/l	ND	117.5	34.2	ND	ND	ND	ND	66.2	22
21	Arsenic mg/l	ND	ND	ND	ND	ND	ND	ND	ND	ND
22	Cadmium mg/l	ND	61	20.3	ND	ND	ND	ND	531	177
23	Copper mg/l	ND	166	55.3	ND	ND	ND	ND	110	36.6
24	Iron mg/l	50	196	122	ND	219	113	80	525	255
25	Manganese mg/l	30	106	58.6	122	350	251	1258	3740	2319
26	Chromium mg/l	ND	ND	ND	ND	ND	ND	ND	ND	ND
27	Aldrin mg/l	ND	ND	ND	ND	ND	ND	ND	ND	ND
28	Dieldrin mg/l	ND	ND	ND	ND	ND	ND	ND	ND	ND
29	Linden mg/l	ND	ND	ND	ND	ND	ND	ND	ND	ND
30	DDT mg/l	ND	ND	ND	ND	ND	ND	ND	ND	ND

Note : G1 : Bramhapuram, G2 : Eloor, G3 : CEPZ (Cochin export processing zone), G4 : Kalamassery, G5 : Ambala mugal, G6 : Pattencherry, G7 : Edayar

Table 11: Groundwater quality results of Kochi for the month of May 2002

S. No.	Location	pH	Conductivity M.Mhos/cm	Total Hardness	Fluoride	Chloride	Sodium	Nitrate	Phospates	Calcium	Magnesium	TDS	Cyanide	Sulphate	Alkalinity	F.Colform	T. Coliform
1.	Bramapuram	6.6	930	192	0.24	200	106	1.1	ND	52	14.88	816	ND	43	10	2160	2000
2.	Eloor	7.15	500	90	0.15	18	13.6	1.73	ND	28	4.8	446	ND	67	12	4	Nil
3.	EPZ	5.09	57	14	0.07	14	5.6	1.39	ND	1.6	2.4	120	ND	ND	8	350	50
4.	Kamalasery	4.64	172	30	0.08	26	19.4	0.91	ND	9.6	1.44	228	ND	3	10	10	Nil
5.	Ambalamugal	5.8	120	36	0.09	20	9.9	0.27	ND	3	5.28	128	ND	9	16	160	10
6.	Mattencherry	6.9	950	310	0.10	118	49	2.55	ND	108	9.6	508	ND	25	190	1600	280
7.	Edayar	5.65	960	380	0.47	90	69	0.90	ND	80	43.2	570	ND	215	30	Nil	Nil

Note: All Parameters are given in mg/L Expect pH and Conductivity (m/S/M) Total Coliform (Coliform colonies per 100 ml) ND : Not detectable

Table 12 : GROUNDWATER QUALITY RESULTS OF KOCHI FOR THE MONTH OF MAY 2002 (HEAVY METALS AND PESTICIDE)

Code	Mercury	Nickel	Zinc	Lead	Arsenic	Cadmium	Copper	Iron	Manganese	Aldrin	Dieldrin	Linden	DDT	Chromium
1.	ND	ND	384	ND	ND	48	ND	243	111	ND	ND	ND	ND	ND
2.	ND	3.13	106	ND	ND	6	ND	224	188	ND	ND	ND	ND	ND
3.	ND	ND	605	ND	ND	43	ND	348	301	ND	ND	ND	ND	ND
4.	ND	18.63	22418	66.25	ND	531	110	525	1258	ND	ND	ND	ND	ND
5.	ND	11.13	1427	117.5	ND	61	166	196	106	ND	ND	ND	ND	ND
6.	ND	ND	302	ND	ND	ND	ND	219	122	ND	ND	ND	ND	ND
7.	ND	ND	118	12.5	ND	ND	23	197	96	ND	ND	ND	ND	ND

Note: All Parameters are given in mg/l Total Coliform (Coliform colonies per 100 ml) ND: Not detectable

Table 13: GROUNDWATER QUALITY RESULTS OF KOCHI FOR THE MONTH OF SEPTEMBER 2001 HEAVY (METALS AND PESTICIDE)

Code	T.Coliform	Mercury	Nickel	Zinc	Lead	Arsenic	Cadmium	Copper	Iron	Manganese	Aldrin	Dieldrin	Linden	DDT	Chromium
1.	550	ND	ND	50	ND	ND	ND	ND	ND	20	ND	ND	ND	ND	ND
2.	100	ND	ND	120	ND	ND	ND	ND	ND	20	ND	ND	ND	ND	ND
3.	320	ND	ND	50	ND	ND	ND	ND	700	590	ND	ND	ND	ND	ND
4.	130	ND	ND	130	ND	ND	ND	ND	70	30	ND	ND	ND	ND	ND
5.	70	ND	ND	80	ND	ND	ND	ND	50	40	ND	ND	ND	ND	ND
6.	50	ND	ND	130	ND	ND	ND	ND	ND	350	ND	ND	ND	ND	ND
7.	10l	ND	ND	23200	ND	ND	ND	ND	80	3740	ND	ND	ND	ND	ND

Note : All Parameters are given in μg/lt. Expect Total Coliform (Coliform colonies per 100 ml) ; ND : Not detectable

Table 14: GROUNDWATER QUALITY RESULTS OF MANALI AREA (Contd../-)

Sl. No.	Location code	M1			M2			M3		
	Parameters	**Min**	**Max**	**Avg.**	**Min**	**Max**	**Avg**	**Min**	**Max**	**Avg.**
BACTERIOLOGICAL PARAMETERS										
1	T. coliform	70	80	75	5000	5000	5000	30000	50000	40000
2	F. coliform	50	80	65	3000	5000	4000	17000	22000	19500
HEAVY METALS										
1	Copper	0.0	0.3.625	0.123	0.0	0.2	0.068	0.0	2.625	0.877
2	Cadmiun	0.0	0.0525	0.018	0.0	0.0175	0.0064	0.0	0.015	0.006
3	Zinc	0.0	6.145	3.073	0.0235	0.08	0.045	0.0	1.05	0.363
4	Manganese	0.1183	0.80	0.521	0.14	2.512	0.935	0.0	35.01	11.764
5	Nickel	0.0	0.0125	0.0042	0.0	0.0023	0.0008	0.0	0.0	0.0
6	Lead	0.0	0.0	0.0	0.0	0.04	0.013	0.0	0.0078	0.003
7	T-Chromium	0.0	0.0128	0.0043	0.0	0.0035	0.0012	0.0	0.0068	0.0023

Note : All Parameters are given in μg/lt. Expect Total Coliform (Coliform colonies per 100 ml) ; ND : Not detectable

Table 14: GROUNDWATER QUALITY RESULTS OF MANALI AREA (Contd/-…)

Sl	Location code	M4			M5			M6		
	Parameters	**Min**	**Max**	**Avg.**	**Min**	**Max**	**Avg**	**Min**	**Max**	**Avg.**
BACTERIOLOGICAL PARAMETERS										
1	Total coliform	5000	5000	5000	3000	3000	3000	800	900	850
2	Feacal coliform	20	2800	1410	800	3000	1900	500	800	650
HEAVY METALS										
1	Copper	0.0	0.475	0.161	0.0	0.005	0.0017	0.0	1.1625	0.39
2	Cadmiun	0.0	0.13	0.044	0.0	0.05	0.017	0.0	0.01	0.003
3	Zinc	0.0268	0.19	0.108	0.0	1.3125	0.443	0.0	0.465	0.175
4	Manganese	0.0	8.28	4.24	0.164	5.042	2.740	0.04	0.690	0.320
5	Nickel	0.0	0.0975	0.0325	0.0	0.002	0.0007	0.0	0.0	0.0
6	Lead	0.0	0.0053	0.002	0.0	0.0333	0.0111	0.0	0.0	0.0
7	T-Chromium	0.0	0.022	0.0073	0.0	0.006	0.0087	0.0	0.0053	0.002

Table 15: GROUNDWATER QUALITY RESULTS OF MANALI AREA

Sl	Location code	M1			M2			M3		
	Parameters	Min	Max	Avg.	Min	Max	Avg	Min	Max	Avg.
01	PH	7.4	7.6	7.5	7.3	7.6	7.4	7.2	7.8	7.5
02	Conductivity	3090	4950	4020	1820	2250	2035	1260	5650	3455
03	TDS	2018	3058	2434	1128	1150	1137	420	3101	1506
04	Alkalinity	354	506	413	323	360	345	92	360	225
05	T. Hardness	234	924	480	171	363	251	137	1170	530
06	C. Hardness	154	600	320	91	342	201	123	700	363
07	Mg. Hardness	27	324	160	21	80	50	14	470	167
08	Chlorides	268	1076	601	63	225	164	295	1410	862
09	Sulphates	464	667	560	270	450	352	38	922	389
10	Nitrate-N	11.1	49	25	1.3	2	1.73	1.9	10	4.72
11	Sodium	600	688	640	384	436	401	64	552	262
12	Fluoride	0.017	0.99	0.36	0.01	0.76	0.27	0.012	0.80	0.34
13	Cyanide	0.0	0.076	0.028	0.0	0.013	0.008	0.0	0.013	0.004
14	Phosphate	0.022	0.61	0.32	0.43	0.64	0.546	0.33	1.58	0.810

Note : All Parameters are given in mg/l expect pH and Conductivity (Micro Mhos /cm), ND : Not detectable

Table 16: GROUNDWATER QUALITY RESULTS OF MANALI AREA

GROUNDWATER QUALITY RESULTS OF MANALI AREA FOR THE MONTH OF SEPTEMBER, 2001														
Name of Locations	pH	Conduc-tivity	TDS	Alkalinity	Total Hard.	Calcium Hard.	Mg. Hard.	Chloride	Sulfate	NO3-N	Sodium	Fluoride	Cyanide	Phos-phate
Borewell nr. Councillor House, Rajendraprasad St., Manali	7.6	3.09	2226	380	282	154	25	460	667	11.1	632	0.083	0.076	0.022
T.Gurusamy House, New Town, Borewell Manali	7.4	1.82	11.28	323	171	90.72	81	225	336.9	1.3	384	0.033	0.0119	0.43
Dug Well nr.Manikandan House, Vinayagar Koil, Kanniammanpettai, Manali	7.6	1.26	996	92	282	266	4	295	208.2	1.9	170	0.21	0.0003	0.33
Hand Pump at Veeran House, Maria mman Koil St., Elandanur, Manali	6.4	4.5		530	1320	966	83	995	878.7	2.7	672	0.052	0.423	0.17
Dug Well at Gangaimman Koil, Sadayankuppam	7.4	3.97	3050	248	393	196	46	1395	371.6	5.9	896	0.02	0.0182	0.394
Borewell at Subramanian House, II Cross Jothinagar, Thiruvottiyur, Manali	7.6	2.58	2248	98	504	378	29	470	402.9	2.9	432	0.01	0.0063	0.007

Note : All Parameters are given in mg/l expect pH and Conductivity (Mili mhos /cm. ND : Not detectable

Table 17: GROUNDWATER QUALITY RESULTS OF MANALI AREA FOR THE MONTH OF SEPTEMBER, 2001

Name of Locations	Cu	Cd	Zn	Mn	Ni	Pb	Total Cr
Borewell nr. Councillor House, Rajendraprasad St., Manali	0.007	ND		0.1183	ND	ND	0.0128
T.Gurusamy House, New Town, Borewell Manali	0.004	0.0018	0.0235	0.1518	0.0023	0.04	0.0035
Dug Well nr.Manikandan House, Vinayagar Koil, Kanniammanpettai, Manali	0.0065	0.0025	0.0395	0.2818	ND	0.0078	0.0068
Hand Pump at Veeran House, Maria mman Koil St., Elandanur, Manali	0.0093	0.001	0.0268	4.425	ND	0.0053	0.022
Dug Well at Gangaimman Koil, Sadayankuppam	0.005	0.0015	0.0163	0.164	ND	0.0333	0.006
Borewell at Subramanian House, II Cross Jothinagar, Thiruvottiyur, Manali	0.0075	ND	0.0595	0.2285	ND	ND	0.0053

Note : All Parameters are given in mg/l. ND : Not detectable

Table 18: GROUNDWATER QUALITY RESULTS OF MANALI AREA FOR THE MONTH OF JANUARY 2002

MICROBIAL EXAMINATION RESULTS FOR MANALI AREA - JANUARY, 2002		
Name of Locations	**Total Coliform**	**Faecal Coliform**
Borewell nr. Councillor House, Rajendra Prasad St, Manali	70	50
T.Gurusamy House, New Town, Borewell, Manali	5000	3000
Dug Well nr.Manikandan House, Vinayagar Koil, Kanniammanpettai, Manali	30000	22000
Hand Pump at Veeran House, Mariamman Koil St, Elandanur, Manali	5000	2800
Dug Well at Gangaimman Koil, Sadayankuppam	3000	800
Borewell at Subramanian House, II Cross Jothinagar, Thiruvottiyur, Manali	900	500

Table 19: GROUNDWATER QUALITY RESULTS OF MANALI AREA FOR THE MONTH OF JANUARY 2002

Name of Locations	pH	TDS	T. Hard	Ca Hard	Chloride	SO4 2	NO3 N	T. Alkal.	Fluoride	Phosphate	Cyanide	Sodium
Borewell nr. Councillor House, Rajendraprasad St., Manali	7.4	2018	234	207.2	268	550	14.4	506	0.017	0.61	0.0072	688
T.Gurusamy House, New Town, Borewell Manali	7.3	1150	363	341.6	63.1	270	1.89	360	0.01	0.64	0.013	384
Dug Well nr.Manikandan House, Vinayagar Koil, Kanniammanpettai, Manali	7.8	420	137	123.2	1410	38	2.25	222	0.012	1.58	0.0105	64
Hand Pump at Veeran House, Maria mman Koil St., Elandanur, Manali	6.4	3960	1504	1092	28.7	1020	4.1	242	0.02	0.02	0.0472	592
Dug Well at Gangaimman Koil, Sadayankuppam	7.6	428	121	112	1220	84	0.19	32	0.004	0.03	0.0092	56
Borewell at Subramanian House, II Cross Jothinagar, Thiruvottiyur, Manali	7.6	2174	637	442	127	106	2.86	130	0.022	0.01	0.0088	424

Note : All Parameters are given in mg/l expect pH and Conductivity (Mili mhos /cm). ND : Not detectable

Table 20: GROUNDWATER QUALITY RESULTS OF MANALI AREA FOR THE MONTH OF JANUARY 2002

HEAVY METAL ANALYSIS RESULTS FOR MANALI AREA-JANUARY 2002							
	Cu	Cr	Cd	Mn	Ni	Pb	Zn
Borewell Nr. Councilor House, Rajendraprasad St., Manali	ND	ND	0.0525	0.645	ND	ND	ND
T. Gurusamy House, New Town Borewell, Manali	ND	ND	0.0175	0.14	ND	ND	0.03
Dug well Nr. Manigandan House, Vinayagar Koil, Kanniammanpettai, Manali	ND	ND	0.015	ND	ND	ND	ND
Hand pump at Veeran House, Mariamman Koil St., Elandanur, Manali	ND	ND	0.13	ND	0.0975	ND	0.1075
Dug well at Gangaimman Koil, Sadayankuppam	ND	0.02	0.05	3.015	ND	ND	1.3125
Borewell at Subramaniyan House, II Cross, Jothi Nagar, Thiruvottiyur, Manali	ND	ND	0.01	0.04	ND	ND	ND

Note : All Parameters are given in µg/lt. ND : Not detectable

Table 21: GROUNDWATER QUALITY RESULTS OF MANALI AREA FOR THE MONTH OF MAY 2002

GROUNDWATER QUALITY RESULTS OF MANALI AREA FOR THE MONTH OF MAY, 2002														
Name of Locations	PH	Conduc-tivity	TDS	Total Hard.	Ca Hard.	Mg. Hard.	Chloride	Sulfate	Nitrate N	Total Alkalinity	Fluo-ride	Cyanide	Phosp hate	Sodium
Borewell nr. Councillor House, Rajendraprasad St., Manali	7.5	4950	3058	924	600	324	1076	464	49	354	0.99	0.0	0.320	600
T.Gurusamy House, New Town, Borewell Manali	7.6	2250	1134	220	170	50	204	450	2	352	0.76	0.0	0.568	436
Dug Well nr.Manikandan House, Vinayagar Koil, Kanniammanpettai, Manali	7.2	5650	3101	1170	700	470	881	922	10	360	0.80	0.0	0.514	552
Hand Pump at Veeran House, Maria mman Koil St., Elandanur, Manali	6.8	5800	3547	0350	660	690	841	1199	15	372	1	0.0	0.145	522
Dug Well at Gangaimman Koil, Sadayankuppam	7.1	800	407	152	114	38	52	147	3	156	0.56	0.0355	0.229	120
Borewell at Subramanian House, II Cross Jothinagar, Thiruvottiyur, Manali	7.3	4100	2309	620	170	350	969	101	6	117	0.22	0.009	0.013	400

Note: All Parameters are given in mg/l expect pH and Conductivity (Mili mhos /cm). ND: Not detectable

Table 22: HEVAY METAL ANALYSIS RESULTS FOR MANALI - MAY, 2002

Name of Location	Cu	Cd	Zn	Mn	Ni	Pb	Cr	Fe
Borewell nr. Councilor House, Rajendraprasad st., Manali	0.3625	0	6.145	0.8	0.0125	0.0	0.0	5.5775
T. Gurusamy House, New Town Borewell, Manali	0.2	0	0.08	2.512	0.0	0.0	0.0	6.43
Dug well near Manigandan House, Vinayagar Koil, Kanniammanpettai, Manali	2.625	0	1.05	35.01	0.0	0.0	0.0	16.5
Hand pum at Veeran House, Mariamman Koil st, Elandanur, Manali	0.475	0	0.19	8.28	0.0	0.0	0.0	97.1
Dug well at Gangaimman Koil, Sadayankuppam	0.0	0	0.0	5.042	0.002	0.0	0.0	6.60
Borewell at Subramaniyan House, II Cross, Jothi Nagar, Thiruvottiyur, Manali	1.1625	0	0.465	0.69	0.0	0.0	0.0	11.7

Note : All parameters are expressed in mg/l.

Table 23: GROUNDWATER QUALITY RESULTS OF VELLORE AREA

SUMMARY STATEMENT FOR HEAVY METALS IN VELLORE DISTRICT OF TAMIL NADU

	Location	V1			V2			V3			V4			V5			V6			V7		
	Parameters	Min	Max	Mean	Min	Max	Mean	Min	Max.	Mean	Min.	Max.	Mean	Min	Max.	Mean	Min.	Max.	Mean	Min.	Max.	Mean
1	Copper	0.09	0.36	0.23	0	0.98	0.49	0.15	1.76	0.96	0	0.46	0.23	0	0.08	0.04	0	0.82	0.41	0	0.19	0.1
2	Chromium	0	0.38	0.19	0	0.01	0.01	0	0.19	0.1	0	0.02	0.01	0	0.05	0.03	0	0.04	0.02	0	0.02	0.01
3	Cadmium	0	0.07	0.04	0	0.14	0.07	0	0.35	0.18	0	0.15	0.08	0	0.013	0.07	0	0.22	0.11	0	0.07	0.04
4	Manganese	0.03	0.03	0.03	0	0.02	0.01	0.003	2.63	1.32	0	0	0	0	0	0	0.01	0.87	0.44	0	0.04	0.02
5	Nickel	0	0.03	0.02	0.01	0.35	0.18	0.01	1.57	0.79	0	0.3	0.15	0	0.14	0.07	0.01	0.51	0.25	0	0	0
6	Lead	0.02	0.14	0.08	0	0.03	0.02	0	0	0	0	0	0	0	0	0	0	5.88	2.94	0	0	0
7	Zinc	0.15	1.01	0.58	0.02	0.39	0.21	0.02	0.7	0.36	0	0.7	0.35	0.03	0.03	0.03	0.09	0.33	0.21	0.11	0.33	0.22
8	Iron	-	-	6.36	-	-	18.16	-	-	11.44	-	-	13.43	-	-	13.03	-	-	8.91	-	-	9.18

SUMMARY STATEMENT FOR PHYSICO-CHEMICAL AND BACTERIOLOGICAL PARAMETERS IN VELLORE DISTRICT OF TAMIL NADU

	Location	V8			V9			V10			V11			V12			V13			V14		
	Parameters	Min.	Max.	Mean	Min	Max.	Mean	Min	Max.	Mean	Min.	Max.	Mean	Min.	Max.	Mean	Min.	Max.	Mean	Min.	Max.	Mean
1	PH	7	7.1	7.06	6.6	7.7	7.06	7	7.6	7.23	7.3	7.6	7.43	7.1	7.6	7.33	7.3	7.4	7.36	7.14	7.6	7.41
2	Conductivity	-	-	830	-	-	8900	-	-	880	-	-	1280	-	-	16000	-	-	6950	-	-	3150
3	TDS	533	9062	3844	358	6419	2500	556	646	588	723	1472	1118	3950	8568	6557	1512	3916	2467	1402	4426	3229
4	T-Hardness	244	2691	1680	69	2650	1007	198	333	279	333	363	345	1605	3030	2291	480	1210	748	312	1523	1085
5	Ca-Hardness (as $caco_3$)	206	1406	808	44.8	1440	565	168	286	213	200	330.4	250.8	820	1232	983	454	480	465	160	1106	692
6	Mg Hardness	440	1210	825	14	22	18	39	140	90	26	2210	1118	235	730	483	22	152	87	100	237	214
7	T-Alkalinity	180	200	187	64	200	128	160	284	205	256	396	328	164	459	351	206	650	391	300	509	410
8	Chloride	111	2812	1462	52	2397	1225	44.02	128	86	111	286	199	2374	3644	3009	500	1320	910	356	1299.5	828
9	Sulphate	3.6	349	141.2	19.4	434	163.5	51.5	90	74	78	158.9	115	600	1062	832	108	637	303	199	554	381
10	Nitrate- N	3	53.3	37	1.81	56	23.2	3.64	8	5.3	31	51.7	43.5	33.3	43.7	40	21.1	64	38	38	71.4	59.1
11	Fluoride	0.012	1.08	0.376	0.001	0.77	0.308	0.03	0.71	0.276	0.004	1.14	0.403	0.02	1.02	0.37	0.019	1.2	0.425	0.032	1.03	0.382
12	Cyanide	0.0086	0.0186	0.0124	0.0045	0.03	0.017	0	0.243	0.1245	0	0.0158	0.011	0	0.0158	0.0133	0	0.006	0.0039	0	0.0074	0.0054
13	Phosphate	0.02	0.151	0.087	0.021	0.11	0.057	0.006	0.11	0.047	0.19	1.37	0.65	0.014	0.11	0.051	0.029	0.3	0.178	0.96	0.1	0.08
14	Sodium	64	832	531	22	82	55.3	88	108	96	112	280	203	120	1700	1039	472	800	584	400	760	615.3
15	Total Coliform	5000	9000	7000	110	140	125	2	90	46	30000	50000	40000	2400	2800	2600	1300	1400	1350	14000	16000	15000
16	F. Coliform	2200	5000	3600	70	80	75	2	26	14	24000	30000	27000	1300	1700	1500	1100	1300	1200	9000	11000	10000

Contd....

SUMMARY STATEMENT FOR HEAVY METALS IN VELLORE DISTRICT, TAMIL NADU

	Location	V8			V9			V10			V11			V12			V13			V14		
	Parameters	Min.	Max.	Mean	Min	Max.	Mean	Min	Max.	Mean	Min.	Max.	Mean	Min.	Max.	Mean	Min.	Max.	Mean	Min.	Max.	Mean
1	Copper	-	0.2	0.2	-	-	-	-	-	-	-	-	-	-	-	-	-	-	1.6225	-	-	0.0275
2	Chromium	0.0375	10.44	5.238	-	-	3.735	-	-	14.81	-	-	-	-	-	0.175	-	-	0.0475	-	-	0.085
3	Cadmium	0	0.155	0.078	-	-	-	-	-	0.0175	-	-	0.035	-	-	0.06	-	-	0.04	-	-	0.1125
4	Manganese	0.06	1.95	1.01	-	-	-	-	-	2.08	-	-	-	-	-	-	-	-	0.6325	-	-	
5	Nickel	0.002	0.2875	0.144	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	0.0525
6	Lead	0	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	0.6225	-	-	-
7	Zinc	0.08	0.11	0.095	-	-	0.0275	-	-	0.175	-	-	0.335	-	-	0.01	-	-	0.735	-	-	2.2825
8	Iron	-	9.96	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-

Table 24: GROUNDWATER QUALITY RESULTS OF VELLORE AREA FOR THE MONTH OF SEPTEMBER 2001

MICROBIAL EXAMINATION RESULTS FOR VELLORE DISTRICT - SEPTEMBER 2001		
Name of Locations	Total Coliform	Faecal Coliform
Ranipet Library opposite	40	40
TCL Anna nagar Sipcot, Ranipet	230	130
Yembrodu Nagar, Jayavel House, Ranipet	700	500
Chitran Vajram Factory well Mardhangal, Amboor Road, Ranipet	2200	1100
Munisamy House, Mahavir Road, Kudiyatham	50000	30000
Nr. Sumangali Cinema Tent Dug Well, Peranampet	30000	30000
Borewell at Maswood & ETP Company,Peranampet	16000	5000
Annamalai Chettiar Dug Well, Chinna Thamma Cheruvu	9000	5000
A.R. Kumar Naidu Well, Ambur Road,Periyavaraikkam	110	80
Panchayat Dug Well, Periyavaraikkam	< 2	< 2
Hand Pump at Vengata Samudram nr. Microwave Tower	50000	30000
Rajratnam Open well at Solur	2400	1300
Hand Pump at Narajapuram-Kachery Rd, Vaniyambadi	1300	1300
Dug Well at Kudiatham Rd, Vaimbattu, Nr Ration Shop	16000	9000

Note : All Parameters are given in µg/lt. Expect Total Coliform (Coliform colonies per 100 ml) ; ND : Not detectable

Table 25: GROUNDWATER QUALITY RESULTS OF VELLORE AREA FOR THE MONTH OF SEPTEMBER 2001

GROUNDWATER QUALITY RESULTS OF VELLORE DISTRICT FOR THE MONTH OF SEPTEMBER, 2001														
Name of Locations	pH	Conductivity	TDS	Alkalinity	Total Hard.	Ca Hard.	Mg Hard.	Chloride	Sulfate	NO3-N	Sodium	Fluoride	Cyanide	Phosphate
Ranipet Library opposite	7.4	2	856	290	498	444	13	105	92.69	24.9	88	0.075	NIL	0.02
TCL Anna nagar Sipcot, Ranipet	7.1	88.3	5922	250	2068	1109	224	1874	306.3	57.3	624	0.06	0.0018	0.013
Yembrodu Nagar, Jayavel House Ranipet	7.6	77.3	15994	200	4334	2968	320	5573	1589.5	18.1	1920	0.06	0.0295	0.05
Chitran Vajram Factory well Mardhangal Amboor Road, Ranipet	6.6	8.3	14412	250	1633	1400	62	1450	170.1	14.5	464	0.044	0.0058	0.02
Munisamy House, Mahavir Road, Kudiyatham	7.2	1.66	1252	186	252	182	16	500	49.25	15.8	368	0.042	Nil	0.01
Nr. Sumangali CInema Tent Dug Well Peranampet	6.5	20	22416	353	4334	1526	657	8397	792.5	62.3	1960	0.041	0.043	0.06
Borewell at Maswood & ETP Company Peranampet	7.1	1.97	1958	220	484	476	1.87	375	90.9	19.1	70	0.019	Nil	0.022
Annamalai Chettiar Dug Well Chinna Thamma Cheruvu	7.1	4.41	9062	180	2691	812	440	2812	349	53.3	832	0.035	0.0186	0.02
A.R. Kumar Naidu Well, Ambur Road, Periyavaraikkam	6.6	14.3	722	200	302	210	22	52	19.4	11.8	82	0.154	Nil	0.04
Panchayat Dug Well, Periyavaraikkam	7	6.02	646	160	333	168	39	128	51.5	3.64	88	0.088	0.243	0.006
Hand Pump at Vengata Samudram near Microwave Tower	7.4	1.24	1472	256	333	222	26	286	158.9	51.7	280	0.065	0.0015	0.38
Rajratnam Open well at Solur	7.1	8.16	7152	430	2238	1232	235	2374	805.9	43.7	1296	0.06	0.0158	0.014
Hand Pump at Narajapuram-Kachery Rd, Vaniyambadi	7.4	3.01	1912	650	554	462	22	500	165	21.1	480	0.056	0.0018	0.206
Dug Well at Kudiatham Rd, Vaimbattu Nr Ration shop	7.5	5.04	4426	420	1532	1106	100	1299.5	554	68	680	0.083	0.0034	0.1

Note : All Parameters are given in mg/l expect pH and Conductivity (Mili mhos /cm). ND: Not detectable

Table 26: GROUNDWATER QUALITY RESULTS OF NORTH ARCOT (VELLORE) AREA FOR THE MONTH OF JANUARY 2002

GROUNDWATER QUALITY RESULTS OF VELLORE DISTRICT FOR THE MONTH OF JANUARY, 2002												
Name of Locations	pH	TDS	Total Hard.	Cal. Hard.	Chloride	SO_4	NO3-N	Total Alkalinity	Fluoride	Phosphate	Cyanide	Sodium
Ranipet Library opposite	7.4	1030	512	342	12450	90	35.5	208	0.03	0.04	0.008	90
TCL Anna nagar Sipcot, Ranipet	7.4	92	1855	1081	69100	308	70.2	72	0.02	0.04	0.0102	680
Yembrodu Nagar, Jayavel House Ranipet	6.8	160	3165	1058	15000	1500	21.6	128	0.018	0.04	0.0249	2520
Chitran Vajram Factory well Mardhangal Amboor Road, Ranipet	6.9	1788	2165	1092	11000	228	21.7	174	0.013	0.06	0.0099	600
Munisamy House, Mahavir Road, Kudiyatham	6.7	2850	996	1036	3210	132	34.8	106	0.01	0.05	0.0069	800
Nr. Sumangali Cinema Tent Dug Well Peranampet	6.8	2614	2060	969	519	196	30	152	0.013	0.05	0.0104	816
Borewell at Maswood & ETP Company Peranampet	7.4	2078	738	846	2670	102	20.1	172	0.011	0.05	0.0048	144
Annamalai Chettiar Dug Well Chinna Thamma Cheruvu	7.1	1938	2105	1406	316	3.6	53.3	182	0.012	0.09	0.0086	696
A.R. Kumar Naidu Well, Ambur Road, Periyavaraikkam	7.7	358	69	44.8	189	37	1.81	64	0.001	0.11	0.0045	22
Panchayat Dug Well, Periyavaraikkam	7.1	556	306	286	294	79	4.4	170	0.03	0.11	0.0098	108
Hand Pump at Vengata Samudram nr Microwave Tower	7.3	1158	363	330.4	3230	108	47.7	396	0.004	1.37	0.0061	216
Rajratnam Open well at Solur	7.3	3950	1605	896	555	600	33.3	164	0.02	0.11	0.0108	1700
Hand Pump at Narajapuram-Kachery Rd, Vaniyambadi	7.3	1512	480	454	1760	108	28.8	206	0.019	0.3	0.006	472
Dug Well at Kudiatham Rd, Vaimbattu Nr Ration shop	7.14	3860	1419	809	439	390	71.4	300	0.032	0.06	0.0074	760

Note: All Parameters are given in mg/l expect pH and Conductivity (Mili mhos /cm). ND: Not detectable

Table 27: GROUNDWATER QUALITY RESULTS OF VELLORE AREA FOR THE MONTH OF JANUARY 2002

HEAVY METAL ANALYSIS RESULTS FOR VELLORE DISTRICT-JANUARY 2002							
	Cu	Cr	Cd	Mn	Ni	Pb	Zn
Ranipet Library, Opposite	0.0925	0.375	0.065	0.025	ND	0.1375	1.0075
TCL Anna Nagar, Sipcot, Ranipet	ND	0.01	0.1425	ND	0.3475	ND	0.02
Yembrodu Nagar, Jayavel House, Ranipet	0.1525	0.19	0.3525	0.0025	1.5725	ND	0.015
Chitran Vajram Factory well Mardhangal Amboor Rd, Ranipet	ND	0.015	0.15	ND	0.2975	ND	ND
Munisamy House, Mahavir Nagar, Kudiyatham	ND	0.045	0.125	ND	0.1425	ND	0.03
Nr. Sumangali Cinema Tent Dug well Peranampet	ND	0.035	0.215	0.87	0.505	5.875	0.0875
Borewell at Masood & ETP Company Peranampet	ND	0.0175	0.0725	0.0425	ND	ND	0.11
Annamali Chettiyar Dug well Chinna Thamma Cheruvu	ND	0.0375	0.155	0.06	0.2875	ND	0.11
A.R. Kumar Naidu Well, Ambur Rd., Periyavaraikkam	ND	3.735	ND	ND	ND	ND	0.0275
Panchayat Dug well, Periyavaraikkam	ND	14.81	0.0175	2.08	ND	ND	0.175
Hand pump at Vengata Samudram nr. Microwave Tower	ND	ND	0.035	ND	ND	ND	0.335
Rajrathnam open well at Solur	ND	0.175	0.06	ND	ND	ND	0.01
Hand pump at Narajapuram-Kachery Rd, Vaniyambadi	1.6225	0.0475	0.04	0.6325	ND	0.6225	0.735
Dug well at Kudiyatham Rd, Vaimbattu nr. Ration shop	0.0275	0.085	0.1125	ND	0.0525	ND	2.2825

Note: All values are given in mg/l. ND: Not detectable

Table 28: GROUNDWATER QUALITY RESULTS OF VELLORE AREA FOR THE MONTH OF JANUARY 2002

MICROBIAL EXAMINATION RESULTS FOR VELLORE DISTRICT - JANUARY, 2002		
Name of Locations	**Total Coliform**	**Faecal Coliform**
Ranipet Library opposite	230	< 2
TCL Anna nagar Sipcot, Ranipet	1400	330
Yembrodu Nagar, Jayavel House, Ranipet	1100	700
Chitran Vajram Factory well Mardhangal, Amboor Rd, Ranipet	2100	1200
Munisamy House, Mahavir Road, Kudiyatham	30000	22000
Nr. Sumangali Cinema Tent Dug Well, Peranampet	16000	11000
Borewell at Maswood & ETP Company,Peranampet	14000	4000
Annamalai Chettiar Dug Well, Chinna Thamma Cheruvu	5000	2200
A.R. Kumar Naidu Well, Ambur Road, Periyavaraikkam	140	70
Panchayat Dug Well, Periyavaraikkam	90	26
Hand Pump at Vengata Samudram nr. Microwave Tower	30000	24000
Rajratnam Open well at Solur	2800	1700
Hand Pump at Narajapuram-Kachery Rd, Vaniyambadi	1400	1100
Dug Well at Kudiatham Rd, Vaimbattu, Nr Ration Shop	14000	11000

Note: All values are given in colonies per 100 ml

Table 29: GROUNDWATER QUALITY RESULTS OF VELLORE AREA FOR THE MONTH OF May 2002

GROUNDWATER QUALITY RESULTS OF VELLORE DISTRICT FOR THE MONTH OF MAY, 2002														
Name of Locations	pH	Conduc-tivity	TDS	Total Hard.	Ca Hard.	Mg Hard.	Chloride	SO_4	NO3-N	Total Alkali.	Fluoride	Cyanide	PO_4	Sodium
Ranipet Library opposite	7.4	2250	1416	444	396	48	291	187	46	360	0.91	0.0	0.650	226
TCL Anna nagar Sipcot, Ranipet	7.4	7050	5181	2200	1360	1840	2005	352	52	234	0.95	0.26	0.010	736
Yembrodu Nagar, Jayavel House Ranipet	7.8	21800	14839	5400	3560	520	6188	1585	16	198	1.27		0.017	232
Chitran Vajram Factory well Mardhangal Amboor Road, Ranipet	6.8	7100	4192	1470	450	124	1981	209	17	158	1	0.0	0.00	56
Munisamy House, Mahavir Road, Kudiyatham	7.2	2550	1314	132	80	1740	547	692	24	192	0.98	0.0	0.0	504
Nr. Sumangali Cinema Tent Dug Well Peranampet	7.0	9400	6457	2660	920	130	2666	246	35	111	0.65	0.0	0.0	752
Borewell at Maswood & ETP Company Peranampet	7.2	2500	1580	680	550	38	425	90	17	252	0.48	0.0	0.01	88
Annamalai Chettiar Dug Well Chinna Thamma Cheruvu	7.0	830	533	244	206	1210	111	71	3	200	1.08	0.01	0.151	64
A.R. Kumar Naidu Well, Ambur Road, Periyavaraikkam	6.9	8900	6419	2650	1440	14	2397	434	56	119	0.77	0.03	0.021	62
Panchayat Dug Well, Periyavaraikkam	7.6	880	561	198	184	140	44.02	90	8	284	0.71	0.0	0.026	92
Hand Pump at Vengata Samudram nr Microwave Tower	7.6	1280	723	340	200	2210	111	78	31	333	1.14	0.0	0.19	112
Rajratnam Open well at Solur	7.6	16000	8568	3030	820	730	3644	1062	42	459	1.02	0.0	0.03	120
Hand Pump at Narajapuram-Kachery Rd, Vaniyambadi	7.4	6950	3916	1210	480	152	1320	637	64	318	1.20	0.0	0.029	800
Dug Well at Kudiatham Rd, Vaimbattu Nr Ration shop	7.6	3150	1402	312	160	327	356	199	38	509	1.03	0.0	0.08	400

Note: All values are in mg/L except pH and Conductivity (Micro mhos/cm)

Table 30: HEVAY METAL ANALYSIS RESULTS FOR VELLORE DISTRICT - MAY 2002

Name of Location	Cu	Cd	Zn	Mn	Ni	Pb	Cr	Fe
Ranipet Library Opposite	0.3625	0	0.15	0.03	0.03	0.02	0.0	6.36
TCL Anna Nagar, Sipcot, Ranipet	0.98125	0	0.39	0.02	0.01	0.03	0.0	18.16
Yembrodu Nagar, Jayavel House, Ranipet	1.76	0	0.70	2.63	0.01	0.0	0.0	11.44
Chitran Vajram Factory well Mardhangal Amboor Rd, Ranipet	0.46	0	0.18	0.0	0.0	0.0	0.0	13.03
Munisamy House, Mahavir Nagar, Kudiyatham	0.08	0	0.03	0.0	0.01	0.0	0.0	13.10
Nr. Sumangali CinemaTent Dug well Peranampet	0.82	0	0.33	0.005	0.01	0.0	0.0	8.91
Borewell at Masood & ETP Company Peranampet	0.19	0	0.07	0.0	0.0	0.0	0.0	9.18
Annamalai Chettiyar Dug well Chinna Thamma Cheruvu	0.2	0	0.08	1.950	0.002	0.0	10.44	9.96

Table 31) a): Physico-Chemical Characteristics of Groundwater in the Problem area of Ankaleshwar (Gujarat)

Area With field code Limits→	**pH 6.5-8.5**	**TDS 500**	**Cond.**	**TH 300**	**Ca 75**	**Mg 30**	**Alk 200**	**Cl 250**	**SO_4 200**	**PO_4**	**TC**	**FC**	**NO_3-N 45**	**F 1.0**	**Na**
1. Near CETP (B) AK-01															
Round 1	7.6	1270	2100	150	25.6	20.8	454	335	213	0.17	30	BDL	0.46	0.92	400
Round 2	7.5	1148	2020	111	20.8	14.3	402	330	26	0.07	30	BDL	BDL	0.65	67
Round 3	7.4	1520	2500	193	40	22.7	456	382	323	0.003	BDL	BDL	6.3	0.6	496
Round 4	7.6	1388	2100	467	372	94	480	393	278	0.01	BDL	BDL	0.53	0.56	
2. Piramal School (B) AK-02															
Round 1	7.1	2336	3700	367	72.0	45.4	602	690	283	0.13	BDL	BDL	72.9	0.70	610
Round 2	7.2	2044	3620	253	47.6	32.6	20	695	369	BDL	BDL	BDL	65.5	0.41	490
Round 3	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--
Round 4	7.5	1690	2500	565	552	13	340	631	254	0.01	BDL	BDL	5.4	0.56	
3. Bharuch Naka(B) AK-03															
Round 1	7.6	2920	5000	286	46.8	41	556	1133	298	0.55	500	110	31.5	0.4	790
Round 2	7.5	4080	6720	386	72.8	49.6	980	1579	613	0.56	900	110	28.4	0.59	870
Round 3	7.5	3416	5700	380	81.4	70.9	597	1217	489	0.65	130	23	19.9	0.8	720
Round 4	7.7	5270	7600	2033	1396	637	714	2428	965	0.58	BDL	BDL	1.65	0.89	

All Values except pH, Total Colliform (TC), Feacal Colliform (FC) and Conductivity are in mg/ l. BDL – Below detectable limit, B- Bore well and D- Dug well. TC and FC values are in MPN. (--) Sample not collected due to damage of Hand pump.

Table 31) b): Heavy Metals in the Groundwater of Ankaleshwar (Gujarat)

Location	Cr	Pb	Zn	Cd	Ni	Fe	Cu	Mn
Limits →	0.05	0.05	5.00	0.01		0.3	0.05	0.1
1. Near CETP (B)								
Code: AK-01								
Round 1	0.004	0.057	BDL	BDL	BDL	BDL	0.009	BDL
Round 2	BDL	BDL	BDL	BDL	0.012	0.404	0.015	0.007
Round 3	0.051	BDL	BDL	BDL	BDL	0.022	BDL	BDL
Round 4	BDL	BDL	0.038	BDL	0.015	0.065	0.026	0.024
2. Piraman School (B)								
Code: AK-02								
Round 1	0.161	0.06	0.016	BDL	BDL	0.155	0.085	0.089
Round 2	0.015	BDL	0.056	0.004	0.036	5.655	0.107	0.21
Round 3	--	--	--	--	--	--	--	--
Round 4	BDL	0.009	0.030	--	BDL	0.035	0.028	0.005
3.Bharuch Naka (B)								
Code: AK-03								
Round 1	0.147	0.054	ND	0.001	ND	ND	0.087	0.127
Round 2	0.037	ND	ND	0.001	ND	0.022	ND	0.056
Round 3	0.072	BDL	1.157	BDL	BDL	0.245	0.008	0.261
Round 4	BDL	BDL	0.166	0.003	BDL	0.419	0.036	0.0651

(--) Sample not collected due to damage of pump. All Values are expressed in ppm (mg/ l) and BDL – Bellow detectable limit

Figure 1: Groundwater monitoring Survey locations of Ankaleshwar Problem Area

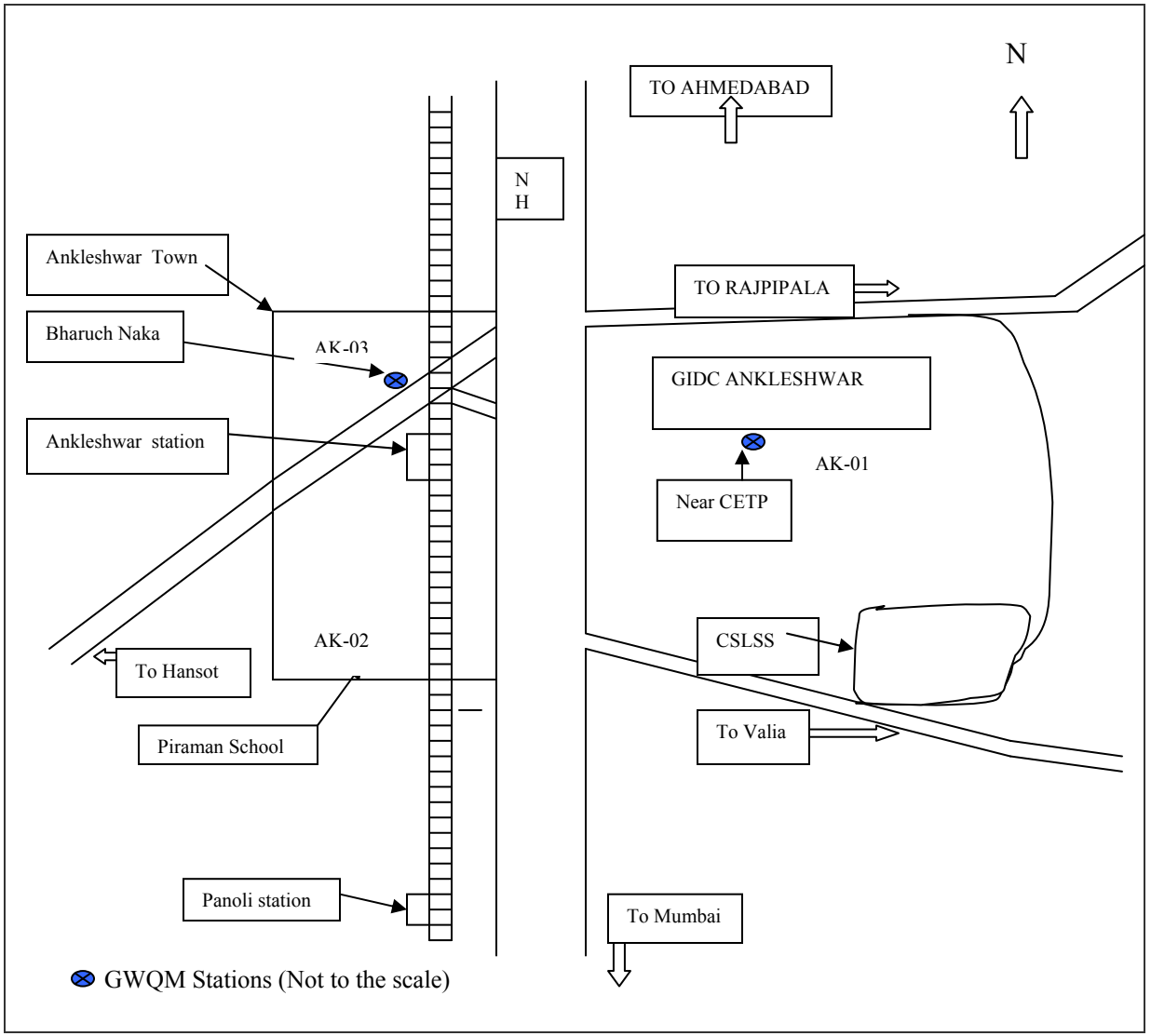
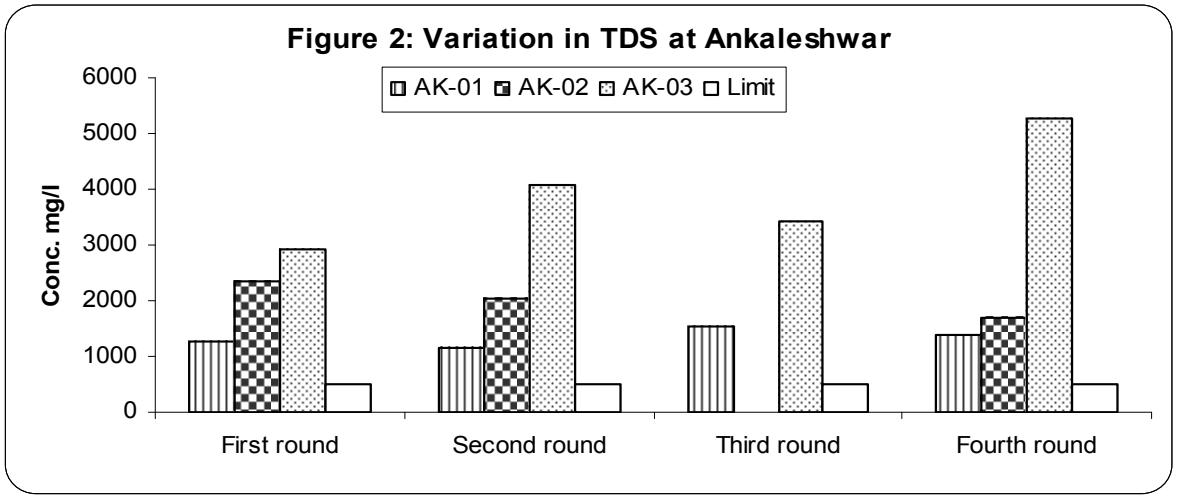


Figure 2) a) : Groundwater Quality graphs for Ankaleshwar



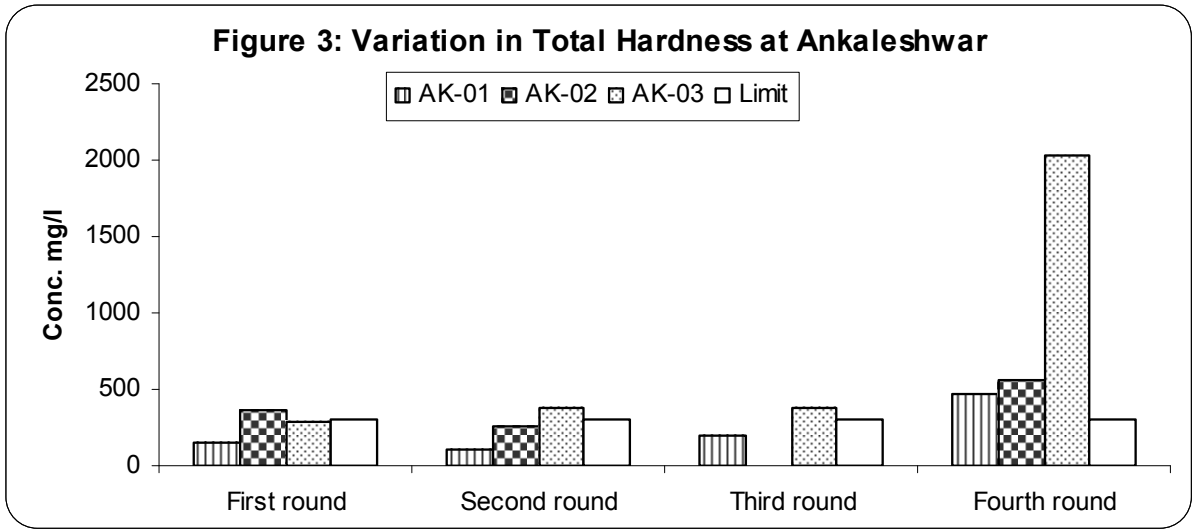
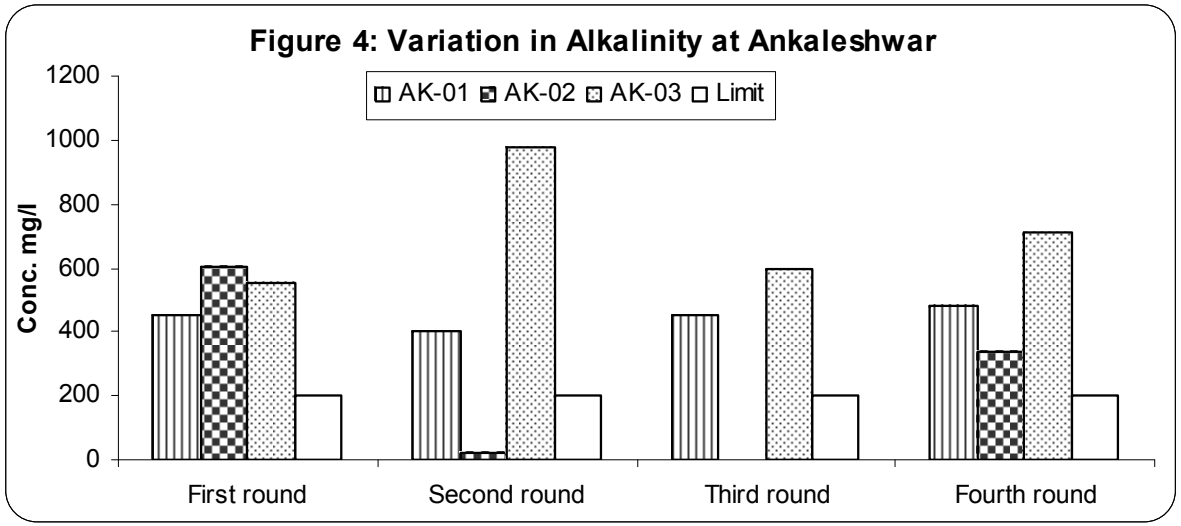


Figure 2) b) : Groundwater Quality graphs for Ankaleshwar



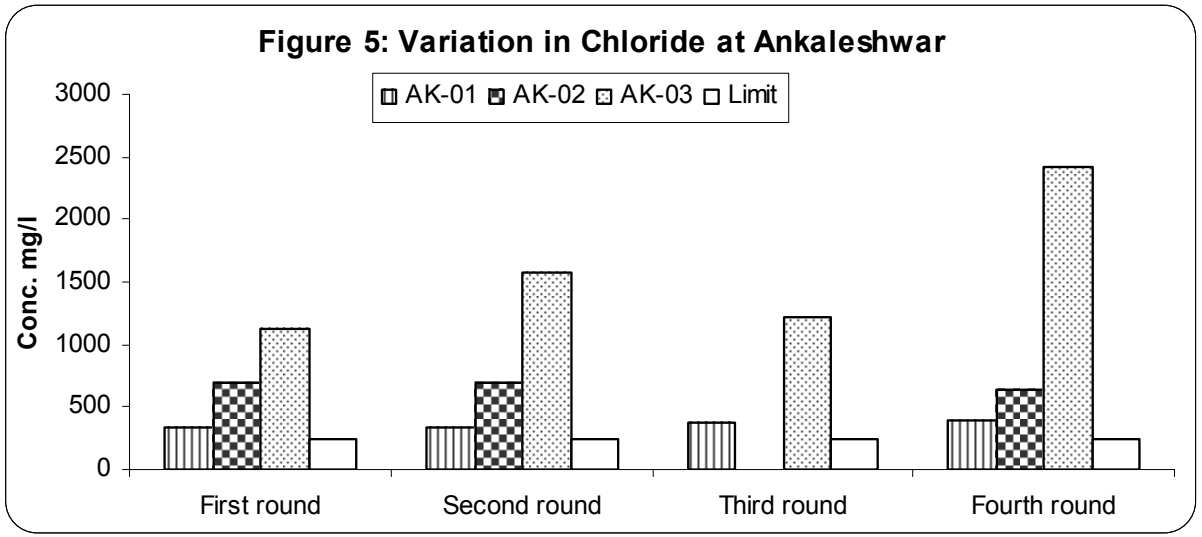
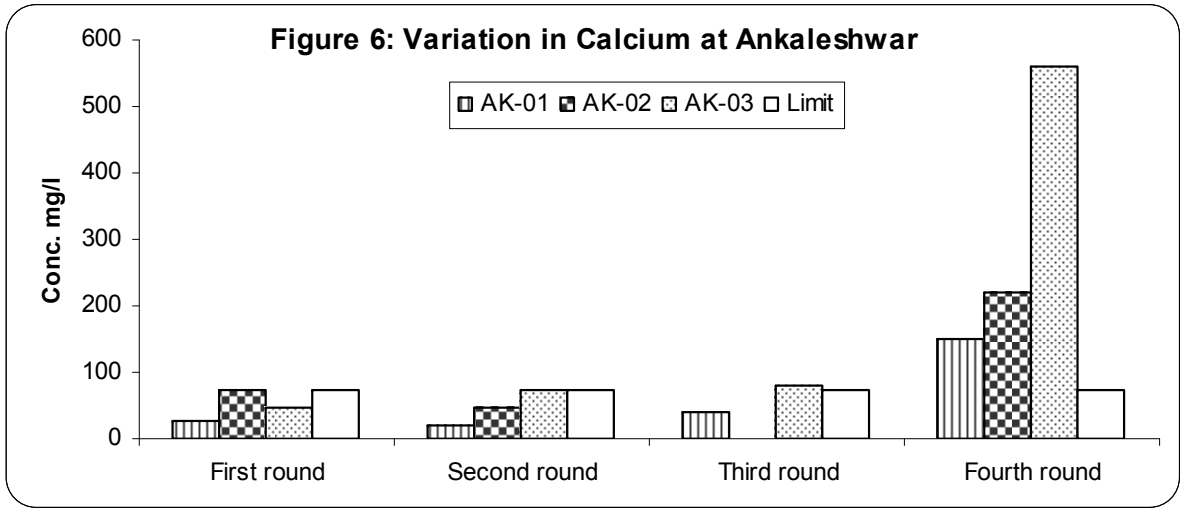


Figure 2) c): Groundwater Quality graphs for Ankaleshwar



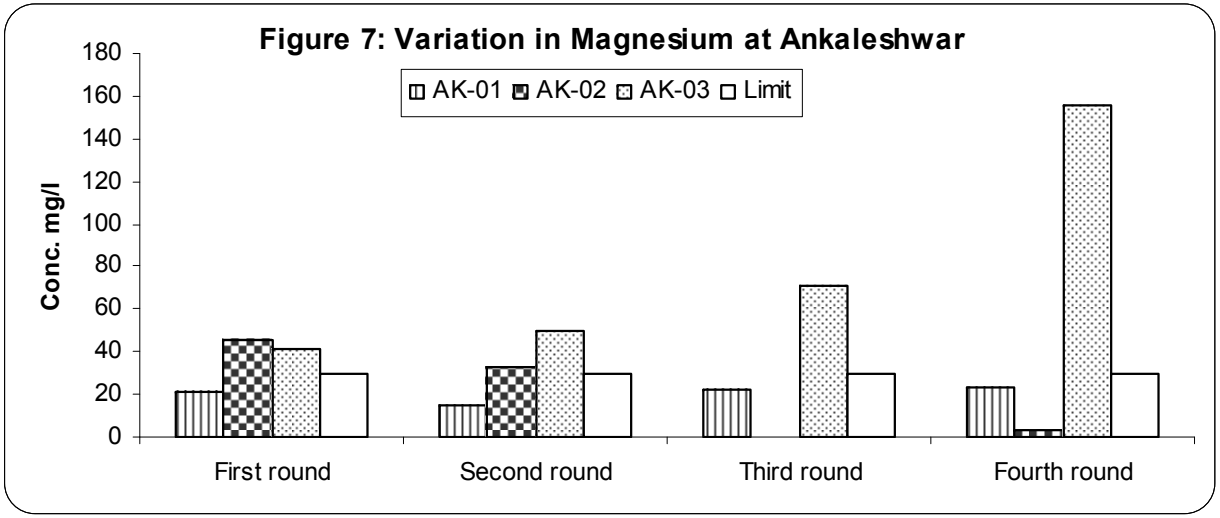
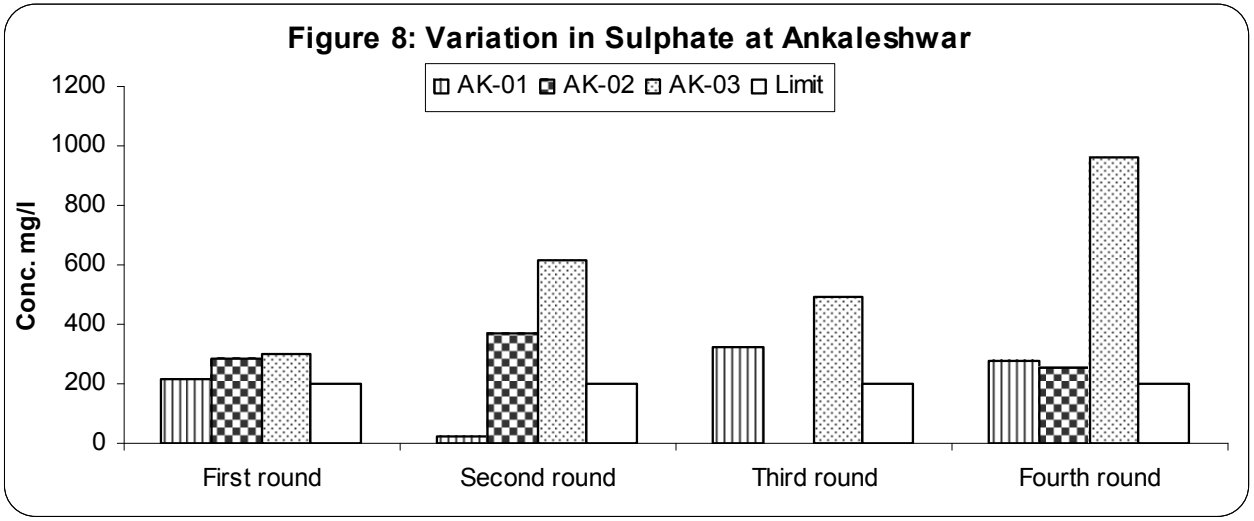


Figure 2) d) : Groundwater Quality graphs for Ankaleshwar



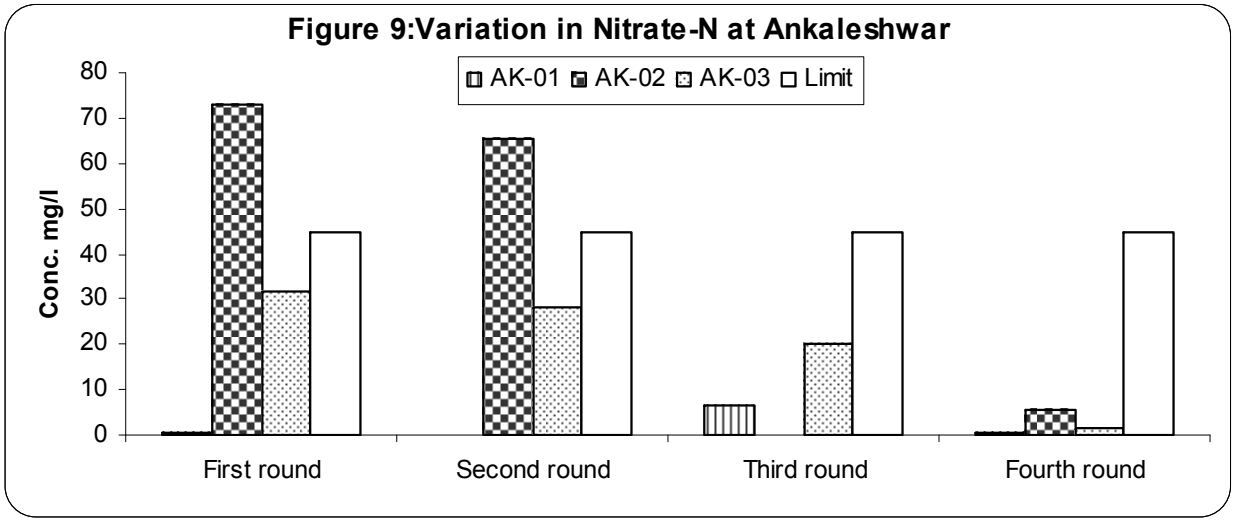


Table 32) a): Physico-Chemical and Microbiological Characteristics of Groundwater of Vapi (Gujarat)

Area / Location With field code Limits→	pH 6.5-8.5	TDS 500	Con	TH 300	Ca 75	Mg 30	Alk 200	Cl 250	SO_4 200	PO_4	TC	FC	NO_3-N 45	F 1.0	Na	CN
1. Near IOC Godown (B) VP-01																
Round 1	7.1	1252	1880	355	81	37	616	217	100	BDL	≥1600	≥1600	42	0.25	81	BDL
Round 2	7.0	964	1910	254	58	27	559	218	73	3.98	BDL	BDL	20	0.29	75	--
Round 3	7.1	1274	1870	354	82	36	508	191	99	0.06	900	30	70.4	0.27	69	--
Round 4	7.3	1206	1660	894	112	150	614	212	81	0.032	23	23	4.2	0.19	62	
2. Charwad road (B) Code: VP-02																
Round 1	7.7	1034	1940	117	22	15	376	355	85	BDL	BDL	BDL	13	1.05	70	BDL
Round 2	7.9	1008	1900	92	18	11	353	365	70	0.04	BDL	BDL	6	1.12	67	--
Round 3	7.9	540	940	88	15	12	189	132	49	0.05	BDL	BDL	5.7	0.27	94	--
Round 4	7.8	1156	1940	334	68	39.9	380	428	85	0.032	30	30	1.3	0.5	292	

Note:All Values except pH, Total Colliform (TC), Feacal Colliform (FC) and Conductivity are expressed in mg/ l. BDL – Bellow detectable limit, B- Bore well and D- Dug well. TC and FC values are in MPN/100ml. Conductivity values are expressed in µmhos/cm.

Table 32) b): Heavy Metals in the Ground Water of Vapi (Gujarat)

Area / Location Limits→	Cr 0.05	Pb 0.05	Zn 5.0	Cd 0.01	Ni	Fe 0.3	Cu 0.05	Mn 0.1
a . Near IOC Godown (B) Code: VP-01								
Round 1	0.325	0.062	0.333	0.001	0.012	0.70	0.019	0.021
Round 2	BDL	BDL	0.196	BDL	0.005	0.704	BDL	0.082
Round 3	0.045	BDL	BDL	BDL	BDL	0.017	0.001	0.167
Round 4	0.002	BDL	BDL	BDL	BDL	0.41	0.018	0.61
b. Charwad road (B) Code: VP-02								
Round 1	0.793	0.048	0.185	0.006	BDL	BDL	0.014	0.073
Round 2	BDL	BDL	0.926	BDL	BDL	0.425	0.003	BDL
Round 3	BDL	BDL	0.515	0.002	BDL	0.737	0.011	BDL
Round 4	BDL	0.003	1.389	BDL	BDL	0.138	0.004	0.007

All Values are expressed in mg/ l. B- Bore well.

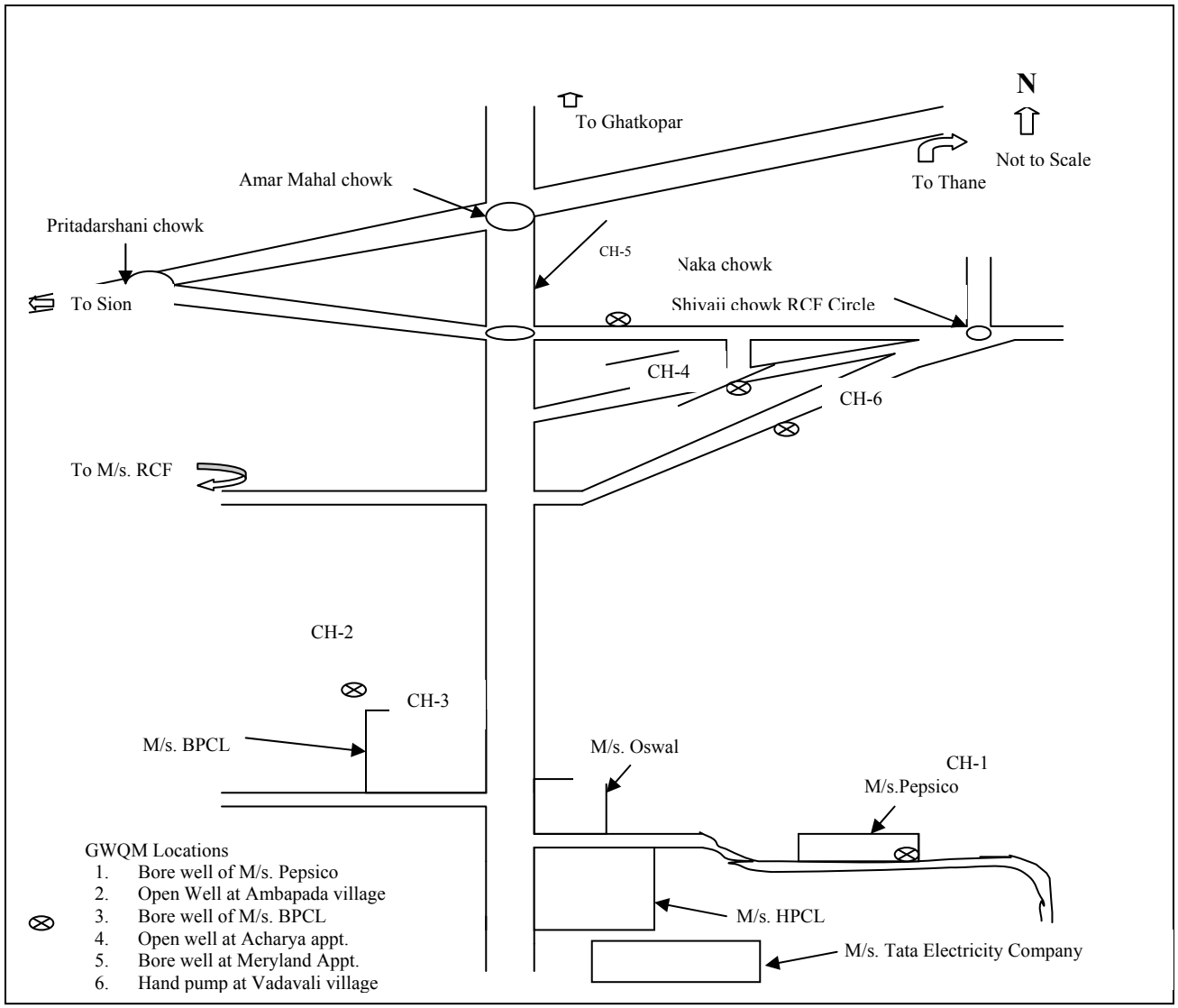
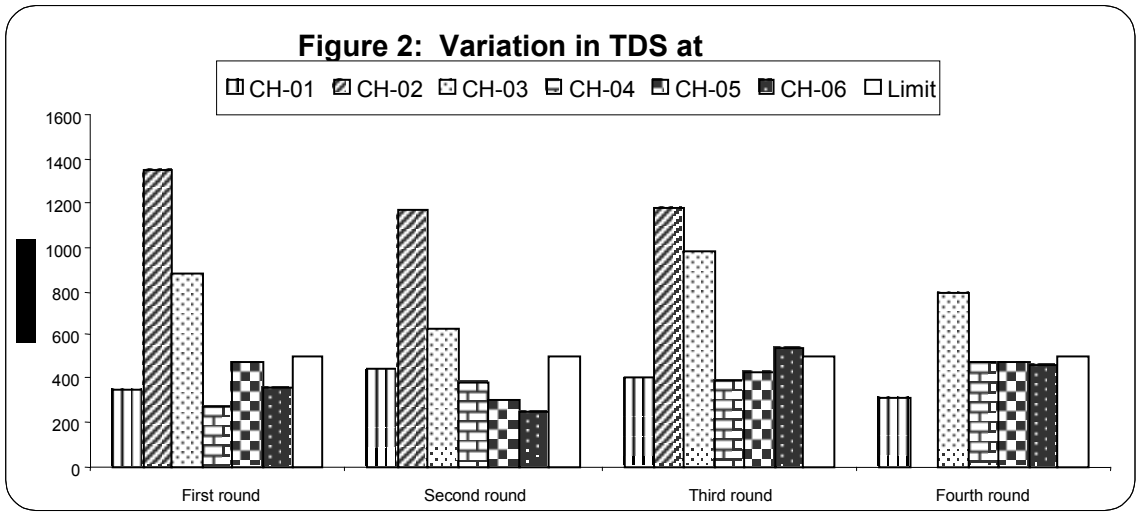


Figure 3: Ground Water Network at Problem area Chembur,

Figure 4) a) Groundwater quality graph of Chembur Problem area



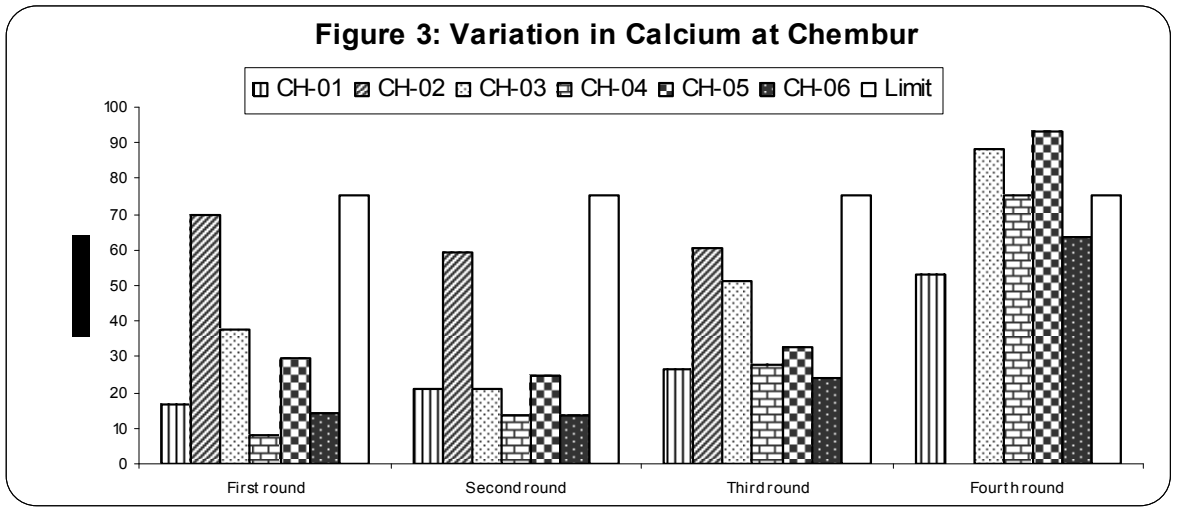
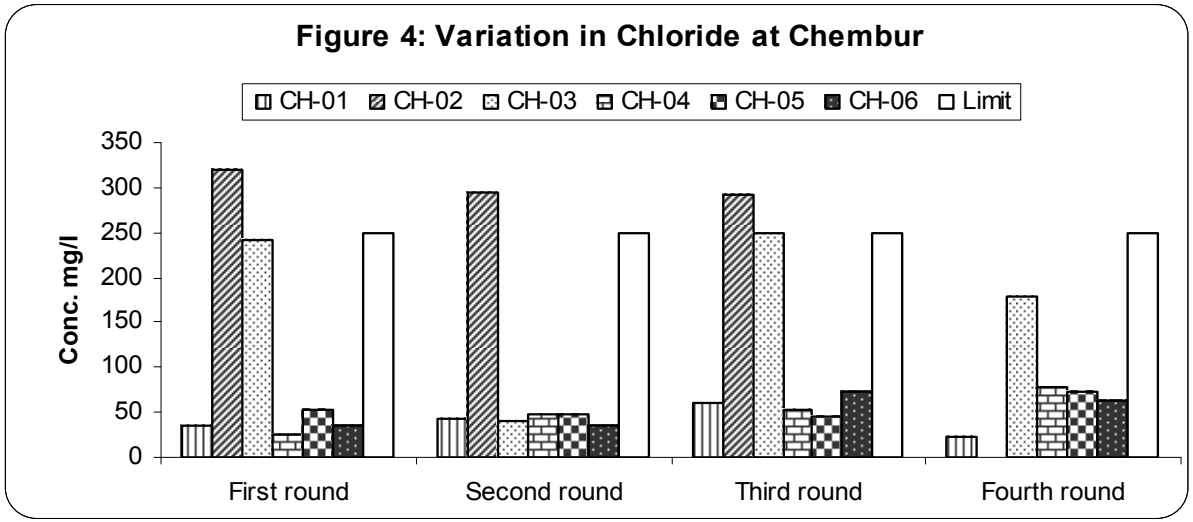


Figure 4) b): Groundwater Quality graphs for Chembur



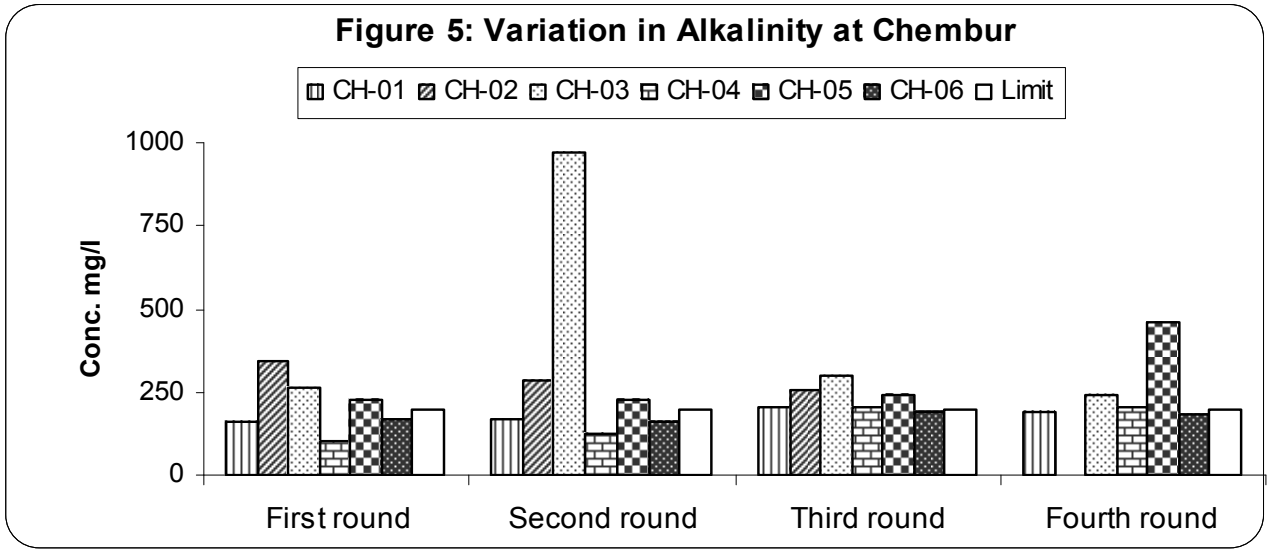
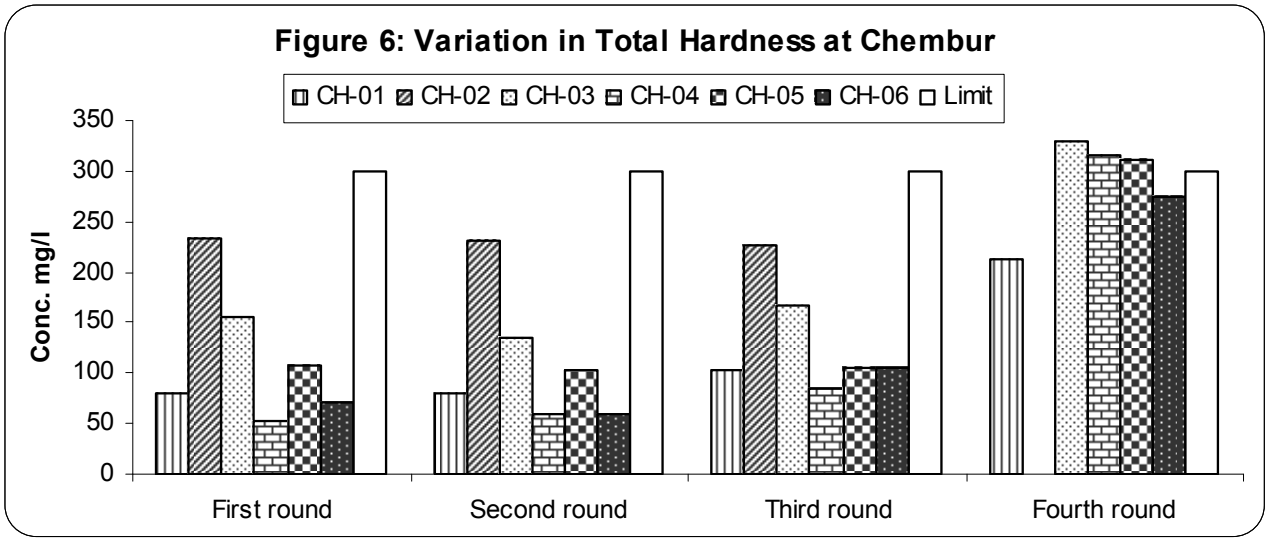


Figure 4) c): Groundwater Quality graphs for Chembur



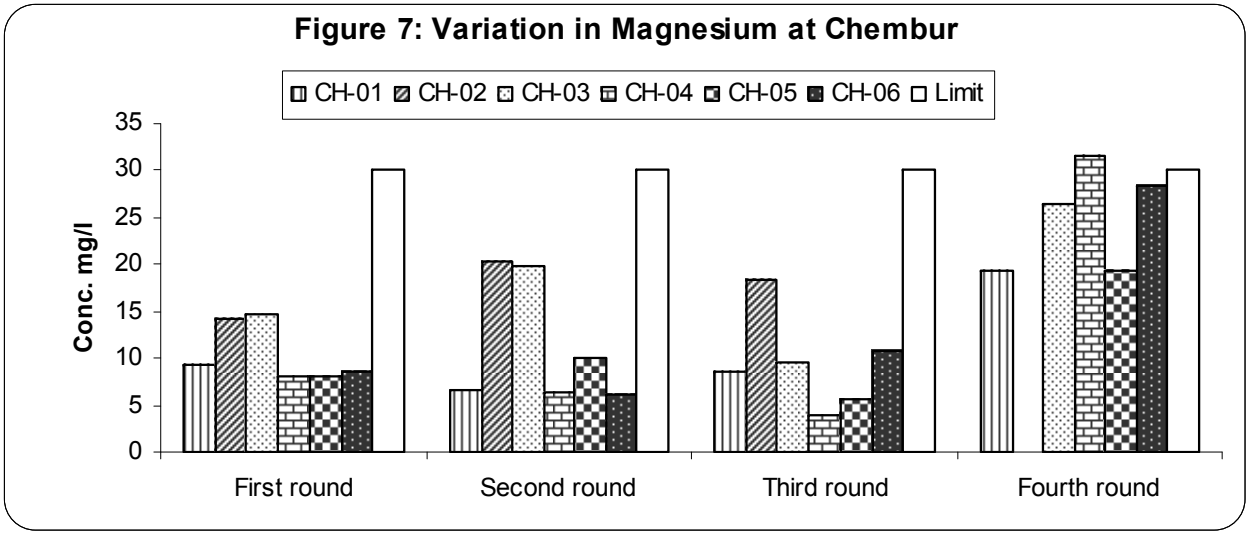
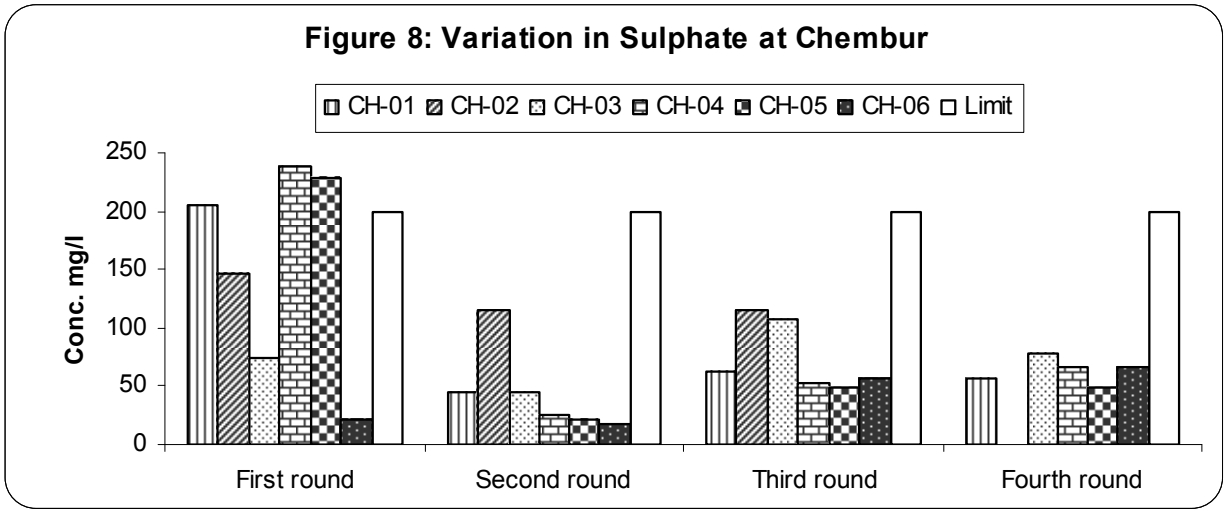


Figure 4) d): Groundwater Quality graphs for Chembur



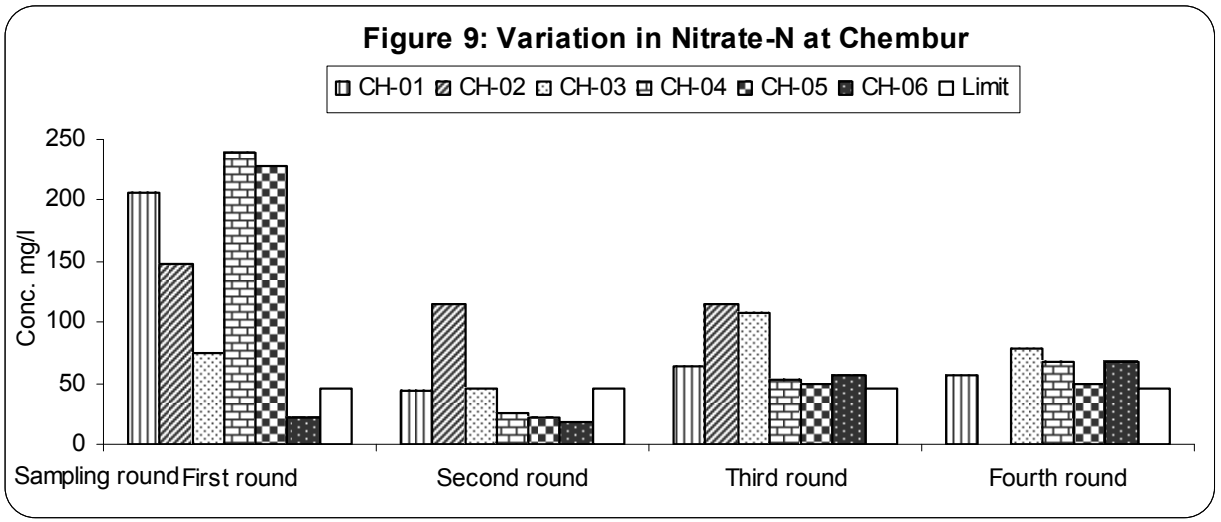


Table 33: Heavy Metals in the Groundwater of Chembur

Area / Location Limit⇒	Cr 0.05	Pb 0.05	Zn 5.0	Cd 0.01	Ni	Fe 0.3	Cu 0.05	Mn 0.1
1. Near Pepsico (B) CH-1								
Round 1	BDL	BDL	0.58	BDL	BDL	0.401	0.002	BDL
Round 2	BDL	BDL		BDL	0.012	0.083	0.005	BDL
Round 3	0.013	BDL	0.012	BDL	BDL	BDL	BDL	BDL
Round 4	0.007	BDL	0.002	BDL	BDL	BDL	BDL	BDL
2. Ambapada (D) CH-2								
Round 1	BDL	BDL	BDL	BDL	BDL	0.170	0.007	BDL
Round 2	BDL	BDL	0.036	BDL	0.004	0.479	0.016	0.168
Round 3	0.014	BDL	BDL	BDL	0.002	BDL	BDL	BDL
Round 4	--	---	--	--	--	--	--	---
3. Near BPCL (B) CH3								
Round 1	BDL	BDL	0.11	BDL	0.005	0.629	0.003	BDL
Round 2	BDL	BDL	BDL	BDL	BDL	0.026	0.001	BDL
Round 3	0.008	BDL	BDL	BDL	0.022	BDL	BDL	0.006
Round 4	BDL	BDL	1.24	BDL	BDL	1.155	0.012	0.365
4.Acharya Ap (D) B CH4								
Round 1	BDL	0.089	BDL	0.002	0.002	BDL	0.004	0.018
Round 2	BDL	BDL	0.007	BDL	0.002	0.055	0.006	0.138
Round 3	0.032	BDL	0.01	BDL	0.039	0.06	0.002	0.101
Round 4	BDL	0.02	BDL	0.002	BDL	BDL	0.002	BDL
5. Meriland Apt. (B) CH5								
Round 1	BDL	BDL	0.009	BDL	0.010	0.004	0.001	BDL
Round 2	BDL	BDL	0.174	BDL	0.029	0.067	0.005	BDL
Round 3	--	--	--	--	--	--	--	--
Round 4	0.343	0.025	0.014	BDL	BDL	0.275	0.008	0.285
6.Vadavali Vill. (B) CH6								
Round 1	BDL	BDL	0.202	BDL	BDL	0.77	0.006	BDL
Round 2	0.026	BDL	0.218	BDL	0.003	0.687	0.015	BDL
Round 3	0.02	BDL	0.065	BDL	0.002	0.422	0.003	0.031
Round 4	BDL	0.002	0.06	0.002	BDL	0.398	0.010	0.013

All Values are expressed in ppm (mg/ l). BDL – Bellow detectable limit.
(--) Sample not collected due to damage of pump

Table 34: Physico-Chemical characteristics of groundwater in the problem area of Tarapur (Maharashtra)

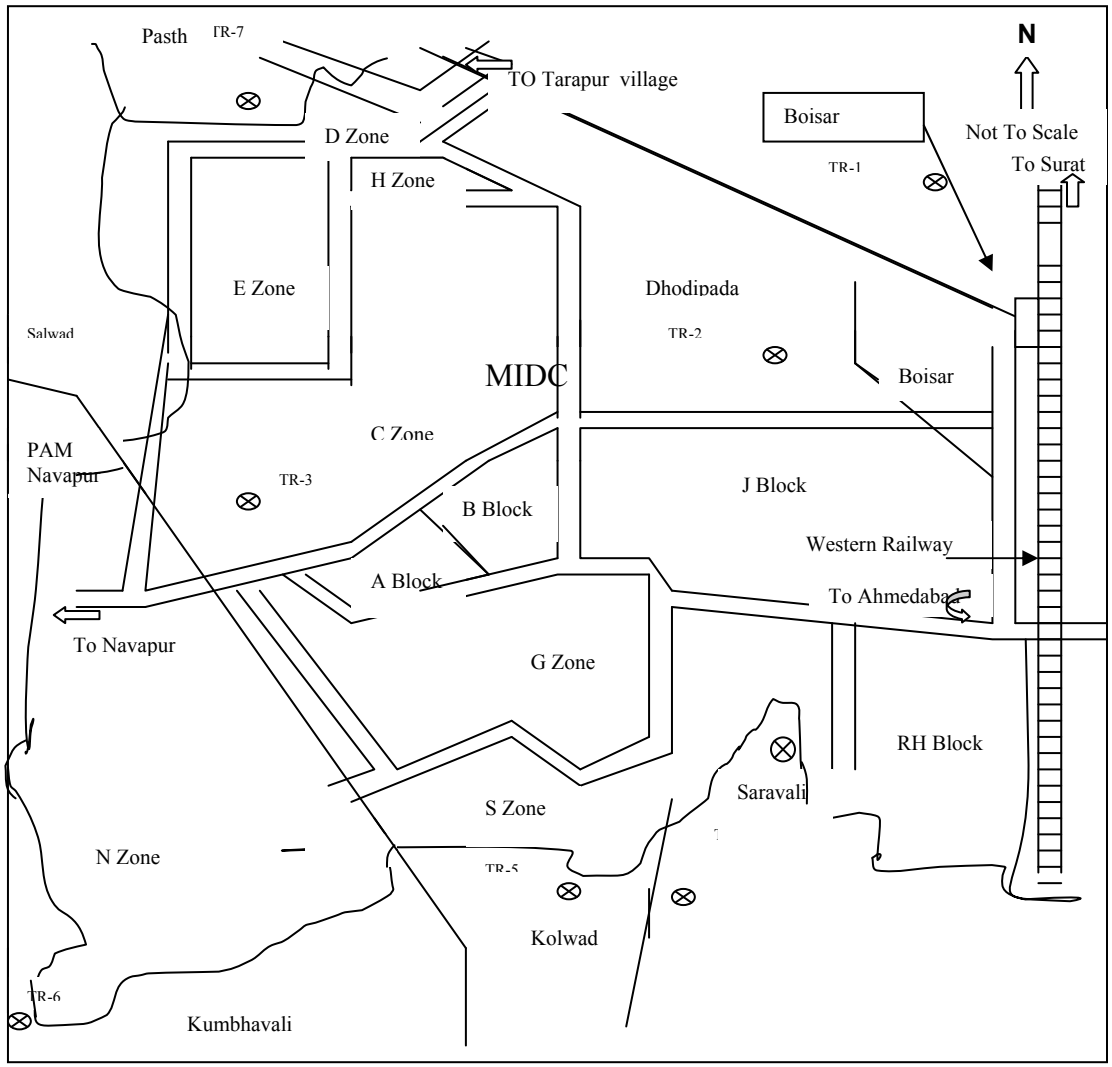
Area / Location With field code	pH	TDS	Cond	TH	Ca	Mg	Alk	Cl	SO_4	PO_4	TC	FC	NO_3-N	F	Na
Limits→	**6.5-8.5**	**500**		**300**	**75**	**30**	**200**	**250**	**200**				**45**	**1.0**	
1. Chandrika Nagar (B) TP 1															
Round 1	7.2	690	990	191	47	18	347	94	48	0.05	≥1600	≥1600	8.7	BDL	38
Round 2	7.2	456	860	168	44	14	353	91	41	0.07	≥1600	≥1600	1.6	0.06	36
Round 3	7.0	652	960	149	38	13	350	81	70	0.04	≥1600	900	6.7	0.214	45
Round 4	7.9	654	980	466	304	162	312	107	69	BDL	BDL	BDL		0.50	50
2. Dhodiapada(B)															
TP2 **Round 1**	7.4	706	1100	193	38	24	388	143	11	BDL	≥1600	≥1600	BDL	0.5	57
Round 2	7.4	568	1100	165	34	20	343	147	17	0.04	17	13	BDL	0.47	56
Round 3	7.3	972	1360	194	49	17	374	186	60	0.06	≥1600	350	34.2	0.592	63
Round 4	7.6	896	1300	628	316	31	432	201	52	0.014	300	300		0.73	62
3. MIDC Centre(D)															
TP3 Round 1	7.5	1690	1900	371	86	38	326	320	328	BDL	≥1600	≥1600	20.3	BDL	54
Round 2	7.8	1452	1830	336	81	32	127	295	274	BDL	≥1600	≥1600	38.2	4.5	62
Round 3	7.7	308	550	75	21	7	192	39	53	0.28	--	--	11.6	0.701	51
Round 4	7.7	1740	1950	1011	624	387	290	346	199	0.099	≥1600	1600		0.44	54
4. Ospada Vill.(B)															
TP4 **Round 1**	7.7	636	940	152	28	20	311	103	34	BDL	≥1600	≥1600	5.3	0.12	56
Round 2	7.6	476	910	140	22	21	265	112	34	BDL	110	80	5.5	0.48	57
Round 3	7.5	550	940	148	30	18	312	88	68	0.02	≥1600	350	7.4	0.811	60
Round 4	7.8	742	1090	483	208	275	362	126	88	BDL	≥1600	≥1600		0.73	67
5. Kolwade Vill(B)															
TP5 **Round 1**	7.4	688	910	155	36	16	222	113	37	BDL	≥1600	≥1600	34.4	0.08	42
Round 2	7.2	476	910	140	22	21	265	112	34	BDL	110	80	5.5	0.48	57
Round 3	7.1	926	1200	207	49	21	274	158	60	0.003	≥1600	350	75.1	0.279	51
Round 4	7.4	1032	1260	591	366	225	190	236	81	BDL	--	--		0.10	50
6. Kumbavali vill(B)															
TP6 **Round 1**	7.8	236	320	53	11	6	153	25	1	BDL	≥1600	≥1600	BDL	0.6	27
Round 2	7.7	208	260	51	12	5	157	21	3	BDL	30	17	2.2	0.76	27
Round 3	7.5	306	560	98	26	8	224	39	5	0.02	130	30	8.9	0.532	35
Round 4	7.9	220	310	154	83	71	150	16	6	BDL	50	9		056	30
7. Pasthal Vill(B)															
TP7 **Round 1**	7.7	1330	2000	180	21	31	427	271	294	BDL	≥1600	≥1600	48.0	BDL	38

All Values except pH, Total Colliform (TC), Feacal Colliform (FC) and Conductivity are expressed in mg/ l. BDL – Below detectable imit,
B- Bore well and D- Dug well. TC and FC values are in MPN/100ml. Conductivity values are expressed in μmhos/cm.

Table 35: Heavy Metals in the Groundwater of Tarapur

Area / Location	Cr	Pb	Zn	Cd	Ni	Fe	Cu	Mn
Limit ⇒	**0.05**	**0.05**	**5.0**	**0.01**		**0.3**	**0.05**	**0.1**
1. Chandrika Nagar (B)								
TP 1 Round 1	BDL	BDL	0.32	BDL	0.017	BDL	0.001	BDL
Round 2	BDL	BDL	0.136	0.001	BDL	0.566	0.02	0.26
Round 3	-	BDL	BDL	BDL	-	-	BDL	BDL
Round 4	BDL	BDL	BDL	BDL	BDL	BDL	0.005	BDL
2. Dhodiapada (B)								
TP 2 Round 1	BDL	BDL	BDL	BDL	BDL	1.015	0.008	BDL
Round 2	BDL	BDL	0.043	BDL	0.021	0.805	0.018	.008
Round 3	0.009	BDL	BDL	BDL	BDL	BDL	BDL	BDL
Round 4	BDL	BDL	BDL	BDL	BDL	0.17	0.006	0.033
3. MIDC Centre (D)								
TP 3 Round 1	BDL	BDL	BDL	BDL	BDL	BDL	0.003	BDL
Round 2	BDL	BDL	0.008	0.005	0.035	0.099	0.011	0.043
Round 3	BDL	BDL	0.01	BDL	0.01	0.154	0.001	0.015
Round 4	BDL	0.009	BDL	BDL	0.031	0.186	0.019	0.196
4. Ospada Vill. (B)								
TP 4 Round 1	BDL	BDL	BDL	BDL	0.007	0.049	0.001	BDL
Round 2	BDL	BDL	0.026	0.007	BDL	0.466	0.01	BDL
Round 3	BDL	BDL	BDL	BDL	BDL	BDL	BDL	BDL
Round 4	BDL	BDL	0.469	BDL	BDL	0.227	0.012	0.015
5. Kolwade Vill. (B)								
TP 5 Round 1	BDL	BDL	BDL	BDL	0.013	BDL	BDL	BDL
Round 2	0.027	BDL	0.005	BDL	BDL	0.177	0.009	BDL
Round 3	BDL	0.024	BDL	BDL	BDL	BDL	BDL	BDL
Round 4	BDL	BDL	0.012	BDL	BDL	0.615	0.008	0.013
6. Kumbavali Vill. (B)								
TP 6 Round 1	BDL	0.042	BDL	0.002	BDL	0.061	0.001	BDL
Round 2	0.107	BDL	0.011	BDL	0.012	0.866	0.006	BDL
Round 3	BDL	-	0.016	BDL	BDL	BDL	0.003	0.002
Round 4	BDL	0.014	BDL	BDL	BDL	0.83	0.003	0.002
7. Pasthal Vill. (B)								
TP 7 Round 1	BDL	0.020	BDL	0.003	0.005	BDL	0.006	BDL

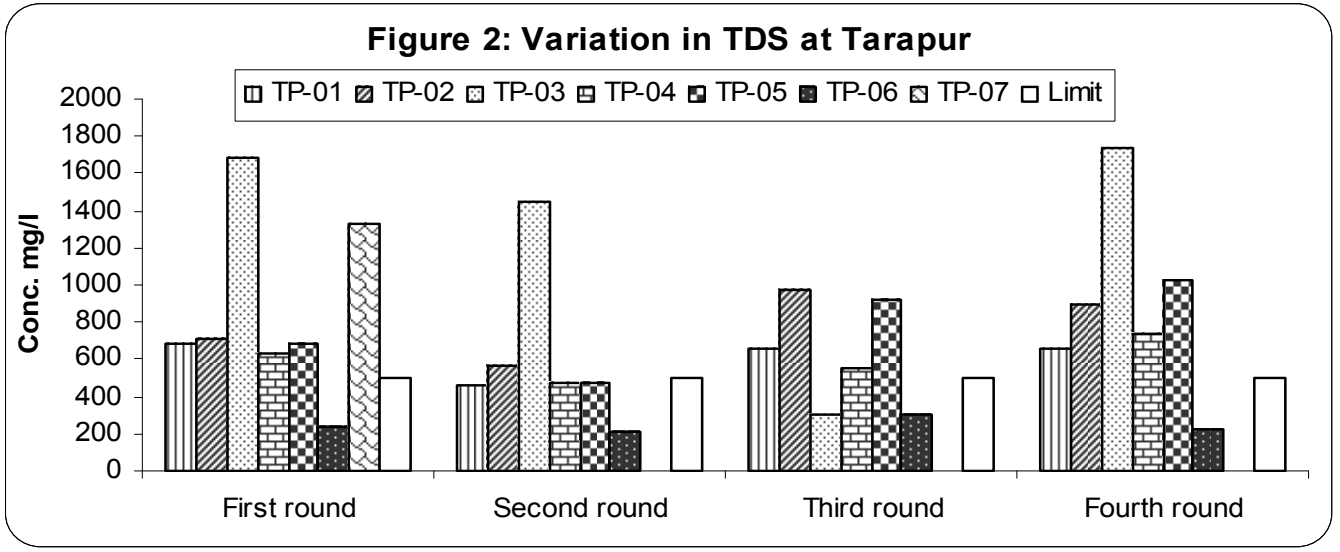
All values are expressed in ppm (mg/ l). BDL – Bellow detectable limit, B- Bore well and D- Dug well.



GWQM stations
1. Borewell in chandrikanagar
2. Handpump at Dhodipada
3. Open well at Sh. Bhairam chikuwadi
4. Handpump at Ospada, Sarvali village
5. Borewell at Kolwade village
6. Bore well at Pathal Village
7. Borewell at Gajanannagar, Kumbhvali, village

Figure 5: Ground Water Monitoring locations at Tarapur

Fig 6) a): GW Quality graphs - Tarapur (Maharashtra)



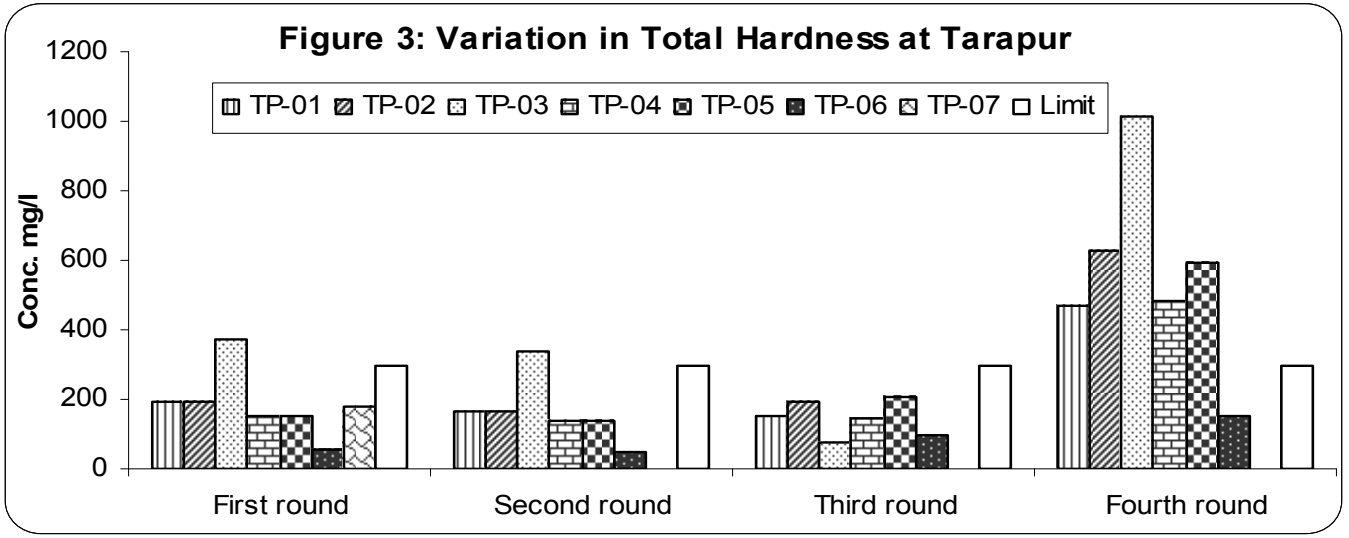
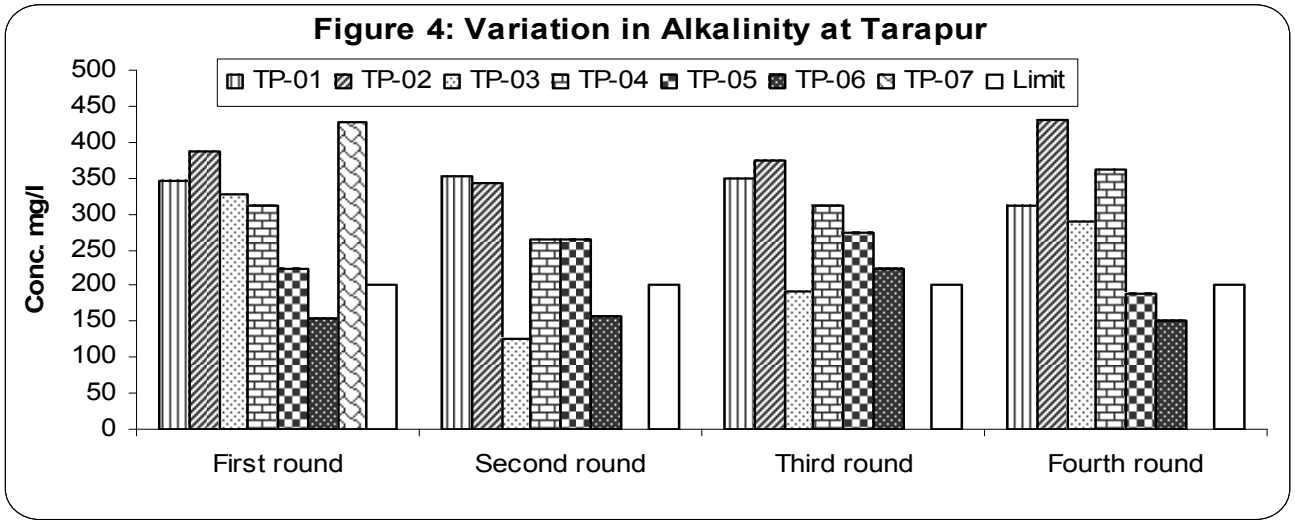


Fig 6) b): GW Quality graphs - Tarapur (Maharashtra)



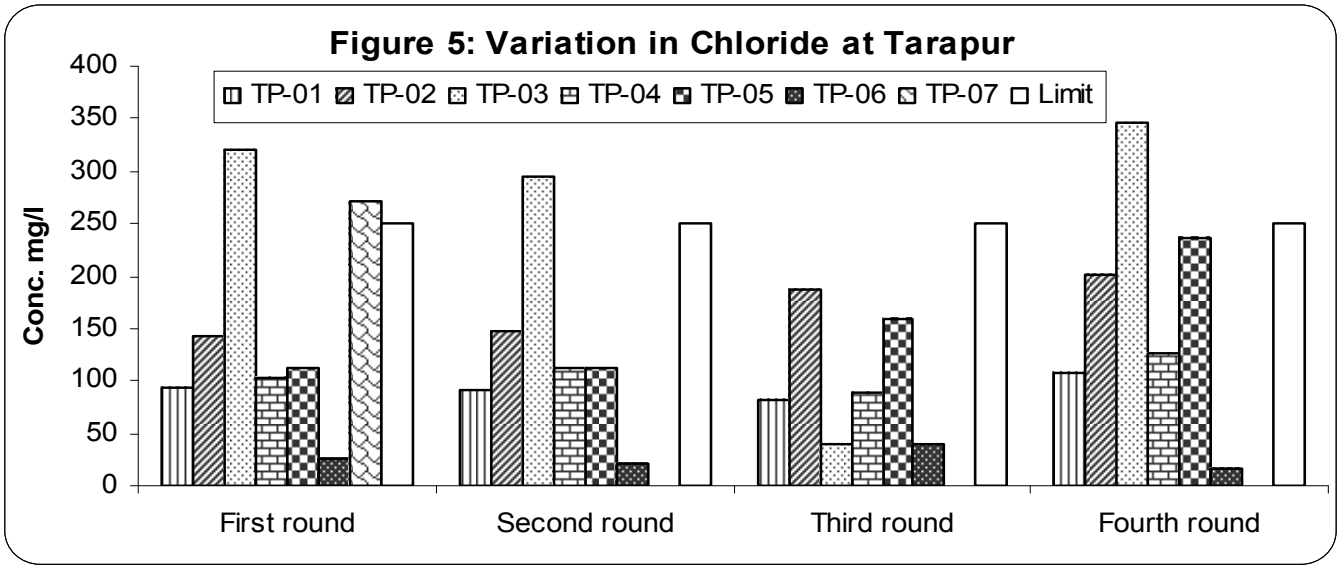
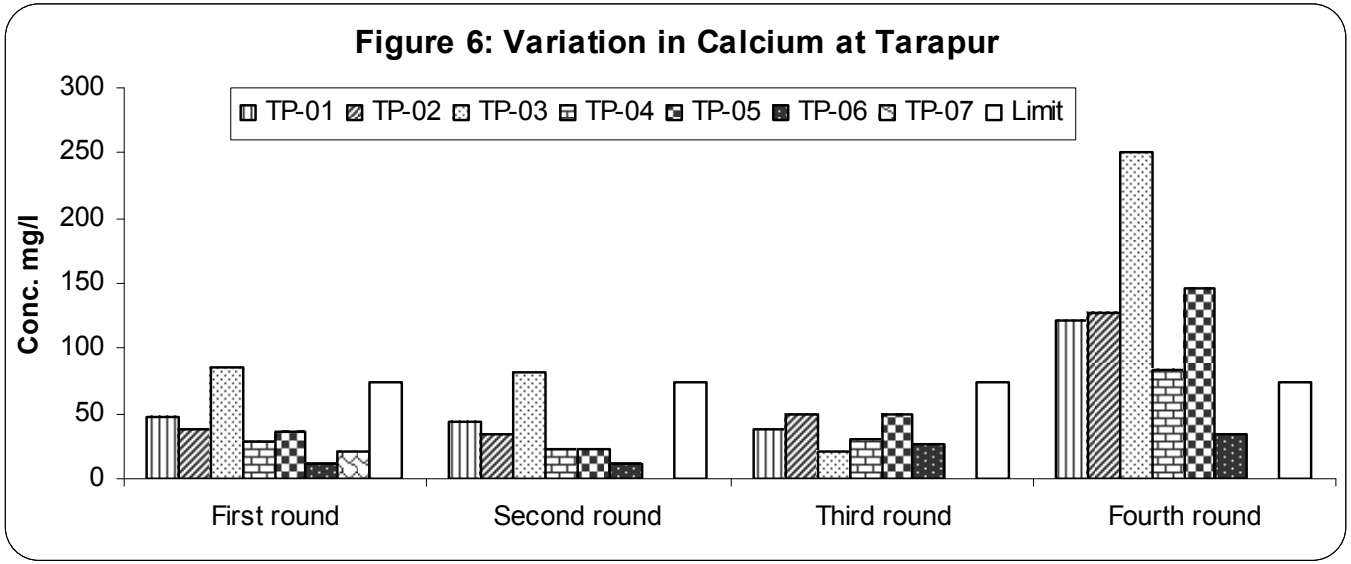


Fig 6) c): GW Quality graphs - Tarapur (Maharashtra)



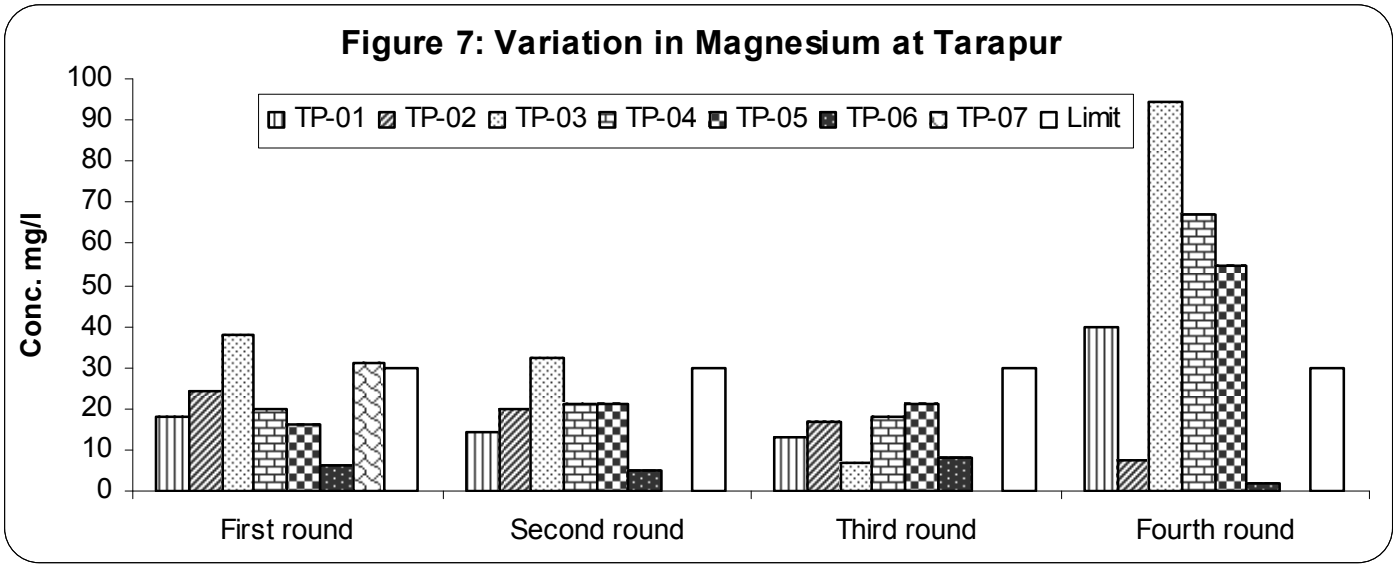
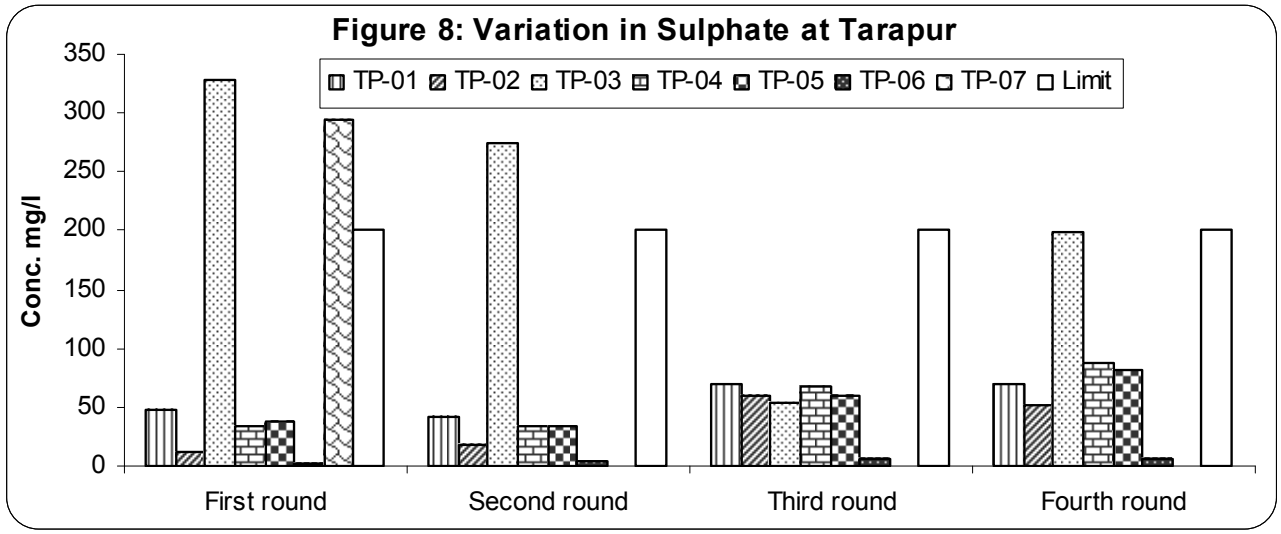


Fig 6) d): GW Quality graphs - Tarapur (Maharashtra)



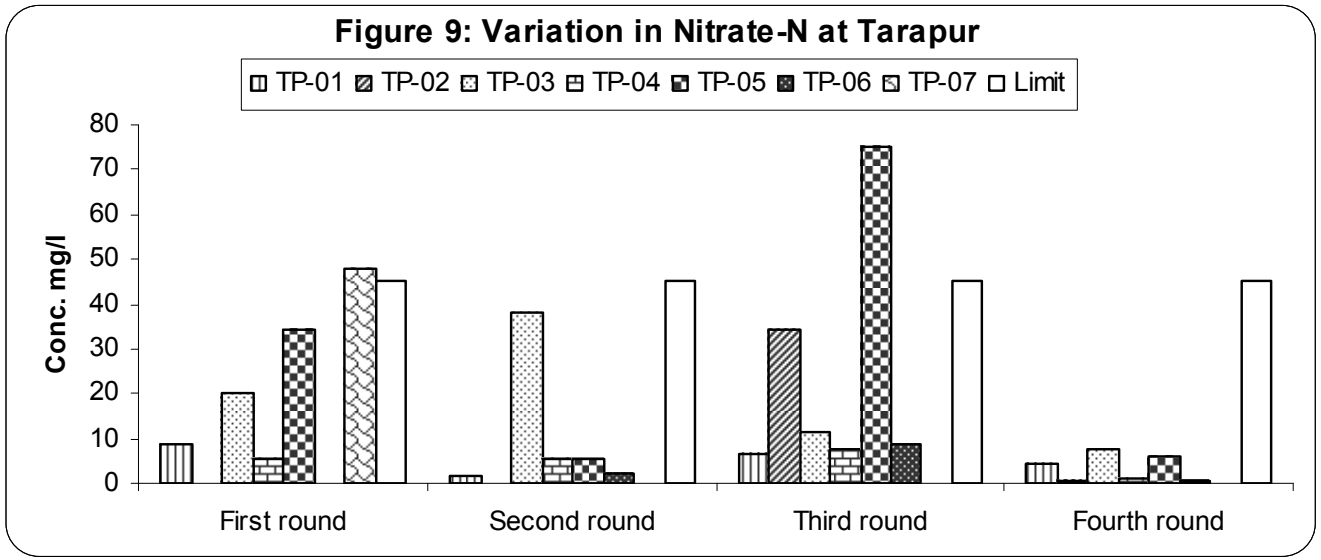


Table 36: Groundwater physico-chemical parameters in Digboi as on May 2002, January 2002 and September 2001

Parameters	Hawkinspara (016)			Kalibari (017)			Missionpara (018)			Golai (019)			Borbil (020)		
	May'02	*Jan'02*	*Sep'01*	*May'02*	*Jan'02*	*Sep'01*	*May'02*	*Jan'02*	*Sep'01*	*May'02*	*Jan'02*	*Sep'01*	*May'02*	*Jan'02*	*Sep'01*
PH	8.5	9.2	7.1	6.5	6.7	7.4	6.8	6.2	7.3	6.7	6.0	7.2	6.6	6.7	7.2
Turbidity (NTU)	1.11	-	-	5.0	-	-	12.5	-	-	3.44	-	-	21.9	-	-
Conductivity (umhos/cm)	352	411	380	296	353	325	315	346	330	237	353	290	179	210	195
T-Hardness (mg/l)	8.20	40.0	08.0	56.42	96.0	18.0	125.58	200	38.0	49.14	136	20.0	56.48	124	14.0
Calcium (mg/l)	3.79	28.4	06.0	13.85	50.0	10	21.88	140.0	26.0	13.85	82.0	14.0	8.82	Nil	08.0
T-alkalinity (mg/l)	124.0	24.0	40.0	74.8	126.0	12.0	148.2	208.0	24.0	46.2	96.0	8.0	90.2	126	12.0
Chloride (mg/l)	1.61	26.0	04.0	42.02	63.0	54	9.69	53.0	14.0	38.25	34.0	34.0	12.93	21.0	20.0
Phosphate (mg/l)	BDL	-	-	BDL	-	-	BDL	-	-	BDL	-	-	BDL	-	-
Fluoride (mg/l)	BDL	0.1		BDL	0.1	-	BDL	0.1	-	BDL	0.03	-	BDL	0.20	-
TDS (mg/l)	196	230.4	210	205	504	350	221	144	205	196	130	165	156	106.5	139
Iron (mg/l)	0.210	-	-	0.51	-	-	0.99	-	-	0.21	-	-	3.14	-	-
Sulphate (mg/l)	-	-	12.0	-	-	32.0	-	-	28.0	-	-	22.0	-	-	18.0
Magnesium (mg/l)	-	-	02.0	-	-	08.0	-	-	12.0	-	-	06.0	-	-	6.0

Table 37: Summary Statement for Heavy Metals in Digboi as on May 2002, January 2002 and September 2001

Heavy Metals	Hawkinspara (016)			Kalibari (017)			Missionpara (018)			Golai (019)			Borbil (020)	
	May'02	Jan'02	Sep'01	May'02	Jan'02	Sep'01	May'02	Jan'02	Sep'01	May'02	Jan'02	Sep'01	May'02	Jan'02	Sep'01
Cu	0.28	NA	0.03	0.08	NA	0.06	0.02	NA	0.01	0.03	NA	0.02	0.01	NA	0.02
Zn	0.50	0.51	0.47	1.80	3.28	1.0	0.49	1.55	0.99	0.47	0.75	ND	0.11	1.5	0.90
Cr	0.01	ND	0.02	0.02	ND	0.01	0.01	ND	0.02	0.01	0.02	0.01	Nd	0.01	ND
Ni	0.01	ND	0.02	0.04	ND	0.03	0.04	ND	0.02	0.06	0.07	0.05	0.07	ND	0.06
Cd	ND	ND	ND	ND	ND	ND	ND	ND	0.01	ND	ND	0.01	ND	ND	ND
Mn	0.02	ND	0.09	9.24	2.59	6.30	2.66	10.13	3.80	0.06	1.00	0.06	3.52	2.46	4.0
Pb	0.08	0.1	0.04	0.02	0.10	0.06	0.03	0.1	0.08	0.07	0.03	0.09	0.14	0.10	0.11
Fe	0.30	0.35	0.18	0.51	0.71	0.6	0.99	0.64	0.32	0.21	0.15	0.2	3.14	1.83	0.20

NA - Not Analyzed ND - Not detectable

Continued

ANNEXURE III

ANNEXURE III: Acknowledgements to the Agencies involved in Metropolitan Cities and Problem Area work

Acknowledgements for Metropolitan cities work

Sl No.	Metropolitan city	Agency	Names of persons
1.	**Agra**	**National Institute of Hydrology (NIH), Roorkee**	**Dr. K. D. Sharma, Director,NIH Dr. K. K. S. Bhatia, Scientist 'F' Environmental Hydrology Div., Dr. C. K. Jain, Scientist 'E1', Environmental Hydrology Div., Dr. Imran Ali, Smt. Babita Sharma, Smt. Beena Prashad, Sri. N. Varadarajan**
2.	**Meerut**	**National Institute of Hydrology, Roorkee**	**-do-**
3.	**Madurai**	**National Institute of Hydrology, Roorkee**	**-do-**
4.	**Vijaiwada**	**National Institute of Hydrology, Roorkee**	**-do-**
5.	**Chennai**	**National Institute of Hydrology, Roorkee**	**-do-**
6.	**Coimbatore**	**National Institute of Hydrology, Roorkee**	**-do-**
7.	**Lucknow**	**Pollution Control Research Institute, (PCRI), BHEL, Haridwar**	**Dr. N.G. Shrivastava, Sr. Manager (PCRI) Dr Neelam Srivastava, Manager (PCRI) Dr. S. Bhatnagar, Manager (PCRI) Shri. P. K. Pahwa, Lab. Assistant, PCRI Shri A. K. P.Singh, Lab. Assistant, PCRI**
8.	**Ludhiana**	**Pollution Control Research Institute, (PCRI), BHEL, Haridwar**	**-do-**

Acknowledgements for Problem Area work

Sl No.	Problem Area	Agency	Names of persons
1.	Durgapur	CPCB Zonal Office - Kolkata	Ms Mita Sharma SEE & Project Co-ordinator Shri B R Naidu, Zonal Officer Dr D P Mukhhopadhyay Sc. C Shri A K Sen Sc. B Analysis of GW samples: Z.O. - Laboratory Typing: Chandrani Bhattacharya
2.	Howrah	CPCB Zonal Office – Kolkata	-do-
3.	Dhanbad	CPCB Zonal Office – Kolkata	-do-
4.	Angul Talcher	Pollution Control Board Orissa, Bhubaneshwar	-do-
5.	Singrauli	CPCB Zonal Office - Kanpur	Shri B P Shukla , Zonal Officer Shri R K Singh Sct B (co-ordinator) Shri V P Yadav AEE Shri B D Pandey Shri Bhagwandin Driver Typing: Ms Manju Srivastav
6.	Visakapatnam	CPCB Zonal Office – Bangalore	Dr. D.C. Sharma, Zonal Officer Shri. V. Pattusamy, Scientist 'C', Co-ordinator Shri. S. Suresh, Environmental Engineer Shri. T.K. Radheyshyam Balaji, Scientist 'B'
7.	Bollaram-Parancheru	CPCB Zonal Office – Bangalore	-do-
8.	Bhadravathi	CPCB Zonal Office – Bangalore	Dr. D. C. Sharma, Zonal Officer Shri. V. Pattusamy, Sc. 'C' Co-ordinator Shri. K.M. Udayakumar, Sc. 'B'

			Shri. Vikaram Rao, JRF **Shri. A. Krishnamurthy, Driver**
9.	**Cochin**	**CPCB Zonal Office – Bangalore**	**Dr. D.C. Sharma, Zonal Office** **Mr. V. Pattusamy, Scientist 'C'-** **Co ordinator** **Mr. M. Madhusudanan, Sc 'C'** **Mr. S. Jeyapaul, SSA;** **Mr. S. Karthikeyan, SSA**
10.	**Manali**	**CPCB Zonal Office – Bangalore**	**- Same team for North Arcot, Tamilnadu**
11.	**North Arcot (Vellore)**	**CPCB Zonal Office - Bangalore**	**Dr. D.C. Sharma, Zonal Officer** **Shri. V. Pattusamy, Sc. 'C'** **Co-ordinator** **Shri. G. Dharmalingam, Sc. 'B'** **Shri. I.A. Kadar, Sr. Tech.** **Shri. Vikram. J. Rao, JRF** **Shri. R. Subramanyan, ;Driver** **Shri. A. Krishnamurthy, Driver** **Shri. P. Munisamy, Attendant**
12.	**Vapi**	**CPCB Zonal Office - Vadodara**	**Dr. S. S. Bala Zonal Officer** **Dr. Utpal Mukherjee Sct C** **Co-ordinator** **Shri S. L. Lokhande** **Shri A Gnanavelu; Shri T. K. Parmar; Ms. Astha Trivedi** **Shri Nilesh Patel; Shri J. G. Bhatt** **Typing & Composing Shri Devraj T**
13.	**Ankleshwar**	**CPCB Zonal Office - Vadodara**	**-do-**
14.	**Chembur**	**CPCB Zonal Office - Vadodara**	**-do-**
15.	**Tarapur**	**CPCB Zonal Office - Vadodara**	**-do-**
16.	**Digboi**	**CPCB Zonal Office - Shillong**	**Shri Shantanu K. Dutta, AEE** **Dr. Z. Changsan, Sc. B** **Shri M.K. Choudhury, Zonal Officer** **Shri Royantis Lyndoh; Shri S. K. Mihsill** **Shri G. Lama**

Continued

ANNEXURE IV

ANNEXURE IV: References used in the Text & Tables for Metropolitan Cities and Problem Area work

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