TECHNOLOGICAL INTERVENTION TO IMPROVE QUALITY OF DRINKING WATER IN URBAN GUJARAT

A Thesis submitted to Gujarat Technological University

for the Award of

Doctor of Philosophy

in

Civil Engineering

by

Anadkat Vijay Laljibhai
Enrollment No: 129990906006

under supervision of
Dr G P Vadodaria
Principal, L D College of Engineering, Ahmedabad

GUJARAT TECHNOLOGICAL UNIVERSITY
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2) External Examiner 2: Name and Signature 3) External Examiner 3 Name and Signature

Abstract

Key Words: Quality of Drinking Water in Urban Gujarat, Water Quality Stress Mapping, Water Treatment Analysis, Technological intervention for improvement of water quality, MIS for Drinking water

This study by Gujarat Technological University (GTU) under PhD programme is taken to assess quality of water supply in all ULBs area and help them to suggest technological options to improve the quality of water in case of any issue in quality of water. It is also aimed to develop MIS for ULBs and make available aneroid based app to citizens of urban Gujarat to know quality of drinking water available to them at any point of time.

Gujarat is a state in Western India, with population in excess of 60 million. Gujarat is one of the most urbanized states of India. It has an urban population of 24 million accounting for 42.6 % of total population. Gujarat falls under semi-arid zone. The long sea coastline along Saurashtra, Kutch and other parts creates the problem of salinity ingress, which affects the ground water quality on coastal belt and because of scanty and uncertain rainfall, the replenishment in dam is also not reliable, hence this areas are always under water deficiency.

Data have been collected from all 167 ULBs of Gujarat state. There are 8 Municipal Corporations and 159 Municipalities. Responsibility of water supply in all these cities lies with Urban Local Bodies and water supply is largely concerned in cities of Gujarat. Based on data collection and analysis it is found that, about 80% house-holds are covered by water supply. Total production of water is about 4100 MLD. About 21% of total production of water is dependent on ground water while 66% is in form bulk purchased water. There is disparity in level of water supply in 92 ULBs, out of total 167 ULBs water supply is less than 100 LPCD. An average duration of water supply in all ULBs is about 1.5 hours.

All WTP in the state are conventional Rapid Sand Filter Plant. No advance technology like UV/ Membrane based/ High filter is being used. Due to high level of dependency on ground water, more than 10% of people. This leads to risk of chemical contamination like

fluorides, Nitrate, TDS, Salinity etc., High level TDS and salinity is common scenario across the state, while problem of salinity water quality is common in west Saurashtra & Kutch area.. Excess fluoride in North & Central Gujarat and excess Nitrate in Central & South Gujarat are found In many cities it is observed that, due to low quantity of water supplied, people often go for tapping private water sources and eventually in many cases it turns out to be ground water, this is an additional risk.

Long term solutions and particularly covering conventional & non conventional methods including comparison of modern technological solutions like filtration media up gradation with technology like microfiltration technology, using multimedia structure in new and existing filter beds, Development of Green infrastructure, promotion of rainwater harvesting, option for U/V against Chlorination etc., are suggested as general recommendation. It has been observed that, there is not much issues related to physical & biological properties/contamination. However, as discussed above, there are issues in some of ULB related to chemical properties like fluoride, Nitrate, Salinity & TDS. Appropriate technological solutions are suggested. Web based MIS & App for monitoring of quality of supplied water in all ULBs. MIS on www.gturesearchonwater.com and APP Gujarat Water are also developed as part of the research work and it is assumed that, it would helpful to community to know quality of water they receive.

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Vijay Anadkat

January, 2017

Ahmedabad

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List of Abbreviation

1.	**A&OE**	Administrative & Office Expenditure
2.	**ADB**	Asian Development Bank
3.	**AMC**	Ahmedabad Municipal Corporation
4.	**AMRUT**	Atal Mission for Rejuvenation and Urban Transformation
5.	**Amt.-**	Amount
6.	**BIS**	Bureau of Indian Standards
7.	**BOD**	Bio-Oxygen Demand
8.	**BOO**	Build-Operate-Own
9.	**BPMC**	Bombay Provincial Municipal Corporations
10.	**CA**	City Administration
11.	**CB & T**	Capacity Building & Training
12.	**CBO**	Community Base Organization
13.	**CEPT**	Centre for Environmental Planning and Technology
14.	**COD**	Chemical Oxygen Demand
15.	**CPHEEO**	Central Public Health and Environmental Engineering Organization
16.	**CT**	Community Toilet
17.	**DOM**	Directorate of Municipalities
18.	**DPR**	Detailed Project Report
19.	**GIDC**	Gujarat Industrial Development Corporation
20.	**GMFB**	Gujarat Municipal Finance Board
21.	**GoG**	Government of Gujarat
22.	**GoI**	Government of India
23.	**GPCB**	Gujarat Pollution Control Board
24.	**GUD & HD**	Gujarat Urban Development & Housing Department
25.	**GUDC**	Gujarat Urban Development Company
26.	**GUDM**	Gujarat Urban Development Mission
27.	**GW**	Ground Water
28.	**GWIL**	Gujarat Water Infrastructure Limited
29.	**GWSSB**	Gujarat Water Supply and Sewerage Board
30.	**HH**	Household
31.	**ICT**	Information and Communications Technology

32. **IEC** Information, Education and Communication
33. **IMR** Infant Mortality Rate
34. **KPIs** Key Performance Indicators
35. **LPCD** Liters Per Capita Per Day
36. **MC** Municipal Corporation
37. **MIS** Management Information System
38. **MoUD** Ministry of Urban Development
39. **NGO** Non Governmental Organization
40. **NIUA** National Institute of Urban Affairs
41. **NOC** No Objection Certificate
42. **NRW** Non Revenue Water
43. **O&M** Operation and Maintenance
44. **PAC** PolyAlluminium Chloride
45. **PAS** Performance Assessment System
46. **PFMS** Project Finance Management System
47. **PPM** Parts Per Million
48. **PPP** Public Private Partnership
49. **SAAP** State Annual Action Plan
50. **SLB** Service Level Benchmark
51. **SLIP** Service Level Improvement Plan
52. **SMC** Surat Municipal Corporation
53. **STP** Sewage Treatment Plant
54. **SW** Surface Water
55. **SWOT** Strength, Weakness, Opportunities and Threats
56. **TDS** Total Dissolved Solids
57. **TS** Technical Sanction
58. **UDPFI** Urban Development Plan Formulation and Implementation
59. **ULBs** Urban Local Bodies
60. **UMC** Urban Management Centre
61. **UWSS** Urban Water And Sanitation Services
62. **WDS** Water Distribution System
63. **WTP** Water Treatment Plant

Glossary: Some of the definitions are given below:

- **Chlorine Residual** chlorine remaining in the water at the end of a specified period.
- **Chlorine Demand** the difference between the amounts of chlorine added to water and amount of residual chlorine remaining in the water at the end of a specified period.
- **Coli form Bacteria** group of bacteria predominantly inhabiting the intestine of human beings and animals, but also occasionally found elsewhere. Used to indicate presence of faecal pollution.
- **Contamination** is the introduction into water of toxic materials, bacteria or other deleterious agents that make the water hazardous and therefore unfit for human use.
- **Palatable Water** that is appealing to the sense of taste, sight and smell. Palatable water need not always be potable.
- **Parts per million (ppm)** or milligrams per litre (mg/l) these terms are used to express the concentrations of dissolved or suspended matter in water. This is preferable, since it indicates how it is determined in the laboratory.
- **Pathogens disease**-producing organisms. Bacteria a group of universally distributed, essentially unicellular microorganisms lacking chlorophyll.
- **pH of water** an expression of the Hydrogen ion concentration. Alkaline water is with pH of above 7 and acidic water has pH of below 7; whereas water with pH 7 is neutral.
- **Pollution** is the introduction into water of substance in sufficient quantity to affect the original quality of water, make it objectionable to sight, taste, smell or make it less useful.
- **Potable Water** that is satisfactory for drinking purposes from the standpoint of its chemical, physical and biological characteristics.
- **Toxic** is harmful, destructive or deadly poisonous. Physiological effect having effect on the normal functions of the body.
- **Virus** the smallest form capable of producing infection and diseases in human beings.

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CHAPTER: 1

Introduction

1.1 Preamble

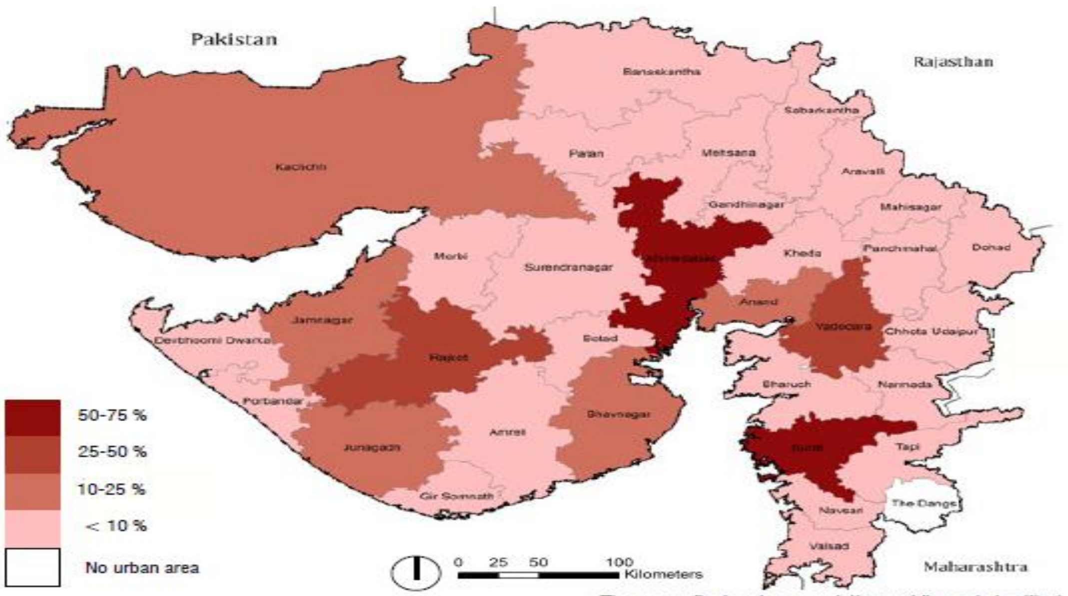
Water is one of the most precious gifts of the nature to all living organisms. Water is considered as driver for development. Fresh water is vital to human life and wellbeing. Along with food and shelter, it forms our most basic need. Healthy, functioning freshwater ecosystems provide reliable and quality water flows upon. Energy, food and health all indispensable to human development rely on the water services provided by natural ecosystems. Water is central to the functioning and resilience of the biosphere. Clean drinking water is essential for the survival. Surface water and ground water are two major sources for the supply of drinking water. Most of the earth water is sea water. Only, 2.5% of total water available on the earth is fresh water without significant levels of dissolved minerals or salt. In total only 0.01% of the total water of the planet is accessible for consumption. Amongst the various needs of water, the most essential need is drinking. India accounts for 2.45% of land area and 4% of water resources of the world but represents 16% of the world population and by 2050 it is expected to cross the 1.5 billion. By 2050, it is estimated that total water demand in India would be almost 1180 BCM. This would be big challenge. As per report by the World Bank & WHO, about 21% communicable disease in India are related to unsafe water which estimates more than 1,600 death daily due to diarrhea. The lack of access to safe water and adequate sanitation is at the core of the main symptoms and causes of poverty. Situation across developing countries is seen similar. It is estimated half the population do not have access to safe water (UNDP, 2006) in developing country; therefore it is also recognised one of the Millennium Development Goals. This research is also framed to assess and to provide technological solution for quality of drinking water in one the progressive state of India.

> ***"Water holds the key to sustainable development, We must work together to protect and carefully manage this fragile, finite resource"***
>
> ***UN Secretary-General Ban Ki-moon, World Water Day, 2013***

1.2 Study Area: Gujarat

Gujarat is a state in Western India. It has an area of 196,024 Sq.Kms with a coastline of 1,600 km. Gujarat is boarded by Rajasthan state in North, Maharashtra in South, Madhya Pradesh in East, Pakistan and Arabian Sea in West. Its capital city is Gandhinagar, while its largest city is Ahmedabad. Gujarat is home to the Gujarati-speaking people of India.

Map: 1.1 Population Residing in Cities by District (Census Data, 2011)



(The map reflects urban population residing only in cities)

TABLE: 1.1 Urbanisation in Gujarat and India

Year	Gujarat			India		
	Urban Population (in millions)	% of Urban Population	Decadal Growth Rate	Urban Population (in millions)	% of Urban Population	Decadal Growth Rate
1951	4.43	27.23		62.4	17.29	
1961	5.31	25.74	19.64	78.90	18.00	26.44
1971	7.49	28.06	41.05	109.10	19.91	38.22
1981	10.60	31.10	41.52	159.50	23.70	46.23
1991	14.24	34.47	34.34	217.20	25.71	36.09
2001	18.22	37.67	32.94	285.40	27.78	21.35
2011	24.19	41.10	29	377.20	31.16	27.60

(Source: Census of India)

Study Area

In Gujarat, all ULBs are responsible to provide and manage basic infrastructure services. There are 167 (presently 170) Urban Local Bodies formed as democratic institutions based on the principle of self-government and represent people's desires and strengths. Eight cities with more than 250,000 populations are governed by the Municipal Corporations constituted under the provision of the Bombay Provisional Municipal Corporation Act, 1949. All other urban areas viz., Class A to Class D municipalities having population more 15,000 are governed by municipalities constitutes under the Gujarat Municipalities Act 1963.

Growing population put pressure on the existing resources, this leads in key resources like water supply. Every year, Gujarat will have to provide basic infrastructure facilities to additional 1 million people persons in urban areas just to maintain the current level of service which is also behind the normal level. Besides, population spill over (outgrowth) beyond administrative boundaries of municipal areas has increased over last decade. In 2001, the number of towns with outgrowths is 39 and about 2.5 million people are residing outside municipal areas as outgrowths.

Now in 2011, it is estimated that more than 45 areas are developed in OG area having more than 3.5 million populations. The proportion of population residing outside municipal areas has been substantial. These areas continue to be administered under rural set up resulting into haphazard developments and faced with the problem of inadequate infrastructure. As the infrastructure grows to meet the growing demand, management of the infrastructure and ensuring high quality service delivery will also be challenging. Providing judicious quantity of water to 100% of urban population is becoming challenges. The proportion of population residing outside municipal areas has been substantial. These areas continue to be administered under rural set up resulting into haphazard developments and faced with the problem of inadequate infrastructure. Over exploitation of ground water and water scarcity have resulted toll to urban water quality.

1.3 Drinking Water Quality in India

The shortage of water in the country is slowly affecting the lives of people as well as the environment around them. Each year it has been observed that during the critical months of summer many part of the country suffers lot due acute water scarcity and non availibility of ground water. As per Census 2011 & WHO-Unicef report 2014[1], it is estimated more than 10% of urban population do not have access to regular safe drinking water. This results, more and more people, in urban India are forced to depends on unsafe water sources like unknown sourced water tanker, deep tube wells etc., In the same report it is observed drinking water in India has health threat with Chemical contaminants namely fluoride, arsenic and selenium. More than 70 million people have risk due to drinking water chemical contamination risk. This is also huge loss of up to 5% of GDP annually[2]

1.4 Drinking Water Quality in Gujarat

Gujarat falls under semi-arid zone. The long sea coastline along Saurashtra, Kutch and other parts creates the problem of salinity ingress, which affects the ground water quality on coastal belt and because of scanty and uncertain rainfall, the replenishment in dam is also not reliable, hence this areas are always under water deficiency. Gujarat occupies 6.39% of country's geographical are however has only 2.28% water resources. Gujarat receives about 80 cm rainfall every year with high coefficients of variance over time & location Though Gujarat has more than 185 rivers and major tributary annul, only 8 rivers are of perennial nature. These all perennial rivers are flowing through southern Gujarat only. Gujarat Surface water sources are also showing huge variance over time and locations.

In the context of complexity of quality of water in various ULBs of Gujarat, there are different issues and problems.For instant, Groundwater quality deteriorates due to the discharge of untreated industrial effluents, urban wastewater, over use of pesticides by irrigators and seawater intrusion. Water quality threat is when water is tapped from sedimentary formation due to water flow in adjacent rock types and mineral compositions of rocks, water quality is affected. Often over-exploitation of groundwater magnifies inherent salts i.e. TDS, fluorides, Chlorides. It is observed that, North Gujarat suffers the

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[1] Progress on Drinking Water and Sanitation 2014 update, WHO-UNICEF

[2] The World Bank Report 2011

most by excessive fluoride followed by Saurashtra – Kachchh and Patan suffer from excessive fluoride in their water supply while, High level TDS and salinity are common scenario across the state. In many cities it is observed that, due to low quantity of water supplied, people often go for tapping private water sources and eventually in many cases it turns out to be ground water.

1.5 Impact of Poor Quality of Drinking Water

The term "water quality" is a widely used expression, which has an extremely broad spectrum of meanings. The term "water quality" is defined as "those physical, chemical or biological characteristics of water by which the user evaluates the acceptability of water". Humans need water supply must be pure and potable for human health. For management of water quality of a water body, one has to define the water quality requirements or water quality goal for that water body. In India, the Central Pollution Control Board (CPCB), an apex body in the field of water quality management. The shortage of water in the country is affecting health and lives of people across the country. Due to excess consumption of fertilizer and pollution of ground and surface water, industry poses a major environmental health hazard. Major water contamination is excess of fluoride, nitrate, iron, TDS and salinity. Ill effect of each can be enlisted as below:

1.5.1 Ill effect of Fluoride: The excessive intake of disease called fluoride which affects multiple tissues, organs and systems in the body. An individual exposed to excessive fluoride intake may suffer from dental fluorosis, non-skeletal manifestations, skeletal fluorosis, or a combination of above referred diseases. The excess fluoride intake may cause dental fluorosis in which mottling of teeth occurs particularly in young children during the age of tooth calcification which alters the structure and appearance of the enamel, producing opacity and brown colouration of the permanent teeth and increases with increase in fluoride content of water. Excessive intake of fluoride can also result in skeletal fluorosis and other skeletal abnormalities which have been observed normally with consumption of water containing more than 3.0 mg/L fluoride. Fluoride when consumed in excess can cause several ailments, besides skeletal and dental fluorosis, which are called non-skeletal fluorosis which has health consequences like Nervousness, depression, tingling sensation of fingers and toes, excessive thirst and urinate more frequently, Muscle weakness, stiffness, pain in muscle and loss of muscle power, very painful

Ill effect of excess of iron

1.5.2 skin rashes, which are per vascular inflammation, pinkish red or non-persistent oval shaped bluish-red spots on the skin, acute abdominal pain, diarrhea, constipation, blood in stool, bloated feelings (gas), tenderness is stomach, feeling of nausea (flu-like symptoms) and mouth sores etc.,

1.5.3 **Ill effect of Arsenic:** Arsenic is a natural metalloid element of the earth's crust in some parts of the world and can also found in water that has flowed through arsenic-rich rocks. Arsenic occurs naturally in the environment as well as human activities like agriculture activities, mining etc; it can be released into water due to activities such as hydrothermal action, dissolution of rocks or human activities. Higher levels of arsenic tend to be found in ground water sources than in surface water sources. Arsenic is showing poisoning effect. In case of arsenic dissolved in water is acutely toxic with number of health problems. It can cause increased risks of cancer in the skin, lungs, bladder and kidney as well as deactivate the function of enzyme. As per 2010 report by National Institute of Health, toxicity of arsenic adversely affects all organs of body with illness like dermal effects, cardiovascular & respiratory effects, gastrointestinal effects, neurological and Reproductive and developmental effects cancer effects, and different types of skin disorders such as skin lesions etc.,

1.5.4 **Ill effect of Nitrate:** Nitrate contamination in surface and groundwater has become an increasingly problem due to excessive use of chemical fertilizers, uncontrolled animal-feeding operations, as well as pesticides and waste contamination through storm and urban runoff all over the country. This is mostly caused by the combined effects of although, nitrate is found in most of the natural waters at moderate concentrations but higher levels are thought to result from human activities. As a result, nitrate concentration in surface and groundwater has largely exceeded the required permissible limits prescribed by various agencies for drinking water, Elevated nitrate concentration in surface and ground water can cause several environmental and public health problems.

- **Primary toxicity:** High nitrate intake can cause abdominal pains, diarrhea, vomiting, hypertension, increased infant mortality, central nervous system birth defects, diabetes, spontaneous abortions, respiratory tract infections, and changes in the immune system.

- **Secondary toxicity:** Secondary toxicity of nitrate is reduced to the reactive nitrite ion. Nitrate has been implicated in methemoglobinemia, especially to infants under six month of age. Methemoglobinemia (MetHb) also referred as haemoid-methemoglobinemia or blue baby syndrome is formed. Symptoms include an unusual bluish grey or brownish grey skin colour, irritability, and excessive crying in children with moderate MetHb levels and drowsiness and lethargy at higher levels. Severe methemoglobin can result in brain damage and death
- **Tertiary toxicity**: Tertiary toxicity of nitrate is due to the reaction between nitrite and secondary or tertiary amine in the human mouth and stomach, under conditions of low gastric acidity, can result in the formation of Nitro compounds.

1.5.5 Ill effect of Excess Iron: iron is one of the most abundant metals of the Earth's crust. The primary concern about the presence of iron in Iron Removal drinking water is its objectionable taste. Iron exists in soils and minerals mainly as insoluble ferric oxide and Iron sulphide (pyrite). It occurs naturally in water in soluble form as the ferrous iron (bivalent iron in dissolved form $Fe^{;}$" or Fe (OH)") or complex form like the ferric iron (trivalent iron: $Fe^{5'}$ or precipitated as $Fe(OH)_3$). It occurs in some areas also as ferrous carbonate, which is slightly soluble. Iron in groundwater normally remains in dissolved state. When water is drawn through bore wells, oxygen from air gets dissolved in water and iron of ferrous state gets oxidized to ferric state and precipitates as suspended solids in water. Therefore water containing iron slowly becomes turbid and highly unacceptable from an aesthetic view point. Iron interferes with laundering operations, impart objectionable stains to plumbing fixtures and also develop taste problems. Carrying capacity of pipelines in the distribution system is reduced due to the deposition of iron oxide and bacterial slimes as a result of the growth of microorganisms (iron bacteria) in iron bearing water. Iron can affect the taste and colour of water. Water becomes brackish colour, rusty sediment, bitter or metallic taste, a problem that frequently results from iron in water is iron bacteria. Iron bacteria are normally considered non-pathogenic, that Is, they are not associated with causing disease. Iron simply Imparts colour to water and normally not associated with any adverse health effects. Excess iron may cause gastrointestinal distress.

1.5.6 Ill effect of Total Dissolved Solids (TDS) & Salinity: TDS level exceed 1000mg/L, is considered unfit for human consumption. Increase level of TDS level are because of Sodium, or Bicarbonate, or Chloride, or Sulphate as well as high amounts of substances such as Calcium, Potassium, Magnesium, and Silica. Some dissolved solids come from organic sources such as leaves, silt, plankton, road salts, fertilizers, pesticides and industrial waste & sewage. Higher TDS water have a heavier taste and a much more prominent "mouth feel," a term used by water connoisseurs to describe the overall sensory impression. The mouth feel may include slight saltiness where there is an appreciable Sodium content in the water. Lower TDS water has virtually no taste, and "express" an airy or light mouth feel. Natural water is like snowflakes - no two are exactly the same. It is affected by the geology, climate, and other environmental and terrestrial factors. Higher TDS may change taste of water to bitter, salty, or metallic it may create unpleasant odors in water. Some of the individual mineral salts that make up TDS pose a variety of health hazards. Most of TDS will be eliminated through excretory channels. But some of this will stay in the body, causing stiffness in the joints, blockages of arteries, hardening of the arteries, kidney stones, gall stones and microscopic capillaries & other passages in which liquids flow through our entire body. Salinity is generally defined as a measure of the dissolved minerals in water. Sodium and magnesium sulfate levels in drinking water lead to laxative effect and also adversely suitability of a water supply for grazing animals.

1.6 Need for Research

Gujarat is one of the industrialized states of the country, with pollution prone industries (like oil refineries and petrochemicals, colour and dyestuff, pharmaceuticals, mineral based industries etc) dominating the industrial structure. There are problems of water contamination arising from solid and liquid waste disposal from industries and human settlements. Though the government has made several attempts to control pollution, it has not been very successful in this task. Gujarat has about 600 large and medium size water polluting factories and about 4300 small scale water polluting industrial units. Gujarat who has large number of solid waste producing units. Some of the industrial centers/ regions are located in South Gujarat, where the pollution has contaminated their drinking water sources. The regions around the major industrial centers like Vadodara, Bharuch, Ankleshwar, Vapi, Valsad, Surat, Navsari etc have polluted water sources, which have affected their drinking water sources adversely. Many times water from hand pumps spew coloured polluted water, wells are contaminated and river / streams are also contaminated. Groundwater quality deteriorates due to the discharge of untreated industrial effluents, urban wastewater, over use of pesticides by irrigators and seawater intrusion either directly from casual disposal or indirectly as seepage from treatment lagoons or infiltration from surface watercourses or canals. This results water contamination at source. It is estimated that, one third total urban population of Gujarat do not get potable water. More and more people in urban Gujarat are dependent on ground water sources; However, Groundwater quality deteriorates due to the discharge of untreated industrial effluents, urban wastewater, over use of pesticides by irrigators and seawater intrusion either directly from casual disposal or indirectly as seepage from treatment lagoons or infiltration from surface watercourses or canals. This leads to water quality threat. Over-exploitation of groundwater magnifies inherent salts i.e. TDS, fluorides, Chlorides across the state. There are region specific issues and require to identified each one and have to make model provide appropriate type of the technological solution at treatment level as well as at monitor level.

Looking to the water quality stress in urban Gujarat initially it was decided to conduct a research related to assessment of quality of drinking water along with health impact in urban Gujarat. However, the thesis committee opined to provide technological options and intervention to improve quality of drinking water. Therefore, the research was modified and set as technical interventions to improve quality of drinking water in urban Gujarat. To keep the research more focus on technical aspect, objective to analyze impact of health was dropped. During the first DPC it was suggested that, it would be better if the research can make frame work to monitor quality of drinking water across all cities of Gujarat. Therefore, it was decided to develop web based MIS system for all ULBs and to acquaint citizens across the state a mobile App. During the discussion and interviews of state and ULB officials, it was suggested and decided to formulate provide Standard Operating Procedure and protocol to improve quality of drinking water during the supply hours in all ULBs. The views and opinion of different experts were to be taken for formulation MIS, SoP & Protocol. There are lot many researches were done for quality of drinking water, however, research related to Urban Gujarat and technological solution in case of water quality stress area is missing The literature review on the similar type of research clearly depicts that study and technological conventional and non conventional solutions to improve quality of drinking water in urban Gujarat area is not offered. The present research was finally focused on assessment of quality of drinking water covering all 170 ULBs of the state, identifying water quality stress area, formulating water quality stress maps, providing suitable technological solution to improve quality of drinking water in their cities, developing web based MIS that can be useful to all ULBs and providing Android based App at free cost to all citizens of Gujarat.

1.7 Outline of thesis

This has been structured in five chapters. **Chapter 1** is an Introduction on the background of quality of drinking water in India and study area Gujarat, highlights of impact of various important drinking water chemical parameters and need for research. **Chapter 2** is a review of literature for drinking water quality methods, technology, and innovative technical options to improve quality of drinking water. **Chapter 3** is a description about aim. Objective, hypothesis, methodology etc., **Chapter 4** describes results of collected data their analysis, mapping of water quality stress area and correlation of various technological options and alternatives to improve quality of drinking water investigates, suggestion for Standard Operating Procedure, water quality improvement protocols, development of Management Information System (MIS) and android based smart phone mobile App for citizens. **Chapter 5** summaries the results of the study and gives recommendations for all ULBs and water utilities and further research.

CHAPTER: 2
Literature Review

Literature reviews begins from water treatment methods, Indian standards for drinking water quality parameters, various methods and technology for improvement of quality of drinking water in India and across the globe. The research is focused on technological alternatives, options to improve the quality of drinking water.

2.1 Water Quality Standards

Water has such a strong tendency to dissolve other substances. When it falls as rain, small amounts of gases such as oxygen and carbon dioxide become dissolved in it; raindrops also carry tiny dust particles and other substances. As it flows over the ground, water picks up fine soil particles, microbes, organic material, and soluble minerals. Groundwater usually acquires more dissolved minerals than dose surface runoff because of its longer direct contact with soil and rock. Potable water must be available in the right quantity and in right quality. Provision of safe drinking water is as an essential requirement. This is because of the linkages between drinking water and health outcomes.

The raw or treated water is analyzed by testing their physical, chemical and bacteriological characteristics. Impure water may have a bad taste, color, odor, or loudly appearance (turbidity), cause hardness, corrosiveness, staining, or damage growing plants and transmit disease. Followings are major Physical, Chemical and Biological Characteristics to be checked for quality of water before supply for dinking purpose.

2.1.1 Physical Characteristics

- **Turbidity:** If a large amount of suspended solids are present in water, it will appear turbid in appearance. The turbidity depends upon fineness and concentration of particles present in water. Turbidity is measured by applying Nephelometry, a technique to measure level of light scattered by the particles at right angles to the incident light beam. The scattered light level is proportional to the particle concentration in the sample. The unit of expression is Nephelometric Turbidity Unit (NTU).

- **Colour:** Dissolved organic matter from decaying vegetation or some inorganic materials may impart colour to the water. It can be measured by comparing the colour of water sample with other standard glass tubes containing solutions of different standard colour intensities. The standard unit of colour is that which is produced by one milligram of platinum cobalt dissolved in one liter of distilled water.
- **Taste and Odour:** Odour depends on the contact of a stimulating substance with the appropriate human receptor cell. Most organic and some inorganic chemicals, originating from municipal or industrial wastes, contribute taste and odour to the water. Taste and odour can be expressed in terms of odour intensity or threshold values.
- **Temperature:** The increase in temperature decreases palatability, because at elevated temperatures carbon dioxide and some other volatile gases are expelled. The ideal temperature of water for drinking purposes is 5 to 12 °C - above 25 °C, water is not recommended for drinking.

2.1.2 Chemical Characteristics

- **pH:** pH value denotes the acidic or alkaline condition of water. It is expressed on a scale ranging from 0 to 14, which is the common logarithm of the reciprocal of the hydrogen ion concentration. The recommended pH range for treated drinking waters is 6.5 to 8.5
- **Acidity:** The acidity of water is a measure of its capacity to neutralize bases. Acidity of water may be caused by the presence of uncombined carbon dioxide, mineral acids and salts of strong acids and weak bases. It is expressed as mg/L in terms of calcium carbonate.
- **Alkalinity:** The alkalinity of water is a measure of its capacity to neutralize acids. It is expressed as mg/L in terms of calcium carbonate. The various forms of alkalinity are (a) hydroxide alkalinity, (b) carbonate alkalinity, (c) hydroxide plus carbonate alkalinity, (d) carbonate plus bicarbonate alkalinity, and (e) bicarbonate

alkalinity, which are useful mainly in water softening and boiler feed water processes. Alkalinity is an important parameter in evaluating the optimum coagulant dosage.

- **Hardness:** If water consumes excessive soap to produce lather, it is said to be hard. Hardness is caused by divalent metallic cat ions. The principal hardness causing cat-ions are calcium, magnesium, strontium, ferrous and manganese ions. The major anions associated with these captions are sulphates, carbonates, bicarbonates, chlorides and nitrates. The total hardness of water is defined as the sum of calcium and magnesium concentrations, both expressed as calcium carbonate, in mg/L. Hardness are of two types, temporary or carbonate hardness and permanent or non carbonate hardness. Temporary hardness is one in which bicarbonate and carbonate ion can be precipitated by prolonged boiling. Non-carbonate ions cannot be precipitated or removed by boiling, hence the term permanent hardness.
- **Chlorides:** Chloride ion may be present in combination with one or more of the cat-ions of calcium, magnesium, iron and sodium. Chlorides of these minerals are present in water because of their high solubility in water. Excessive presence of chloride in water indicates sewage pollution.
- **Sulphates:** Sulphates occur in water due to leaching from sulphate mineral and oxidation of sulphides. Sulphates are associated generally with calcium, magnesium and sodium ions. Sulphate in drinking water causes a laxative effect. It also causes odour and corrosion problems under aerobic conditions.
- **Iron:** Iron is found on earth mainly as insoluble ferric oxide. When it comes in contact with water, it dissolves to form ferrous bicarbonate under favourable conditions. This ferrous bicarbonate is oxidised into ferric hydroxide, which is a precipitate. Iron can impart bad taste to the water, causes discolouration in clothes and incrustations in water mains.
- **Total Solids:** The sum total of foreign matter present in water is termed as 'total solids'. Total solids are the matter that remains as residue after evaporation of the sample and its subsequent drying at a defined temperature (103 to 105 °C). Total solids consist of volatile (organic) and non-volatile (inorganic or fixed) solids. Further, solids are divided into suspended and dissolved solids. Solids that can settle by gravity are settling able solids. The others are non-settle able solids.

- **Nitrates:** Nitrates in surface waters occur by the leaching of fertilizers from soil during surface run-off and also nitrification of organic matter. Presence of high concentration of nitrates is an indication of pollution. Concentration of nitrates above 45 mg/L causes a disease.
- **Arsenics:** Arsenic contamination of groundwater is a form of groundwater pollution which is often due to naturally occurring high concentrations of arsenic in deeper levels of groundwater.

2.1.3 Bacteriological Characteristics: Bacterial examination of water is very important. It causes water borne diseases like Bacterial e.g. cholera, typhoid fever, Protozoa e.g. dysentery, Viral e.g. hepatitis A, diarrhoea etc., Water polluted by sewage contains one or more species of disease producing pathogenic bacteria. Pathogenic organisms cause water borne diseases, and many non pathogenic bacteria such as E.Coli, a member of coli form group, also live in the intestinal tract of human beings. Coli form itself is not a harmful group but it has more resistance to adverse condition than any other group.

TABLE: 2.1 Water related diseases and preventive strategies

Classification	Transmission	Examples	Preventive Strategies
Preventive Strategies Water-borne (Waterborne diseases can also be washed)	Disease is transmitted by indigestion (Faecal – Oral route)	• Diarrhoea • Cholera • Typhoid • Hepatitis (A & E)	• Improve quality of drinking water. • Prevent casual use of other unimproved sources. • Improve sanitation.
Water washed (water scare)	• Infections of the intestinal track. • Skin or eye infections. • Infections caused by lice or mites.	• Scabies • Trachoma • Conjunctivitis • Amoebiasis • Giardiasis	• Increase water quantity. • Improve accessibility & reliability of domestic water supply. • Improve hygiene & sanitation
Water Based	The pathogen spends part of its lifecycle in an animal, which is water based. The pathogen is transmitted by indigestion or by penetration of the skin	• Guinea worm • Schistosomiasis	• Decrease need of contact with infected water. • Control vector host populations. • Improve quality of water (for some types) • Improve sanitation
Water related Insect	vector Spread by insects that breed or bite near water.	• Malaria • Filariasis • River blindness	• Improve surface water management. • Destroy insect breeding sites. • Use mosquito netting. • Use insecticides

(Source:IS:10500 & WHO)

Standards for Quality of Water

Water should conform to some acceptable guidelines e.g. WHO and IS: 10500 and PHED standards. As per IS: 10500, followings are important physical, chemical standards and bacteriological set for quality of water.

TABLE:2.2 Standards for Quality of Water

No	**Characteristics**	**Acceptable in ppm (mg/l)**	**Permissible Limit in the absence of alternate sources (Causes for Rejection)**
	Physical Characteristics		
1	Turbidity(NTU)	**1**	**10**
2	Colour (Units on cobalt scale)	**5**	**25**
3	Taste & Odour	**Unobjectionable**	**Objectionable**
4	pH	**7 to 8.5**	**<6.5 or>9.2**
	Chemical Characteristics		
5	Total Dissolved Solids (ppm)	**500**	**2000**
6	Total Hardness (as CacO3)(ppm)	**200**	**600**
7	Chloride (as cl)	**250**	**1000**
8	Sulphates (as SO4)	**200**	**400**
9	Fluorides(as F)	**1**	**1.5**
10	Nitrate (as NO3)	**45**	**No Relaxation**
11	Calcium(as Ca)	**75**	**200**
12	Magnesium (as mg)	**<=30**	**No Relaxation**
13	Iron (as Fe)	**0.30**	**No Relaxation**
14	Arsenic	**0.01**	**0.05**
15	Residual Chloride (ppm)	**0.20**	**---**
	Bacteriological Standards		
Organisms		**Guideline value**	
All water intending for drinking			
E-coli or theromtolerant coli form bacteria		Must not be detectable in 100 ml sample	
Treated water entering the distribution system			
E-coli or theromtolerant coli form bacteria		Must not be detectable in 100 ml sample	

(Source: IS Standard IS:10500:2012 second revision)

2.2 Water Sampling

The basic objective of a water analysis laboratory is to produce accurate data describing the physical-chemical characteristics of water samples under study. Quality assurance is the total programme for assuring the reliability of analytical data.

Sampling is an important tool in understanding the water quality. It is always to be ensured that a small portion of water referred to as a sample which represents the whole water body, is collected for a detailed investigation. This is as good as testing the entire water body or total supplied water. Sample containers are bottles made of either glass or virgin plastic. There are three important water sampling methods viz., Grab or Catch Sample, Composite Sample and Integrated Sample. There are four types of sample based on source/depth of sampling. Samples for chemical & bacteriological analysis should be collected separately as the method of sampling and preservation is completely different from each other. Suggestive quantity of sample is as under:

- Quantity of sample for General Analysis: 2 litres (non-acidified).
- Quantity of sample for Bacteriological Analysis: 250 ml in sterilized bottles.
- Quantity of sample for Metals Analysis: 1000 ml acidified sample for metal analysis.

- **Surface water samples:** Water samples collected from the surface using glass bottles or polyethylene bottles are called surface water samples. Normally, they are collected from source, at WTP and at GSR. This method gives a representation of the water samples at the surface and is useful for rapid assessments. This method can be used when depth samplers are not available.
  - **Procedure:** Lower the bottle with lid closed, to a depth of about 20-30 cms below the water surface. Open the lid and collect the water carefully. Do not allow air bubble to enter the bottle. Closed the lid and remove the bottle form the water body.
- **Bottom water samples:** Water samples collected from the bottom of the water body are called bottom water samples. Bottom water samples are useful in understanding the variation in the physical, chemical and biological characteristics of a water body such as temperature, dissolved oxygen, phosphates, nitrates etc. and productivity with respect to depth.
  - **Procedure:** For knee-deep and shallow water bodies, follow the surface water sampling procedure. For deep water bodies use depth samplers for colleting

samples. A simple water sampler is Mayer's water sampler. It is the simplest device used for collecting water sample from a depth of up to 20-30 cms. Mayer's water sampler consists of an ordinary glass bottle with capacity of about 1-2 litters. It is half enclosed in a metal case and has weight made of lead attached to the base. Two strong nylon graduated ropes are tied to it, one to the neck of the bottle and the other to the cork. The bottle is lowered to the desired depth using the neck rope. The stopper is opened by pulling the rope of the cork, The water fills the bottle. When the bottle is full (indicated by the disappearance of the bubbles), the rope of the cork is released in order to close the mouth of bottle. The sample is lifted using the neck rope. The water sample collected is transferred into a polyethylene or a glass bottle carefully without allowing air bubbles.

- **Collection of water from the Connection:** In order to get quality of water at HH level, it is desirable to take water from the tap. Timeliness and cleanliness are important when collecting any water sample. Use the sterile collection bottles the lab sends you and not your own bottles to take a sample. In some cases it must be kept cold prior to testing. Care must be taken to prevent anything but the water from contacting the inside of the bottle or the cap.
-
    - **Procedure:** Run the water several minutes to clear the line. Take the sample midstream in disinfected virgin plastic/pet bottle of at least 500 ml capacity. Do not touch the sides of the collection bottle, the opening or inside of the cap. If needed, store the sample in the refrigerator before taking to the lab within 48 hours of collection.

- **Column water sample:** In order to get information on changes in water quality parameters, such as temperature and source of contamination, water samplers are collected separately from different depths at interval of 0.50m. or 1 m. This is known as column water sampling.

2.3 Methods to test Water Samples

The CPHEEO recommended following methods to taste parameters of drinking water.

TABLE: 2.3 Methods to test for parameters for Water-quality Monitoring

Sr.No.	Parameter	Method
	Physical	
1.	Colour	Visual Comparison Method
		Spectrophotometric Method
2.	Odour	Threshold odour test
3.	Taste	Flavour threshold test
		Falvour rating assessment
		Flavour profile analysis
4.	pH	pH meter
		PH Paper
5.	Turbidity	Nephelometer
6.	Conductivity	By Conductivity Meter
7.	Dissolved Solids	Filtration and Evaporation method
		Computation from conductivity measurement
	Chemical	
1.	Alkalinity	pH meter
		Potentiometric Titration
		Titration method
2.	Total Hardness	EDTA titrimetric method
3.	Iron	Atomic absorption spectrometric method
		Inductively coupled plasma method
4.	Chloride	Argentometric method
5.	Residual Free Chlorine	Iodometric method I
		Iodometric method II
		Ampermetric titration method
		Low level amperometric titration method
		DPD ferrous tittrimetric method
		DPD colorimetric method
		By chloroscopes
6.	Calcium	EDTA titrimetric method
7.	Magnesium	EDTA titrimetric method
8.	Manganese	Atomic absorption spectrometric method
		Inductively coupled plasma method
		Per sulphate method
9.	Sulphate	Ion chromatographic method
		Gravimetric method with ignition of residue
		Gravimetric method with drying of residue
		Turbidimetric method
10.	Nitrate	U.V spectrophotometric screening method
		Nitrate electrode method
		Cadmium reduction method
		Automated cadmium reduction method
		Automated hydrazine method
		U.V spectrophotometric screening method
		Nitrate electrode method
11.	Fluoride	Ion selective electrode method
		SPADNS method
12.	Sodium	Atomic absorption spectrometric method
		Inductively coupled plasma method
		Flame emission photometric method
13.	Potassium	Atomic absorption spectrometric method
		Inductively coupled plasma method
		Flame emission photometric method

Sr.No.	Parameter	Method
14.	Phenolic Compounds	Chloroform extraction method
		Direct photometric method
15.	Cyanide	Cyanide selective electrode method
		Colorimetric Method
	Heavy Metals	
1.	Copper	Atomic absorption spectrometric method
		Inductively coupled plasma method
		Neocuproine method
		Bathocuproine method
2.	Nickel	Atomic absorption spectrometric method
		Inductively coupled plasma method
		Heptoxime method
		Dimethylglyoxime method
3.	Mercury	Cold vapour atomic absorption method
		Dithiozone method
4.	Cadmium	Atomic absorption spectrometric method
		Inductively coupled plasma method
		Dithiozone method
5.	Arsenic	Atomic absorption spectrometric method
		Inductively coupled plasma method
		Silver diethyldithiocarbamate method
		Mercuric bromide stain method
6.	Lead	Atomic absorption spectrometric method
		Inductively coupled plasma method
		Dithiozone method
7.	Zinc	Atomic absorption spectrometric method
		Inductively coupled plasma method
		Zincon method
8.	Chromium	Atomic absorption spectrometric method
		Inductively coupled plasma method
		Colorimetric method
9.	Aluminium	Atomic absorption spectrometric method
		Inductively coupled plasma method
		Eriochrome cyanine method
	Pesticides	
1.	Dieldrin	Liquid-liquid extraction Gas Chromatographic Method-I Liquid-liquid extraction Gas Chromatographc Method-II
2.	OdourAldrin	
3.	Taste Endrin	
4.	Lindane	
5.	Heptachlor	
6.	Heptechlor Epoxide	
7.	o.p-DDT	
8.	p.p.-DDT	
9.	Pp'-DDE	
10.	BHC	
11.	Methoxychlor	
12.	Chloride	
	Radioactivity	
1.	"Alpha" activity	Counting method
2.	"Beta' activity	Counting method
	Bacteriology	
1.	Total Coli form	Membrane Filter Technique
		Multiple Tube Fermentation Technique
2.	Faecal Coli form	Membrane Filter Technique
		Multiple Tube Fermentation Technique

(Source: IS standard IS:10500-2012)

2.4 Conventional Water Treatment:

Conventional water treatment consists of coagulation, flocculation, filtration and disinfection to provide clean and safe drinking water to the public.

2.4.1 Coagulation: The coagulation process involves adding salts, such as alum, ferric sulphate, ferric chloride or poly electrolytes to water. These chemicals are called coagulants, and have a positive charge. The positive charge of the coagulant neutralizes the negative charge of dissolved and suspended particles in the water. When this reaction occurs, the particles bind together, or coagulate. The larger particles, or floe, are heavy and quickly settle to the bottom. This settling process is called clarification. Coagulation and sedimentation can only remove between 27 and 84 percent of viruses and between 32 and 87 percent of bacteria. Usually, the pathogens that are removed as they get attached to the dissolved substances that are removed by coagulation. As coagulation does not remove all of the viruses and bacteria in the water, it cannot produce safe drinking water.

2.4.2 Filtration: The next step in a conventional water treatment system is filtration, which removes particulate matter from water by forcing the water to pass through porous media. The filtration system consists of filters with varying sizes of pores, and is often made up of sand, gravel and charcoal. There are two basic types of sand filtration; slow sand filtration and rapid sand filtration.

Slow sand filtration is considered as a biological process, as the filtration rate is low and contact time is more. The bacteria thus developed establish a community on the top layer of sand and clean the water as it passes through, by digesting the contaminants in the water. The layer of microbes is called biofilm. Slow sand filtration systems require large areas of land to operate, because the flow rate of the water is between 0.1 and 0.3 rn^3 per hour. Slow sand filtration removes bacteria, protozoa and viruses, and produces essentially clean water, though it is still advisable to also use a disinfectant. Due to simple 0 & M, this system is more preferred in smaller rural water supply schemes.

Rapid sand filtration is a physical process that removes suspended solids from the water. Rapid sand filtration is much more common than slow sand filtration, because rapid sand fitters have fairly high flow rates and require relatively little space to operate. In fact, during rapid sand filtration, the water flows at a rate up to 20 m^3 / nr. The particles that are removed from the water during filtration depend upon the size of filters that are used. Rapid sand filtration removes suspended particles, which may have bacteria attached, but in general remove very less bacteria, protozoa, or viruses. In water treatment plants, filtration removes a large number of contaminants, but still requires disinfection to produce drinking water that is safe.

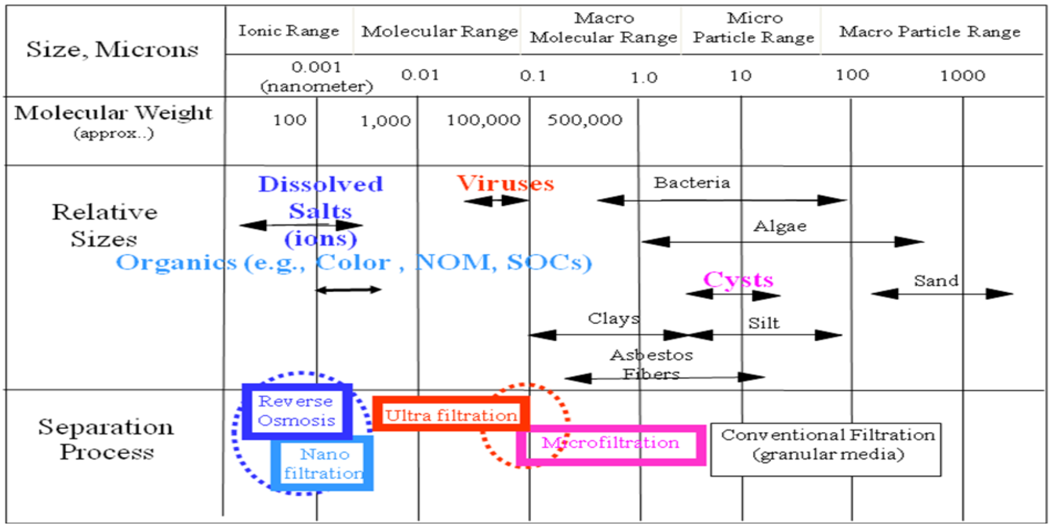
2.4.3 Disinfection: Water is disinfected prior to distribution. To ensure water is free from any biological impurities, water is disinfected prior to distribution. Chlorination is preferred choice for disinfection because of its versatility and cheapness. Chlorine can be applied for the deactivation of most microorganisms, excluding protozoa. There exists several technologies for treatment of household water and many such technologies are widely used. These treatment technologies include a number of physical and chemical methods. The physical methods include settling, filtering particularly through cloth, boiling, heating (fuel and solar), SODIS and UV disinfection with lamps. The chemical methods include coagulation-flocculation and precipitation, adsorption, ion exchange and chemical disinfection particularly by using chlorine.

2.5 Modern Water Treatment Practice: Membrane Separations for Application to Drinking Water

It is also observed that, lot of countries are developing modern water treatment plant by using Membrane techniques which comprise of Reverse Osmosis, Nano-filtration, Electro dialysis.

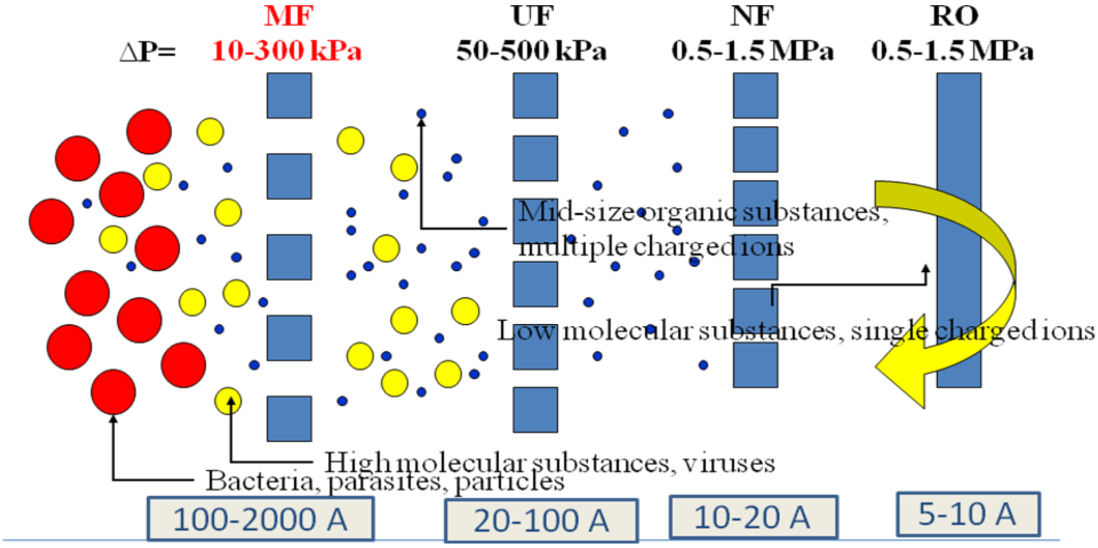
2.5.1 Reverse osmosis: Reverse osmosis (RO) is a water purification technology that uses a semi permeable membrane to remove ions, molecules, and larger particles from drinking water. In reverse osmosis, an applied pressure is used to overcome osmotic pressure, which is driven by chemical potential differences of the solvent. Reverse osmosis can remove many types of dissolved and suspended species from water, including bacteria. The result is that the solute is retained on the pressurized side of the membrane and the pure solvent is allowed to pass to the other side. In the normal osmosis process, the solvent naturally moves from an area of low solute concentration, through a membrane, to an area of high solute concentration. The driving force for the movement of the solvent is the reduction in the free energy of the system when the difference in solvent concentration on either side of a membrane is reduced, generating osmotic pressure due to the solvent moving into the more concentrated solution. Applying an external pressure to reverse the natural flow of pure solvent, thus, is Reverse Osmosis.

2.5.2 Nano Filtration: Nanofiltration is a relatively recent membrane filtration process



used most often with low total dissolved solids water such as surface water and fresh groundwater, with the purpose of softening and removal of disinfection. Nano-filtration is a membrane filtration-based method that uses nanometer sized cylindrical through-pores that pass through the membrane at 90°. Nano-filtration membranes have pore sizes from 1-10 nanometers, smaller than that used in microfiltration and ultra filtration, but just larger than that in Reverse Osmosis. Membranes used are predominantly created from polymer thin films. Materials that are commonly used include polyethylene terephthalate or aluminum.

2.5.3 Electro-dialysis: Electro Dialysis (ED) is a membrane process, during which ions are transported through semi permeable membrane, under the influence of an electric potential. The membranes are cat ion- or anion-selective, which basically means that either positive ions or negative ions will flow through. Action-selective membranes are Polyelectrolyte's with negatively charged matter, which rejects negatively charged ions and allows positively charged ions to flow through. By placing multiple membranes in a row, which alternately allow positively or negatively charged ions to flow through, the ions can be removed from water. In some columns concentration of ions will take place and in other columns ions will be removed. The concentrated saltwater flow is circulated until it has reached a value that enables precipitation. At this point the flow is discharged. This technique can be applied to remove ions from water. Particles that do not carry an electrical charge are not removed. Action-selective membranes consist of sulphonated polystyrene, while anion-selective membranes consist of polystyrene with quaternary ammonia. Sometimes pre-treatment, in which suspended solids with a diameter that exceeds 10 µm, is done to avoid blockage of membrane pores.



2.6 Comparison between various Practice and Technology for Water Treatment:

Pros and cons of Conventional Filtration and Membrane based Filtration technologies are summarised:

TABLE 2.4 Comparison between various methods for Water Treatment

1. Conventional Filtration		
Method	**Pros**	**Cons**
• Coagulation, sedimentation followed by filtration either by slow sand or rapid sand	• Water filters are not limited in type or size of contaminants they can remove. • Water filters are able to remove far more contaminates than any other purification method • They use the chemical adsorption process • Water filters also extract from drinking water the chlorine-resistant protozoa • Do not require the costly energy • Rapid water filters allot water inadequate contact time with the inadequate contact time with the filter media.	• Not remove all minerals • Backwash & continuous maintenance require • Limited control over bacterial load
2.Memberane based Filtration		
Method	**Pros**	**Cons**
• Process depends upon a semi- permeable membrane through which pressurized water forced either RO, Electro-dialysis or desalination	• They are valuable water purification process when mineral-free water is the desired end product • Process removes some chemical components including fluoride. • Process also removes alkaline mineral as well as acidic water • Removes 95% + bacteriological load	• They are still incredibly inefficient process. • Normally, process wastes three litters of water for every one litre of purified water it produces • Costlier • Removal leaves tasteless unhealthy drinking water

(Source: Analytic data based on details collected for different methods)

2.7 Various Technological options: Based on Need of upgrading properties of water: These can be summarised as tabulated below.

TABLE:2.5 Universal Practice to improve quality of water for Normal Properties

Property	Contaminated part	Universal Practice
	Physical Property	
Turbidity	Suspended fine sand, clay, other small particles	Use sand filter for large quantities of suspended particulates or use a sediment filter or sedimentation (allowing the particles to settle out of suspension) for smaller quantities of sediment
Colour	Hydrogen Sulphide gas (rotten egg odour)	Remove by using chlorination and a sedimentation filter
Odour	Many odour and taste problems other than rotten egg smells	An oxidizing (i.e. greensand) filter followed by activated carbon filter
	Chemical Property	
TDS	Temporary or permanent hardness	Activated carbon filter /RO
Ph	Acidity: pH lower than 7	pH correction using either a tank-type neutralizing filter for respective correction
Radio nucleotides	Very critical property	Radon can be removed with an activated carbon filter
		Radium can be removed with RO, carbon exchange & distillation
	Biological Property	
Biological load/ MPAN/B-coil	Bacteria/ fungus	Chlorination/ UV ray/ Ionisation

(Source: Analytic data based on details collected for different methods)

2.8 Various Technological Options to improve Quality of Water Treatment: For Additional Treatment requirement

Water purification is the process of removing undesirable chemicals, biological contaminants, suspended solids and gases from contaminated water. The aims of the treatment are to remove unwanted constituents in the water and to make it safe to drink. Purifying water may reduce the concentration of particulate matter including suspended particles, parasites, bacteria, algae, viruses, fungi, as well as reducing the amount of a range of dissolved and particulate material derived from the surfaces that come from runoff due to rain. There are wide range of techniques are available to remove contaminants. The methods used include physical processes such as filtration, sedimentation, and membrane technology; biological processes such as slow sand filters or biologically active carbon; chemical processes such as flocculation and chlorination and the use of electromagnetic radiation such as ultraviolet light. Sometimes, it is required to carry out additional water treatment to remove chemicals and biological impurities particular limited to region, area specific and depends upon sources of water and ambient quality of water. It has been observed that, most harmful chemicals like fluoride, Nitrate, Arsenics, Iron or TDS exceed desirable limit as set by WHO or BIS;10500, in water may make water unfit for potable purpose. Therefore it is attempted here to enlist technological options available and used the worldwide to improve quality of water by providing additional treatment. These consist of technology to improve chemical properties to remove Fluoride, Nitrate, Arsenics, TDS & Salinity and Iron removal are as describe below:

2.8.1 Fluoride Removal Technologies: Groundwater contaminant is a major chemical impurity issue for drinking water supply. As per IS: 10500 it desirable to have fluoride less than 1.5ppm. The excessive intake of fluoride causes fluorosis, a disease affecting the multiple tissues, organs and systems in the body. Defluoridation of drinking water is the only practicable option to overcome the problem of excessive fluoride in drinking water, where alternate source is not available. Number of technologies, for several defluoridation processes based on adsorption and ion exchange in filter systems, coagulation and precipitation and membrane filtration processes have been developed and tested globally. The common methods **used for** the removal of fluoride from drinking water can be listed as described below:

2.8.1.1 Adsorption and ion-exchange: Adsorption processes involve the passage of water through a contact bed where fluoride is removed by ion exchange or surface chemical reaction with the solid bed matrix of activated alumina. The adsorbents commonly used for fluoride removal include activated alumina, carbon, bone charcoal and synthetic ion exchange resins. For example, activated alumina is a granular, highly porous material consisting essentially of aluminum trihydrate. After a period of operation, a saturated column must be refilled or regenerated. The adsorption behaviour of fluoride by various adsorbents varies significantly, depending on the bonding between fluoride species and active sites on the surface of the specific adsorbent. Fluoride removal capacity of alumina can be removed up to 4 ppm.

2.8.1.2 Bone char: Bone charcoal as the oldest known water defluoridation agent, as first used in 1940. Removal of fluoride by adsorption on fishbone charcoal in a moving media adsorption system. It depends upon the pH value. It works only at PH 3 .0 or less therefore it is required to adjust pH by adding acidic agents. Adjustment of pH is expensive, time consuming, skill requirement and affects quality of water after treatment for pH value. Therefore, it has limited usage.

2.8.1.3 Degreased and alkali treated bones: Bone contains calcium phosphate. It has a great affinity for fluoride. The bone is degreased, dried and powdered. The powder can be used as a contact bed for removal of fluoride in water. Degreased and alkali treated bones are effective in the removal of fluoride from initial fluoride concentration. The exhausted bed is regenerated with sodium hydroxide solution. However, use of bone char based deflurodation technologies in India has social acceptability limitations.

2.8.1.4 Activated carbon: Carbons prepared from different carbonaceous sources showed fluoride removal capacity after alum impregnation. Alkali digested alum impregnated paddy husk carbon was an efficient defluoridating agent. Carbonized saw dust when quenched in 2% alum solution forms an excellent defluoridating carbon. The defluoridating process is between carbon and fluoride. After continued use and on exhaustion the carbon can be regenerated by passing 0.2 to 0.5% alum solutions. Alkali digested (1 % KOH) and alum soaked (2% alum) carbon removed 320 mg fluoride per kg and showed maximum removal efficiency at pH 7.0.

2.8.1.5 Tamarind gel and seed : Concentration of fluoride from the solution of sodium fluoride of 10 mg/L could be brought down to 2 mg/L by the addition of tamarind gel alone and to 0.05 mg/L by the addition of small quantity of chloride with the tamarind gel. Tamarind seed is also used for the sportive removal of fluoride from synthetic aqueous solution as well as from field water samples. Due to issues related to handling, operation and costing, it is not feasible to adopt method at city level water supply. It can be applied limited to HH level only.

2.8.1.6 Coagulation-precipitation: The aluminum sulphate and lime based coagulation-flocculation sedimentation process for defluoridation was adopted by NEERI as Nalgonda technique and developed for the low cost use. Nalgonda technique is based on combined use of alum and lime in a two-step process and has been claimed as the most effective technique for fluoride removal. Nalgonda Technique involves addition of aluminum salts, lime and bleaching powder followed by rapid mixing, flocculation sedimentation, filtration and disinfection. Aluminum salt may be added as aluminum sulphate or aluminum chloride or combination these two. Aluminum salt is only responsible for removal of fluoride from water. The dose of aluminum salt increases with increase in the fluoride and alkalinity levels of the raw water. The selection of either aluminum sulphate or aluminum chloride also depends on the sulphate and chloride contents of the raw water to avoid exceeding their permissible limits. Lime facilitates formation of dense floes for rapid setting. Bleaching powder is added to the raw water at the rate of 3mg/L for disinfection. Besides fluorides, turbidity, colour, odor, pesticides and organics are also removed. The bacterial load is also reduced significantly.

2.8.1.7 Chemo defluoridation Technique: Chemo-defluoridation technique is also developed by NEERI. In which, the salts of calcium and phosphorous have been used to reduce the raw water fluoride concentration in the range 5 -**1**0.0 mg/L to < 1.0 mg/L. Required dose of chemicals are added in the fluoride contaminated raw water and mixed properly. The chemicals react to form the chemical complex which absorbs fluoride and precipitate out. After 15 to 20 minutes of mixing of the chemicals, water is allowed to flow by gravity into the sand filter at the rate of 300 400 ml/min. Filtered water with fluoride concentration less than **1** mg/L is collected in the third plastic container and can be used for drinking and cooking purposes. The layer of chemical complex precipitate formed on the sand filter also removes some fluoride from the water during filtration. After about 1 to 2 months of operation, filter is choked by the formation of thick layer of sludge, which can be removed easily.

2.8.1.8 Reverse osmosis and Nano-filtration: Membrane techniques for removal of fluoride shows, the rejection of fluoride ion higher than 98%. These may be in form of nano-filtration or RO system. Similarly, dialysis and electro-dialysis techniques are also effectively utilized for removal of fluoride. However, membrane technology is costlier.

2.8.1.9 Emerging defluoridation technologies: Besides the techniques mentioned earlier, Crystal actor Memstill technology, Water Pyramid solution, Solar Dew Collector system etc., are also emerging defluridation technologies across the globe. However, these require skilled manpower and at experimental basis, hence not discussed.

2.8.2 Nitrate Removal Technologies

Nitrate contamination in surface and groundwater has become an increasingly problem. Although, nitrate is found in most of the natural waters at moderate concentrations but higher levels are thought to result from human activities. This is mostly caused by the combined effects of chemical fertilizers, uncontrolled animal-feeding operations, as well as pesticides and waste contamination through storm and urban runoff. As a result, nitrate concentration in surface and groundwater has largely exceeded the required permissible limits. Higher concentration of nitrate in surface and ground water can cause several environmental and public health problems. Some of them are given below.

- **Primary toxicity:** High nitrate intake can cause abdominal pains, diarrhea, vomiting, hypertension, increased infant mortality, central nervous system birth defects, diabetes, spontaneous abortions, respiratory tract infections, and changes in the immune system.

- **Secondary toxicity:** Secondary toxicity of nitrate is microbial reduced to the reactive nitrite ion by intestinal bacteria. Nitrate has been implicated in methemoglobinemia, especially to infants under six month of age. Methemoglobinemia (MetHb) also referred as haemo-methemoglobinemia or blue baby syndrome is formed when nitrite (for our purposes, formed from the endogenous bacterial conversion of nitrate from drinking water} oxidizes the ferrous iron in hemoglobin (Hb) to the ferric form.

- **Tertiary toxicity** Tertiary toxicity of nitrate is due to the reaction between nitrite and secondary or tertiary amine in the human mouth and stomach, under conditions of low gastric acidity, can result in the formation of N - nitroso compounds, some of which are known to be carcinogenic, teratogenic and mutagenic.

To protect consumers from the adverse effects associated with the high nitrate intake, nitrate consumption should be limited. BIS has stipulated desirable standard of 45 mg/l and WHO has guideline value of 50 mg/l. Nitrate is a stable and highly soluble ion with less potential for co-precipitation or adsorption. These properties make it difficult to be removed from water by some popular processes such as chemical coagulation, lime softening and filtration which are effective for removing most of the pollutants including heavy metals but unfortunately, they do not work for nitrate. Hence, treatment of nitrate is typically very complicated and expensive. Following methods exist for removal of nitrates from drinking water. Adsorption/Ion exchange Biological denitrification Catalytic reduction Reverse osmosis Electrodialysis Blending. The utility of these techniques has been limited due to their expensive operation and subsequent disposal problem of the generated nitrate waste brine. These techniques require frequent careful maintenance and sampling to achieve and confirm effective operation. Improperly installed, operated or maintained plants can result in nitrate passing through the treatment process and in some cases concentrating the nitrate above the incoming levels.

Adsorption/ion-exchange techniques

2.8.2.1 Adsorption/ion exchange: Ion exchange process seems to be the most popular physico-chemical process for small water suppliers contaminated by nitrate because of its simplicity, effectiveness, selectivity and recovery and relatively low cost. The ion exchange process involves passage of nitrate contaminated water through a resin bed containing strong base anion exchange resins that are charged with chloride, As water passes over the resin bed, the resin takes up the nitrate ions in exchange for chloride until the exchange capacity is exhausted. The exhausted resin is then regenerated using a concentrated solution of sodium chloride (brine). The disadvantages of ion exchange are high associated cost and the production of highly concentrated brine waste. The backwash solution, which is high in nitrate, must be properly disposed of.

2.8.2.2 Biological denitrification : Biological denitrification is carried out by facultative bacteria that use nitrate as a terminal electron acceptor for respiration under anoxic conditions. It converts the nitrate to nitrogen gas. There are two types of biological denitrification, the autotrophic and heterotrophic denitrification. Heterotrophic denitrification is a process that uses various carbon compounds as energy and electron sources such as ethanol, methanol etc., while autotrophic denitrification bacteria uses hydrogen, iron or sulphur 081 compounds as energy source and carbon dioxide or bicarbonate as carbon source. The main advantages of heterotrophic denitrification are the high denitrifying rates and treatment capacity. However, products of microbial activity and incomplete degraded organic compounds imparted to the treated water require extensive post treatment to safeguard the drinking water quality. The process is generally time consuming, operates under limited temperature ranges, requires extensive maintenance and mostly used for treating water with higher value of nitrate concentration.

2.8.2.3 Catalytic reduction/denitrification: Metallic catalysts are the process in which, nitrate reacts with hydrogen gas or formic acid and it is converted into nitrogen and water using a solid catalyst. The activity and selectivity of metallic catalysts plays a crucial role for the effective conversion of nitrate to nitrogen gas. However this technique has limitations of possible catalyst fouling, post-treatment requirement due to the production of by-products and production of large quantity of sludge.

2.8.2.4 Reverse Osmosis: Reverse Osmosis is an established technology for removal of various contaminants of water. In order to increase the life of membrane in reverse osmosis (RO) process, pre-treatment of contaminated water is essential which is generally achieved by passing it through sand filter, activated carbon filter and micron filter to remove iron organic matter, excess free chlorine and suspended matter. Limitations of the process are high operational cost, disposal of rejects and substantial quantity of reject water.

2.8.2.5 Electrodialysis: Electrodialysis (ED) is an electrically driven process that uses a voltage potential to drive charged ions through a semi-permeable membrane reducing the nitrate in source water. The separation is accomplished by alternately placed cat ion and anion selective parallel membranes across the current path to form an ED cell. DC voltage potential induces the cat ion to migrate towards the anode through cationic membrane and the anions to migrate towards the cathode through anionic membrane. Electro-dialysis reversal system periodically reverses the polarity of electric field. This is an expensive technique, requires high degree of pre treatment, skilled labour and disposal or additional treatment of the concentrate (brine).

2.8.2.6 Blending/dilution of water: Blending is another method which also reduces nitrates in/from drinking water. In this process, nitrate contaminated water is mixed with clean water (nitrate free water) from another source to lower or dilute overall nitrate concentration of raw (untreated) water.

2.8.3 Techniques for removal of arsenic from water: Arsenic is a natural metalloid element of the earth's crust. It can also found in water that has flowed through arsenic-rich rocks. Arsenic occurs naturally in the environment and can be released into water through natural activities such as hydrothermal action, dissolution of rocks or human activities. Agricultural applications, mining, and smelting also contribute to arsenic releases in the environment. As per Bureau of Indian Standards; the maximum permissible limit of Arsenic in the drinking water is 0.05 mg/L (50ug/L). Arsenic dissolved in water is acutely toxic and can lead to a number of health problems. There are several methods available for removal of arsenic from water in conventional treatment plants. The most commonly used technologies include oxidation, co-precipitation and adsorption onto coagulated floes, lime treatment, adsorption onto absorptive media, ion exchange resin and membrane techniques.

2.8.3.1 Oxidation/reduction: Arsenic in groundwater may occur as arsenite As(lll) and arsenate As(V) in different proportions. Most arsenic treatment technologies are very effective in removing the pentavalent form of arsenic (arsenate), but the removal efficiency of the trivatent form (arsenite) is very low. Therefore, many treatment technologies include oxidation as a pre-treatment step to convert As(lll) to As(V). Atmospheric oxygen, hypochlorite and permanganate are most commonly used for oxidation process of arsenic. Other chemicals that are used include gaseous chlorine, ozone and other oxidizing agents. Natural oxidation of arsenic by air is very slow and can take several weeks, but the above chemicals can oxidise arsenic rapidly.

2.8.3.2 Coagulation and precipitation: Coagulation/precipitation (C/P) is a treatment method for arsenic removal using either metal salts or lime softening. C/P uses the conventional chemical and physical treatment processes of chemical addition, rapid mix, coagulation, flocculation, and filtration. In this method a coagulant (e.g. alum or ferric chloride) is added and rapidly mixed for about one minute. Aluminium or ferric hydroxide micro-flocs are formed (coagulation). The water is then gently stirred for a few minutes (flocculation) and the majority of the micro-flocs agglomerate into larger settable floes. During the coagulation-flocculation process many micro-particles and negatively charged ions are attached onto the floes. Arsenic also attaches to the fiocs (adsorption). Subsequently sedimentation and filtration (co-precipitation) are used to separate the floes, together with the adsorbed arsenic. Commonly used coagulants are alum, ferric chloride, and ferric sulphate.

2.8.3.3 Lime softening: Lime softening, excess lime treatment, split lime treatment and lime-soda softening are all effective in reducing arsenic. Lime softening uses addition of Ca(OH)., and Na,CO_3 for removal of carbonate and non-carbonate hardness and is also capable of removal of arsenic present in water. Addition of lime increases the pH and creates a shift in the carbonate equilibrium. Bicarbonate gets converted to carbonate as the pH increases and calcium is precipitated as calcium carbonate. The formation of calcium carbonate, magnesium hydroxide and ferric hydroxide enhances the removal of arsenic. Sludge disposal is a problem in this treatment method and is recommended to have this type of treatment only if hardness must also be removed.

2.8.3.4 Sorption technique: When arsenic-contaminated water is passed through a sorption media bed, its media can remove arsenic. The commonly used media are activated alumina, activated carbon, iron and manganese coated sand, activated carbon, kaolinite clay, and hydrated ferric oxide. The efficiency and the total amount of water treated depend on the media and the water composition, as different contaminants and components of water compete for the available sites on the media. In most of the cases arsenic removal is very effective if oxidation is carried out before sorption.

2.8.3.5 Membrane techniques: Microfiltration (MF), ultra filtration (UF), nanofiltration (NF), reverse osmosis (RO) and electrodialysis reversal (EDR) can remove arsenic through filtration, electric repulsion, and adsorption of arsenic-bearing compounds. The use of MF and UF membranes is dependent on the size distribution of arsenic bearing particles in water. To increase removal efficiency with a low percentage of particulate arsenic content. MF can be combined with coagulation processes.

2.8.3.6 Other arsenic removal technologies: Following other than above ,Solar oxidation and removal of arsenic (SORAS), Electrodialysis reversal , Solar oxidation and removal of arsenic (SORAS), SONO arsenic mitigation filter, Arsenic removal unit attached to tube well etc.,

2.8.4 Desalination is a process that removes dissolved minerals from various feed water sources. Most of them are dependent on mainly membrane basis technologies. Choice of desalination process/technology depends upon a variety of factors and is highly site-specific.

2.8.4.1 Reverse Osmosis: Reverse osmosis (RO) is currently one of the fastest growing techniques for the desalination of different types of water. In RO, the feed water is pumped at high pressure through permeable membranes, separating salts from the water. The feed water has to be pretreated to remove bio-fouling and scaling. The quality of water produced depends upon the pressure, the concentration of salts in the feed water and salt permeation constant of the membranes. Product water quality can be improved by adding a second pass of membranes. The product water from RO plants have TDS levels ranging between 30 to 500 mg/L.

2.8.4.2 Electrodialysis: Electro-dialysis is an electro-membrane process in which transport of ions present in contaminated or blackish is accelerated due to an electric potential difference applied externally. An electro-dialysis cell consists of a large number of narrow compartments through which the feed water for desalination is pumped. These compartments are separated by alternative placed cat ion and anion selective membranes in a parallel fashion across the current path to form an ED cell. The ED process is usually only suitable for brackish feed waters with a salinity of up to 12,000 mg/L TDS. With higher salinities the process rapidly becomes more costly than other desalination processes. This is because the consumption of power is directly proportional to the salinity of the water to be treated. As a rule of thumb, approximately 1 kWH is required to extract 1 Kg additional salt using ED/EDR

2.8.4.3 Distillation processes: Distillation is one of the oldest and most commonly used methods of water desalination. Distillation is basically a phase separation method whereby saline water is heated to produce water vapour which is then condensed to produce potable or fresh water. Distillation processes such as Multistage-flash (MSF).

2.8.4.3.1 Single/Multi-stage flash distillation (SSF/MSF): Multistage flash distillation is still the most commonly used technique, particularly where energy is still not an issue or inexpensive. In MSF plant, a stream of heated brine flows through a vessel consists of 40 chambers, or stages, each operating at a slightly lower pressure than the previous one. As the brine enters each chamber or stage, a portion of it "flashes" into steam and is then condensed to produce a pure distillate. The concentrated brine remaining at the end of the process is rejected as blow down. Depending upon the number of flashes, the process could be termed as SSF or MSF.

2.8.4.3.2 Multi-Effect Evaporation (MEE)/Multi-Effect Distillation (MED): Multi-effect distillation has a greater potential as an evaporation technique. It Is also similar to condensation but requires a heating device like a boiler or waste heat from any other sources like thermal plants etc., Steam extracted from low and medium pressure turbines provides the heat necessary for evaporation.

2.8.4.3.3 Vapour Compression Desalination (VCD):VCD is a distillation process where the evaporation of sea or saline water is obtained by the application of heat delivered by compressed vapour. Since, compression of the vapour enhances or increases both the pressure and temperature of the vapour. The effect of compressing water vapour can be done by either by Thermal Vapour Compression or Vertical Tube Evaporators.

2.8.4.3.4 Solar Humidification /Solar Stills: Solar energy is one of the most promising applications of renewable energies to seawater desalination. Solar still is basically a large scale shallow water pond if saline water (about 10 cm deep) spread over a large surface area and covered with glass over. The natural sunlight is used for evaporating the saline water and the condensed vapour is collected from the glass-case. Well-managed and maintained solar stills require a solar collection area of about one square meter to produce up to six liters of fresh water per day. The main advantage of this process is its relative simplicity to operate and service.

2.8.4.3.5 Membrane distillation: Membrane distillation uses a specialized membrane which passes water vapour only but not liquid water. This membrane is placed over a moving stream of warm water, and as the water vapour passes through the membrane it is condensed on a second surface which is at a lower temperature than that of the feed water

2.8.5 Techniques for Iron Removal: Iron is one of the most abundant metals of the Earth's crust, the major constituents of the lithosphere and comprises approximately 5%. The primary concern about the presence of iron in Iron Removal drinking water is its objectionable taste. Iron in groundwater normally remains in dissolved state. When water is drawn through bore wells, oxygen from air gets dissolved in water and iron of ferrous state gets oxidized to ferric state and precipitates as suspended solids in water. Water containing iron slowly becomes turbid and highly unacceptable from an aesthetic view point. Iron interferes with laundering operations, impart objectionable stains to plumbing fixtures and also develop taste problems. Permissible limit of iron in drinking water as per BIS: 10500 are 1 mg/L, however, the desirable limit is 0.3 mg/L. Iron can affect the taste and colour of water. Water becomes brackish colour, rusty sediment, bitter or metallic taste, a problem that frequently results from iron in water is iron bacteria, which are normally considered non-pathogenic. Excess iron may cause gastrointestinal distress. Certain types of bacteria thrive in water with iron content and give it a rotten egg smell. Oxidation by aeration or use of chemicals like chlorine, chlorine-dioxide or potassium permanganate followed by filtration alone or by settling and filtration can bring about the precipitation of iron and its removal. Similarly zeolites as well as catalytic oxidation method can also be used for the removal of iron. Some of the treatment methods for various forms of iron are as following;

- Aeration: Introducing oxygen to the water source to convert soluble iron to its insoluble form
- Filtration: Media used to entrap and screen out oxidized particles of iron.
- Water Softener: Removal of soluble iron by ion exchange.
- Manganese Greensand: An ion exchange sand material which is capable of removing iron. Adsorbs dissolved iron and requires chemical regeneration.
- Ion Exchange: Substituting an acceptable ion (such as sodium) for soluble iron.
- Sequestering: Adding chemical agents to water to keep metals like iron in solution to prevent characteristic red stains.

2.9 Millennium Development Goals (MDG)

At the Millennium Summit in September 2000, the largest gathering of world leaders in history adopted the UN Millennium Declaration, committing their nations to a new global partnership to reduce extreme poverty and setting out a series of time-bound targets, with a deadline of 2015 that had known as the Millennium Development Goals (MDG). It had the world's time-bound and quantified targets for addressing extreme poverty in its many dimensions-income poverty, hunger, disease, lack of adequate shelter, and exclusion-while promoting gender equality, education, and environmental sustainability. MDG is an internationally agreed framework of 8 goals and 18 targets was complemented by 48 technical indicators to measure progress.

For safe drinking water, MDG set **Goal No 7 which read as "Ensure Environmental Sustainability" It targeted "**Halve**, by 2015, the proportion of people without sustainable access to safe drinking water and basic sanitation".**

Goal: 7 has following indicators

- Indicator No.30. Proportion of population with sustainable access to an improved water source, urban and rural

- Indicator No. 31. Proportion of population with access to improved sanitation, urban and rural

In India, the Central Statistics Office (CSO) under Ministry of Statistics and Programme Implementation is the nodal agency entrusted with statistical tracking of the Millennium Development Goals (MDGs). The CSO has detailed out Report highlighting India's achievement under the MDGs. Being the second most populated country in the world and all the MDGs being vital in the Indian context, the nation's progress has a very decisive role in determining the global status. The progress under Goal 7 in India at the end of year 2015 was observed as under:

Indicator: Proportion of population with sustainable access to an improved water source- urban and rural Providing safe drinking water: The drinking water facility requires analysing the access to different sources of drinking water and sufficiency of drinking water. The accessibility of drinking water at household level has other aspect like the distances travelled by members of a household to reach the source of drinking water. The quality of drinking water is also a very important component in maintaining good health of the population. Many households attempt to improve the quality of water they drink by adopting various methods for treating the water before drinking. In NSS 69th round (July- Dec 2012), the improved source of drinking water include: 'bottled water1 ', 'piped water into dwelling', 'piped water to yard/plot', 'public tap / standpipe', 'tube well/ borehole', 'protected well', 'protected spring', and 'rainwater collection'. During 2012, at all India level, 87.8% households had improved source of drinking water while 86.9% households in rural and 90.1% households in urban area had access to improved source of drinking water. The quality of drinking water, sufficiency of drinking water and availability within premises of households, etc are other important related concerns. As described in CSO report, the 69th round NSS (July –Dec 2012) had ascertained, the selected households' perception on the quality of drinking water they received from the principal source. It was ascertained whether the water was 'bad in taste', 'bad in smell', 'bad in taste and smell', 'bad due to other reasons' or had 'no defect'. The result shows that 88.1 percent households in urban India was getting good quality of drinking water. Similarly in urban areas of most of the bigger states, more than 70 percent of households got 'good quality' of drinking water. Though target of MDG is achieved in Urban India, however, it has not been reached to 100% coverage safe drinking water by any of India state including Gujarat

2.10 Sustainable Development Goal

On 19 July 2014, the UN General Assembly's Open Working Group (OWG) on Sustainable Development Goals (SDGs) forwarded a proposal for the SDGs to the Assembly. The proposal contained 17 goals with 169 targets covering a broad range of sustainable development issues. These included ending poverty and hunger, improving health and education, making cities more sustainable, combating climate change, and protecting oceans and forests. On 5 December 2014, the UN General Assembly accepted the Secretary-General's Synthesis Report which stated that the agenda for the post-2015 SDG process would be based on the OWG proposals. The Sustainable Development Goals (SDGs), officially known as "Transforming our world: the 2030 Agenda for Sustainable Development is a set of seventeen aspirations". "Global Goals" targets 169 indicators of targets. They are accepted and spearheaded by the United Nations, through a deliberative process involving its 193 Member States, as well as global civil society.

Sustainable Development Goals (SDG)

Water and sanitation are at the very core of sustainable development. Safe drinking water and adequate sanitation and hygiene are pillars of human health and well-being. In addition to domestic purposes, water is needed for food, energy and industrial production – uses that are highly interconnected and potentially conflicting. These various uses generate wastewater, which may cause pollution if not properly managed. Water is also needed to ensure healthy ecosystems, which, in turn, can improve the quantity and quality of freshwater, as well as overall resilience to human-induced and environmentally induced changes. The effects of climate change are often reflected in shifts in water availability. Consequently, water is a key factor in managing risks related to famine, disease epidemics, migration, and inequalities within and among countries, political instability and natural disasters. Cutting across all these sectors, water can be instrumental in the implementation of integrated solutions. To ensure sustainable management of water and sanitation for all, it is essential to look at the water cycle in its entirety, including all uses and users. SDG 6 seeks to do: by expanding the Millennium Development Goal (MDG) focus on drinking water and basic sanitation to include water, wastewater and ecosystem resources, and together with target SDG 11.5 on water-related disasters, it covers all the main aspects related to freshwater in the context of sustainable development. Bringing these aspects together under one goal is a first step towards addressing sector fragmentation and enabling coherent and sustainable management, thus making SDG 6 a major step forward towards a sustainable water future.

"By 2030, achieve universal and equitable access to **safe and affordable drinking water for all**" One of the most essential uses of water is for drinking and hygiene purposes within households. This use is captured in target 6.1, which seeks to secure safe and affordable drinking water for all. Water "for all" households represents an important share of total water use (target 6.4). **"Safe" drinking water means that it is free of contaminants**; the treatment needed to reach "safe" is directly dependent on the quality of the raw water (targets 6.2, 6.3 and 6.6).

As 6.1 have more relevancies with quality of water. It is elaborated as under:

Target 6.1: Drinking Water: “By 2030, achieve universal and equitable access to safe and affordable drinking water for All”

Target Text	Normative Interpretation
By 2030, achieve universal	Implies all exposures and settings including households, schools, health-care facilities and workplaces
and equitable	Implies progressive reduction and elimination of inequalities among population subgroups
Access	Implies sufficient water to meet domestic needs is reliably available close to home
to safe	**Safe drinking water is free from pathogens and elevated levels of toxic chemicals at all times**
and affordable	Payment for services does not present a barrier to access to or prevent people from meeting basic human needs
drinking water	Water used for drinking, cooking, food preparation and personal hygiene
for all	Suitable for use by men, women, girls and boys of all ages, including people with disabilities

Indicator 6.1.1. Which is set as “Proportion of population using safely managed drinking water services” This can be defined, elaborated as explained below:

Population using an improved drinking water source (piped water into dwellings, yards or plots; public taps or standpipes; boreholes or tube wells; protected dug wells; or protected springs and rainwater) that is located on premises and available when needed and which is free of faecal and priority chemical contamination. This indicator builds on the MDG indicator “proportion of population using an improved drinking water source” (where “improved” was used as a proxy for “safe” due to the lack of data on drinking water quality), but also incorporates aspects of quality (“safe”, free of contamination), accessibility (“located on premises”) and availability (“available when needed”) to further address the normative criteria of the human right to water. This indicator can be disaggregated by service level: no services, basic services and safely managed services. The monitoring of access “for all”, as well as the aspect of affordability, call for disaggregation of data to capture potential inequalities across socioeconomic strata, including within households. In certain regions, it may be useful to add an indicator on time spent collecting water, to further analyse the “basic services” situation. It is also imperative to monitor access beyond the households, in institutional settings such as schools, health-care facilities and workplaces.”

2.11 Uniform Protocol Drinking Water Quality Monitoring by Govt of India:

The Ministry of Environment & Forests, Government of India has notified the Uniform Protocol on Water Quality Monitoring Order, 2005; however, some critical issues in the previous notification warrant specialized guidance on provision of safe drinking water in the country. In view of the above, Ministry of Drinking Water and Sanitation, Government of India revised the same by in 2013 with emphasis on water quality and safety.

In the revised Uniform Drinking Water Quality Monitoring Protocol, more emphasis on and relevance to drinking water quality are put. Protocols with regard to following requirements are clearly mentioned.

- Specific laboratory requirements at State, district and sub-district drinking water testing laboratories
- Frequency of testing of drinking water sources of important parameters
- Suggestive list of instrumentation, glassware, equipments, chemicals
- Simple messaging formats on risks assessments and follow-up corrective actions
- Awareness generation amongst the community not to consume water for cooking and drinking purposes from the contaminated sources.
- Corrective actions for chemical contaminants by identifying safe source and identifying suitable treatment technologies

It is also suggested that the State-level Water Quality Review Committee would be constituted. The c Water Quality Assessment Authority (WQAA) shall monitor the action taken by the SPCB/CPCB (State/Central Pollution Control Board) on abatement of pollution of drinking water sources. Provision It is also The action taken report shall be submitted to the State Water and Sanitation Mission (SWSM) and Public Health Engineering Department (PHED) periodically under intimation to the Ministry of Drinking Water and Sanitation, Government of India.

2.12 Service Level Benchmark by Ministry of Urban Development, Govt of India

The Ministry of Urban Development (MoUD) developed Service Level Bench (SLB) marks covering all basic service like water supply, sewerage, solid waste management and storm water drain. It was aimed to help effect performance improvements in the identified service sectors by (i) helping local decision-makers identify gaps, plan and prioritise improvement measures; (ii) enabling the identification and transfer of best practice; (iii) enhancing accountability to customers for service delivery levels; (iv) providing a framework that can underlie contracts/agreements with service providers; and (v) making it possible to link decision-making on financial allocations to service outcomes.

All SLBs are developed after two years long exercise and involving lot of experts of the country. A Handbook of Service Level Benchmarking is also published and it was expected that, all State governments and cities would adopt this performance monitoring framework at the Urban Local Body (ULB)/parastatal level, and undertake to regularly collate and analyse the performance data to improve the quality of the decision-making process in the sectors identified in this Handbook. Its adoption by all States shall facilitate uniform measurements and reporting systems, which will be of immense help to the management of the service utilities in making the right comparisons aimed at improving the efficiency of the infrastructure.

For water supply service, followings nine Service Level Benchmarks are suggested by the MoUD.

1. Coverage of water supply connections: 100%
2. Per capita supply of water: 135 LPCD
3. Extent of metering of water connections : 100%
4. Extent of non-revenue water (NRW): 20%
5. Continuity of water supply : 24 hours
6. **Quality of water supplied : 100%**
7. Efficiency in redressal of customer complaints : 80%
8. Cost recovery in water supply services : 100%
9. Efficiency in collection of water supply-related charges : 90%

However, MoUD has not specified monitoring and follow up action process for implementation of all SLBs.

2.13 AMRUT Mission by Govt of India

On 25th June, 2015, Govt. of India launched the Atal Mission for Rejuvenation and Urban Transformation **(AMRUT)** with an outlay of Rs. 50,000 crore covering 500 selected cities of the country greater then population of 1 lakh and a number of statutory towns. Under the AMRUT Mission, each city would get 90% of budgetary allocation per year for Five years.

Smart city Mission by Govt of India

The purpose of the Atal Mission for Rejuvenation and Urban Transformation (AMRUT) is to

1. **Universal Coverage of Water Supply & Sewerage**
2. Increase the amenity value of cities by developing greenery and well maintained open spaces; and
3. Reduce pollution by switching to public transport or constructing facilities for non-motorized transport.

The mission is also supported by the reforms and capacity building at ULBs level. As per the State Annual Action Plan 2015-16 submitted by all states, it is estimated that **Rs. 79,000 crore** would be required for **universal coverage of water in 474 cities across the country**. Out of which Gujarat has estimated Rs. 5798 core for universal coverage of water. Process of sanctioning these projects is undertaken by the MoUD.

2.14 Smart City Mission by Govt of India

During June 2015, Central Government approved the Smart Cities Mission with outlays of Rs.48, 000 crore covering 100 selected cities of the country. Under the Smart Cities Mission, each selected city would get central assistance of Rs.100 crore per year for five years. This Mission of building 100 smart cities intends to promote adoption of smart solutions for efficient use of available assets, resources and infrastructure with the objective of enhancing the quality of urban life and providing a clean and sustainable environment. It will be implemented through ‘area based’ approach. The components of area-based development in the Smart Cities Mission are city improvement (retrofitting), city renewal (redevelopment) and city extension (green-field development) plus a Pan-city initiative in which Smart Solutions are applied covering larger parts of the city.

Till date 60 cities in the country are selected as smart city. Out of which 30 cities have also suggested on line water quality monitoring in their smart city plan.

CHAPTER: 3

Need, Objective & Scope of Study

3.1 Research Gap:

Gujarat is one of the industrialized states of the country. It falls under semi-arid zone and considered as water scare area. Therefore, Gujarat's drinking water problems are not limited to availability of water, but also extend to quality of drinking water. Along with these, chronic illnesses owing to presence of chemical contaminants in drinking water have been on a rise. Due to high level of dependency on ground water, the ground water table in Gujarat has been rapidly depleting by 3¬5 meters every year due to over-exploitation of ground water. Since the water table has gone down significantly, the water obtained at such low depths may get heavily contaminated with fluoride depending on its content in the lower aquifers. Moreover, Gujarat's long coastline of about 1,600 km with two large gulfs has resulted in salinity ingress in coastal areas, thus compounding the problems in the drinking water sector. Nitrate is also now increasingly found to contaminate ground water due to excessive use of fertilizers in agriculture. Thus, high levels of Fluoride, Nitrate and Salinity are largely responsible for making ground water unfit for drinking in the State. Therefore, lot of research were done in past on quality of water. But these all are related to rural water supply schemes. Moreover, all these research had more focus on water quality impact analysis of one or two selected chemical property like excess fluoride or nitrate or arsenic etc., Gujarat is urbanized state with more than 42% of population live in urban area however, research works on drinking water quality in urban area are missing. The research work, which can also be helpful to all ULB, citizens and all stakeholders is need of an hour. Therefore, it is attempted to provide technological solutions to improve quality of drinking water in urban Gujarat as well frame work to monitor quality of drinking water across all cities of Gujarat

3.2 Research Question:

In the context of complexity of quality of water in various ULBs of Gujarat, there are different issues and problems. It has been observed and noted in various studies that:

- There are problems of water contamination arising from solid and liquid waste disposal from industries and human settlements. Gujarat is one of the industrialized states of the country, with pollution prone industries (like oil refineries and petrochemicals, colour and dyestuff, pharmaceuticals, mineral based industries etc) dominating the industrial structure. Though the government has made several attempts to control pollution, it has not been very successful in this task. Gujarat has about 600 large and medium size water polluting factories and about 4300 small scale water polluting industrial units. Gujarat who has large number of solid waste producing units. Some of the industrial centres/ regions are located in South Gujarat, where the pollution has contaminated their drinking water sources. The regions around the major industrial centres like Vadodara, Bharuch, Ankleshwar, Vapi, Valsad, Surat, Navsari etc have polluted water sources, which have affected their drinking water sources adversely. Many times water from hand pumps spew coloured polluted water, wells are contaminated and river / streams are also contaminated. This results irreparable and poor quality of water at source.
- Groundwater quality deteriorates due to the discharge of untreated industrial effluents, urban wastewater, over use of pesticides by irrigators and seawater intrusion either directly from casual disposal or indirectly as seepage from treatment lagoons or infiltration from surface watercourses or canals
- Water quality threat is when water is tapped from sedimentary formation due to water flow in adjacent rock types and mineral compositions of rocks, water quality is affected. Often over-exploitation of groundwater magnifies inherent salts i.e. TDS, fluorides, Chlorides.

Therefore, Research Question is

“Whether all municipalities of Gujarat, one of the most progressive states of India are supplying quality water to their citizens? What are suitable technological options to improve quality-stressed drinking water?”

3.3 Objective and Scope of work:

With aiming to assess and to provide various technological options for better quality of water supply, following are objectives of the research work.

- To check basic parameters of quality of drinking water of all municipal area of Gujarat
- To identify Water Quality Stress areas of Urban Gujarat
- To find conventional and non-conventional technological options to improve quality of water
- To provide probable various technological options to improve the quality of drinking water.
- To develop web based MIS & App for monitoring of quality of supplied water in all ULBs

3.4 Hypothesis:

Gujarat falls under water scare region and it is likely that, some of Municipal Drinking Water may have Water Quality Stress

3.5 Study Limitation:

- OG area of all ULBs are not covered
- Collection of Water Sample at WTP side/ Storage places
- Purpose of MIS & App Development is to provide new monitoring tool

3.6 Methodology: The research methodology has been be framed based on achievement of the study objectives and divided in to two parts viz., Primary sources and Secondary sources. Secondary sources essentially consists of literature survey like GPCB, CPHEEO norms standards, central and state policy lead to existing situation of water supply facilities. Gujarat Urban Development Mission (GUDM) is nodal agency for water supply & sewerage projects across the state, therefore data related to water supply plan, policy & programme were collected from the GUDM. CEPT University in association UMC & GUDM had formulated Performance Assessment System (www.pas.org) covering all ULBs of Gujarat were also studied to frame the research. This was also supported by primary survey including extensive field evaluation including sample collection and test at selected municipalities, interviews with stakeholders in different municipalities

Methodology

This study covers total 167 Municipalities and Municipal Corporation area of Gujarat for Quality of water supply to their citizen. Testing of sample of drinking water for quality with at least 3 samples from each ULBs at different time period are done through third party water quality laboratory. Plotting is made for water quality stress area for Fluoride, Nitrate, Salinity and TDS to formulate ACAD maps. Combinations of various conventional and non conventional water quality improvement methods are suggested. Collected data were analyzed and mapped to for quality of drinking water covering 167 cities of Gujarat.

Technological options by Literate review were analysed and correlated situation of urban Gujarat drinking water scenario. Appropriate Technological Options were identified for each water quality stress area. Techo-Econo analysis for each technical solution was made to suggest appropriate technological solution. Standard Operating Procedure for collection of water samples in all Municipalities & Municipal Corporations are suggested considering CPHEEO, MoUD & BIS recommendation and suitable to Gujarat cities. Recommendation in form of protocol is also made to facilitate quality drinking water during supply hours in all 167 cities.

To generate MIS for day to day & time to time water quality sampling data at ULBs level web site www.gtureserchonwater.com is developed and registered. A master data sheet is also prepared to allow adding, updating or deleting existing ULBs or water zone in bigger municipal corporations. Data entry work was explained to all officials of all ULBs of Gujarat. Besides, to provide information of water quality supplied to citizens on their water zone area of own city an android based mobile App with name “Urban Water” is launched and made available from Google play store at free of cost. This App is linked with the MIS & web site as discussed above. By this study, it is attempted to cover all stakeholders.

Detailed Methodology can be explained with following flow diagram

Data Collection

Primary

Details from ULBs

- Samples collection to check quality of water at different ULBs
- Data collection for existing treatment and monitoring facilities in different ULBs in Gujarat
- Questionnaire/ interview with official and officers of state, ULB Sample surveys to cover major quality stress area/ULBs of Gujarat
- Stakeholder consultation

Secondary

Literature Review

- Water Quality Standards e.g. Service Level Benchmark and IS, CPHEEO
- Govt of Gujarat Gazette on water supply
- Technological Research for improving quality of water e.g. conventional, non-conventional methods, various treatment and methods across the globe
- Techno Economy solution
- Technology for monitoring

Data Analysis

- Water Quality Stress Index
- Water quality stress Map for different area/ zone for urban Gujarat
- Identification of appropriate technology for water quality treatment

Research Work

- Providing Water Quality Stress Map covering all ULBs of Gujarat
- Providing technological options for different ULBs with suitable technology
- Development of Web based MIS and Android Based APP for citizen to facilitate monitoring work
- Recommend Standard Operating Procedure (SoP) for collection of water samples and Protocol for Maintaining quality of drinking water during supply hours

CHAPTER: 4

Results & Discussions

Water supply is a State responsibility under the Indian Constitution while the role of Central government is mainly around establishing the policy framework for the management of water resources and provides funds for WSS projects through central budgetary support. States generally plan, design, execute & operate water supply schemes through their State Departments or State Water Boards. Since the assignment of responsibilities to municipalities is a state responsibility, different states have followed different approaches. After 74th Constitution Amendment Act, ULBs are made more responsible for water supply. The responsibility for water supply and sanitation at the central and state level is shared by various Ministries. At the central level, the Ministry of Urban Development share the responsibility for urban water supply and sanitation. The Ministry of Urban Development (MoUD) is the nodal ministry of the central government that coordinates urban WSS sector activities; the Central Public Health and Environmental Engineering Organization (CPHEEO) is its technical arm. MoUD receives assistance from the Ministry of Health and Family Welfare, Ministry of Water Resources (MoWR), Ministry of Environment and Forests, and the Planning Commission for all cross-cutting issues related to urban water and sanitation. MoWR has some responsibility in the regulation of ground water. Here in this chapter it is attempted to collect data from all ULBs, water authorities, line agencies, and state pollution control board etc., essentially required for the research work. All collected data and information analysed and based on which water quality stress areas are identified and mapped.

4.1 Gujarat Water Scenario

The rainfall pattern in Gujarat is erratic and uneven which leads to imbalances in distribution of water in different regions. About 95 % of total annual rainfall occurs during few days of monsoon period (June to September) due to Seasonal winds from the South-West direction. There is wide variation in availability and distribution of rainfall across the

Results and Discussions

State and numbers of rainy days are also very limited. Gujarat at present has only 2% of the country's water resources with 5% of the country's population. Gujarat has four distinct regions namely (1) South (and Central) Gujarat i.e. South of the Sabarmati River, (2) North Gujarat (3) Saurashtra (4) Kachchh.

The state has three major groups of rivers flowing in different directions.

- The major rivers of Central and Northern Gujarat are Narmada, Sabarmati and Mahi.
- Rivers flowing through the Saurashtra region are Mithi, Khari, Bhadar, Shetrunji and Bhogavo.
- Rivers in the Southern part of the state include Narmada, Tapi, Purna, Ambika, Auranga and Damanganga

There are total 185 river basins in the State. The total water availability in the state is 50 BCM, of which surface water accounts for 38 BCM and ground water accounts for the

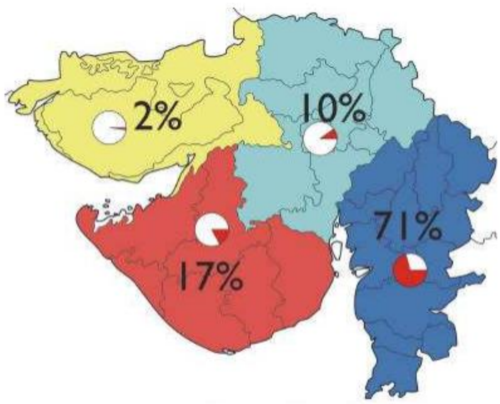
TABLE: 4.1 Availibility of Fresh Water in Gujarat

Area	% of Area	Rainfall (in mm)	Total in MCM	Surface Water in MCM	Ground Water in MCM	%	Storage Capacity	% of Storage
South & Central	25	>1200	35700	31750	3950	71.40	10400	69.33
North	20	800-1000	5300	2000	3300	10.60	2100	14.00
Saurashtra	33	400-800	7900	3600	4300	15.80	2250	15.00
Kutch	22	<400	1100	650	450	2.20	250	1.67
Total	**100**		**50000**	**38000**	**12000**	**100**	**15000**	**100**

(Source: https://guj-nwrws.gujarat.gov.in/)

balance 12 BCM. Of the 38 BCM of surface water, more than 80% is being used for irrigation purposes, leaving limited supply for drinking and industrial uses, which are therefore, largely dependent on ground water.

Kutch is an arid zone, with scanty rainfall and no perennial rivers. North Gujarat area has rechargeable aquifer but rainfall in this region is very less while ground withdrawal is very high due to excessive irrigation and industrial water demand, leading to the depletion of ground water table. South and Central Gujarat are heavily agricultural and



(Sources:: https://guj-nwrws.gujarat.gov.in/)

industrial areas, the over use of chemical fertilizer and industrial waste has polluted the ground water; the region near coast is also contaminated because of salinity ingresses. Saurashtra region comprises of rocky formation, it has very low recharging capacity, so ground water replenishment is very low. While North Gujarat, Saurashtra and Kutch constitute 71% of total geographical area of the State, they account for less than 30% of the water resources. Further, more than 40% rainwater flows into the sea as run off every year due to absence of water conservation structures. The regional imbalances are reflected in the per capita water availability levels also. South and Central Gujarat region's per capita availability is almost double of the aggregate availability of North Gujarat, Saurashtra and Kutch region. With increasing population and economic growth, water demand is likely to pick up considerably in the future. The agricultural consumption in the total demand, resulting in relatively reduced availability for domestic and industrial uses.

Growing pollution of water sources, especially through industrial effluents, is affecting the availability of safe water besides causing environmental and health hazards. In many parts of the state, certain stretches of rivers are both heavily polluted and devoid of flows to support aquatic ecology, cultural needs and aesthetics. Most of Ground water resources of the State are limited to only 1/3 area of the State (alluvial area inclusive of sand stones) i.e. Central Gujarat, North Gujarat, Surendranagar District and some parts of the Kachchh. The State has to suffer from frequent droughts due to scanty and erratic rainfall. During previous century, the State had to suffer from droughts for every third year. As a result, groundwater is utilized as the main source for agriculture, industries and domestic purposes. Hence, groundwater table is being depleted at the rate of 3 to 5 m per year as the abstraction of groundwater is more than the recharge in these regions. As a result, quantity of groundwater resources goes on decreasing and quality also goes on deteriorating in some areas along with coastal areas. Groundwater, though part of hydrological cycle and a community resource, is still perceived as an individual property and is exploited inequitably and without any consideration to its sustainability leading to its over-exploitation in certain areas. Natural water bodies and drainage channels are being encroached upon, and diverted for other purposes. Groundwater recharge zones are often blocked. Access to water for sanitation and hygiene is an even more serious problem. Inadequate sanitation and lack of sewage treatment are polluting the water sources. There is more than 1600 km long coast line in the Western side of the State that is about 1/3 of the total coast line of the nation. In the coastal areas of the Saurashtra and Kachchh, as abstraction of the ground water is more than the recharge, sea water is intruded in the aquifers and salinity gets increased and ground water gets polluted. In contrary to this, more water is utilized through canals for irrigation. Hence, water logging and salinity is increased in soils of these areas and cultivable land is converted into non-fertile areas. Climate change may also increase the sea levels. This may lead to salinity intrusion in ground water aquifers / surface waters and increased coastal inundation in coastal regions, adversely impacting habitations, agriculture and industry in such regions. Characteristics of catchment areas of streams, rivers and recharge zones of aquifers are changing as a consequence of land use and land cover changes, affecting water resource availability and quality. As surface and ground water resources of the State are extremely limited, it has become necessary to develop the water resources of the State through integrated planning. Gujarat has made serious efforts in all the important areas of water sector such as source augmentation, source management and distribution management through reduction of dependence on the scarce ground water resources. This has been achieved through water grid and master planning and implementation of several schemes under Saradar Sarovar project, Sujalam Sufalam Yojana Swarinm Jayanti Shaheri Vikas Yojana etc. Efforts are being made but there are significant demand - supply gaps or lack of desired levels of progress.

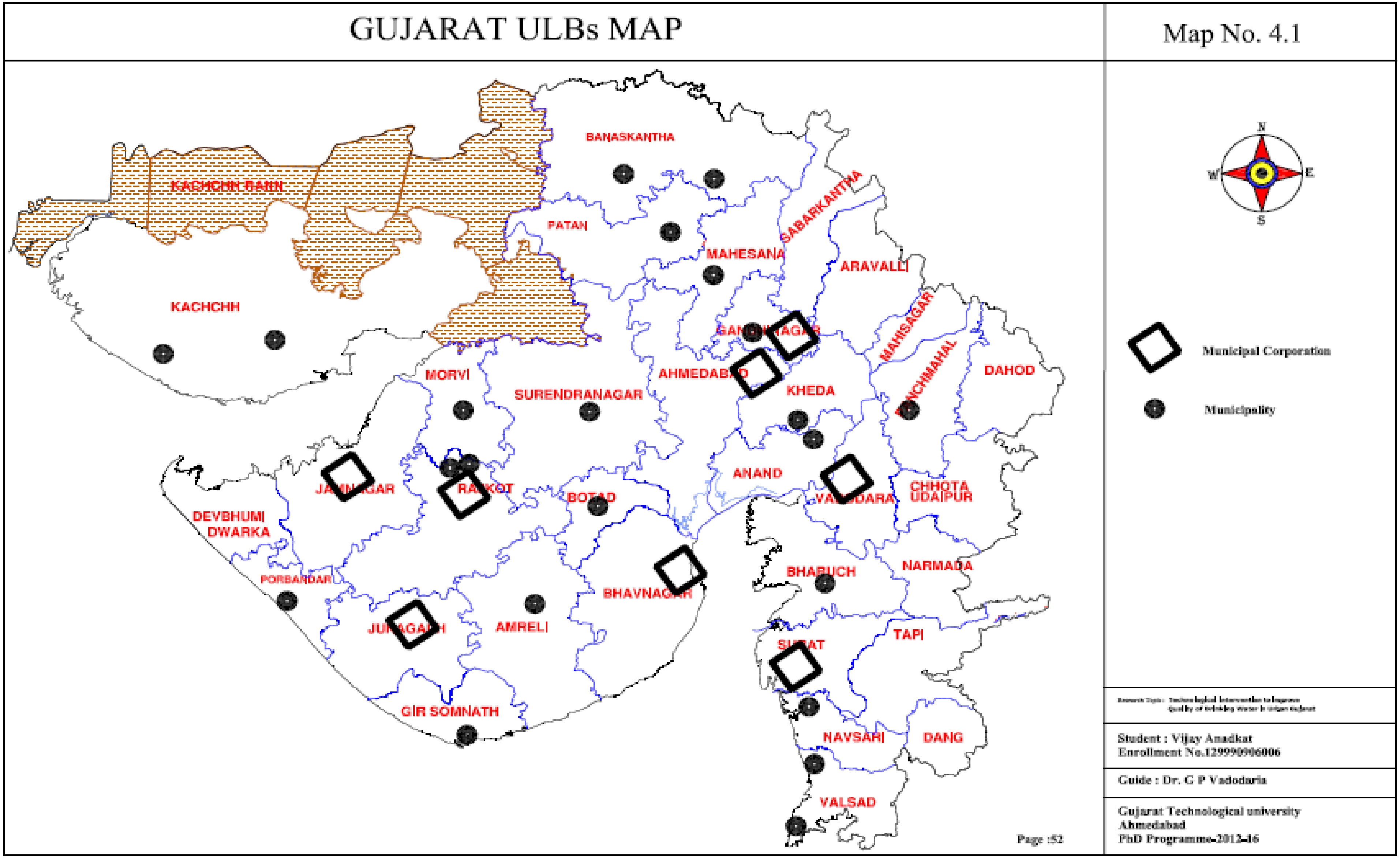
4.2 Gujarat ULBs

Urban local bodies in Gujarat are formed as democratic institutions based on the principle of self-government and should represent people's desires and strengths. Presently, eight cities with more than 2.5 lakhs population are governed by the Municipal Corporations constituted under the provision of the Bombay Provisional Municipal Corporation Act, 1949. All other urban areas viz., Class A to Class D municipalities having population more 15000 are governed by municipalities constitutes under the Gujarat Municipalities Act 1963.

- **Municipal Corporations: Population with more than 2,50,000(Total 8):** Ahmedabad, Surat, Vadodara, Rajkot, Bhavnagar, Jamnagar, Junagadh & Gandhinagar
- **A class Municipalities: Population with more than 1,00,000 (Total 22):** Gandhidham, Nadiad, Anand, Morbi, Mahesana, Surendranagar, Bharuch, Vapi, Navsari, Veraval, Porbandar, Godhara, Bhuj, Botad, Patan, Palanpur, Jetpur, Valsad, Kalol, Gondal, Deesa, Amreli
- **B class Municipalities: Population from 50,001 to 1,00,000 (Total 33):** Dahod, Anjar, Dhoraji, Khambhat, Mahuva, Vijalpor, Himmatnagar, Dholka

Savarkundala, Keshod, Wadhvan, Dhangadhra, Ankleshwar, Kadi, Modasa, Palitana, Mangrol, Borsad, Visnagar, Okha, Bardoli, Halol, Upleta, Una, Unja, Sidhhpur, Viramgam, Petlad, Sihor, Bilimora, Mandavi(K), Dabhoi, Sanand

- **C class Municipalities: Population from 25,001 to 50,000 (Total 59):** Kapadvanj, Jasdan, Chhaya, Ranavav, Vankaner, Padra, Jambusar, Limadi, Dahegam, Thangadh, Khambhaliya, Kodinar, Vyara, Chaklasi, Radhanpur, Bhachau, Balasinor, Dwarka, Rajula, Lunavada, Bavla, Mahemdabad, Karamsad, Rajpipla, Bagsara, Gariyadhar, Umreth, Salaya, Dhandhuka, Halvad, Idar, Manavadar, Karjan, Manasa, Gadhada, Dhanera, Tarsadi, Sikka, Kaalol, Zalod, Paradi, Rapar, Kanakpur Kansad, Kalavad, Tharad, Umargam, Talaja, Vadnagar, Jafarabad, Songadh, Sutrapada, Jamjodhpur, Dhrol, Chhotaudepur, Kheda, Vijapur, Babara, Khedbrahma, Dakor
- **D class Municipalities: Population from 15,001 to 25,000 (Total 45):** Dharampur, Vallbhvidhyanagar, Prantij, Pethapur, ,Oad, Chorvad, Bhanvad, Kathlal, Bhabhar, Kheralu, Chotila, Lathi, Talala, Devgadhbaria, Anklav, Vadali, Harij, Boriavi, Jamraval, Bareja, Visavadar, Santrampur, Bhayavadar, Shahera, Savali, Talod, Mandavi(S), Thara, Barvala, Bayad, Kanjari, Patadi, Mahudha, Gandevi, Chalala, Sojitra, Damnagar, Kutiyana, Maliyamiyana, Chanasma,Vallabhipur, Thasara, Bantawa, Amod, Vanthali


GUJARAT ULBs MAP
Map No. 4.1
KACHCHH RANN
KACHCHH
BANASKANTHA
PATAN
MAHESANA
SABARKANTHA
ARAVALLI
GANDHINAGAR
AHMEDABAD
KHEDA
MAHISAGAR
PANCHMAHAL
DAHOD
MORVI
SURENDRANAGAR
JAMNAGAR
RAJKOT
BOTAD
ANAND
VADODARA
CHHOTA UDAIPUR
DEVBHUMI DWARKA
PORBANDAR
BHAVNAGAR
BHARUCH
NARMADA
JUNAGADH
AMRELI
SURAT
TAPI
GIR SOMNATH
NAVSARI
DANG
VALSAD
N
S
E
W
Municipal Corporation
Municipality
Student : Vijay Anadkat
Enrollment No.129990906006
Guide : Dr. G P Vadodaria
Gujarat Technological university
Ahmedabad
PhD Programme-2012-16
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All Municipal Corporation and Municipalities have elected official since long. In case of Municipal Corporations the Mayor, while in case of municipalities the President of municipality, is chief elected representative in the concerned city and ULB. In municipal corporations, Municipal Commissioner is the chief executive officer deputed to the city from Indian Administrative Service cadre. At municipality, the chief officer is the chief executive officer. Local Bodies are expected to have a profound impact on the performance of the economy of the country by utilizing local resources and tapping human potentialities to the fullest. They are responsible for the improvement of the efficiency of programmes and services, to mobilize local resources and to provide coherent planning and delivery of the services at the local level. All municipal acts in Gujarat provide for functions, duties and responsibilities to be carried out by the municipal government. These are divided in two categories obligatory or discretionary with following major functions

- **Obligatory functions**
    - Supply of pure and wholesome water;
    - Construction & maintenance of public streets; naming streets & numbering houses.
    - Lighting and watering public streets;
    - Cleansing public streets, places and sewers;
    - Regulation of offensive, dangerous or obnoxious trades and callings or practices;
    - Maintenance or support of public hospitals;
    - Establishment and maintenance of primary schools;
    - Registration of births and deaths;
    - Removing obstructions and protections in public streets, bridges and other places;
- **Discretionary functions**
    - Laying out of areas;
    - Securing or removing dangerous buildings or places;
    - Construction and maintenance of public parks, gardens, libraries, museums, rest houses, leper homes, orphanages and rescue homes for women, etc.;
    - Planting and maintenance of roadside and other trees;
    - Housing for low income groups;
    - Organizing public receptions, public exhibitions, public entertainment, etc.;
    - Provision of transport facilities with the municipality;
    - Promotion of welfare of municipal employees;

Results and Discussions

In Gujarat, Narmada, Water Resources, Water Supply & Kalpsar Department in short, Water Resources Department (WRD) is responsible to manage, develop, conserve and protect water and related resources. It responsible of effective planning of usage of the water sources, to prepare Water Policy of the State and review it periodically, to obtain quantitative, timely and qualitative information and review it from time to time, to utilise the water resources, to increase the underground water recharge, to control salinity ingress in the gulf areas, to transfer water to the scarcity hit areas and areas facing acute shortage of water etc., Govt of Gujarat has formed Sardar Sarovar Narmada Nigam Limited for execution world's second largest concrete dam on Narmada River. It is now considered as life line of Gujarat As, Narmada water is major source of water for ULBs, a separate company named Gujarat Water Infrastructure Ltd. (GWIL), is also formed to establish bulk water pipe grid based on Narmada water in Gujarat state for satisfying water needs of Gujarat state through bulk supply for the growth of Gujarat. GWIL is responsible distribute and sell of bulk water across the state. All ULBs are responsible for water supply within their municipal boundaries while Gujarat Water Supply Sewerage Board (GWSSB) is responsible to support infrastructure development and for bulk water supply to these ULBs. For plans, programmes and Projects, Gujarat Urban Development Mission (GUDM) is established and functioning since 2006. GUDM is as nodal agency, under Urban Development & Urban Housing Department. GUDM is responsible to plan, execute water supply and sewerage projects of all ULBs of the state to be developed either with state govt grant or central govt grant GUDM also gets support by Gujarat Urban Development Company (GUDC) and GWSSB for execution of water supply projects in municipal area.

For financial support, Govt of Gujarat formulated Gujarat Municipal Finance Board. State Gujarat Infrastructure Development Board (GIDB) for supporting state level water supply projects to be developed in Public Private Partnership (PPP) mode.

To control & monitor level of water pollution, Gujarat Pollution Control Board (GPCPB) is functioning under direct control of Central Pollution Control Board. Gujarat has high level of utilisation of ground water,

Gujarat Water Resources Development Corporation Ltd. (GWRDC) was created in 1975 with a view to concentrate on ground water investigation, exploration, management & recharge works in the State of Gujarat. GWRDC is functioning under the Narmada Water Supply & Water Resources Department of Govt. of Gujarat with separate Board of Directors.

4.3 Sources of Water

The major source of water supply in all ULBs of Gujarat is through bulk purchase of raw and treated water from Narmada Canal/pipe line. There are 22 cities which are having own surface water source through dam, lake or river. However, 13 cities are dependent on ground water. It has been also observed more than 50% of total ULBs have multiple source dependency ULBs in North Gujarat and Central Gujarat are more dependent on ground water sources. Cities in South area have advantage of local surface water, while cities in Saurashtra and Kutch are mostly dependent Narmada pipe line or canal based bulk treated and raw water sources. Gujarat Water Infrastructure Limited (GWIL) and Gujarat Water Supply & Sewerage Board (GWSSB) are executing water grid of Narmada pipeline/canal to cover most of area of Gujarat. Narmada based water supply is an emerging source of water in Gujarat. Details of all source with drawing capacity is shown in Annexure: 1. Summary of source of water in all ULBs of the state is as shown below;

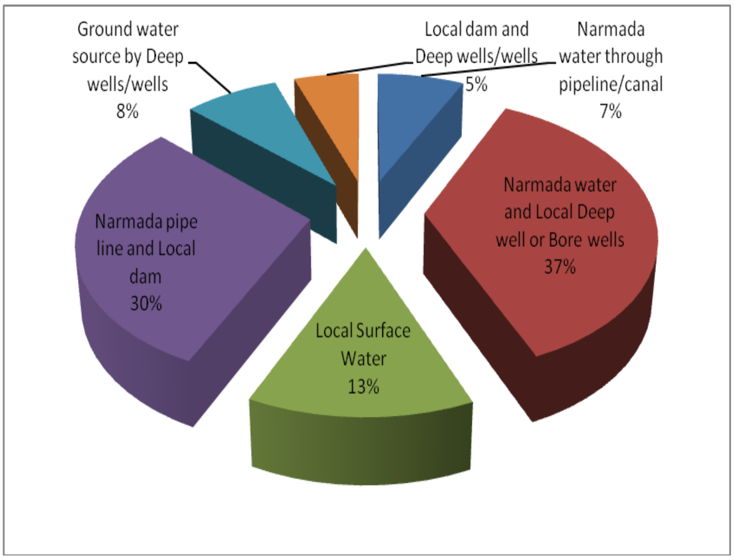
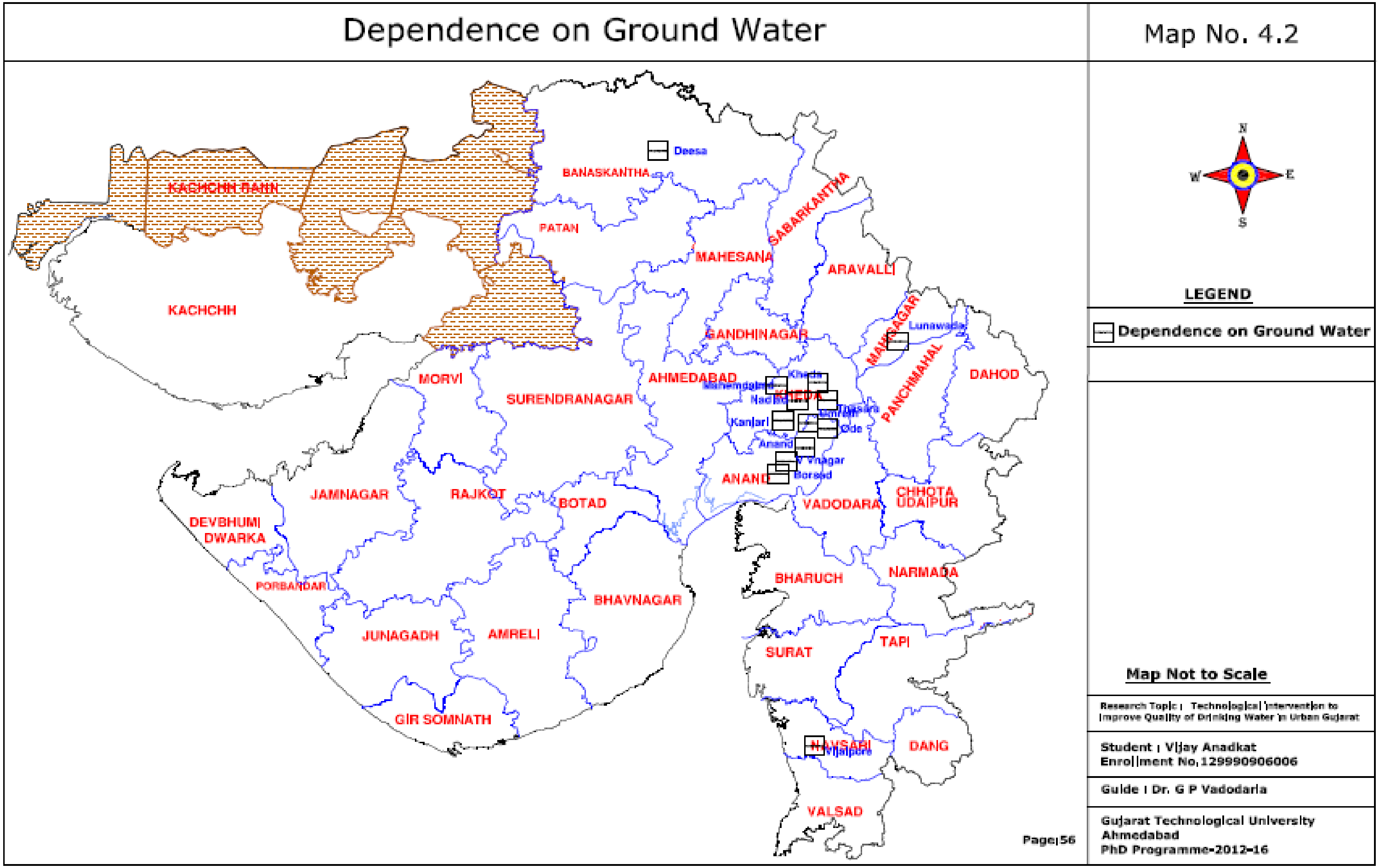


TABLE 4.2 Source of Water in all ULBs

Sr. No	Source of Water	No of cities	%
1	Narmada water through pipeline/canal	**12**	**7**
2	Narmada water and Local Deep well or Bore wells	**61**	**37**
3	Local Surface Water	**22**	**13**
4	Narmada pipe line and Local dam	**50**	**30**
5	Ground water source by Deep wells/wells	**13**	**8**
6	Local dam and Deep wells/wells	**9**	**5**
	Total…	**167**	**100**

(Source: Gujarat Urban Development Mission 2016)

As the dependency of ground water is high in these regions, water quality issues are also prominent here. These clearly show the need to look at alternate sources of water in these areas..


Dependence on Ground Water
Map No. 4.2
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Dependence on Ground Water
Map Not to Scale
Research Topic : Technological Intervention to Improve Quality of Drinking Water in Urban Gujarat
Student : Vijay Anadkat
Enrollment No. 129990906006
Guide : Dr. G P Vadodaria
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KACHCHH RANN
KACHCHH
BANASKANTHA
Deesa
PATAN
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SABARKANTHA
ARAVALLI
GANDHINAGAR
MAHISAGAR
Lunawada
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VADODARA
CHHOTA UDAIPUR
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SURENDRANAGAR
JAMNAGAR
RAJKOT
BOTAD
DEVBHUMI DWARKA
PORBANDAR
JUNAGADH
AMRELI
BHAVNAGAR
GIR SOMNATH
BHARUCH
NARMADA
SURAT
TAPI
NAVSARI
Vijalpore
DANG
VALSAD

4.4 Water Treatment Facilities in Urban Gujarat

In Gujarat about one third of ULBs are getting treated water from Narmada pipe lined base bulk water. For which, GWIL & GWSSB executed 181 Water Treatment Plan with total capacity of 3000[3] MLD at different locations more than 162 Out of eight Municipal Corporations, seven have Water Treatment Plant. Similarly, 48 municipalities have functional WTPs. There are 7 municipalities require modification in the plant. About 16 municipalities, out of 167 ULBs, there is not water treatment plant at all. While 13 municipalities are supplying ground water and therefore, do not require WTP. Water supply in these municipalities is being done after giving the chlorine treatment. List of such ULBs is attached as Annexure: 2.

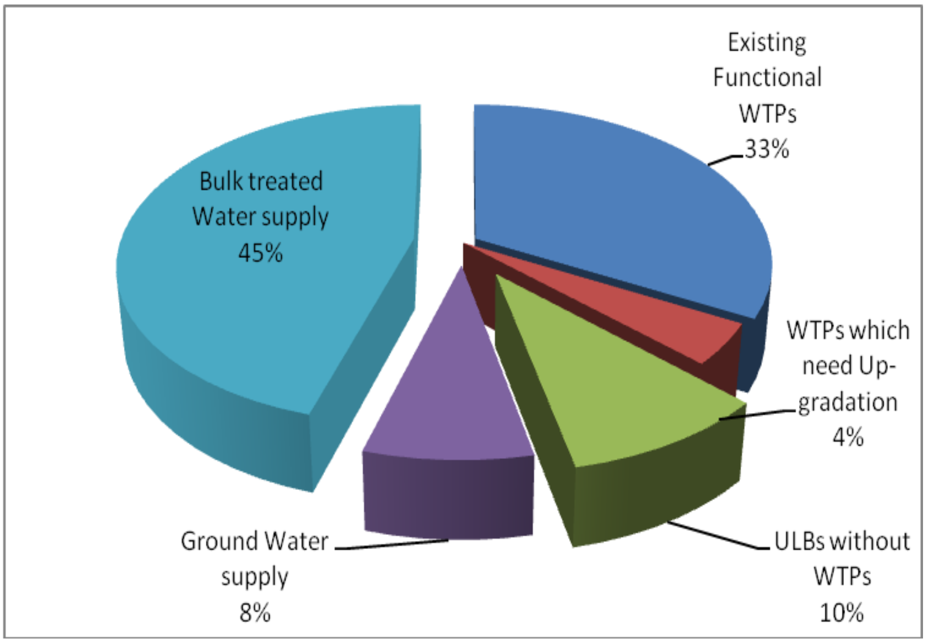


TABLE:4.3 Status of WTP in all ULBs

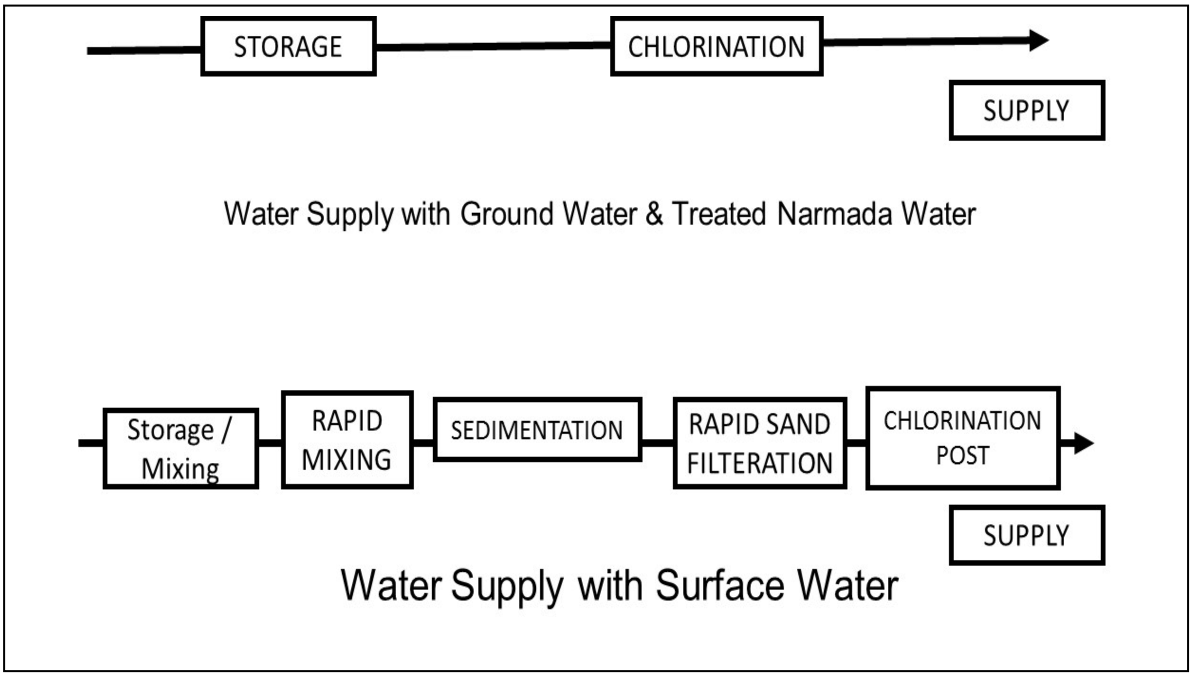
Status	No of ULBs
Existing Functional WTPs	55
WTPs which need Up-gradation	7
ULBs without WTPs	16
Ground Water supply	13
Bulk treated Water supply	76
Total	**167**

(Source: Gujarat Urban Development Mission,2016)

[3] Integrated Water management state wide water supply grid power point presentation by Mahesh Singh Member Secretary GWSSB, 2014

Results and Discussions

It has been observed that, all WTP in all ULBs are conventional Rapid Sand Filter Plant, followed by the Chlorination.



There is no advance technology like UV/ Membrane based/ Nano-filtering process, any other WTP across the state

At many water treatment plants, the raw water is very clean having turbidity less than 10 NTU during non-monsoon period. Whenever the turbidity is so low, alum or Poly Aluminum Chloride (PAC) is not added, although the water passes through all the units such as flocculators and settling tanks before passing through rapid sand filters. Alum is being added as coagulant in most of municipalities while PAC, which is in liquid form, is being used in Municipal Corporations WTPs.

In few plants, non mechanical devices such as hydraulic jumps are being used for mixing of chemicals. Also, paddles of flash mixer were non functional in some water treatment plants. Some of the water treatment plants are using bleaching powder for chlorination, while majority are using liquid chlorine. The operation and maintenance of chlorinator was far from satisfactory and chlorine dosing is often on approximation.

Overall status of WTP in municipal corporation area is up to the mark, however, in municipalities it is lacking.

Some of photographs of WTPs in different ULBs are attached in Annexure: 10

4.5 Assessment of Water Supply in all ULBs

Data has been collected from 159 Municipalities and 8 Municipal Corporation of Gujarat. It has been observed that there is considerable disparity in form of coverage, supply in LPCD, duration, no of days in a month etc., ULB wise details are shown in Annexure;3. Municipalities' class wise summary of all important aspects of water supply is prepared and discussed here.

4.5.1 Water supply Coverage: Coverage of house hold level water supply network and connections in all ULBs and class wise varies from as low as 18 % to 100 %. More than 76 ULBs out of total 167 are having coverage less than 80%. However, it has been claimed that the areas that are not covered by pipelines are provided water through non pipeline means (e.g. tankers). Junagadh with 50%, Vapi with 18%, Halol with 48%, and Ranavav & Thangadh with 19% and Maliyamiyana with 34% are least level of water supply network coverage in their respective class of ULBs. Class wise details can be summarized as shown in Table; 4.4.

TABLE 4.4 Water supply coverage in % in all ULBs

	Coverage in %		
ULBs	**Min**	**Max**	**Average**
MC	50	100	87.5
Class A	18	100	73.27
Class B	48	100	77.66
Class C	19	100	77.58
Class D	34	100	82.28
		Average in all ULBs	**79.65%**

(Source: Govt of Gujarat Gazette, CEPT- PAS data 2016)

4.5.2 Water supply in LPCD: Service level bench mark by Ministry of Urban Development, Govt of India, as well as CPHEEO benchmark suggests 135 LPCD while IS:1172:1983 standards give value of water supply per capita in range 100-150 LPCD. The state average water supply per capita per day is observed 110 litres per day. There is disparity in level of water supply, in 92 ULBs water supply is less than 100 LPCD while only 32 ULBs are able to supply water supply of more than 135 LPCD. Besides, there is wide variation in level of water supply amongst all class of ULBs. Junagadh with having average water supply of 52 LPCD is the least in all municipal corporations. In case of municipalities, Porbandar with 59 LPCD in A class municipalities, Okha with 38 LPCD in B class municipalities, Umargam with 21 LPCD in C class municipalities and Chorvad with 37 LPCD D class municipalities are the least level of water supply in their class ULBs. Against which, water supply of 254 LPCD in Gandhinagar is the highest level of water supply in all municipal corporations. Similarly for municipal towns, Bharuch with 173 LPCD in A class municipalities, Viramgam with 158 LPCD in B class municipalities, Umreth with 18 LPCD in C class municipalities and Thara with 251 LPCD in D class municipalities are the highest level of water supply in their respective class of ULBs. There is not much difference observed during last 2 years of data collection. However, because of the high level of dependency on Narmada water and semi-arid zone of the state minor seasonal variations of level of water supply are also observed. Municipality wise details are shown in Annexure: 4 and summary of water supply in LPCD in different categories are tabulated as under:

TABLE:4.5 Level of Water supply in all ULBs

ULBs	**Supply in LPCD**		
	Min	**Max**	**Average**
MC	52	254	136
Class A	59	173	108
Class B	38	158	103
Class C	21	168	90
Class D	37	251	111
		Average in all ULBs	**110**

(Source: Govt of Gujarat Gazette, CEPT PAS data 2016)

4.5.3 Duration of Water Supply: In all ULBs water supply is on intermittent type. None of ULBs supplies water on 24x7 days continuous system. More than 80 ULBs are supply water with average of 1 hour per day. Only 39 ULBs are supplying water more than 2 hours per day. Water supply duration varies from 20 minute/day to 9 hours /day. Normally, it is practice to supply once in day, however in some ULBs morning and evening water supply is also observed. There are disparities in duration of water supply across the state. Rajkot with 20 minute/day, Porbandar, Jetpur & Gondal with 45minutes/day, Modasa with average 27 minutes Umargam, Vankaner, Jambusar Khedbrahma & Khambhaliya with average 27 minutes and Damnagar with 27 days/month is the least in their respective classes of ULBs. The average number of hours of water supply in the state is 101 minutes (about 1.5 hours).

There are no significant variations in continuity and number of water supply days in a month across A, B, C, D classes & municipal corporations of cities. ULB wise details of

Frequency of water supply

duration of water supply is shown in Annexure: 5, summary of which is described below in Table: 4.6.

TABLE:4.6 Duration of water supply at all ULBs

ULB class	Water Supply Duration in minutes		
	Min	**Max**	**Average**
MC	20	240	92
Class A	45	240	107
Class B	30	240	97
Class C	30	240	89
Class D	30	540	119
		Average in all ULBs	**101**

(Source: Govt of Gujarat Gazette, CEPT PAS data 2016)

4.5.4 Frequency of Water Supply in number of days per month: The average number of supply days per month is 24 days/month in all ULBs. Municipal Corporations provide water supply with an average of 25 days in a month. However, daily water supply in 5 Municipal Corporations while two municipal corporations, Jamnagar & Junagadh supply water on alternate day while Bhavnagar supplies 5 days/week. In case of municipalities, Out of total 159 municipalities, 100 municipalities have daily water supply, however, 25 cities has less than 10 days/month water supply. It is also observed that, few municipalities like Sihor, Manavadar, Damnagar etc., are supplying total 5 days/week means once in week. Details of all ULB with number of water supply days/month are given in Annexure: 5.

Summary details of frequency of water supply in days/month in all ULBs are as shown in Table: 4.7.

TABLE: 4.7
Frequency of water supply in days/month in all ULBs

ULB class	Frequency of Water Supply in days /month		
	Min	**Max**	**Average**
MC	15	30	26
Class A	8	30	24
Class B	8	30	23
Class C	5	30	22
Class D	5	30	24
		Average in all ULBs	**24**

(Source: Govt of Gujarat Gazette, CEPT PAS data 2016)

4.5.5 Actual Water Supply: There is high level of Unaccounted for Water (UFW) in major ULBs of the state. There is not any scientific water audit is done for all ULBs however, based on the tax data/no of connection and calculation of Non-Revenue water

(NRW) done by the CEPT university under PAS programme, following results can be summarised.

TABLE:4.8 Level of Non Revenue Water (NRW) in all ULBs

ULB class	NRW in %		
	Min	**Max**	**Average**
MC	7	42	26
Class A	5	46	17
Class B	5	59	19
Class C	1	51	20
Class D	3	53	21
		Average in all ULBs	**21**

(Source: Govt of Gujarat Gazette, CEPT PAS data 2016)

This impacts actual supply of water reaching the consumer. While the acceptable level is about 15 per cent (according to CPHEEO norms),against which Rajkot with 42%, Palanpur with 46%, Dholka with 59% , Paradi with 53% and Maliyamiyana with 53% are the highest in their class of towns and are of very much concern.

4.6 Status of Waste Water (Sewerage)

Status of Sewerage system in Gujarat is not very good. Out of total estimated 5,452,769 HH of all cities of Gujarat 1,205,483 HH are covered **with underground drainage connection which amounts about 22% of coverage. Only 12 cities are covered with 100% UGD connectivity while 51 cities have UGD coverage ranges from 50% to 90%. 104 cities have UGD coverage below 50%. Rest of HH have either connection with own septic/soak pit arrangement or outlet at nearby natural stream or open ground.**

167 cities of Gujarat generate about 4385 MLD waste water out of which only 2115 MLD waste water is being treated by STPs.Presently, only **6 STPs** in Municipal Corporations and **15 STPs** in municipalities are functional. Rest of ULBs are yet to have functional STPs. Out of these total 21 cities 12 are of oxidation ponds. In Gujarat, reuse and recycling of waste water is not practised. Only Surat Municipal Corporation has initiated the practice of recycling of waster and presently, 1% of total waste water collected through sewerage network is being recycled or reused.

Test results of quality of supplied water

In most of municipalities, it has been seen that, untreated waste water is released either in open low lying area/local lake or river bed. This is big threat to quality of water.

TABLE : 4.9 Untreated wastewater discharge (in MLD)

Region	No of Cities	Pond	River	Land	Sea/Creek/Gulf	Total
Central Gujarat	54	6.44	198.08	169.77	18	392.29
Saurashtra	64	0.5	28.7	202.03	89.42	320.65
South Gujarat	16	0.44	41.58	74.2	4.4	120.62
North Gujarat	26	17.16	15	71.85	0	104.01
Kachchh	6	0	0	31.66	0	31.66
Total	**166**	**24.54**	**283.36**	**549.51**	**111.82**	**969.23**

(Source: PAS report, CEPT University 2010)

However, Govt of Gujarat has planned 100% coverage of sewerage under “Swarinm Jayanti Mukhya Mantri Shaheri Vikas Yojana” (SJMMSVY) scheme. Out of total allocation for urban infrastructure projects, allocations for underground drainage projects are Rs.5700 crore. In SJMMSVY programme 98 works in 82 Nagarpalika completed and 77 works in 76 Nagarpalika in progress which has been planned to complete by end of March 2017. It is expected to have all STPs of all ULB by 2030.

4.7 Test results of quality of supplied water

Data from 167 municipalities and municipal corporation covering all urban area of Gujarat state in form of sources of water, treatment facilities, piped water network, level of services, in form LPCD, duration of supply, details of testing facilities, water sampling test report are collected. Interviews with ULBs officials, state officials are conducted to verify and conciliation of data. More than 550 water samples and water quality test reports / sample from 167 municipalities and municipal corporations for different time period at supply level are collected. Collected water samples are tested at Public Health laboratory covering all critical physical, chemical and biological parameters. Sampling and analysis of water quality is considered the most valuable tool for identification of contamination and confirmation of the quality of water (AusAID, 2005b). It is not worthwhile to note that, llimited access to data, non availibility of data, and limited number of visits per ULBs and wide spread covering 169 municipalities and municipal corporations with varied situation result in assessment based on preliminary data. However, every effort has been made to get accurate data and test results. Details of some sample collected water sample and test results are annexed in Annexure: 7

4.8 Mapping of Drinking Water Quality Stress area

As per Central Ground water Board data (http://cgwb.gov.in/gw_profiles/st_Gujarat.htm), in Gujarat, out of 33 districts in the state, 20 are partly affected by salinity problem, 18 are partly affected by fluoride problem, and 22 districts are partly affected by Nitrate. Details are as tabulated

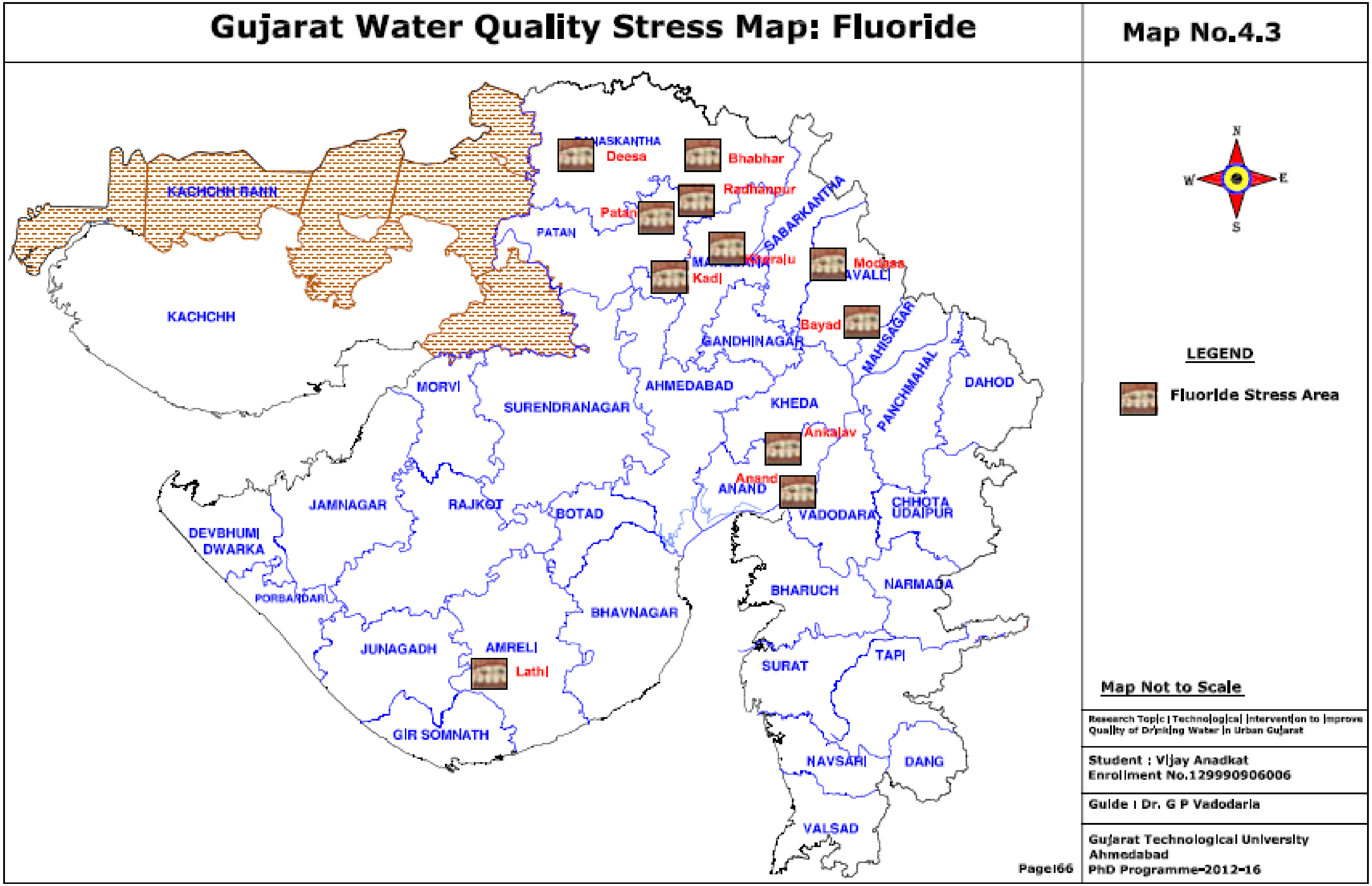
TABLE:4.10 Ground Water Quality Problems in Gujarat

Contaminants	Districts affected (in part)
Salinity (EC > 3000 US/cm at 25 ° C)	Ahmedabad, Amreli, Anand, Bharuch, Bhavnagar, Banaskantha, Dohad, Porbandar, Jamnagar, Junagadh, Kachchh, Mehsana, Navsari, Patan, Panchmahals, Rajkot, Sabarkantha, Surendranagar, Surat, Vadodara
Fluoride (>1.5 mg/l)	Ahmedabad, Amreli, Anand, Banaskantha, Bharuch, Bhavnagar, Dohad, Junagadh, Kachchh, Mehsana, Narmada, Panchmahals, Patan, Rajkot, Sabarkantha, Surat, Surendranagar, Vadodara
Iron (>1.0 mg/l)	Ahmedabad, Banaskantha, Bhavnagar, Kachchh, Mehsana Narmada
Nitrate (>45 mg/l)	Ahmedabad, Amreli, Anand, Banaskantha, Bharuch, Bhavnagar, Dohad, Jamnagar, Junagadh, Kachchh, Kheda, Mehsana, Narmada, Navsari, Panchmahals, Patan, Porbandar, Rajkot, Sabarkantha, Surat, Surendranagar, Vadodara,

(Source: http://cgwb.gov.in/gw_profiles/st_Gujarat.htm)

These data is combined urban and rural area of Gujarat. Due to lying on coastline & and excessive withdrawal of groundwater from coastal aquifers has lead to ingress of seawater in the coastal aquifers in coastal areas of Kachchh and Saurashtra. Many of the habitats in the state suffer from more than one water quality problem. High level of industrialization and urbanization of Gujarat lead to problems of water contamination from solid and liquid waste disposal from industries and human settlements. Modern farming and high level of consumption of fertilizer and pesticides are also affecting ambient quality of surface as well as subsurface water sources. More than 500 water sample test results are collected across the state covering all 169 ULBs at different time period and they are analyzed for quality of drinking covering physical, chemical & biological parameters. It is found that, contamination issues related to Physical & Biological properties are minimum across the state, however, chemical contamination like fluoride, Nitrate, Salinity; TDS are seen in different part of the state. For cross verification, all results are checked with results published by the National Rural Drinking Water Programme, Ministry of Drinking Water and Sanitation, Govt of India., as detailed in Annexure: 9. Then after, results of water quality test reports have been mapped for major quality stress for above mentioned chemical contamination and shown below:

4.8.1 Drinking water quality stress area: Fluoride : Water sample analysis shows, Deesa, Patan, Radhanpur, Bhabhar, Modasa, Anand, Anklav, Kadi, Kheralu , Lathi etc.,are showing more than1.5 ppm of fluoride particularly in case of ground water sampling either ULBs are using deep well for water supply or people are using own bore well for their where municipal water is not available. These ULBs are mapped for water quality stress for Fluoride as shown in Map No. 4.3


Gujarat Water Quality Stress Map: Fluoride
Map No.4.3
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Fluoride Stress Area
KACHCHH RANN
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Deesa
Bhabhar
Radhanpur
Patan
SABARKANTHA
Kheralu
Kadi
Modasa
Bayad
GANDHINAGAR
MAHISAGAR
PANCHMAHAL
DAHOD
MORVI
SURENDRANAGAR
AHMEDABAD
KHEDA
Ankalav
Anand
ANAND
VADODARA
CHHOTA UDAIPUR
JAMNAGAR
RAJKOT
BOTAD
DEVBHUMI DWARKA
PORBANDAR
BHARUCH
NARMADA
BHAVNAGAR
JUNAGADH
AMRELI
Lathi
SURAT
TAPI
GIR SOMNATH
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Map Not to Scale
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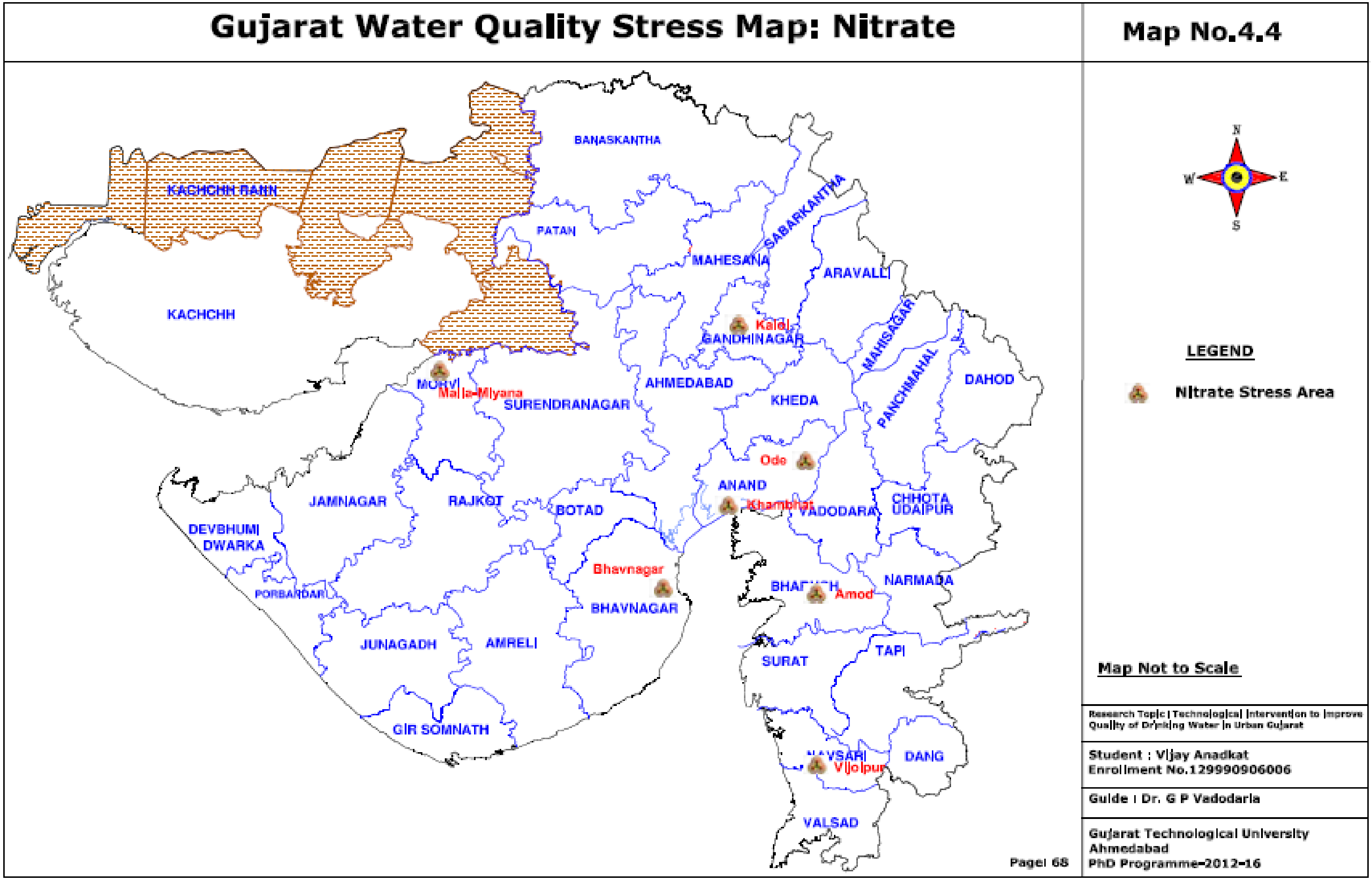
4.8.2 Drinking water quality stress area: Nitrate

Central Groundwater Board (CGWB) observes 22 districts; out of 33 have partial impact of excess of Nitrate in ground water as well surface water. Content of Nitrate is increasing in ambient water due to excess use of fertilisers in farms, non availibility of STPs in more than 145 ULBs, excessive use of ground water, etc., Data collected as part of the Centre for Development Alternatives (CDA, 2011) showed that several districts of the state had high nitrate content in ground water. Of the samples tested in Ahmedabad, 43% had nitrate content above the permissible limit. More than 70% of samples collected from ground water in Gandhinagar, Anand, Junagadh, Jamnagar, Rajkot and Sabarkantha also had nitrate contents above the permissible limit.

Our water sample of Bhavnagar, Ode, Kalol (G), Malia-miyana, Vijalpor, Khambhat etc,

Shows higher level of nitrate i.e. more than 45 ppm. These ULBs are mapped for water quality stress map as shown in map: 4.4


Gujarat Water Quality Stress Map: Nitrate
Map No.4.4
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Nitrate Stress Area
Map Not to Scale
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Kalol
AHMEDABAD
MORVI
Malia-Miyana
SURENDRANAGAR
KHEDA
MAHISAGAR
PANCHMAHAL
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ANAND
Khambhat
VADODARA
CHHOTA UDAIPUR
JAMNAGAR
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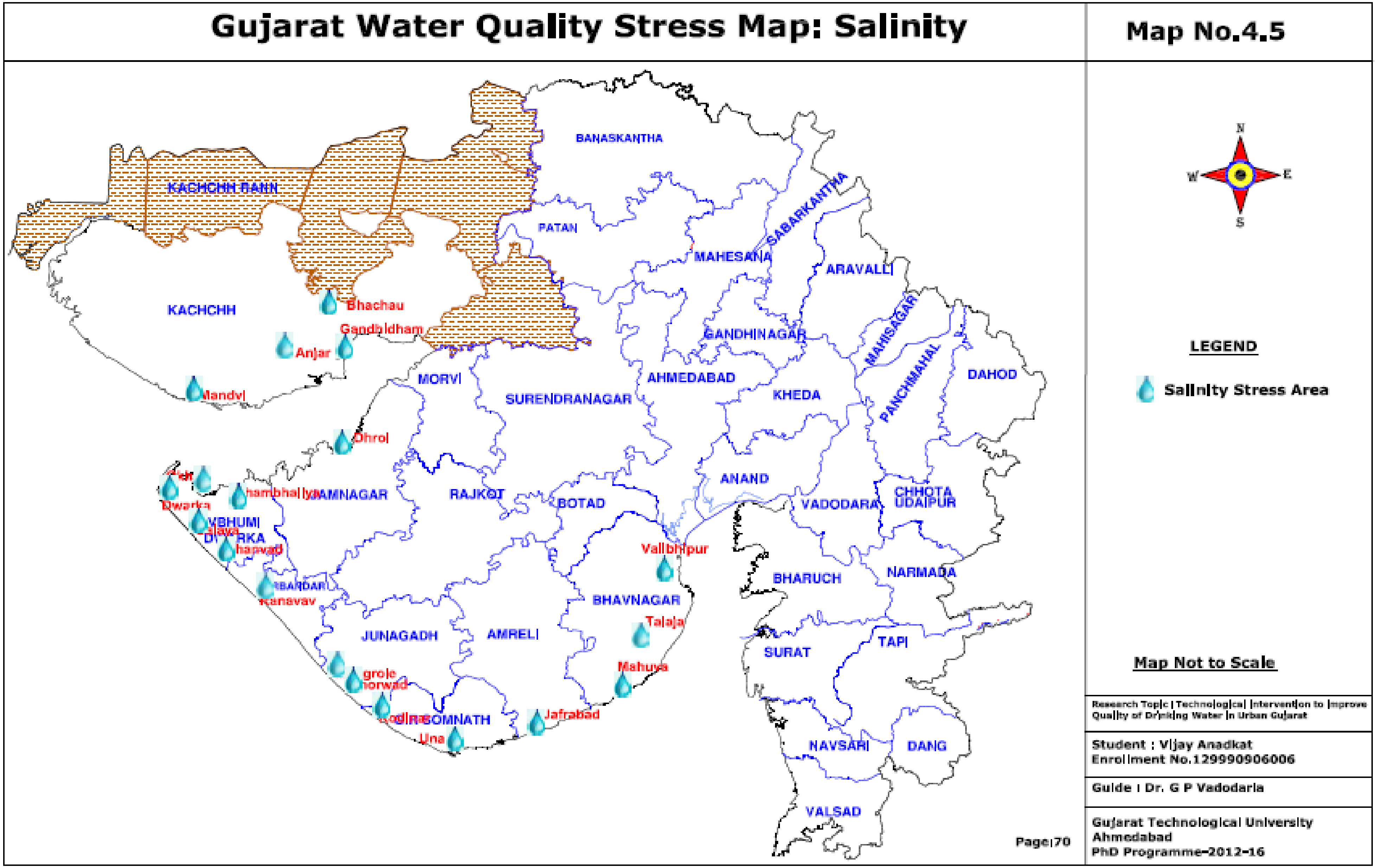
BOTAD
DEVBHUMI DWARKA
PORBANDAR
Bhavnagar
BHAVNAGAR
Amod
NARMADA
JUNAGADH
AMRELI
SURAT
TAPI
GIR SOMNATH
Vijolpur
DANG
VALSAD

4.8.3 Drinking water quality stress area: Salinity

Salinity is one of the most significant and widespread forms of ground water pollution in coastal regions of Gujarat that includes districts of Saurashtra and Kachchh As per an estimate by the Costal Salinity Prevention Cell of Govt of Gujarat, salinity ingress has impacted more than 1,300 villages and 12 Lakhs hectare of land along 1600 kms of long coastal area.

It also estimates that 7 coastal districts of Saurashtra and Kachchh are under effect of salinity. In results of water test sampling, it found that, more than 16 ULBs on coastal area are partially or fully affected. These ULBs are Anjar, Mandavi, Bhachau, Gandhidham, Dhrol, Okha, Dwarka, Khambhaliya, Bhanvad, Ranavav, Mangrol,Chorwad, Jafrabad,Mahua,Talaja, Vallabhipur etc., These are plotted and mapped as shown in Map 4.5. Salinity is a major cause of concern in coastal urban area and in absence of any alternative safe source of drinking water; the communities have to consume saline water which leads to health issues mainly kidney stone and skin diseases. By the CSPC, it has been observed that on an average, a household has to spend around Rs. 8,000 to Rs. 10,000/ year on health mitigation due to consumption of saline water in rural area, which can be similar in case of urban.


Gujarat Water Quality Stress Map: Salinity
Map No.4.5
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LEGEND
Salinity Stress Area
Map Not to Scale
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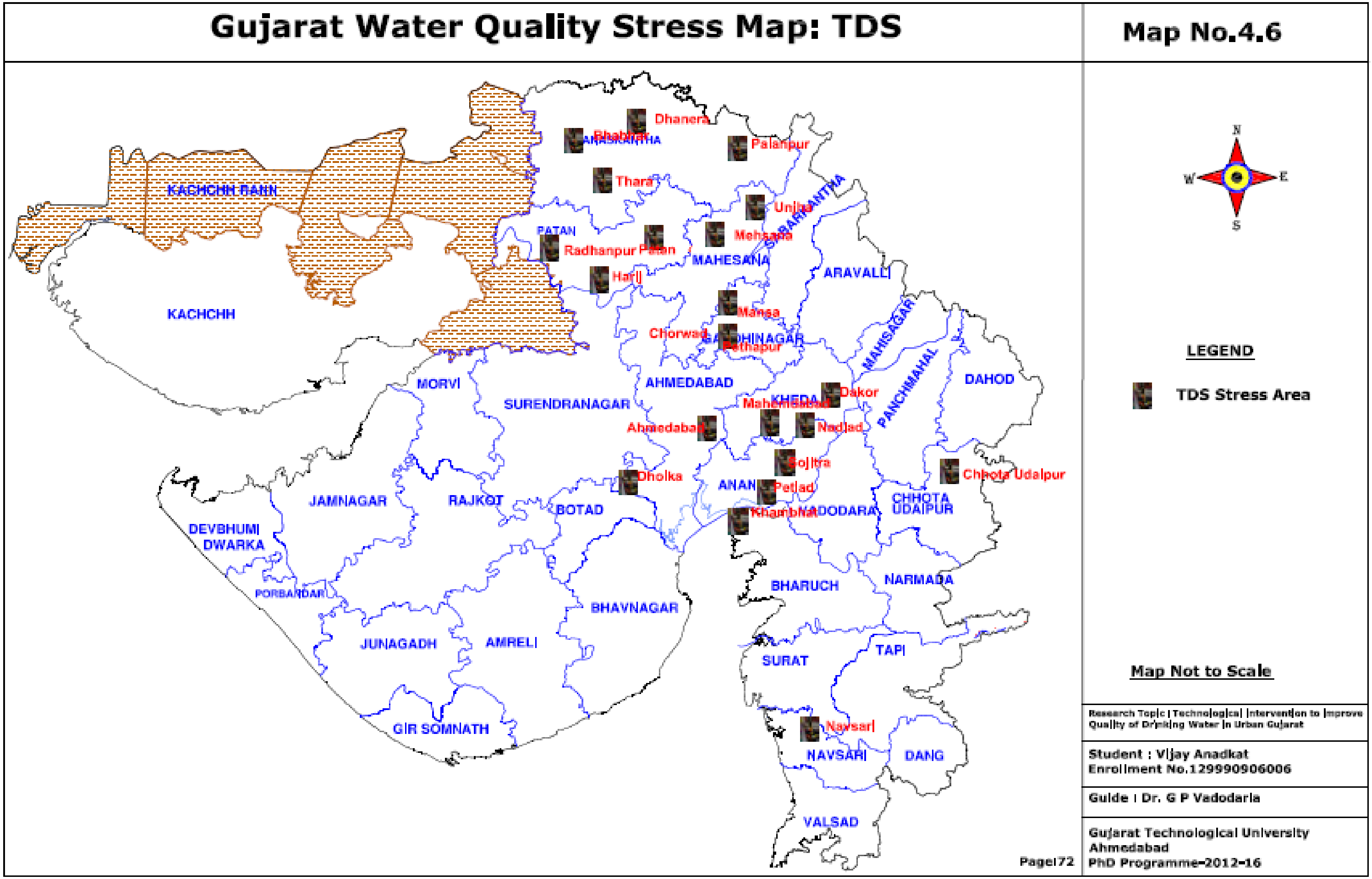
KACHCHH
BANASKANTHA
PATAN
MAHESANA
SABARKANTHA
ARAVALLI
GANDHINAGAR
MAHISAGAR
PANCHMAHAL
DAHOD
AHMEDABAD
KHEDA
SURENDRANAGAR
MORVI
RAJKOT
JAMNAGAR
BOTAD
ANAND
VADODARA
CHHOTA UDAIPUR
BHARUCH
NARMADA
BHAVNAGAR
AMRELI
JUNAGADH
SURAT
TAPI
NAVSARI
DANG
VALSAD
Bhachau
Gandhidham
Anjar
Mandvi
Dhrol
Dwarka
Kutiyana
Vallbhipur
Talaja
Mahuva
Jafrabad
Una
Ranavav

4.8.4 Drinking water quality stress area: Total Dissolved Solids (TDS) :

Higher value of TDS in ground water across the urban Gujarat is common phenomena. However, to be more precise, as per the Costal Salinity Prevention Cell report during 2006, it has been observed that 7 district of the State has higher values of TDS than permissible limit.

Water sample test result also observed high value of TDS in ULBs of North & Central Gujarat including Ahmedabad. These are Patan, Randhanpur, Dhanera, Thara, Planpur, Unjha, Mehsana, Harij, Mansa, Pethapur, Ahmedabad, Mahemdabad, Dholka, Petlad, Sojitra, Khambhat, and Chhota udepur, Navsari etc., Because of lesser availibility of municipal water people are forced to depend on ground water.

Over a period of time, due to overexploitation of ground water, water table is depleting and quality of water in terms of TDS is also be impacted. These results, many citizens are forced to consume groundwater with TDS content as high as 2500 mg/l. Many studies have also recorded large expenditure on the purchase of water purifying equipment at the household level. Water test results with TDS more than 1500 TDS in ULBs are mapped as under:


Gujarat Water Quality Stress Map: TDS
Map No.4.6
N
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LEGEND
TDS Stress Area
Map Not to Scale
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KACHCHH RANN
KACHCHH
Dhanera
Palanpur
Thara
Unjha
Mehsana
PATAN
Radhanpur
MAHESANA
Harij
ARAVALLI
Mansa
Chorwad
AHMEDABAD
DAHOD
MORVI
SURENDRANAGAR
Dakor
Ahmedabad
Nadiad
Sojitra
Dholka
Petlad
Chhota Udaipur
JAMNAGAR
RAJKOT
BOTAD
CHHOTA UDAIPUR
DEVBHUMI DWARKA
BHARUCH
NARMADA
PORBANDAR
BHAVNAGAR
JUNAGADH
AMRELI
SURAT
TAPI
GIR SOMNATH
Navsari
NAVSARI
DANG
VALSAD
MAHISAGAR
PANCHMAHAL

4.9 Financial Analysis of various WTP technologies

While considering Water Treatment Plant (WTP) options and alternatives, it is crucial to consider all aspects that input into the ultimate long term viability and sustainability. These depend on technology choice and the financial implications thereof. Technical experts and administrators together take suitable decision on WTPs. It is natural and decision makers emphasis on use of appropriate technologies, which should low cost, robust, low operator attention systems etc., Therefore, it is attempted to provide some macro level financial analysis for conventional water treatment plant v/s modern membrane based water treatment plant. A significant influencing factor as to sustainability is affordability in terms of capital cost and ongoing running costs of water treatment. It is particularly important to consider this aspect in instances where the initial capital layout of a technologically attractive system is considered to be too high in comparison to competing, yet technologically less sustainable technologies. It is generally observed that capital cost of membrane based technology plant is about 5 to 6 times costlier than conventional rapid sand water treatment plant depending upon the treatment capacity of plant. In case of operating and maintenance cost of membrane based plant cost saving can be made towards lower labour, and chemical requirements however, cost of membrane replacement add amount.

TABLE: 4.11 Financial Analysis of Conventional WTP v/s Membrane based WTP

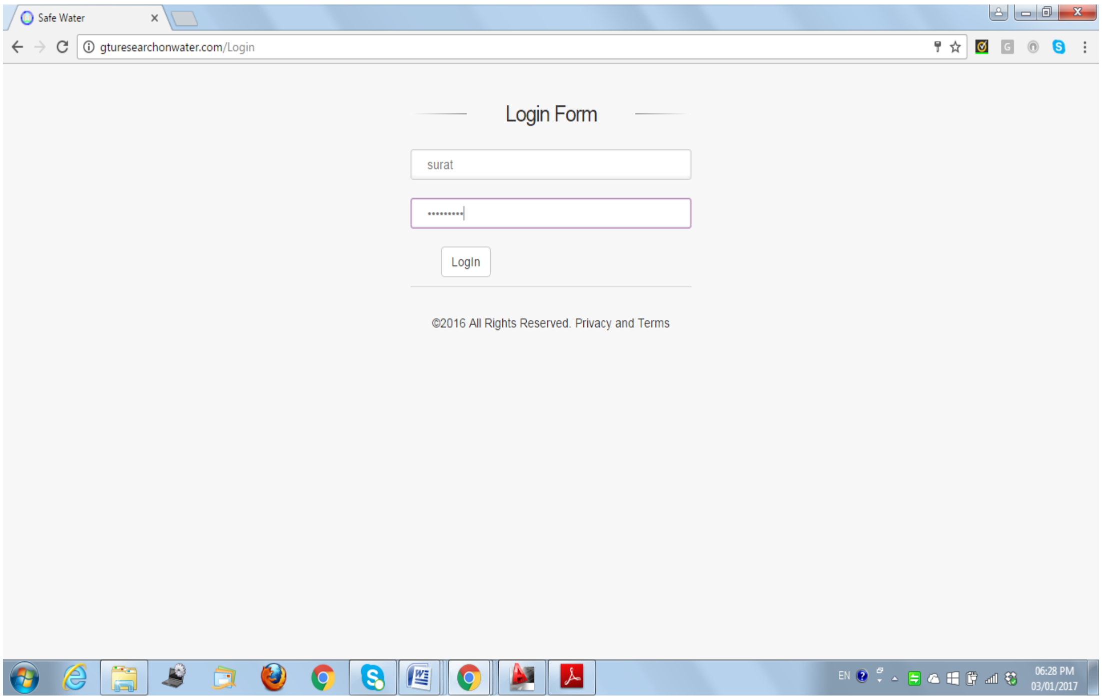
S. No.	Type of Water Purification Technology	Specific capital Cost (Rs./LPD)	O&M Cost (Paisa/ Liter of purified water)	Removals
Conventional WTP				
1.	Rapid sand type	1 to 1.5	0.03	Bacteria/ Virus/ Turbidity/ Suspended Solids
Membrane WTP				
1.	Ultra Filtration (UF)	10	0.10	Bacteria/ Virus/ Turbidity/ Suspended Solids
2.	Physio-chemical+UF	20	0.20	Single contaminant such as Iron/ Arsenic/ Fluoride
3.	UF+NF/RO	50	0.5	Multi-contaminants such as salinity, heavy metals etc
(Source:GWSSB SOR, discussion with officials of GWSSB)				

4.10 Development of Web Site and Management Information System (MIS) for Quality of supplied drinking water

It is proposed to develop web based water quality management information system. It is hosted as www.gtureserachonwater.com .It is a monitoring tool to track the quality of water across the municipalities in the State. Initially it is proposed that, MIS application that monitors daily quality of water supply in all the 159 Municipalities and 8 Municipal Corporations of the state of Gujarat. It is expected that each ULBs will enter details of water quality test report from each distribution point. Each ULB would get daily consolidated report on quality of supplied drinking water. This will also help health department to find source of water borne disease and take appropriate action in further. These MIS systems will work_

1. Hardware & Software Requirements: Desktop system with internet facility. Browsers like Internet Explorer, Mozilla Firefox etc.
2. How to access the application Open the browser. Type the URL (Address) of the application http://gturesearchonwater.com/
3. Type Username and password to access the application: fixed user ID = name of city & pass ward: name of city@123

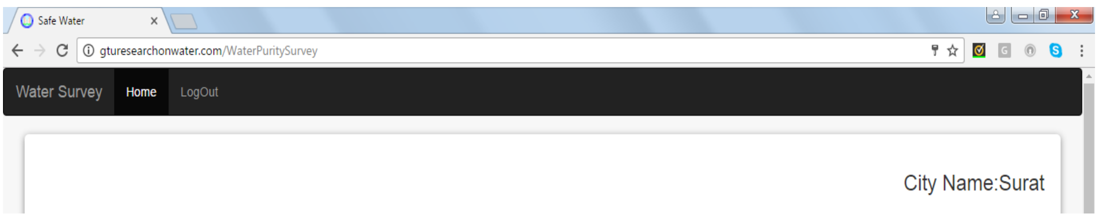
   For example, for Surat city user ID is Surat & passes ward=surat@123



4. Once login is approved data entry can be made for quality of water covering 4 physical properties, 25 chemical properties, and 1 biological property along with availibility of residual chlorine in water.

5. After completing entry of all 30 properties, (or if data is not available can also be opted for ‘0’) , results can be save as shown below:

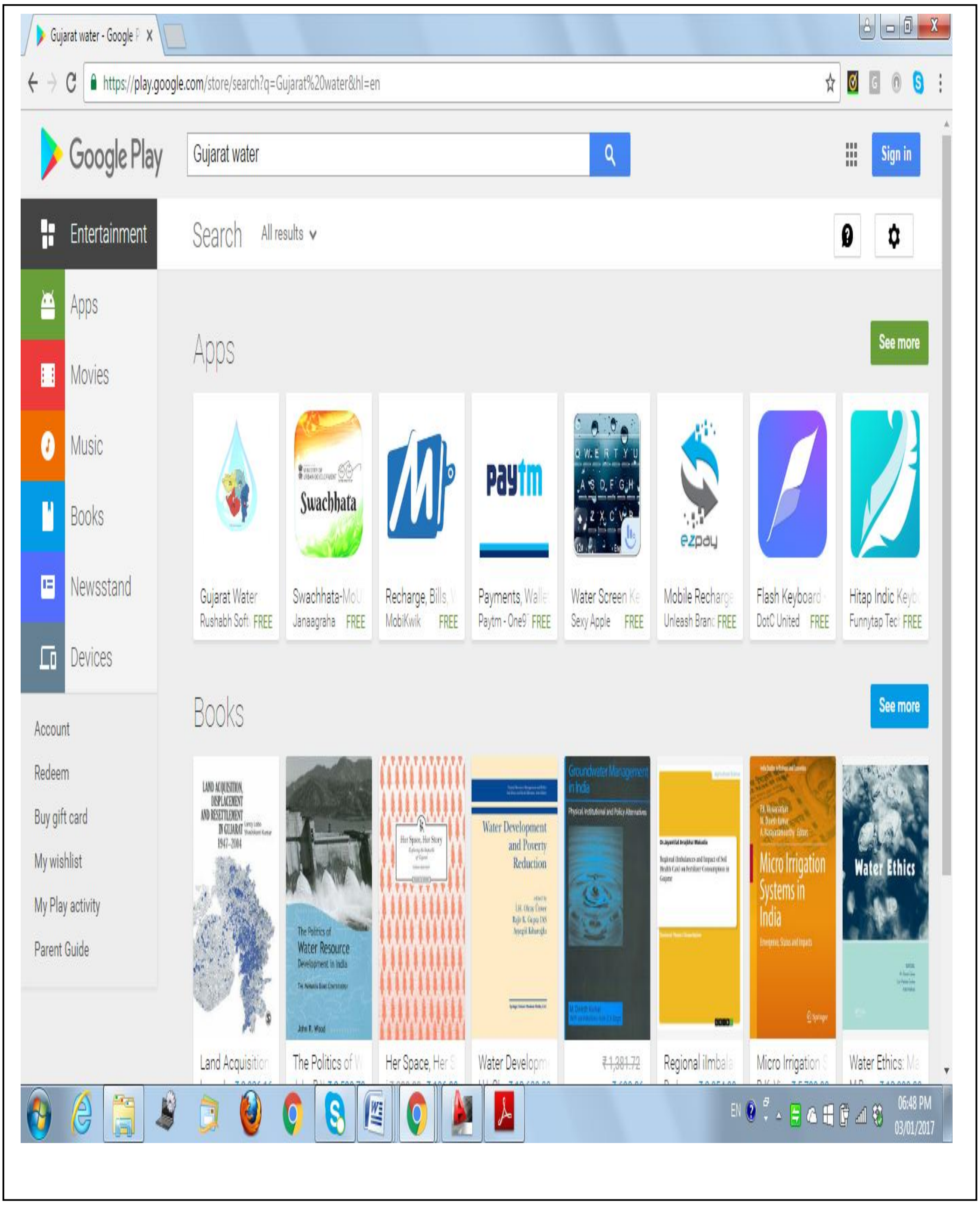
6. It is also possible to delete or cancel any record
7. When users completes his work or wants to come out of the application, then the user has to click on the logout option as shown below:



4.11 Android based Mobile App

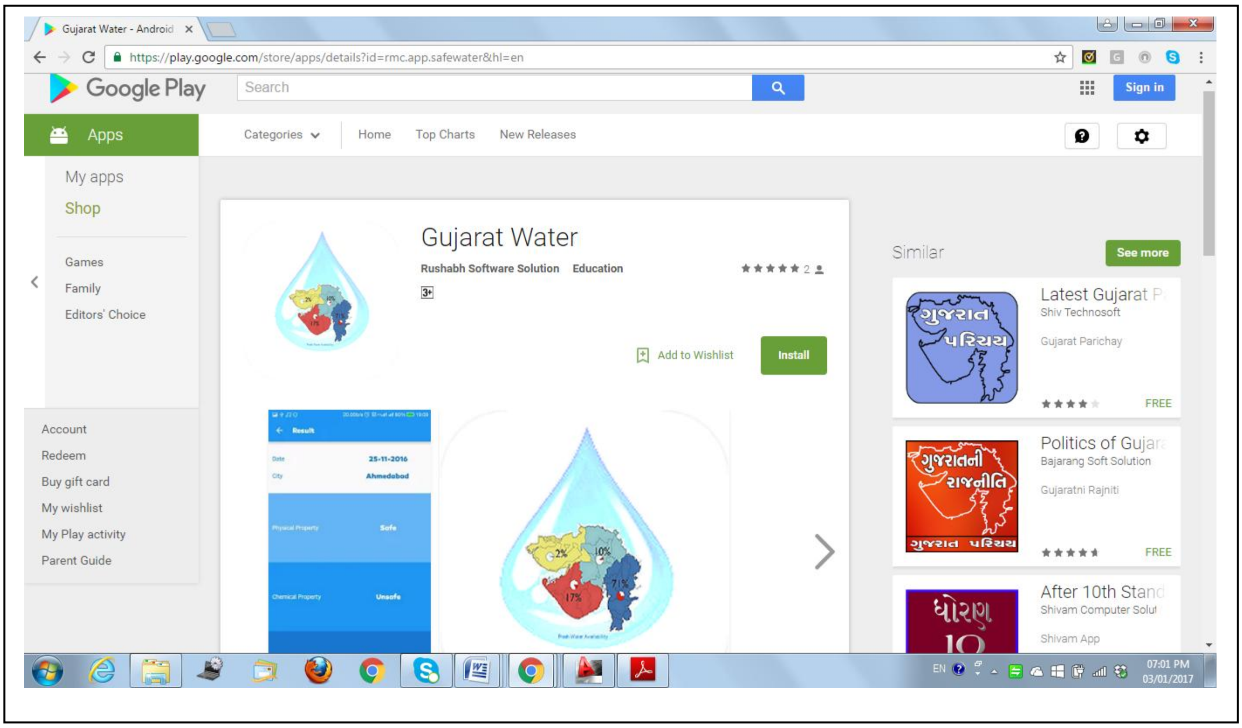
Above MIS on quality of supplied drinking water is linked with an android based mobile application which is available to all citizens, stakeholders. It can be down loaded from Google play store at free of cost. To find it search in Google Play- store as “Gujarat Water”.

1. Download in any mobile which works on android platform. Install in mobile. Application requires about 3 mb of space.

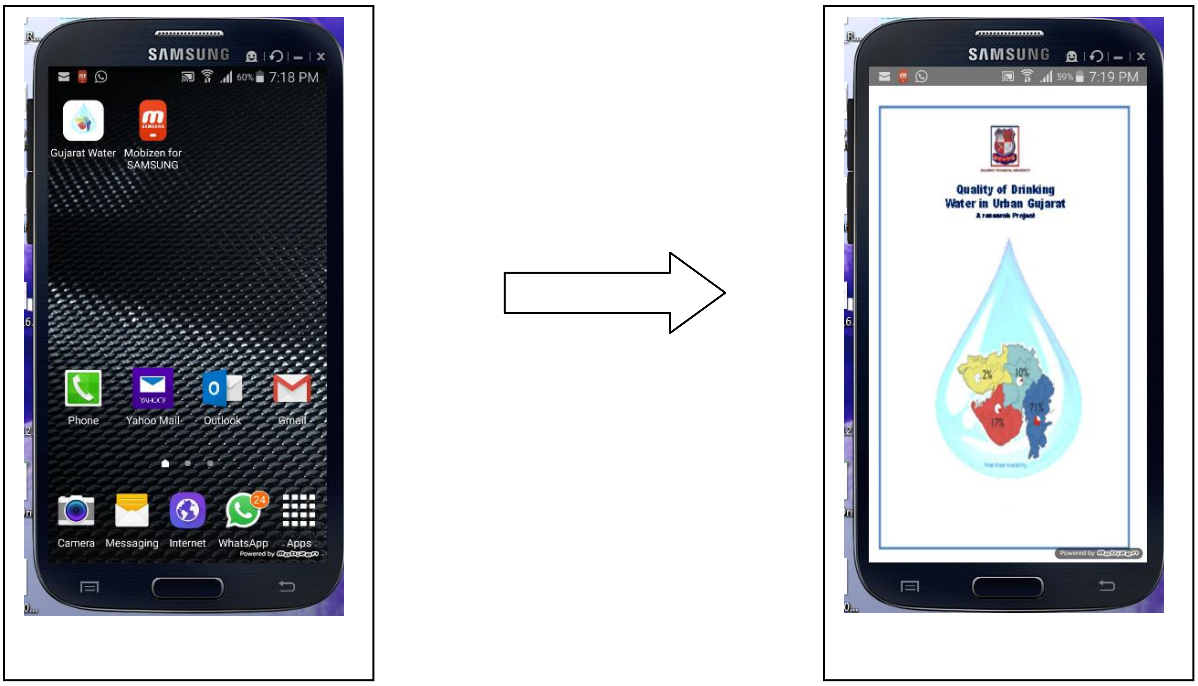


Mobile App

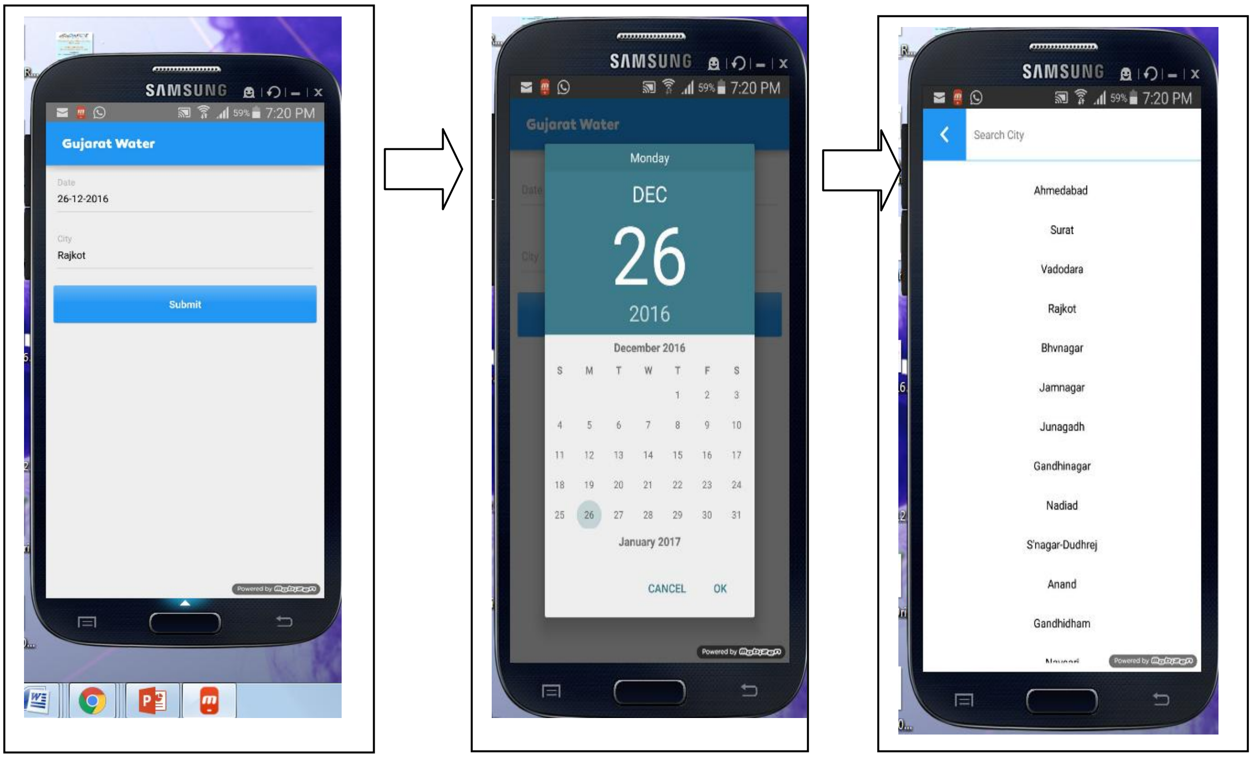
App provide following details on Google Play store



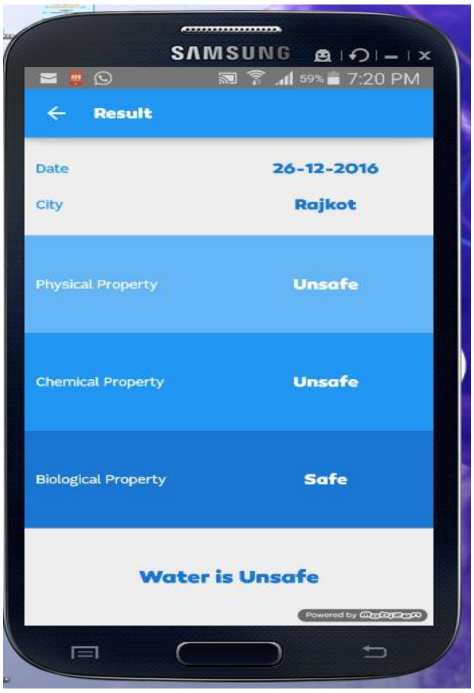
2. On installation of app will give following screens on mobile



3. To get result of supplied drinking water on any date choose from calendar and pop-up menu as shown below:



4. **Result will be as shown below:**



4.12 Discussion

- Gujarat falls under semi-arid zone and water scare area, having absence of perennial rivers is a great concern. Rate of urbanization in Gujarat is also at faster pace which results to continuous increase demand of water in urban area. ULBs as well citizens are forced to exploit groundwater sources. Overexploitation of groundwater in urban areas in the state over the time has threatened to all sources in quality as well as quantity
- Out Growth (OG) beyond administrative boundaries of municipal areas has increased over last decade. In 2001, the number of towns with outgrowths is 39 and about 2.5 million people are residing outside municipal areas as outgrowth area. In 2011, it is estimated that more than 45 areas are developed in OG area having more than 3.5 million populations. The proportion of population residing outside municipal areas has been substantial. These areas also forced ULBs to widen demand –supply gap
- There are 7 municipalities require modification in the plant, About 16 municipalities, out of 167 ULBs, there is not water treatment plant at all. While 13 municipalities are supplying ground water and therefore, do not require. In brief, Municipal Corporations, the Capacity of Water Treatment Plant (WTP) for existing need of water is available while in case of municipalities, status of WTP is required attention. In all ULBs practice

of conventional rapid sand filter plant followed by chlorination is adopted. None of ULBs have facility of modern water treatment plant.

- Low level of water supply pipe network and coverage, level of water supply in LPCD & duration of water supply are of great concerns. None of ULBs supplies continuous water supply (24x7). It is practiced globally to have 24x7 water supplies with metering to reduce chances of contaminations, reduce NRW, and ensure better quality of water. This needs some attention towards implementation of 24x7 water supply.
- High level of NRW in half of ULBs need to have water auditing
- Only 16 ULBs out of 167, have functional STPs which is big threat against ambient surface as well as subsurface water sources
- Municipal Corporation has its own water quality monitoring laboratory and chemist that monitors water quality. Periodic tests are conducted with appropriate sampling at WTP, ESR and in few cases at consumer end. However, there is no Standard Operating Procedure (SoP) about number, time, location, and test etc., for quality of drinking water. It is also observed than only in 5 Municipal corporations have reporting formats. Whereas municipalities which are having on water treatment plant depends on district level GWSSB laboratory for quality monitoring. In case of municipalities which are supplying treated bulk water from Narmada does not have any mechanism of water sample testing. In all cases, the quality sampling report is reviewed by Chief officer / Commissioner, there is no provision of third party monitoring or audit for water quality results
- It is general practice across all ULBs to test level of chlorine to check quality of drinking water to ensure disinfection. However, decision making on no of samples to be tested by ULB at various levels and type of tests to be conducted which is the most critical to maintaining desired water quality is missing. Besides, in Municipal Corporations as well as in municipalities, strong linkage needs to be established in terms of failed water samples and corrective measures by engineering department
- Except in 4 municipal corporations, there is need of capacity building of chemist, water supply engineers about quality of water. It is really required to know, appropriate technological options to be understood and implemented.
- Maintenance and up-dating of MIS records is largely not done in most of ULBs on regular basis.
- It has been observed that, at ULBs level, there is lot of confusion over options and alternative of rainwater harvesting techniques.

CHAPTER: 5

Conclusion

Based on data collection from all 167 ULBs of Gujarat state, discussion with most of chief officers of all municipalities and city engineers (water works) of all municipal corporation, discussion with officials of the state, consultant who have designed the water supply projects, officials of Gujarat Water Supply & Sewerage Board, Gujarat Pollution Control Boards, UMC & CEPT university officials engaged with PAS projects etc., leads to the research outcomes. In addition, drinking Water Quality stress mapping on AutoCAD and development of MIS & Android base App can be resulted into an important support tools to know the quality of water by the end user. In depth review of Literatures has helped to investigate appropriate techniques and technology to improve quality of drinking water.

5.1 Conclusion & Major Outcome:

The main objectives of this study are to suggest appropriate techniques and technologies to improve the drinking-water quality all urban area. The first and second objectives of the research are to analyze and assess the quality of current water sources across the state. Outcomes of the first and second objectives are summarised as under.

The major source of water supply in all ULBs of Gujarat is through bulk purchase of raw and treated water from Narmada Canal/pipe line. Bulk purchase is the main source of water production across all cities. There are 22 cities which are having own surface water source through dam, lake or river. Total 13 ULBs are fully dependent on ground water supplies. Beside, more than 1/4th ULBs have secondary source of water is ground water. This shows high level of dependency of ground water. All WTP are conventional Rapid Sand Filter Plant, followed by the Chlorination. Besides, 16 ULBs are without WTPs & 7 ULBs need up gradation. Average water supply coverage of network is about 80% and all ULBs have intermittent supply with duration as low as 20 minutes per day. In terms of

Conclusion

LPCD water supply level is also not so much encourages, more than half of total ULBs in state have level of water supply is less than 100 LPCD. Therefore, water quality issues are prominent here. None of tested water failed in bacteriological /biological property. Very few samples have high level of turbidity. However, it has been observed failure of water samples in terms of chemical properties like Nitrate, TDS, Fluorides and Chlorides etc., North Gujarat suffers the most by excessive fluoride followed by Saurashtra – Kachchh. South Gujarat area particularly suffers Nitrate; however Nitrate is also seen surface water in Bhavnagar and other part of Saurashtra region. High level TDS and salinity is common scenario across the state. Salinity water quality stress is seen in west Saurashtra & Kutch area. All these have been mapped.

A third objective of the research is to study conventional and non-conventional technological options to improve quality of water. Over a period of time, lot of research, patent & options are viable to improve the quality of drinking water across the globe. All these options are either limited to small community level water supply or rural areas., even though it is also attempted to identify long term solutions and particularly covering conventional & non conventional methods including comparison of modern technological solutions like filtration media up gradation with technology like microfiltration technology, using multimedia structure in new and existing filter beds, Development of Green infrastructure, promotion of rainwater harvesting, option for U/V against Chlorination etc.,

Fourth objective of the research is to provide probable various technological options to improve the quality of drinking water. The study was carried out based on the results obtained and discussion. It has been observed that, there is not much issues related to physical & biological properties/contamination. However, there are issues in some of ULB related to chemical properties like fluoride, Nitrate, Salinity & TDS. Appropriate technological solutions are suggested.

Fifth objective is to develop web based MIS & App for monitoring of quality of supplied water in all ULBs. MIS on www.gturesearchonwater.com is developed. Taking it as back end support, an android based mobile App;"**Gujarat Water**", is also developed.

5.2 Major Contributions

Adopting good management and monitoring procedures are important in assuring safe drinking water. This is seen in the multiple barriers approach taken to prevent, protect and treat water so that it is of good quality of drinking-water quality and help in mitigating or eliminating diseases in the whole urban area of Gujarat. Looking to the international practice and available option quality of water in Urban Gujarat can be improved by any one or combination of the following points:

5.2.1 Technology options to improve quality of drinking water: Additional Treatment: Fluoride Removal:

As per IS: 10500 it desirable to have fluoride less than 1.5ppm. Number of technologies, for several defluoridation processes based on adsorption and ion exchange in filter systems, coagulation and precipitation and membrane filtration processes have been developed and tested globally. Suggestive methods used for the removal of fluoride from drinking water can be described as below:

- **Adsorption and ion-exchange:** In case of high level of fluoride, the passage of water through a contact bed where fluoride is removed by ion exchange or surface chemical reaction with the solid bed matrix of activated alumina.
- **Activated carbon:** Prepare layer of carbon saw dust in alum solution forms. Spread one layer above rapid sand filter an excellent defluoridating carbon. The defluoridating process is between carbon and fluoride. Alkali digested (1 % KOH) and alum soaked (2% alum) carbon removed 320 mg fluoride per kg and showed maximum removal efficiency at pH 7.0.
- **Coagulation-precipitation:** The aluminum sulphate and lime based coagulation-flocculation sedimentation process for defluoridation can also be adopted. Technique (NEERI suggested) involves addition of aluminum salts, lime and bleaching powder followed by rapid mixing, flocculation sedimentation, filtration and disinfection. Aluminum salt may be added as aluminum sulphate or aluminum chloride or combination these two. Aluminum salt is only responsible for removal of fluoride from water. The dose of aluminum salt increases with increase in the fluoride and alkalinity levels of the raw water. The selection of either aluminum sulphate or aluminum chloride also depends on the sulphate and chloride contents of the raw water to avoid exceeding their permissible limits. Lime facilitates formation of dense floes for rapid setting. Bleaching powder is added to the raw water at the rate of 3mg/L for disinfection.

- **Chemo defluoridation Techniques:** Chemo-defluoridation technique can also be used in which, the salts of calcium and phosphorous in required dose of chemicals are added in the fluoride contaminated raw water and mixed properly. After **1**5 to 20 minutes of mixing of the chemicals, water is allowed to flow by gravity into the sand filter at the rate of 300 400 ml/min. Filtered water with fluoride concentration will have less than **1** mg/L. The layer of chemical complex precipitate formed on the sand filter also removes some fluoride from the water during filtration. After about 1 to 2 months of operation, filter will be required to clear with layer of formation of thick layer of sludge.
- **Reverse osmosis and Nano-filtration:** Membrane techniques for removal of fluoride shows, the rejection of fluoride ion higher than 98%. These may be in form of nano-filtration or RO system. Similarly, dialysis and electro-dialysis techniques are also effectively utilized for removal of fluoride. However, membrane technology is costlier, therefore it can be utilized to treat limited to quantity of drinking water & water for cooking and have water kiosk

5.2.2 Technology options to improve quality of drinking water: Additional Treatment : Nitrate removal

As per IS: 10500 it desirable to have Nitrate level should be less than 45 ppm. Number of technologies, for several defluoridation processes based on adsorption and ion exchange in filter systems, coagulation and precipitation and membrane filtration processes have been developed and tested globally. Suggestive methods used for the removal of Nitrate from drinking water can be described as below:

Adsorption/Ion exchange, Biological de-nitrification, Catalytic reduction, Reverse osmosis Electro dialysis, blending of water are suggestive techniques for Nitrate. Improperly installed, operated or maintained plants can result in nitrate passing through the treatment process and in some cases concentrating the nitrate above the incoming levels.

- **Adsorption/ion exchange:** Ion exchange process involves passage of nitrate contaminated water through a resin bed containing strong base anion exchange resins that are charged with chloride, As water passes over the resin bed, the resin takes up the nitrate ions in exchange for chloride until the exchange capacity is exhausted. The exhausted resin is then regenerated using a concentrated solution of sodium chloride (brine).

Catalytic reduction/de-nitrification

- **Catalytic reduction/de-nitrification:** Metallic catalysts are the process in which, nitrate reacts with hydrogen gas or formic acid and it is converted into nitrogen and water using a solid catalyst. The activity and selectivity of metallic catalysts plays a crucial role for the effective conversion of nitrate to nitrogen gas.
- **Membrane based WTP: Reverse Osmosis & Electro-dialysis:** Reverse Osmosis is an established technology for removal of various contaminants of water. In order to increase the life of membrane in reverse osmosis (RO) process, pre-treatment of contaminated water is essential which is generally achieved by passing it through sand filter, activated carbon filter and micron filter to remove iron, organic matter, excess free chlorine and suspended matter. Electrodialysis (ED) is an electrically driven process that uses a voltage potential to drive charged ions through a semi-permeable membrane reducing the nitrate in source water. The separation is accomplished by alternately placed cat ion and anion selective parallel membranes across the current path to form an ED cell. DC voltage potential induces the cat ion to migrate towards the anode through cationic membrane and the anions to migrate towards the cathode through anionic membrane. Electro-dialysis reversal system periodically reverses the polarity of electric field. Both are expensive technology and can be used limited to establish water kiosk
- **Blending/dilution of water:** Blending is another method which also reduces nitrates in/from drinking water. In this process, nitrate contaminated water is mixed with clean water (nitrate free water) from another source to lower or dilute overall nitrate concentration of raw (untreated) water.

5.2.3 Technology options to improve quality of drinking water: Additional Treatment : Salinity & TDS removal

It has been observed that high value of salinity and TDS is seen across the state where ground water is source of supply. **Desalination** is a process that removes dissolved minerals from various feed water sources. Most of them are dependent on mainly membrane basis technologies. Choice of desalination process/technology depends upon a variety of factors and is highly site-specific.

- **Reverse Osmosis:** Reverse osmosis (RO) is currently one of the fastest growing techniques for the desalination of different types of water. The product water from RO plants have TDS levels ranging between 30 to 500 mg/L.

- **Electro dialysis**: Electro-dialysis is an electro-membrane process in which transport of ions present in contaminated or blackish is accelerated due to an electric potential difference applied externally.

- **Solar Humidification /Solar Stills:** Solar energy is one of the most promising applications of renewable energies to seawater desalination. Solar still is basically a large scale shallow water pond if saline water (about 10 cm deep) spread over a large surface area and covered with glass over. The natural sunlight is used for evaporating the saline water and the condensed vapour is collected from the glass-case. Well-managed and maintained solar stills require a solar collection area of about one square meter to produce up to six liters of fresh water per day. This is also of limited use.

5.2.4 Filtration Media up gradation: Technology like microfiltration technology which eliminated sand filtration, coagulation and flocculation, filter beds and cartridges can be adopted for bigger Municipal Corporation where more technically qualified staffs are available. Conventional clarifiers with ultra filtration membrane in proposed projects, Refurbishment of existing clarifiers can be adopted where the problem of fluoride and high level of TDS are observed. Scope for using multimedia structure in new and existing filter beds can be adopted instead of constructing new water treatment plant.

5.2.5 Development of MIS & APP:

To generate MIS for day to day & time to time basis, water quality sampling data at ULBs level web site **www.gtureserchonwater.com** is developed and registered. A master data sheet is also prepared to allow adding, updating or deleting existing ULBs or water zone in bigger municipal corporations. In order to have uniformity, data entry work was explained to all the officials of all ULBs of Gujarat.

Additionally to provide information of water quality supplied to citizens on their water zone area of own city, an android based mobile App with name **“Urban Water”** is developed and made available to common people from Google play store at free of cost.

This App is linked with the MIS & web site.

5.3 Recommendations:

Based on data collection & analysis, the following are recommendations for ULBs.

5.3.1 Promoting Natural Water Infra structure: International trend is to preserve and develop green and natural water infrastructure, suitable analysis for Grey V/S Green Infrastructure Development be made and adopted. Globally, it has been accepted to scaling up Natural infrastructure; however it far from achieving the necessary scale that is commensurate. Institutional inertia and knowledge gaps surrounding natural infrastructure benefits and nexus linkages. Hard engineered solutions have dominated water management systems and education curriculums up to this point. In many key institutions, decision makers and constituents do not have a strong understanding of the multiple benefits of natural infrastructure. Therefore, it is essential to create through I-E-C activities making the case for natural infrastructure by comparing quantifiable ecological and economic benefits to grey infrastructure, poses considerable challenges. Water management institutions often lack the technical capacity and resources to identify, evaluate, and design natural infrastructure. Further, those who benefit from natural infrastructure often receive those benefits for free, and therefore may be less inclined to voluntarily pay for maintenance of the natural system, despite the fact that the natural infrastructure benefits could be degraded or lost without sufficient protection and management. Even when natural infrastructure beneficiaries are willing to support the protection of the asset, the lack of adequate, flexible financing mechanisms may prevent investment. Long time horizons. Natural infrastructure solutions are still emerging and often require a longer period of time to establish than business as usual "grey infrastructure" options. For projects that restore degraded ecosystems to revive natural infrastructure, the ecological processes to establish the natural infrastructure could take many years, so they often do not have the short-term certainty that may be possible for engineered infrastructure to meet compliance requirements under shorter timelines. Furthermore, regulated entities do not necessarily perceive natural infrastructure as eligible to comply with environmental regulations.

5.3.2 Rain water Harvesting: While major dams reservoirs are being built, water harvesting, which is an age old concept, can be applied with modern techniques which are generally low in cost, can be implemented within local jurisdictions, incrementally, are environment friendly, are decentralized and close to the point of use and thus bring in multiple benefits to the localized region.

Conclusion

The concepts of rainwater harvesting are simple:

- Conserving the water where it falls
- Increasing the retention time and surface area of contact of water with the ground to facilitate recharge
- Directing the rainwater into the aquifer through recharge structures
- The ground water reservoir forms the most economical means of storage as well as the most dispersed form of supply

5.3.3 Automation and Instrumentation of WTP: It is strongly recommended that, all WTPS within Municipal Corporations areas, "A" class & "B "class ULBs should have fully automation & instrumentation in WTP. This includes operation & maintenance of WTP by using SCADA. It also includes online water quality testing.

5.3.4 Development of Water Safety Plan & Quality Surveillance system

A water safety plan is a plan to ensure the safety of drinking water through the use of a comprehensive risk assessment and risk management approach that encompasses all steps in water supply from catchment to consume (WHO, 2006). Water safety plans are considered by the WHO as the most effective means of maintaining a safe supply of drinking water to the public. Their use should ensure that water is safe for all forms of human consumption and that it meets regulatory water standards relating to human health. In order to produce a plan, a thorough assessment of the water supply process from water source to the consumer's tap must be carried out by the water provider. Hazards and risks should be identified, and appropriate steps towards minimizing these risks are then investigated. Therefore, it is strongly recommended that all ULBs should have Water Safety Plan and Quality surveillances system.

5.3.5 Proposed Standard Operating Procedure for collection of Water Samples

For recommended collection and frequency of samples for water quality by water agencies and surveillance agencies following SOPs have been prepared based on the Manual on Water Supply and Treatment, III Edition, May 1999, Government of India, Ministry of Urban Development, New Delhi.

Standard Operating Procedure

Standard Operating Procedure (SoP) for different class of ULBs are recommended based on the population, level of supply and practice suggested by CPHEOO for ULBs are as under:

Municipal Corporations: The SoP for Municipal Corporation's area is suggested as_

TABLE:5.1 Suggested Minimum Sampling Frequency and by water supply agency

Population Served	Maximum Interval between successive sampling	Minimum no. of samples to be taken from entire distribution system
Municipal corporation	One day	One day

Followings are suggested for assessment of quality of water in terms of numbers of samples to be collected from different sources, frequencies, numbers of samples, different parameters to be tested for the sampling.

TABLE:5.2 Frequency and Parameter to be tested by water supply agency

Sl.No	Size and Source	Frequency	Parameters					Heavy Metal & Pesticide	Problem parameters like As, cr, Fe & Mn, Fluoride	Remarks
			Residual Chlorine	Physical	Chemical	Bacteo-roligical	Biological			
1	2	3	4	5	6	7	8	9	10	11
1	Ground water	Weekly	√							From source & distribution system
		Quarterly				√				
		Twice a year		√	√				√	
		Annually						√		
2	Ground water(Hand pump)	Twice a year		√	√	√			√	Preferable in summer
3	Surface water	Fortnightly		√	√					
3a	a. Raw water, source and intake point	Quarterly				√				
		Annually						√	√	
		Occasional					√			
3b	b. Filtered water	Monthly		√		√				
3c	c. Clear water storage reservoir	Fortnightly	√	√	√					
		Monthly				√				
3d	d. Distribution system	Weekly	√							
		Monthly				√				
		Quarterly		√	√					

Conclusion

A & B class Municipalities: City population more than 1,00,000 are designated as **A** class municipalities while having city population more than 50,000 and less than 1,00,000 are designated as B class mnicipalities. The SoP for A class and B class are suggested as under:

TABLE: 5.3 Suggested Minimum Sampling Frequency and by water supply agency

Population Served	Maximum Interval between successive sampling	Minimum no. of samples to be taken from entire distribution system
A & B class municipalities	Three day	Three day

Followings are suggested for assessment of quality of water in terms of numbers of samples to be collected from different sources, frequencies, numbers of samples, different parameters to be tested for the sampling.

TABLE: 5.4 Frequency and Parameter to be tested by A & B class municipalities

Sl.No	Size and Source	Frequency	Parameters					Heavy Metal & Pesticide	Problem parameters like As, cr, Fe & Mn, Fluoride	Remarks
			Residual Chlorine	Physical	Chemical	Bacteo-roligical	Biological			
1	**2**	**3**	**4**	**5**	**6**	**7**	**8**	**9**	**10**	**11**
1	Ground water	Weekly	√							From source & distribution system
		Quarterly				√				
		Twice a year		√	√					
		Occasional						√	√	
2	Ground water (Hand pump)	Twice a year		√	√	√			√	Preferable in summer
3	Surface water	Fortnightly		√	√					
3a	a. Raw water, source and intake point	Quarterly				√				
		Annually								
		Occasional					√	√	√	
3b	b. Filtered water	Monthly		√		√				
3c	c. Clear water storage reservoir	Fortnightly	√	√	√					
		Monthly				√				
3d	d. Distribution system	Weekly	√							
		Monthly				√				
		Quarterly		√	√					

SoP for C & D Class Municipalities:

In Gujarat , city population more than 25,000 and less than 50000 are designated as **C** class municipalities, while D class municipalities means having population more than 15,000 and less than 25,000. The SoP for C class and D class are suggested as under:

TABLE: 5.5 Suggested Minimum Sampling Frequency and C and D Class Municipalities

Population Served	Maximum Interval between successive sampling	Minimum no. of samples to be taken from entire distribution system
C & D class municipalities	Three days	Three days

Followings are suggested for assessment of quality of water in terms of numbers of samples to be collected from different sources, frequencies, numbers of samples, different parameters to be tested for the sampling.

TABLE: 5.6 Frequency and Parameter to be tested by C & D class municipalities

No	Size and Source	Frequency	Parameters					Heavy Metal & Pesticide	Problem parameters like As, cr, Fe & Fluoride	Remarks
			Residual Chlorine	Physical	Chemical	Bacteo-roligical	Biological			
1	**2**	**3**	**4**	**5**	**6**	**7**	**8**	**9**	**10**	**11**
1	Ground water	Weekly	√							From source & distribution system
		Quarterly				√				
		Twice a year		√	√					
		Occasional						√	√	
2	Ground water (Hand pump)	Twice a year		√	√	√			√	Preferable in summer
3	Surface water	Fortnightly		√	√					
3a	a. Raw water, source and intake point	Quarterly				√				
		Annually								
		Occasional					√	√	√	
3b	b. Filtered water	Monthly		√		√				
3c	c. Clear water storage reservoir	Fortnightly	√	√	√					
		Monthly				√				
3d	d. Distribution system	Weekly	√							
		Monthly				√				
		Quarterly		√	√					

5.3.6 Installation of water Kiosk: It is suggested that in case of issues related to contamination of chemical properties, water kiosk can be installed. It is successful implemented at Dwarka, New Delhi. This can be developed and installed by involving community & should have self sustainable model. It generally costs Rs.5 per 20liters.

5.3.7 Capacity Building Programme: Capacity Building is the process of developing and strengthening the skills, instincts, abilities, processes and resources that organizations and communities need to survive, adapt, and thrive in the fast-changing world. Capacity Building (CB) is widely recognized as one of the key ingredients of sustainable development. It is recommended to have intense Capacity building plan of Urban Local Bodies (ULB) to enable them for challenging task of preparation of water safety plan, supply and monitoring of water quality, better operation and maintenance of water treatment plant, use and handling of chemicals like Alum, PAC & Chlorine etc., management of SoP and MIS

5.4 Future Scope of Work

1. The research work is done considering quality of drinking water by taking 2 to 3 samples per ULB and their analysis. Water samples are also taken from WTP or /ESR. The research work can be extended for water sample collection from users' water tap with more numbers of samples. Researcher can take more water samples in order to clarify preliminary results, provide composite samples rather than point samples, and to take into account any annual or seasonal differences.
2. The research has outcome of mapping of drinking water quality stress areas across the state on AutoCAD maps. The future research work can extend with preparation of GIS based maps.
3. All water quality stress maps are prepared considering water test results across all ULBs of the State. It is required to prepare mapping of quality of water within each city by using appropriate mapping tools.
4. Research may be done to examine the possibility of mapping groundwater characteristics in all urban area across the State with topographical data and how waste water & industrial discharges will be affected by soil types and infiltration conditions and the impact on the quality of the water sources.
5. Impact analysis of poor quality of drinking water on health and socio-economic aspects could not be covered, for which future research work can be done
6. MIS and development of maps are done with assumptions that water quality test results will be entered and updated by concern ULBs, the present study can also be extended for use of automatic updating & identification of location of users and providing real time value of quality of drinking water.

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Annexure: 1
Sources of Water in all ULBs of Gujarat

S.No	No.	Name of ULBs	Class of Municipalities	Population as per Census 2011	App. Qty in MLD
Sources of water: Narmada water through pipeline/canal					
1	1	Botad	A	1,30,327	15
2	2	Mahuva	B	82,772	10
3	3	Dhangadhra	B	75,133	9
4	4	Halol	B	59,605	7
5	5	Dhandhuka	C	32,475	4
6	6	Talaja	C	27,882	4
7	7	Sutrapada	C	26,132	4
8	8	Chorvad	D	22,720	3
9	9	Barvala	D	17,951	3
10	10	Damnagar	D	16,614	2
11	11	Maliyamiyana	D	15,964	2
12	12	Vallabhipur	D	15,882	2
TOTAL (12)				5,23,457	65
Sources of water: Narmada water and Local Deep well or Bore wells					
13	1	Mahesana	A	184,991	22
14	2	Bharuch	A	169,007	20
15	3	Bhuj	A	143,286	17
16	4	Patan	A	125,497	15
17	5	Kalol	A	113,153	14
18	6	Anjar	B	87,183	10
19	7	Khambhat	B	83,715	10
20	8	Dholka	B	79,531	10
21	9	Savarkundala	B	78,354	9
22	10	Kadi	B	73,228	9
23	11	Mangrol	B	63,794	8
24	12	Viramgam	B	55,821	7
25	13	Petlad	B	55,330	7
26	14	Mandavi	B	51,376	6
27	15	Dabhoi	B	51,240	6
28	16	Kapadvanj	C	49,308	6
29	17	Padra	C	43,366	5
30	18	Jambusar	C	43,344	5
31	19	Limbadi	C	42,769	5
32	20	Dahegam	C	42,632	5
33	21	Thangadh	C	42,351	5
34	22	Sanand	B	41,530	5
35	23	Chaklasi	C	39,581	5
36	24	Radhanpur	C	39,558	5
37	25	Bhachau	C	39,532	5
38	26	Bavla	C	36,206	4
39	27	Karamsad	C	35,285	4
40	28	Bagsara	C	34,521	4

Annexure

S.No	No.	Name of ULBs	Class of Municipalities	Population as per Census 2011	App. Qty in MLD
41	29	Halvad	C	32,024	4
42	30	Mansa	C	30,347	4
43	31	Gadhada	C	29,872	4
44	32	Sikka	C	28,814	3
45	33	Kalol (P)	C	28,777	3
46	34	Rapar	C	28,407	3
47	35	Tharad	C	27,954	3
48	36	Vadnagar	C	27,790	3
49	37	Vijapur	C	25,558	3
50	38	Babra	C	25,270	3
51	39	Dakor	D	24,396	3
52	40	Prantij	D	23,596	3
53	41	Pethapur	D	23,497	3
54	42	Kathlal	D	22,071	3
55	43	Bhabhar	D	21,894	3
56	44	Chotila	D	21,364	3
57	45	Lathi	C	21,173	3
58	46	Anklav	D	21,003	3
59	47	Vadali	D	20,646	2
60	48	Harij	D	20,253	2
61	49	Boriavi	D	19,865	2
62	50	Bareja	D	19,690	2
63	51	Visavadar	D	19,515	2
64	52	Talod	D	18,298	2
65	53	Thara	D	18,060	2
66	54	Bayad	D	17,886	2
67	55	Patadi	D	17,725	2
68	56	Mahudha	D	17,722	2
69	57	Sojitra	D	16,713	2
70	58	Chansma	D	15,932	2
71	59	Bantawa	D	15,291	2
72	60	Amod	D	15,237	2
73	61	Vanthali	D	14,554	2
Sources of water: Local Surface Water					
74	1	Navsari	A	160,941	19
75	2	Valsad	A	114,636	14
76	3	Dahod	B	94,578	11
77	4	Bardoli	B	60,821	7
78	5	Bilimora	B	53,187	6
79	6	Vyara	C	39,789	5
80	7	Balasinor	C	39,330	5
81	8	Rajpipla	C	34,845	4
82	9	Karjan	C	30,405	4
83	10	Tarsadi	C	29,305	4
84	11	Zalod	C	28,720	3

Annexure

S.No	No.	Name of ULBs	Class of Municipalities	Population as per Census 2011	App. Qty in MLD
85	12	Paradi	C	28,495	3
86	13	Kanakpur Kansad	C	28,327	3
87	14	Umargam	D	27,859	3
88	15	Songadh	C	26,515	3
89	16	Chhotaudepur	C	25,787	3
90	17	Dharampur	D	24,178	3
91	18	Devgadh Baraiya	D	21,030	3
92	19	Santrampur	D	19,465	2
93	20	Shahera	D	19,175	2
94	21	Mandavi	D	18,214	2
95	22	Gandevi	D	16,827	2
Sources of water: Narmada pipe line and Local dam					
96	1	Ahmedabad	MC	55,77940	1250
97	2	Surat	MC	44,67,797	910
98	3	Vadodara	MC	16,70,806	456
99	4	Rajkot	MC	12,86,678	320
100	5	Bhavnagar	MC	5,93,368	120
101	6	Jamnagar	MC	4,79,920	95
102	7	Junagadh	MC	3,19,462	22
103	8	Gandhinagar	MC	2,06,167	77
104	9	Gandhidham	A	247,992	31
105	10	Morbi	A	194,947	24
106	11	Surendranagar	A	177,851	22
107	12	Veraval	A	154,636	19
108	13	Porbandar	A	151,770	19
109	14	Godhara	A	143,644	18
110	15	Jetpur	A	118,302	15
111	16	Gondal	A	112,197	14
112	17	Amreli	A	105,573	13
113	18	Dhoraji	B	84,545	11
114	19	Himmatnagar	B	81,137	10
115	20	Keshod	B	76,193	10
116	21	Wadhvan	B	75,755	9
117	22	Modasa	B	67,648	8
118	23	Palitana	B	64,497	8
119	24	Okha	B	62,052	8
120	25	Upleta	B	58,775	7
121	26	Una	B	58,528	7
122	27	Unja	B	57,108	7
123	28	Sidhhpur	B	56,402	7
124	29	Sihor	B	54,547	7
125	30	Jasdan	C	48,483	6
126	31	Chhaya	C	47,699	6
127	32	Ranavav	C	46,018	6
128	33	Vankaner	C	43,881	5
129	34	Kodinar	C	41,492	5

Annexure

S.No	No.	Name of ULBs	Class of Municipalities	Population as per Census 2011	App. Qty in MLD
130	35	Khambhaliya	C	41,374	5
131	36	Rajula	C	38,489	5
132	37	Dwarka	C	38,873	5
133	38	Gariyadhar	C	33,949	4
134	39	Salaya	C	33,246	4
135	40	Manavadar	C	30,850	4
136	41	Kalavad	C	28,314	4
137	42	Jafarabad	C	27,167	3
138	43	Jamjodhpur	C	25,892	3
139	44	Dhrol	C	25,883	3
140	45	Bhanvad	D	22,142	3
141	46	Talala	D	21,060	3
142	47	Jamraval	D	19,777	2
143	48	Bhayavadar	D	19,404	2
144	49	Chalala	D	16,721	2
145	50	Kutiyana	D	16,581	2
Sources of Water: Deep wells/wells					
146	1	Nadiad	A	218,095	27
147	2	Anand	A	198,282	25
148	3	Deesa	A	111,160	14
149	4	Vijalpor	B	81,245	10
150	5	Borsad	B	63,377	8
151	6	Lunavada	C	36,954	5
152	7	Mahemdabad	C	35,368	4
153	8	Umreth	C	33,762	4
154	9	Kheda	C	25,575	3
155	10	Vallbhvidhyanagar	D	23,783	3
156	11	Oad	D	23,250	3
157	12	Kanjari	D	17,881	2
158	13	Thasara	D	15,806	2
Sources of Water: Local dam and Deep wells/wells					
159	1	Vapi	A	163,630	20
160	2	Palanpur	A	122,344	15
161	3	Ankleshwar	B	73,928	9
162	4	Visnagar	B	63,073	8
163	5	Idar	C	31,176	4
164	6	Dhanera	C	29,578	4
165	7	Khedbrahma	C	25,001	3
166	8	Kheralu	D	21,843	3
167	9	Savali	D	18,467	2

Annexure: 2
Status of Water Treatment Plant

Gujarat ULBs with Functional Water Treatment plants						
Sr.No	**No**	**City**	**ULBs**	**Demand in MLD**	**Functional WTP**	**Remarks**
1	1	Ahmedabad	MC	1056	YES	
2	2	Amreli	A	18	YES	
3	3	Ankleshwar	B	12	YES	
4	4	Bardoli	B	10	YES	
5	5	Bharuch	A	27	YES	
6	6	Bhavnagar	MC	99	YES	
7	7	Bilimora	B	8	YES	
8	8	Dahod	B	16	YES	
9	9	Devgadhbaria	D	4	YES	
10	10	Dhanera	C	5	YES	
11	11	Dhangadhra	B	12	YES	
12	12	Dharampur	D	4	YES	
13	13	Dhoraji	B	13	YES	
14	14	Gandevi	D	3	YES	
15	15	Gandhinagar	MC	36	YES	
16	16	Gariyadhar	C	6	YES	
17	17	Godhara	A	23	YES	
18	18	Gondal	A	20	YES	
19	19	Halol	B	12	YES	
20	20	Himmatnagar	B	15	YES	
21	21	Idar	C	5	YES	
22	22	Jamnagar	MC	93	YES	
23	23	Jasdan	C	8	YES	
24	24	Jetpur	A	20	YES	
25	25	Kadi	B	13	YES	
26	26	Kalavad	C	5	YES	
27	27	Kalol	A	18	YES	
28	28	Kapadvanj	C	8	YES	
29	29	Karjan	C	5	YES	
30	30	Khambhaliya	C	7	YES	
31	31	Khambhat	B	13	YES	
32	32	Mahesana	A	40	YES	
33	33	Mahuva	B	14	YES	
34	34	Maliyamiyana	D	3	YES	
35	35	Modasa	B	12	YES	
36	36	Navsari	A	27	YES	
37	37	Palitana	B	11	YES	
38	38	Rajkot	MC	228	YES	

Annexure

Sr.No	No	City	ULBs	Demand in MLD	Functional WTP	Remarks
39	39	Rajpipla	C	5	YES	
40	40	Santrampur	D	4	YES	
41	41	Savali	D	3	YES	
42	42	Sihor	B	9	YES	
43	43	Songadh	C	4	YES	
44	44	Surat	MC	717	YES	
45	45	Surendranagar	A	29	YES	
46	46	Tharad	C	5	YES	
47	47	Umargam	C	5	YES	
48	48	Unja	B	9	YES	
49	49	Upleta	B	9	YES	
50	50	Vadodara	MC	289	YES	
51	51	Valsad	A	23	YES	
52	52	Vankaner	C	6	YES	
53	53	Vapi	A	29	YES	
54	54	Vyara	C	6	YES	
55	55	Wadhvan	B	13	YES	
Gujarat ULBs with Water Treatment Plants which require up-gradation						
56	1	Anjar	B	10	YES	Up gradation is required
57	2	Chaklasi	C	5	YES	
58	3	Dakor	C	3	YES	
59	4	Jafarabad	C	1	YES	
60	5	Kathlal	D	5	YES	
61	6	Pethapur	D	4	YES	
62	7	Sojitra	D	4	YES	
Gujarat ULBs without Functional WTP/ Water Treatment Plants						
63	1	Chhotaudepur	C	4	No WTP	WTPs are required , out of which in some ULB WTP construction work is in progress
64	2	Dabhoi	B	8	No WTP	
65	3	Dhandhuka	C	5	No WTP	
66	4	Jambusar	C	7	No WTP	
67	5	Jamraval	D	3	No WTP	
68	6	Junagadh	MC	59	No WTP	
69	7	Kanakpur Kansad	C	5	No WTP	
70	8	Kodinar	C	7	No WTP	
71	9	Lathi	D	3	No WTP	
72	10	Mahudha	D	3	No WTP	
73	11	Mangrol	B	12	No WTP	
74	12	Petlad	B	9	No WTP	
75	13	Ranavav	C	9	No WTP	
76	14	Salaya	C	6	No WTP	
77	15	Sutrapada	C	4	No WTP	

Annexure

Sr.No	No	City	ULBs	Demand in MLD	Functional WTP	Remarks
78	16	Veraval	A	25	No WTP	
Gujarat ULBs with Ground Water Supply –No need of Water Treatment Plants						
79	1	Anand	A	34	Ground Water – NO WTP is required	Ground water as sources of water supply – No need of WTP- only chlorination
80	2	Borsad	B	10		
81	3	Deesa	A	20		
82	4	Kanjari	D	3		
83	5	Kheda	C	4		
84	6	Lunavada	C	6		
85	7	Mahemdabad	C	6		
86	8	Nadiad	A	36		
87	9	Oad	D	3		
88	10	Thasara	D	3		
89	11	Umreth	C	5		
90	12	Vallbhvidhyanagar	D	3		
91	13	Vijalpor	B	15		
Gujarat ULBs with Bulk Narmada Treated water supply–No need of Water Treatment Plants						
92	1	Amod	D	2	Bulk Treated Water	Narmada Bulk water Treated water Supply - WTPs are not required
93	2	Anklav	D	3	Bulk Treated Water	
94	3	Babara	C	3	Bulk Treated Water	
95	4	Bagsara	C	6	Bulk Treated Water	
96	5	Balasinor	C	7	Bulk Treated Water	
97	6	Bantawa	D	2	Bulk Treated Water	
98	7	Bareja	D	3	Bulk Treated Water	
99	8	Barvala	D	3	Bulk Treated Water	
100	9	Bavla	C	6	Bulk Treated Water	
101	10	Bayad	D	3	Bulk Treated Water	
102	11	Bhabhar	D	4	Bulk Treated Water	
103	12	Bhachau	C	8	Bulk Treated Water	
104	13	Bhanvad	D	4	Bulk Treated Water	
105	14	Bhayavadar	D	3	Bulk Treated Water	
106	15	Bhuj	A	28	Bulk Treated Water	
107	16	Boriavi	D	3	Bulk Treated Water	
108	17	Botad	A	23	Bulk Treated Water	
109	18	Chalala	D	3	Bulk Treated Water	
110	19	Chanasma	D	2	Bulk Treated Water	
111	20	Chhaya	C	8	Bulk Treated Water	
112	21	Chorvad	D	4	Bulk Treated Water	
113	22	Chotila	D	4	Bulk Treated Water	
114	23	Damnagar	D	3	Bulk Treated Water	
115	24	Dahegam	C	7	Bulk Treated Water	

Annexure

Sr.No	No	City	ULBs	Demand in MLD	Functional WTP	
116	25	Dholka	B	15	Bulk Treated Water	Narmada Bulk water Treated water Supply - WTPs are not required
117	26	Dhrol	C	4	Bulk Treated Water	
118	27	Dwarka	C	6	Bulk Treated Water	
119	28	Gadhada	C	5	Bulk Treated Water	
120	29	Gandhidham	A	36	Bulk Treated Water	
121	30	Halvad	C	6	Bulk Treated Water	
122	31	Harij	D	3	Bulk Treated Water	
123	32	Jamjodhpur	C	4	Bulk Treated Water	
124	33	Kaalol	C	5	Bulk Treated Water	
125	34	Karamsad	C	6	Bulk Treated Water	
126	35	Keshod	B	13	Bulk Treated Water	
127	36	Khedbrahma	C	4	Bulk Treated Water	
128	37	Kheralu	D	3	Bulk Treated Water	
129	38	Kutiyana	D	3	Bulk Treated Water	
130	39	Limadi	C	7	Bulk Treated Water	
131	40	Manasa	C	5	Bulk Treated Water	
132	41	Manavadar	C	5	Bulk Treated Water	
133	42	Mandavi(K)	B	9	Bulk Treated Water	
134	43	Mandavi(S)	D	3	Bulk Treated Water	
135	44	Morbi	A	33	Bulk Treated Water	
136	45	Okha	B	11	Bulk Treated Water	
137	46	Padra	C	8	Bulk Treated Water	
138	47	Palanpur	A	21	Bulk Treated Water	
139	48	Paradi	C	5	Bulk Treated Water	
140	49	Patadi	D	3	Bulk Treated Water	
141	50	Patan	A	20	Bulk Treated Water	
142	51	Porbandar	A	25	Bulk Treated Water	
143	52	Prantij	D	4	Bulk Treated Water	
144	53	Radhanpur	C	7	Bulk Treated Water	
145	54	Rajula	C	6	Bulk Treated Water	
146	55	Rapar	C	5	Bulk Treated Water	
147	56	Sanand	B	7	Bulk Treated Water	
148	57	Savarkundala	B	12	Bulk Treated Water	
149	58	Shahera	D	3	Bulk Treated Water	
150	59	Sidhhpur	B	9	Bulk Treated Water	
151	60	Sikka	C	6	Bulk Treated Water	
152	61	Talaja	C	4	Bulk Treated Water	
153	62	Talala	D	3	Bulk Treated Water	
154	63	Talod	D	3	Bulk Treated Water	
155	64	Tarsadi	C	5	Bulk Treated Water	
156	65	Thangadh	C	7	Bulk Treated Water	

Annexure

Sr.No	No	City	ULBs	Demand in MLD	Functional WTP	
157	66	Thara	D	3	Bulk Treated Water	Narmada Bulk water Treated water Supply - WTPs are not required
158	67	Una	B	10	Bulk Treated Water	
159	68	Vadali	D	3	Bulk Treated Water	
160	69	Vadnagar	C	5	Bulk Treated Water	
161	70	Vallabhipur	D	3	Bulk Treated Water	
162	71	Vanthali	D	2	Bulk Treated Water	
163	72	Vijapur	C	4	Bulk Treated Water	
164	73	Viramgam	B	9	Bulk Treated Water	
165	74	Visavadar	D	3	Bulk Treated Water	
166	75	Visnagar	B	13	Bulk Treated Water	
167	76	Zalod	C	5	Bulk Treated Water	

Annexure: 3
Coverage of Water Supply

Sr.No	No.	City	Population as per census 2011	Area in sq.kms	No of HH tapped	WS network Coverage in %
Coverage of Water Supply in A Class Municipalities						
1	1	Vapi	1,63,630	22	8,201	18
2	2	Morbi	1,94,947	24	22,980	49
3	3	Porbandar	1,51,770	38	17,630	51
4	4	Veraval	1,54,636	10	17,281	54
5	5	Botad	1,30,327	37	18,079	63
6	6	Gandhidham	2,47,992	30	44,808	64
7	7	Anand	1,98,282	41	32,200	65
8	8	Godhara	1,43,644	20	20,371	65
9	9	Bharuch	1,69,007	19	26,362	69
10	10	Surendranagar	1,77,851	37	29,739	75
11	11	Kalol	1,13,153	17	20,390	77
12	12	Jetpur	1,18,302	36	20,289	78
13	13	Deesa	1,11,160	21	19,839	78
14	14	Valsad	1,14,636	14	26,794	78
15	15	Gondal	1,12,197	74	19,294	81
16	16	Mahesana	1,84,991	32	43,840	83
17	17	Palanpur	1,22,344	23	24,712	89
18	18	Navsari	1,60,941	18	34,586	90
19	19	Bhuj	1,43,286	6	35,840	91
20	20	Nadiad	2,18,095	28	44,012	95
21	21	Amreli	1,05,573	58	23,000	98
22	22	Patan	1,25,497	48	28,417	100
Coverage of Water Supply in B Class Municipalities						
23	1	Halol	59,605	21	8,357	48
24	2	Palitana	64,497	12	6,664	52
25	3	Vijalpor	81,245	4	11,400	53
26	4	Sihor	54,547	32	6,586	57
27	5	Bilimora	53,187	16	7,710	60
28	6	Una	58,528	37	7,672	67
29	7	Keshod	76,193	16	11,861	68
30	8	Okha	62,052	32	10,486	70
31	9	Dhoraji	84,545	15	13,554	72
32	10	Savarkundala	78,354	8	11,647	72
33	11	Dahod	94,578	7	17,040	75
34	12	Mahuva	82,772	6	11,965	75
35	13	Bardoli	60,821	7	10,848	77
36	14	Ankleshwar	73,928	10	16,700	79

Annexure

Sr.No	No.	City	Population as per census 2011	Area in sq.kms	No of HH tapped	WS network Coverage in %
37	15	Viramgam	55,821	99	9,962	79
38	16	Khambhat	83,715	70	16,277	80
39	17	Himmatnagar	81,137	9	15,932	80
40	18	Anjar	87,183	18	17,189	81
41	19	Unja	57,108	45	12,150	81
42	20	Mangrol	63,794	45	10,531	82
43	21	Upleta	58,775	51	10,980	82
44	22	Wadhvan	75,755	20	14,800	83
45	23	Borsad	63,377	25	10,600	83
46	24	Sidhhpur	56,402	45	12,150	83
47	25	Dholka	79,531	15	16,808	84
48	26	Petlad	55,330	9	9,541	85
49	27	Modasa	67,648	13	13,036	86
50	28	Dhangadhra	75,133	39	13,206	88
51	29	Sanand	41,530	40	8,350	88
52	30	Visnagar	63,073	8	17,174	95
53	31	Kadi	73,228	20	21,255	98
54	32	Mandavi(K)	51,376	15	11,003	100
55	33	Dabhoi	51,240	24	9,930	100
Coverage of Water Supply in C Class Municipalities						
56	1	Umargam	27,859	13	1,380	19
57	2	Chhaya	47,699	18	3,999	35
58	3	Ranavav	46,018	18	5,320	42
59	4	Thangadh	42,351	12	3,567	42
60	5	Jafarabad	27,167	29	3,470	49
61	6	Chaklasi	39,581	23	4,159	50
62	7	Sikka	28,814	8	3,190	51
63	8	Babara	25,270	6	2,924	57
64	9	Salaya	33,246	3	3,135	58
65	10	Kanakpur Kansad	28,327	7	4,890	60
66	11	Paradi	28,495	13	3,714	62
67	12	Radhanpur	39,558	36	5,690	63
68	13	Rajula	38,489	5	5,203	65
69	14	Tharad	27,954	15	3,708	65
70	15	Halvad	32,024	18	5,160	65
71	16	Chhotaudepur	25,787	4	3,934	66
72	17	Vankaner	43,881	5	5,550	68
73	18	Vyara	39,789	8	6,825	68
74	19	Vijapur	25,558	3	5,221	69
75	20	Karamsad	35,285	17	6,164	71

Annexure

Sr.No	No.	City	Population as per census 2011	Area in sq.kms	No of HH tapped	WS network Coverage in %
76	21	Vadnagar	27,790	42	4,510	71
77	22	Dwarka	38,873	42	6,636	72
78	23	Kaalol	28,777	8	5,542	73
79	24	Songadh	26,515	6	4,641	73
80	25	Bagsara	34,521	9	5,070	74
81	26	Dahegam	42,632	27	6,732	74
82	27	Kheda	25,575	22	4,074	77
83	28	Gadhada	29,872	7	4,658	78
84	29	Talaja	27,822	14	3,940	79
85	30	Jasdan	48,483	36	8,199	79
86	31	Limadi	42,769	17	7,431	79
87	32	Jambusar	43,344	4	7,317	83
88	33	Bhachau	39,532	9	8,678	83
89	34	Idar	31,176	16	7,160	84
90	35	Khedbrahma	25,001	27	4,500	85
91	36	Dhanera	29,578	9	5,299	86
92	37	Kodinar	41,492	17	7,485	86
93	38	Padra	43,366	7	9,050	86
94	39	Dhandhuka	32,475	9	5,917	87
95	40	Bavla	36,206	23	8,993	89
96	41	Gariyadhar	33,949	6	6,200	89
97	42	Dakor	24,396	16	5,500	89
98	43	Lunavada	36,954	13	7,163	89
99	44	Tarsadi	29,305	7	6,163	89
100	45	Dhrol	25,883	10	4,186	90
101	46	Umreth	33,762	20	8,330	92
102	47	Zalod	28,720	9	4,979	92
103	48	Khambhaliya	41,734	3	8,650	96
104	49	Kapadvanj	49,308	19	10,355	97
105	50	Mahemdabad	35,368	16	7,348	97
106	51	Rapar	28,407	12	5,925	98
107	52	Manasa	30,347	27	6,981	100
108	53	Jamjodhpur	25,892	21	5,842	100
109	54	Kalavad	28,314	36	6,106	100
110	55	Manavadar	30,850	6	7,012	100
111	56	Balasinor	39,330	39	8,388	100
112	57	Rajpipla	34,845	5	6,800	100
113	58	Karjan	30,405	15	7,102	100
114	59	Sutrapada	26,132	18	NA	NA

Annexure

Coverage of Water Supply in D Class Municipalities						
Sr.No	No.	City	Population	Area in sq.kms	No of HH tapped	WS network Coverage in %
115	1	Maliyamiyana	15,964	77	1,050	34
116	2	Chorvad	22,720	22	2,100	45
117	3	Anklav	21,003	22	2,573	56
118	4	Shahera	19,175	30	2,168	60
119	5	Kanjari	17,881	10	2,381	60
120	6	Vallbhvidhyanagar	23,783	2	3,148	67
121	7	Thasara	15,806	14	2,396	68
122	8	Devgadhbaria	21,030	10	2,893	69
123	9	Gandevi	16,827	4	2,779	71
124	10	Kutiyana	16,581	36	2,513	72
125	11	Mahudha	17,722	5	2,853	74
126	12	Thara	18,060	6	3,210	75
127	13	Barvala	17,951	32	2,650	75
128	14	Talala	21,060	10	3,389	78
129	15	Dharampur	24,178	16	4,190	80
130	16	Pethapur	23,497	25	4,198	80
131	17	Oad	23,250	14	4,083	80
132	18	Bhabhar	21,894	2	3,966	80
133	19	Boriavi	19,865	15	3,500	80
134	20	Jamraval	19,777	42	2,837	81
135	21	Damnagar	16,614	12	2,531	81
136	22	Visavadar	19,515	4	3,824	83
137	23	Prantij	23,596	20	4,250	85
138	24	Harij	20,253	4	3,742	85
139	25	Kheralu	21,843	4	4,013	86
140	26	Chotila	21,364		4,056	88
141	27	Vadali	20,646	43	4,019	88
142	28	Bhayavadar	19,404	9	4,121	89
143	29	Vanthali	14,554	20	2,803	90
144	30	Lathi	21,173	6	4,190	91
145	31	Bareja	19,690	16	3,996	91
146	32	Bayad	17,886	25	3,720	91
147	33	Kathlal	22,071	26	3,687	92
148	34	Talod	18,298	22	3,697	92
149	35	Chalala	16,721	22	3,235	93
150	36	Mandavi(S)	18,214	8	3,853	95
151	37	Patadi	17,725	14	3,298	98
152	38	Bhanvad	22,142	9	5,726	100
153	39	Santrampur	19,465	16	3,715	100

Annexure

Sr.No	No.	City	Population as per census 2011	Area in sq.kms	No of HH tapped	WS network Coverage in %
154	40	Savali	18,467	6	3,205	100
155	41	Sojitra	16,713	14	3,465	100
156	42	Chanasma	15,932	3	3,428	100
157	43	Vallabhipur	15,852	6	3,078	100
158	44	Bantawa	15,291	14	3,126	100
159	45	Amod	15,237	19	2,976	100
Coverage of Water Supply in Municipal Corporations						
160	1	Junagadh	3,19,462	13	1,36,276	50
161	2	Ahmedabad	55,77,940	466	11,56,434	76
162	3	Surat	44,67,797	327	9,53,026	87
163	4	Gandhinagar	2,02,776	57	47,000	95
164	5	Jamnagar	4,79,920	132	1,68,997	96
165	6	Vadodara	16,70,806	160	4,66,990	98
166	7	Rajkot	12,86,678	129	2,79,281	98
167	8	Bhavnagar	5,93,368	108	2,29,870	100

Annexure: 4
Level of Water supply in LPCD in all ULBs

Water supply less than 100 LPCD in all ULBs					
S.No.	No	City	ULB class	Coverage of water network in %	Water supply in LPCD
1	1	Umargam	C	19	21
2	2	Sutrapada	C	NA	24
3	3	Jafarabad	C	49	25
4	4	Vankaner	C	68	35
5	5	Chorvad	D	45	37
6	6	Okha	B	70	38
7	7	Ranavav	C	42	43
8	8	Vadali	D	88	45
9	9	Thangadh	C	42	51
10	10	Junagadh	MC	50	52
11	11	Dwarka	C	72	53
12	12	Kodinar	C	86	55
13	13	Tarsadi	C	89	58
14	14	Chhaya	C	35	59
15	15	Porbandar	A	51	59
16	16	Halol	B	48	62
17	17	Rajula	C	65	62
18	18	Radhanpur	C	63	63
19	19	Barvala	D	75	67
20	20	Botad	A	63	67
21	21	Maliyamiyana	D	34	67
22	22	Dholka	B	84	68
23	23	Manavadar	C	100	68
24	24	Zalod	C	92	68
25	25	Sikka	C	51	69
26	26	Idar	C	84	70
27	27	Kutiyana	D	72	70
28	28	Damnagar	D	81	71
29	29	Rapar	C	98	71
30	30	Salaya	C	58	71
31	31	Babara	C	57	72
32	32	Sihor	B	57	72
33	33	Tharad	C	65	72
34	34	Vapi	A	18	72
35	35	Gadhada	C	78	75
36	36	Gondal	A	81	75

Annexure

S.No.	No	City	ULB class	Coverage of water network in %	Water supply in LPCD
37	37	Jamraval	D	81	76
38	38	Chalala	D	93	78
39	39	Chotila	D	88	78
40	40	Bhayavadar	D	89	79
41	41	Limadi	C	79	79
42	42	Mahuva	B	75	79
43	43	Paradi	C	62	79
44	44	Shahera	D	60	80
45	45	Una	B	67	80
46	46	Vallabhipur	D	100	80
47	47	Anand	A	65	81
48	48	Mangrol	B	82	81
49	49	Upleta	B	82	81
50	50	Prantij	D	85	82
51	51	Gariyadhar	C	89	83
52	52	Halvad	C	65	83
53	53	Jambusar	C	83	83
54	54	Bayad	D	91	84
55	55	Bhachau	C	83	84
56	56	Bhanvad	D	100	84
57	57	Kheda	C	77	84
58	58	Talaja	C	79	84
59	59	Anjar	B	81	85
60	60	Bagsara	C	74	85
61	61	Boriavi	D	80	85
62	62	Kapadvanj	C	97	85
63	63	Harij	D	85	86
64	64	Bantawa	D	100	87
65	65	Dhoraji	B	72	87
66	66	Kaalol	C	73	87
67	67	Kalavad	C	100	87
68	68	Keshod	B	68	87
69	69	Vijalpor	B	53	88
70	70	Dhandhuka	C	87	89
71	71	Gandhidham	A	64	89
72	72	Balasinor	C	100	90
73	73	Dahod	B	75	90
74	74	Santrampur	D	100	91
75	75	Bilimora	B	60	93
76	76	Dakor	C	89	93

Annexure

S.No.	No	City	ULB class	Coverage of water network in %	Water supply in LPCD
77	77	Godhara	A	65	93
78	78	Lathi	D	91	94
79	79	Palanpur	A	89	94
80	80	Jetpur	A	78	95
81	81	Mahudha	D	74	96
82	82	Mandavi(K)	B	100	96
83	83	Vanthali	D	90	96
84	84	Dhangadhra	B	88	97
85	85	Chaklasi	C	50	98
86	86	Dahegam	C	74	98
87	87	Nadiad	A	95	98
88	88	Savarkundala	B	72	98
89	89	Morbi	A	49	99
90	90	Wadhvan	B	83	99
91	91	Dhrol	C	90	100
92	92	Khedbrahma	C	85	100
Water supply -101-135 LPCD in all ULBs					
93	1	Karamsad	C	71	101
94	2	Khambhaliya	C	96	103
95	3	Vadnagar	C	71	104
96	4	Himmatnagar	B	80	105
97	5	Talala	D	78	106
98	6	Jasdan	C	79	107
99	7	Surendranagar	A	75	107
100	8	Bhabhar	D	80	108
101	9	Pethapur	D	80	108
102	10	Amod	D	100	109
103	11	Gandevi	D	71	110
104	12	Kanjari	D	60	110
105	13	Palitana	B	52	110
106	14	Bardoli	B	77	112
107	15	Jamjodhpur	C	100	112
108	16	Rajkot	MC	98	113
109	17	Rajpipla	C	100	113
110	18	Lunavada	C	89	114
111	19	Kalol	A	77	115
112	20	Kanakpur Kansad	C	60	115
113	21	Sidhhpur	B	83	115
114	22	Unja	B	81	115
115	23	Dhanera	C	86	116

Annexure

S.No.	No	City	ULB class	Coverage of water network in %	Water supply in LPCD
116	24	Vadodara	MC	98	116
117	25	Visnagar	B	95	118
118	26	Amreli	A	98	119
119	27	Deesa	A	78	121
120	28	Mahesana	A	83	121
121	29	Modasa	B	86	124
122	30	Jamnagar	MC	96	125
123	31	Patan	A	100	126
124	32	Vijapur	C	69	127
125	33	Ankleshwar	B	79	128
126	34	Savali	D	100	128
127	35	Thasara	D	68	128
128	36	Khambhat	B	80	130
129	37	Bareja	D	91	132
130	38	Dabhoi	B	100	133
131	39	Songadh	C	73	134
132	40	Talod	D	92	134
133	41	Kadi	B	98	135
Level of Water supply –More than 135 LPCD in all ULBs					
134	1	Ahmedabad	MC	76	136
135	2	Anklav	D	56	138
136	3	Bavla	C	89	145
137	4	Bharuch	A	69	173
138	5	Bhavnagar	MC	100	148
139	6	Bhuj	A	91	136
140	7	Borsad	B	83	137
141	8	Chanasma	D	100	158
142	9	Chhotaudepur	C	66	156
143	10	Devgadhbaria	D	69	163
144	11	Dharampur	D	80	144
145	12	Gandhinagar	MC	95	254
146	13	Karjan	C	100	152
147	14	Kathlal	D	92	136
148	15	Kheralu	D	86	145
149	16	Mahemdabad	C	97	152
150	17	Manasa	C	100	151
151	18	Mandavi(S)	D	95	196
152	19	Navsari	A	90	142
153	20	Oad	D	80	153
154	21	Padra	C	86	141

Annexure

S.No.	No	City	ULB class	Coverage of water network in %	Water supply in LPCD
155	22	Patadi	D	98	140
156	23	Petlad	B	85	140
157	24	Sanand	B	88	149
158	25	Sojitra	D	100	155
159	26	Surat	MC	87	141
160	27	Thara	D	75	251
161	28	Umreth	C	92	168
162	29	Vallbhvidhyanagar	D	67	169
163	30	Valsad	A	78	150
164	31	Veraval	A	54	150
165	32	Viramgam	B	79	158
166	33	Visavadar	D	83	159
167	34	Vyara	C	68	160

Annexure: 5
Duration of Water Supply in all ULBs

Water Supply Duration less than 1 hour/day					
Sr.No	**No**	**City**	**ULB Class**	**WS in LPCD**	**Duration in Minutes/day**
1	1	Rajkot	MC	113	20
2	2	Modasa	B	124	27
3	3	Jambusar	C	83	27
4	4	Khambhaliya	C	103	27
5	5	Khedbrahma	C	100	27
6	6	Umargam	C	21	27
7	7	Vankaner	C	35	27
8	8	Damnagar	D	71	27
9	9	Junagadh	MC	52	27
10	10	Chhaya	C	59	30
11	11	Thangadh	C	51	30
12	12	Zalod	C	68	30
13	13	Bantawa	D	87	30
14	14	Bhanvad	D	84	30
15	15	Bhayavadar	D	79	30
16	16	Chotila	D	78	30
17	17	Jetpur	A	95	45
18	18	Morbi	A	99	45
19	19	Porbandar	A	59	45
20	20	Anjar	B	85	45
21	21	Halol	B	62	45
22	22	Mangrol	B	81	45
23	23	Visnagar	B	118	45
24	24	Babara	C	72	45
25	25	Chhotaudepur	C	156	45
26	26	Dhandhuka	C	89	45
27	27	Dhrol	C	100	45
28	28	Gariyadhar	C	83	45
29	29	Jamjodhpur	C	112	45
30	30	Jasdan	C	107	45
31	31	Kapadvanj	C	85	45
32	32	Kodinar	C	55	45
33	33	Manavadar	C	68	45
34	34	Jamraval	D	76	45
35	35	Lathi	D	94	45
36	36	Maliyamiyana	D	67	45
37	37	Visavadar	D	159	45

Annexure

Sr.No	No	City	ULB Class	WS in LPCD	Duration in Minutes/day
38	38	Bhavnagar	MC	148	45
39	39	Jamnagar	MC	125	45
40	40	Amreli	A	119	60
41	41	Bhuj	A	136	60
42	42	Gondal	A	75	60
43	43	Kalol	A	115	60
44	44	Palanpur	A	94	60
45	45	Patan	A	126	60
46	46	Surendranagar	A	107	60
47	47	Dhangadhra	B	97	60
48	48	Mandavi(K)	B	96	60
49	49	Palitana	B	110	60
50	50	Savarkundala	B	98	60
51	51	Sidhhpur	B	115	60
52	52	Una	B	80	60
53	53	Unja	B	115	60
54	54	Dhanera	C	116	60
55	55	Dwarka	C	53	60
56	56	Halvad	C	83	60
57	57	Idar	C	70	60
58	58	Jafarabad	C	25	60
59	59	Kalavad	C	87	60
60	60	Ranavav	C	43	60
61	61	Rapar	C	71	60
62	62	Salaya	C	71	60
63	63	Songadh	C	134	60
64	64	Tharad	C	72	60
65	65	Vadnagar	C	104	60
66	66	Bayad	D	84	60
67	67	Bhabhar	D	108	60
68	68	Chanasma	D	158	60
69	69	Chorvad	D	37	60
70	70	Devgadhbaria	D	163	60
71	71	Harij	D	86	60
72	72	Kheralu	D	145	60
73	73	Kutiyana	D	70	60
74	74	Savali	D	128	60
75	75	Shahera	D	80	60
76	76	Talala	D	106	60
77	77	Talod	D	134	60
78	78	Vadali	D	45	60

Annexure

Sr.No	No	City	ULB Class	WS in LPCD	Duration in Minutes/day
79	79	Vallabhipur	D	80	60
80	80	Vadodara	MC	116	60
Water Supply Duration More than 1 hour/day but less than 2 hours/day					
81	1	Okha	B	38	63
82	2	Chalala	D	78	66
83	3	Santrampur	D	91	69
84	4	Viramgam	B	158	72
85	5	Dholka	B	68	75
86	6	Wadhvan	B	99	75
87	7	Manasa	C	151	75
88	8	Mahesana	A	121	90
89	9	Bilimora	B	93	90
90	10	Dabhoi	B	133	90
91	11	Dahod	B	90	90
92	12	Dhoraji	B	87	90
93	13	Himmatnagar	B	105	90
94	14	Kadi	B	135	90
95	15	Upleta	B	81	90
96	16	Bhachau	C	84	90
97	17	Dahegam	C	98	90
98	18	Gadhada	C	75	90
99	19	Karjan	C	152	90
100	20	Lunavada	C	114	90
101	21	Rajpipla	C	113	90
102	22	Umreth	C	168	90
103	23	Prantij	D	82	90
104	24	Botad	A	67	120
105	25	Deesa	A	121	120
106	26	Gandhidham	A	89	120
107	27	Godhara	A	93	120
108	28	Vapi	A	72	120
109	29	Veraval	A	150	120
110	30	Keshod	B	87	120
111	31	Sanand	B	149	120
112	32	Sihor	B	72	120
113	33	Vijalpor	B	88	120
114	34	Bagsara	C	85	120
115	35	Balasinor	C	90	120
116	36	Bavla	C	145	120
117	37	Kaalol	C	87	120
118	38	Kheda	C	84	120

Sr.No	No	City	ULB Class	WS in LPCD	Duration in Minutes/day
119	39	Padra	C	141	120
120	40	Radhanpur	C	63	120
121	41	Sutrapada	C	24	120
122	42	Talaja	C	84	120
123	43	Tarsadi	C	58	120
124	44	Vyara	C	160	120
125	45	Bareja	D	132	120
126	46	Kanjari	D	110	120
127	47	Kathlal	D	136	120
128	48	Pethapur	D	108	120
129	49	Vanthali	D	96	120
Water Supply Duration More than 2 hours/day					
130	1	Valsad	A	150	150
131	2	Ankleshwar	B	128	150
132	3	Dakor	C	93	150
133	4	Karamsad	C	101	150
134	5	Limadi	C	79	150
135	6	Mahemdabad	C	152	150
136	7	Oad	D	153	150
137	8	Patadi	D	140	150
138	9	Ahmedabad	MC	136	150
139	10	Gandhinagar	MC	254	150
140	11	Anand	A	81	180
141	12	Nadiad	A	98	180
142	13	Borsad	B	137	180
143	14	Khambhat	B	130	180
144	15	Mahuva	B	79	180
145	16	Kanakpur Kansad	C	115	180
146	17	Rajula	C	62	180
147	18	Sikka	C	69	180
148	19	Amod	D	109	180
149	20	Anklav	D	138	180
150	21	Mahudha	D	96	180
151	22	Thara	D	251	180
152	23	Bharuch	A	173	240
153	24	Navsari	A	142	240
154	25	Bardoli	B	112	240
155	26	Petlad	B	140	240
156	27	Chaklasi	C	98	240
157	28	Paradi	C	79	240
158	29	Vijapur	C	127	240

Annexure

Sr.No	No	City	ULB Class	WS in LPCD	Duration in Minutes/day
159	30	Barvala	D	67	240
160	31	Boriavi	D	85	240
161	32	Dharampur	D	144	240
162	33	Gandevi	D	110	240
163	34	Thasara	D	128	240
164	35	Vallbhvidhyanagar	D	169	240
165	36	Surat	MC	141	240
166	37	Mandavi(S)	D	196	360
167	38	Sojitra	D	155	540

Annexure: 6
Frequency of Water Supply in all ULBs

Sr.No.	No.	City	ULB Class	Avg Supply in minutes/day	Water supply frequency No of days/month
Water supply frequency in less than or equal to 10 days /month					
1	1	Damnagar	D	27	5
2	2	Manavadar	C	45	5
3	3	Kalavad	C	60	7
4	4	Jafarabad	C	60	7
5	5	Sikka	C	180	7
6	6	Bhanvad	D	30	8
7	7	Botad	A	120	8
8	8	Sihor	B	120	8
9	9	Dhandhuka	C	45	10
10	10	Dhrol	C	45	10
11	11	Gandhidham	A	120	10
12	12	Dahod	B	90	10
13	13	Jambusar	C	27	10
14	14	Dhoraji	B	90	10
15	15	Keshod	B	120	10
16	16	Gondal	A	60	10
17	17	Kutiyana	D	60	10
18	18	Limadi	C	150	10
19	19	Khambhaliya	C	27	10
20	20	Mahuva	B	180	10
21	21	Thangadh	C	30	10
22	22	Upleta	B	90	10
23	23	Vadali	D	60	10
24	24	Veraval	A	120	10
25	25	Wadhvan	B	75	10
Water supply frequency on alternate day or 5 days /week					
26	1	Anjar	B	45	15
27	2	Babara	C	45	15
28	3	Bagsara	C	120	15
29	4	Bantawa	D	30	15
30	5	Barvala	D	240	15
31	6	Bhachau	C	90	15
32	7	Devgadhbaria	D	60	15
33	8	Bhayavadar	D	30	15
34	9	Bhuj	A	60	15
35	10	Chhotaudepur	C	45	15

Annexure

Sr.No.	No.	City	ULB Class	Avg Supply in minutes/day	Water supply frequency No of days/month
36	11	Chorvad	D	60	15
37	12	Halol	B	45	15
38	13	Idar	C	60	15
39	14	Jamnagar	MC	45	15
40	15	Jamjodhpur	C	45	15
41	16	Jasdan	C	45	15
42	17	Jamraval	D	45	15
43	18	Jetpur	A	45	15
44	19	Kapadvanj	C	45	15
45	20	Junagadh	MC	27	15
46	21	Surendranagar	A	60	15
47	22	Kheralu	D	60	15
48	23	Kodinar	C	45	15
49	24	Lathi	D	45	15
50	25	Mandavi(K)	B	60	15
51	26	Porbandar	A	45	15
52	27	Radhanpur	C	120	15
53	28	Rajula	C	180	15
54	29	Ranavav	C	60	15
55	30	Rapar	C	60	15
56	31	Savarkundala	B	60	15
57	32	Vankaner	C	27	15
58	33	Talaja	C	120	15
59	34	Una	B	60	15
60	35	Vallabhipur	D	60	15
61	36	Vanthali	D	120	15
62	37	Vijapur	C	240	15
63	38	Visavadar	D	45	15
64	39	Zalod	C	30	15
65	40	Okha	B	63	16
66	41	Bhavnagar	MC	45	26
67	42	Visnagar	B	45	26
Water Supply on daily basis					
68	43	Ahmedabad	MC	136	150
69	44	Amod	D	109	180
70	45	Amreli	A	119	60
71	46	Anand	A	81	180
72	47	Anklav	D	138	180
73	48	Ankleshwar	B	128	150
74	49	Balasinor	C	90	120

Sr.No.	No.	City	ULB Class	Avg Supply in minutes/day	Water supply frequency No of days/month
75	50	Bardoli	B	112	240
76	51	Bareja	D	132	120
77	52	Bavla	C	145	120
78	53	Bayad	D	84	60
79	54	Bhabhar	D	108	60
80	55	Bharuch	A	173	240
81	56	Bilimora	B	93	90
82	57	Boriavi	D	85	240
83	58	Borsad	B	137	180
84	59	Chaklasi	C	98	240
85	60	Chalala	D	78	66
86	61	Chanasma	D	158	60
87	62	Chhaya	C	59	30
88	63	Chotila	D	78	30
89	64	Dabhoi	B	133	90
90	65	Dakor	C	93	150
91	66	Deesa	A	121	120
92	67	Dahegam	C	98	90
93	68	Dhanera	C	116	60
94	69	Dhangadhra	B	97	60
95	70	Dharampur	D	144	240
96	71	Dholka	B	68	75
97	72	Dwarka	C	53	60
98	73	Gadhada	C	75	90
99	74	Gandevi	D	110	240
100	75	Gandhinagar	MC	254	150
101	76	Gariyadhar	C	83	45
102	77	Godhara	A	93	120
103	78	Halvad	C	83	60
104	79	Harij	D	86	60
105	80	Himmatnagar	B	105	90
106	81	Kaalol	C	87	120
107	82	Kadi	B	135	90
108	83	Kalol	A	115	60
109	84	Kanakpur Kansad	C	115	180
110	85	Kanjari	D	110	120
111	86	Karamsad	C	101	150
112	87	Karjan	C	152	90
113	88	Kathlal	D	136	120
114	89	Khambhat	B	130	180

Annexure

Sr.No.	No.	City	ULB Class	Avg Supply in minutes/day	Water supply frequency No of days/month
115	90	Kheda	C	84	120
116	91	Khedbrahma	C	100	27
117	92	Lunavada	C	114	90
118	93	Mahemdabad	C	152	150
119	94	Mahesana	A	121	90
120	95	Mahudha	D	96	180
121	96	Maliyamiyana	D	67	45
122	97	Manasa	C	151	75
123	98	Mandavi(S)	D	196	360
124	99	Mangrol	B	81	45
125	100	Modasa	B	124	27
126	101	Morbi	A	99	45
127	102	Nadiad	A	98	180
128	103	Navsari	A	142	240
129	104	Oad	D	153	150
130	105	Padra	C	141	120
131	106	Palanpur	A	94	60
132	107	Palitana	B	110	60
133	108	Paradi	C	79	240
134	109	Patadi	D	140	150
135	110	Patan	A	126	60
136	111	Pethapur	D	108	120
137	112	Petlad	B	140	240
138	113	Prantij	D	82	90
139	114	Rajkot	MC	113	20
140	115	Rajpipla	C	113	90
141	116	Salaya	C	71	60
142	117	Sanand	B	149	120
143	118	Santrampur	D	91	69
144	119	Savali	D	128	60
145	120	Shahera	D	80	60
146	121	Sidhhpur	B	115	60
147	122	Sojitra	D	155	540
148	123	Songadh	C	134	60
149	124	Surat	MC	141	240
150	125	Sutrapada	C	24	120
151	126	Talala	D	106	60
152	127	Talod	D	134	60
153	128	Tarsadi	C	58	120
154	129	Thara	D	251	180

Annexure

Sr.No.	No.	City	ULB Class	Avg Supply in minutes/day	Water supply frequency No of days/month
155	130	Tharad	C	72	60
156	131	Thasara	D	128	240
157	132	Umargam	C	21	27
158	133	Umreth	C	168	90
159	134	Unja	B	115	60
160	135	Vadnagar	C	104	60
161	136	Vadodara	MC	116	60
162	137	Vallbhvidhyanagar	D	169	240
163	138	Valsad	A	150	150
164	139	Vapi	A	72	120
165	140	Vijalpor	B	88	120
166	141	Viramgam	B	158	72
167	142	Vyara	C	160	120

Annexure: 7
Non-Revenue Water (NRW) in all ULBs

Sr.No.	No.	City	ULB Class	Avg WS in LPCD	NRW
NRW in A Class Municipalities					
1	1	Gandhidham	A	89	14
2	2	Nadiad	A	98	14
3	3	Anand	A	81	11
4	4	Morbi	A	99	NA
5	5	Mahesana	A	121	6
6	6	Surendranagar	A	107	8
7	7	Bharuch	A	173	29
8	8	Vapi	A	72	17
9	9	Navsari	A	142	10
10	10	Veraval	A	150	17
11	11	Porbandar	A	59	31
12	12	Godhara	A	93	15
13	13	Bhuj	A	136	10
14	14	Botad	A	67	11
15	15	Patan	A	126	5
16	16	Palanpur	A	94	46
17	17	Jetpur	A	95	10
18	18	Valsad	A	150	19
19	19	Kalol	A	115	32
20	20	Gondal	A	75	21
21	21	Deesa	A	121	14
22	22	Amreli	A	119	19
NRW in B Class Municipalities					
23	1	Dahod	B	90	9
24	2	Anjar	B	85	14
25	3	Dhoraji	B	87	22
26	4	Khambhat	B	130	20
27	5	Mahuva	B	79	39
28	6	Vijalpor	B	88	6
29	7	Himmatnagar	B	105	6
30	8	Dholka	B	68	59
31	9	Savarkundala	B	98	11
32	10	Keshod	B	87	7
33	11	Wadhvan	B	99	13
34	12	Dhangadhra	B	97	35
35	13	Ankleshwar	B	128	19
36	14	Kadi	B	135	12
37	15	Modasa	B	124	19

Sr.No.	No.	City	ULB Class	Avg WS in LPCD	NRW
38	16	Palitana	B	110	23
39	17	Mangrol	B	81	16
40	18	Borsad	B	137	41
41	19	Visnagar	B	118	22
42	20	Okha	B	38	11
43	21	Bardoli	B	112	13
44	22	Halol	B	62	10
45	23	Upleta	B	81	16
46	24	Una	B	80	13
47	25	Unja	B	115	21
48	26	Sidhhpur	B	115	21
49	27	Viramgam	B	158	36
50	28	Petlad	B	140	5
51	29	Sihor	B	72	17
52	30	Bilimora	B	93	30
53	31	Mandavi(K)	B	96	13
54	32	Dabhoi	B	133	7
55	33	Sanand	B	149	14
NRW in C Class Municipalities					
56	1	Bavla	C	145	11
57	2	Dhandhuka	C	89	16
58	3	Babara	C	72	22
59	4	Bagsara	C	85	9
60	5	Jafarabad	C	25	14
61	6	Rajula	C	62	31
62	7	Karamsad	C	101	14
63	8	Umreth	C	168	27
64	9	Dhanera	C	116	15
65	10	Tharad	C	72	31
66	11	Jambusar	C	83	7
67	12	Gariyadhar	C	83	1
68	13	Talaja	C	84	17
69	14	Gadhada	C	75	16
70	15	Chhotaudepur	C	156	46
71	16	Zalod	C	68	11
72	17	Dwarka	C	53	22
73	18	Khambhaliya	C	103	8
74	19	Salaya	C	71	31
75	20	Dahegam	C	98	13
76	21	Manasa	C	151	16
77	22	Kodinar	C	55	5

Annexure

Sr.No.	No.	City	ULB Class	Avg WS in LPCD	NRW
78	23	Sutrapada	C	24	27
79	24	Dhrol	C	100	10
80	25	Jamjodhpur	C	112	12
81	26	Kalavad	C	87	12
82	27	Sikka	C	69	26
83	28	Manavadar	C	68	31
84	29	Bhachau	C	84	9
85	30	Rapar	C	71	48
86	31	Chaklasi	C	98	14
87	32	Dakor	C	93	21
88	33	Kapadvanj	C	85	16
89	34	Kheda	C	84	32
90	35	Mahemdabad	C	152	18
91	36	Vadnagar	C	104	27
92	37	Vijapur	C	127	16
93	38	Balasinor	C	90	13
94	39	Lunavada	C	114	20
95	40	Halvad	C	83	19
96	41	Vankaner	C	35	28
97	42	Rajpipla	C	113	15
98	43	Kaalol	C	87	14
99	44	Radhanpur	C	63	29
100	45	Chhaya	C	59	50
101	46	Ranavav	C	43	17
102	47	Jasdan	C	107	13
103	48	Idar	C	70	28
104	49	Khedbrahma	C	100	5
105	50	Kanakpur Kansad	C	115	8
106	51	Tarsadi	C	58	25
107	52	Limadi	C	79	23
108	53	Thangadh	C	51	30
109	54	Songadh	C	134	21
110	55	Vyara	C	160	19
111	56	Karjan	C	152	12
112	57	Padra	C	141	18
113	58	Paradi	C	79	51
114	59	Umargam	C	21	34
NRW in D Class Municipalities					
115	1	Dharampur	D	144	23
116	2	Vallbhvidhyanagar	D	169	18
117	3	Prantij	D	82	25

Annexure

Sr.No.	No.	City	ULB Class	Avg WS in LPCD	NRW
118	4	Pethapur	D	108	11
119	5	Oad	D	153	18
120	6	Chorvad	D	37	44
121	7	Bhanvad	D	84	23
122	8	Kathlal	D	136	18
123	9	Bhabhar	D	108	19
124	10	Kheralu	D	145	15
125	11	Chotila	D	78	14
126	12	Lathi	D	94	23
127	13	Talala	D	106	8
128	14	Devgadhbaria	D	163	16
129	15	Anklav	D	138	28
130	16	Vadali	D	45	29
131	17	Harij	D	86	26
132	18	Boriavi	D	85	17
133	19	Jamraval	D	76	16
134	20	Bareja	D	132	26
135	21	Visavadar	D	159	21
136	22	Santrampur	D	91	16
137	23	Bhayavadar	D	79	42
138	24	Shahera	D	80	22
139	25	Savali	D	128	17
140	26	Talod	D	134	12
141	27	Mandavi(S)	D	196	24
142	28	Thara	D	251	21
143	29	Barvala	D	67	23
144	30	Bayad	D	84	20
145	31	Kanjari	D	110	12
146	32	Patadi	D	140	14
147	33	Mahudha	D	96	3
148	34	Gandevi	D	110	26
149	35	Chalala	D	78	41
150	36	Sojitra	D	155	13
151	37	Damnagar	D	71	18
152	38	Kutiyana	D	70	17
153	39	Maliyamiyana	D	67	53
154	40	Chanasma	D	158	24
155	41	Vallabhipur	D	80	19
156	42	Thasara	D	128	19
157	43	Bantawa	D	87	13
158	44	Amod	D	109	35

Sr.No.	No.	City	ULB Class	Avg WS in LPCD	NRW
159	45	Vanthali	D	96	16
NRW in Municipal Corporations					
160	1	Ahmedabad	MC	136	32
161	2	Surat	MC	141	26
162	3	Vadodara	MC	116	38
163	4	Rajkot	MC	113	42
164	5	Bhavnagar	MC	148	23
165	6	Jamnagar	MC	125	7
166	7	Junagadh	MC	52	19
167	8	Gandhinagar	MC	254	24

Annexure: 8
Some Unfit Water Sample Results

DISTRICT LABORATORY, BHAVNAGAR

Gujarat Water Supply & Sewerage Board

REPORT ON SHORT CHEMICAL EXAMINATION OF WATER

The Ex.Enineer,
Filtar Plant & Pumping Station,
Bhavnagar Mahanagar Palika.

Senders Ref. No.	O.W.No 459 Dt.02.07.15
Date of Collection	02.07.15
Date of Arrival at Lab.	03.07.15
Collected by:-	Sender

Sr. No	Laboratory Ref. No. / WTU/CW	Requirement (Acceptable Limit)	Permissible Limit in the Absence Of Alternate Surce	673	674	675	676	677
	Source	IS-10500:2012 (S.R)		Pure Water Takhteshwar Filtar Plant Shetrunji Dam	Raw Water Chitra Filtar Plant Shetrunji Dam	Pure Water Chitra Filtar Plant Shetrunji Dam	Raw Water Nilambag Filter Plant Raw Water Gaurishankar Talav	Pure Water Nilambag Filter Plant Gaurishankar Talav
	Village			Bhavnagar	Chitra	Chitra	Bhavnagar	Bhavnagar
	Taluka			Bhavnagar	Bhavnagar	Bhavnagar	Bhavnagar	Bhavnagar
	District			Bhavnagar	Bhavnagar	Bhavnagar	Bhavnagar	Bhavnagar
1	Colour Hazen Units	5	15	CL	CL	CL	CL	CL
2	Odour	Agreeable	Agreeable	Objectionable	Objectionable	Objectionable	Objectionable	Objectionable
3	Turbidity NTU	1	5	45.00	90.00	47.00	27.00	56.00
4	Dissolved Solids mg/l	500	2000	400	376	334	276	278
5	pH	6.5 to 8.5	No Relaxation	7.38	7.34	7.40	7.35	7.32
6	Total Hardness (as CaCO3) mg/l	200	600	112	106	100	128	120
7	Calcium (as Ca) mg/l	75	200	32	24	21	21	27
8	Magnesium (as Mg) mg/l	30	100	8	[illegible]	12	19	13
9	Chlorides (as Cl) mg/l	250	1000	140	60	60	60	80
10	Sulphates (as SO4) mg/l	200	400	18	15	15	25	23
11	Nitrates (as NO3) mg/l	45	No Relaxation	9.38	130.90	27.99	11.44	9.80
12	Fluorides (as F) mg/l	1.0	1.5	0.83	[illegible]	0.81	0.85	0.12
13	Alkalinity (as CaCO3) mg/l	200	600	140	180	120	128	120
14	--			--	--	--	--	--
15	--			--	--	--	--	--
	OPINION →			UNFIT	UNFIT	UNFIT	UNFIT	UNFIT

Opinion for Potability is given Considering above 13 Test Parameter Only

The result indicate that the water is Fit/Unfit

N.B (1) Execessive Turbidity if any may be removed before use.

(2) CL=Colourless (3) UO = Unobjectionable

No. DLA/BVN/ 172 of 2015

Dt. 09 07 -15

Note:-

1) Test report is issued for assessing chemical fitness as per the bis 10500:2012 for the given drinking water sample only

2) This report should not be taken as a basis to getting license from any government authority

(B.I.Vyas)
Junior Scientific Assistant

Phone No : 02692 266504

DISTRICT LABORATORY
Gujarat Water Supply &Sewerage Board
ANAND

REPORT ON SHORT CHEMICAL EXAMINATION OF WATER

Name & Address:-
The Chief Officer
Ode Nagar Seva Sadan
At : Ode
Ta : Anand
Di : Anand

Senders Ref.No. :- 185/2015 dt 11.12.15
Date of Arrival :- 11.12.15
Collected by :- **Senders**

Laboratory Ref.No. CW.		ACW-3462	ACW-3463	ACW-3464	ACW-3465
Main Source		Bore Well	Bore Well	Bore Well	Bore Well
Source		-	-	-	-
Location		Water Works, Old Water Tank, Opp. New Bus Stand	Water Works, New Water Tank, Ramnath Mahadev	Water Works, Khristi Vas Tank, Nr. Rohit Vas	Water Works, Navapura Water Tank, Navapura
Date of Collection		11.12.15	11.12.15	11.12.15	11.12.15
Village		Ode	Ode	Ode	Ode
Habitation		-	-	-	-
Taluka		Anand	Anand	Anand	Anand
District		Anand	Anand	Anand	Anand
Sr.No.	CHARACTERISTIC	Analytical Value			
1	Colour Hazen Unit	Colourless	Colourless	Colourless	Colourless
2	Odour	Agreeable	Agreeable	Agreeable	Agreeable
3	Turbidity NTU	Nil	Nil	Nil	Nil
4	Total Dissolved Solids mg/l	990	790	664	582
5	pH	7.80	7.78	7.84	7.86
6	Total Hardness (as $CaCO_3$) mg/l	372	440	376	364
7	Calcium (as Ca) mg/l	62	67	62	54
8	Magnessium (as Mg) mg/l	52	65	53	55
9	Chloride (as Cl) mg/l	100	[illegible]	[illegible]	[illegible]
10	Sulphate (as SO_4) mg/l	39	42	39	34
11	Nitrate (as NO_3) mg/l	**72.90**	**93.98**	44.90	44.10
12	Fluoride (as F) mg/l	0.10	0.59	0.82	0.76
13	Total Alkalinity (as $CaCO_3$) mg/l	536	376	368	304
OPINION AS PER IS-10500:2012(S.R)		UNFIT	UNFIT	FIT	FIT

LABORATORY INCHARGE

N.B. Execessive Turbidity if any may be removed before use.
Note :- CL = Colourless. Fit=Fit for Potable use. Unfit=Unfit for Potable use.
O.W.No. DL/ANAND/ 266 /2015. dt. २९ / १२ /2015

PUBLIC HEALTH ENGINEERING LABORATORY
Gujarat Water Supply & Sewerage Board
RAJKOT
SHORT CHEMICAL EXAMINATION REPORT OF DRINKING WATER SAMPLE

RMC/WW/Nyari/Dt.26/06/2015

Name & Address:- Sender's Ref.No.

The Dy.Ex.Engineer
Rajkot Municipal Corporation
Water Works Department, Dhebarbhai Road
RAJKOT

Date of Collected :- 26/06/2015
Date of Arrival at Lab:- 26/06/2015
Collected by:- SENDER

Sr.No.	Laboratory Ref. No.RCW	IS-10500:2012 (S.R) Requirement (Acceptable limit)	Permissible Limit in the Absence of Alternate Source	453	454	455
	Source			Dam Water	Raw Water	Treated Water
				Nr.Valve Tower, Nyari-1 Damsite Kalawad Road	at Nyari WTP	at Nyari WTP
	GPS Mapping No.			0	0	0
	Village			RAJKOT	RAJKOT	RAJKOT
	Taluka			RAJKOT	RAJKOT	RAJKOT
	District			RAJKOT	RAJKOT	RAJKOT
1	Colour Hazen Units, Max	5	15	Nil	Nil	Nil
2	Odour	Agreeable	Agreeable	Agreeable	Agreeable	Agreeable
3	Turbidity NTU, Max	1	5	57.20	75.00	9.70
4	Total Dissolved Solids mg/l, Max	500	2000	350	410	350
5	pH Value	6.5 to 8.5	No Relaxation	7.92	7.91	7.80
6	Total Hardness (as $CaCO_3$) mg/l	200	600	144	220	188
7	Calcium (as Ca^{+2}) mg/l, Max	75	200	27	38	35
8	Magnessium (as Mg^{+2}) mg/l, Max	30	100	19	31	25
9	Chlorides (as Cl^{-}) mg/l, Max	250	1000	88	64	56
10	Sulphates (as $SO4^{-2}$) mg/l, Max	200	400	29	44	38
11	Nitrates (as NO_3^{-}) mg/l, Max	45	No Relaxation	24.60	22.00	18.60
12	Fluorides (as F^{-}) mg/l, Max	1	1.5	0.11	0.11	0.08
13	Alkalinity (as $CaCO_3$) mg/l, Max	200	600	112	104	96
*	OPINION for Potability is given considering above 13 test parameters only. The Result indicate that the water is FIT/UNFIT			UNFIT	UNFIT	UNFIT

* It is recommended that the acceptadle limit is to be implemented.value in excess mentioned under " acceptable" render the water not suitable, but still may be tolerated in the absence of an altarnative source but up to the limits indicated under "premissible limit in the absence of alternate source" above which the source will have be rejected .

No.PHEL/[illegible]/of 2015
Dt.[illegible]/[illegible]/2015

[M. C. Acharya]
Scientific Officer

DISTRICT LABORATORY
Gujarat Water Supply &Sewerage Board
NAVSARI

Phone (02637)-231460

REPORT ON SHORT CHEMICAL EXAMINATION OF WATER

Name & Address:-
The Chief Officer
Vijalpore Nagar Palika
Community Hall
Ghelakhadi Road,
Vijalpore-396450

Senders Ref No.
Date of Arrival : 15.09.'15
Collected by : Senders

Laboratory Ref.No. NCW	NCW-2628	NCW-2629	NCW-2630	NCW-2631	NCW-2632
Main Source	Bore	Bore	Bore	Bore	Bore(Old)
Source	Tap Water	Tap Water	Tap Water	Tap Water	Tap Water
Location	of Mankodiya	of City Gardan	of Maruti Nagar	of Akar Park	of Doli Talav(Old)
Date of Collection	15.09.'15	15.09.'15	15.09.'15	15.09.'15	15.09.'15
Village	Vijalpore	Vijalpore	Vijalpore	Vijalpore	Vijalpore
Habitation	Mankodiya F	City Gardan F	Maruti Nagar F	Akar Park F	Doli Talav F
Taluka	Jalalpore	Jalalpore	Jalalpore	Jalalpore	Jalalpore
District	Navsari	Navsari	Navsari	Navsari	Navsari
Latitude	--	--	--	--	--
Longitude	--	--	--	--	--

Sr. No.	CHARACTERISTIC	Analytical Value				
1	Colour Hazen Unit	Colourless	Colourless	Colourless	Colourless	Colourless
2	Odour	Aggreable	Aggreable	Aggreable	Aggreable	Aggreable
3	Turbidity NTU	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
4	Total Dissolved Solids mg/l	1710	1200	2250	2020	/1300
5	[illegible]	[illegible]	7.00	8.20	8.30	7.20
6	Total Hardness(as $CaCO_3$)mg/l	768	580	872	904	580
7	Calcium (as Ca) mg/l	154	128	174	181	120
8	Magnessium (as Mg) mg/l	94	63	106	110	68
9	Chloride (as Cl) mg/l	552	336	808	632	392
10	Sulphate (as SO_4) mg/l	79	66	89	92	62
11	Nitrate (as NO_3) mg/l	8.15	31.10	29.38	43.90	39.87
12	Fluoride (as F) mg/l	0.31	0.29	0.33	0.30	0.38
13	Total Alkalinity(as $CaCO_3$)mg/l	304	432	326	424	456
14		--	--	--	--	--
15		--	--	--	--	--
OPINION AS PER IS-10500.2012(S.R)		UNFIT	FIT	UNFIT	UNFIT	FIT

N.B. Excessive Turbidity if any may be removed before use.
Note :- CL = Colourless, Fit=Fit for Potable use. Unfit=Unfit for Potable use.

District Laboratory
Guj. Water Supply & Sew. Board,
7/1875, Chopdar Street,
Khatriwad, Junathana,
Navsari - 396 445.

O.W.No. DLN/ 146 /of 2015
Dt. 18 / 09 /2015

(D.P. PARMAR)
SCIENTIFIC OFFICER

Annexure

Phone:(02637)-231460

DISTRICT LABORATORY
Gujarat Water Supply &Sewerage Board
NAVSARI

REPORT ON SHORT CHEMICAL EXAMINATION OF WATER

Name & Address:-
The Chief Officer
Vijalpore Nagar Palika
Community Hall,
Ghelakhadi Road,
Vijalpore-396450

Senders Ref No : [illegible]
Date of Arrival : 15.09.'15
Collected by : Senders

Sr. No.	Laboratory Ref.No. NCW.	NCW-2633	NCW-2634	NCW-2635	NCW-2636	NCW-2637
	Main Source	Bore(New)	Bore(Old)	Bore(New)	Bore	Bore
	Source	Tap Water	Tap Water	Tap Water	Tap Water	Tap Water
	Location	of Doli Talav(New)	of Ramnagar (Old)	of Ramnagar (New)	of Shaneshvar Nagar	of Dadanagar
	Date of Collection	15.09.'15	15.09.'15	15.09.'15	15.09.'15	15.09.'15
	Village	Vijalpore	Vijalpore	Vijalpore	Vijalpore	Vijalpore
	Habitation	Doli Talav F.	Ramnagar F.	Ramnagar F.	Shaneshvar Nagar F.	Dadanagar F.
	Taluka	Jalalpore	Jalalpore	Jalalpore	Jalalpore	Jalalpore
	District	Navsari	Navsari	Navsari	Navsari	Navsari
	Latitude	--	--	--	--	--
	Longitude	--	--	--	--	--
Sr. No.	**CHARACTERISTIC**	**Analytical Value**				
1	Colour Hazen Unit	Colourless	Colourless	Colourless	Colourless	Colourless
2	Odour	Aggreable	Aggreable	Aggreable	Aggreable	Aggreable
3						
4	Total Dissolved Solids mg/l	3500	4500	1220	900	910
5	pH	8.00	8.40	7.35	7.40	8.40
6	Total Hardness(as $CaCO_3$)mg/l	1224	2280	432	248	160
7	Calcium (as Ca) mg/l	245	456	86	50	32
8	Magnessium (as Mg) mg/l	149	278	53	30	20
9	Chloride (as Cl) mg/l	1384	1280	456	240	224
10	Sulphate (as SO_4) mg/l	124	230	45	27	18
11	Nitrate (as NO_3) mg/l	36.18	25.57	29.16	14.69	8.15
12	Fluoride (as F) mg/l	0.30	0.36	0.45	0.60	0.63
13	Total Alkalinity(as $CaCO_3$)mg/l	448	376	288	472	520
14	--	--	--	--	--	--
15	--	--	--	--	--	--
	OPINION AS PER IS-10500:2012(S.R)	UNFIT	UNFIT	FIT	FIT	FIT

N.B. Execessive Turbidity if any may be removed before use
Note :- CL = Colourless. Fit=Fit for Potable use. Unfit=Unfit for Potable use.

District Laboratory
Guj. Water Supply & Sew. Board,
7/1875, [illegible]

O.W.No. DLN/ /of 2015

(D.P. PARMAR)

Annexure

TALUKA LABORATORY

Gujarat Water Supply &Sewerage Board

SANTRAMPUR

REPORT ON BACTERIOLOGICAL EXAMINATION OF WATER

Name & Address:-

Chief Officer

Santrampur Nagarpalika

Santrampur

Senders Ref.No. :- SNP/Pa Pu/Vasu/315

Dt.of Collection :- 18-03-2015

Dt.of Arrival at Lab. :- 18-03-2015

Collected by :- **SENDER**

Laboratory Ref.No.TBBW		1242	1243	1244
Source		Tap water	Hand Pump	Hand Pump
Location		Nr House f Arvindbhai Chandan's Nagarpalika house Connection	In Mahmadi Society	Nr House f Motibhai Prajapti
Village		Santrampur	Santrampur	Santrampur
Taluka		Santrampur	Santrampur	Santrampur
District		Mahisagar	Mahisagar	Mahisagar
Sr.No.	**CHARACTERISTIC**	**Analytical Value**		
1	MPN of Total Coliforms per 100ml of Sample	<2	20	22
2	MPN of Faecal Coliforms per 100ml of Sample	<2	<2	<2
3	Free Chlorine in ppm at Lab	0.10	0.00	0.00
OPINION FOR POTABILITY (IS-10500:2012 Second Revision)		**FIT**	**UNFIT**	**UNFIT**

Note :- **FIT**=Fit for Potable use **UNFIT**=Unfit for Direct Potable use However proper Chlorination may render it FIT for Potable purpose.

(1) Water sample were collected by Sender

(2) > Indicates greater than or equal to

(3) < Indicates less than

(4) It is advisable to keep the residual chlorine concentration upto 2.00 ppm at source

O.W.No. :- 536 /15 Dt. 9/4/2015

Junior Scientific Assistant

Annexure

DISTRICT LABORATORY
Gujarat Water Supply &Sewerage Board
SURAT

REPORT ON SHORT CHEMICAL EXAMINATION OF WATER

Name & Address:-
The Chief Officer,
Bardoli Nagar Palika,
At-Post-Tal-Bardoli
Dist.-Surat-394601

Senders Ref No :- O/W No.NPB/[illegible]/2015 Dtd.25/06/2015
Date of Arrival :- 01/07/15
Collected by :- Sender

Laboratory Ref No. SCW.		SCW-1390	SCW-1391	SCW-1392	SCW-1393	SCW-1394
Main Source		Tube Well	Tube Well	Tube Well	Tube Well	Tube Well
Source		Raw Water	Raw Water	Raw Water	Raw Water	Raw Water
Location		Ramji Mandir Area	Juna Power House Area	Bharwad Vasahat Area	Jalaram Hudko Society Area	Navdurga Area
Date of Collection		01/07/'15	01/07/'15	01/07/'15	01/07/'15	01/07/'15
Village		Bardoli	Bardoli	Bardoli	Bardoli	Bardoli
Habitation		Bardoli	Bardoli	Bardoli	Bardoli	Bardoli
Taluka		Bardoli	Bardoli	Bardoli	Bardoli	Bardoli
District		Surat	Surat	Surat	Surat	Surat
Latitude		--	--	--	--	--
Longitude		--	--	--	--	--
Sr. No.	CHARACTERISTIC	Analytical Value				
1	Colour Hazen Unit	Colourless	Colourless	Colourless	Colourless	Colourless
2	Odour	Agreeable	Agreeable	Agreeable	Agreeable	Agreeable
3	Turbidity NTU	Nil	Nil	Nil	Nil	Nil
4	Total Dissolved Solids mg/l	840	780	1070	800	1700
5	pH	7.61	7.75	7.81	7.75	7.73
6	Total Hardness(as $CaCO_3$)mg/l	476	400	588	452	396
7	Calcium (as Ca) mg/l	95	80	118	90	79
8	Magnessium (as Mg) mg/l	58	49	72	55	48
9	Chloride (as Cl) mg/l	160	184	200	116	768
10	Sulphate (as SO_4) mg/l	50	42	61	47	42
11	Nitrate (as NO_3) mg/l	40.18	39.23	**75.79**	**82.97**	**83.29**
12	Fluoride (as F) mg/l	0.64	0.70	0.89	0.67	0.54
13	Total Alkalinity(as $CaCO_3$)mg/l	360	400	600	464	400
14	--	--	--	--	--	--
15	--	--	--	--	--	--
OPINION AS PER IS-10500:2012(S.R)		FIT	FIT	UNFIT	UNFIT	UNFIT

(D P PARMAR)
SCIENTIFIC OFFICER

N.B. Execessive Turbidity if any may be removed before use.
Note :- CL = Colourless. Fit=Fit for Potable use. Unfit=Unfit for Potable use.
O.W.No. DLS/ 196 /2015.
DATE [illegible]

Laboratory Incharge, Taluka Laboratory,
C/O The Deputy Executive Engineer,
Public Health Sanitary Sub Division,
First Floor, Jalbhavan,
Mamlatdar Kacheri Compound,
DHANERA - 385310. Dist.: B.K.

Phone :

E mail : [illegible]dhanera@gmail.com

[illegible]

REPORT ON SHORT CHEMICAL EXAMINATION OF WATER

Name & Address
Chief Officer
Dhanera Nagarpalika
Dhanera

Sender's Ref. No. : 188
Ref. Date : 09-Mar-16
Sample Collected By : Sender

Sr. No.	Lab. Reference : CW No.	***	***	455	456	457	458	459
*	Date of Collection	Value as per IS 10500 : 2012		17-Mar-16	17-Mar-16	17-Mar-16	17-Mar-16	17-Mar-1
*	Date of Arrival at Laboratory	(Second Revision)		18-Mar-16	18-Mar-16	18-Mar-16	18-Mar-16	18-Mar-1
*	Source of Water Sample	Requirement [Acceptable Limit]	* Permissible Limit in the absence of Alternate Source	Sump,Village Samarvada	Tube Well ,Nr Moraniya	Tube Well ,Nr Vivekand	Tube Well ,Nr Tharad Road	Tube Well ,N Gayatrimand
*	Village	***	***	Samarvada	Dhanera	Dhanera	Dhanera	Dhanera
*	Taluka	***	***	Dhanera	Dhanera	Dhanera	Dhanera	Dhanera
*	District	***	***	Banaskantha	Banaskantha	Banaskantha	Banaskantha	Banaskanth
1	Colour - Hazen Units	5	25	Nil	Nil	Nil	Nil	Nil
2	Odour	U.O.	U.O.	U.O.	U.O.	U.O.	U.O.	U.O.
3	Turbidity - NTU	1	5	Nil	Nil	Nil	Nil	Nil
4	Dissolve Solids - mg/l	500	2000	131	778	1282	1282	1114
5	pH	6.5 to 8.5	No Relaxation	8.40	8.27	8.09	8.27	7.93
6	Total Hardness (as $CaCO_3$) mg/l	200	600	96	76	100	68	156
7	Calcium (as Ca^{+2}) mg/l	75	200	26	18	24	14	26
8	Magnesium (as Mg^{+2}) mg/l	30	100	7	8	10	8	22
9	Chloride (as Cl^-) mg/l	250	1000	28	176	388	388	304
10	Sulphate (as SO_4^{-2}) mg/l	200	400	1	52	68	50	103
11	Nitrates (as NO_3^-) mg/l	45	No Relaxation	2.22	24.37	62.02	48.73	35.44
12	Fluoride (as F^-) mg/l	1.0	1.5	0.18	1.60	1.73	1.84	1.62
13	Alkalinity (as $CaCO_3$) mg/l	200	600	98	320	344	304	372
*	OPINION FOR POTABILITY :	***	***	FIT	UNFIT	UNFIT	UNFIT	UNFIT

Abbrivation : U.O. = Unobjectionable, Note : Excessive Turbidity, if any may be removed before use.

* It is recommended that the acceptable limit is to be implemented. Values in excess of those mentioned unde "acceptable" render the water not suitable, but still may be tolerated in the absence of an alternative source but up t the limits indicated under "permissible limit in the absence of alternate source" above which the sources will have to b rejected.

Outward No.: CAR / /of 2010
Date : / /2010

Laboratory Incharge

Annexure: 9
Water Test results in rural area of all District of Gujarat (As per National Rural Drinking Water Programme, Ministry of Drinking Water and Sanitation, Govt of India)

(Source: http://indiawater.gov.in/imisreports/Reports/WaterQuality/)

Year 2013-14

Ministry of Drinking Water & Sanitation
National Rural Drinking Water Programme
Format E6- District Quality Profile For Lab Testing (2013-2014)

State - GUJARAT District - All District Financial Year - 2013-2014

S.No.	District	Total Sources Tested	No. of Sources with Single Chemical Contaminants						No. of Sources with Bacteriological Contaminants		No. of Sources with Multiple Contaminants	
			Iron	Fluoride	Salinity	Nitrate	Arsenic	Other	E-Coli (MPN /100 ml)	Coliform	In Iron, Fluoride, Salinity, Nitrate & Arsenic	also with Other Contaminants
1	AHMADABAD	3267	0	2	25	75	0	57	0	0	38	22
2	AMRELI	3194	0	13	1	161	0	194	15	147	177	338
3	ANAND	3408	0	39	6	249	0	136	1	154	74	85
4	ARAVALLI	0	0	0	0	0	0	0	0	0	0	0
5	BANAS KANTHA	2876	0	372	8	561	0	111	0	0	232	42
6	BHARUCH	3596	0	0	5	7	0	48	2	64	125	229
7	BHAVNAGAR	5311	0	6	0	172	0	342	35	463	34	77
8	BOTAD	0	0	0	0	0	0	0	0	0	0	0
9	CHHOTAUDEPUR	0	0	0	0	0	0	0	0	0	0	0
10	DANG	2598	0	0	0	46	0	34	17	63	0	0
11	DEVBHOOMI DWARKA	0	0	0	0	0	0	0	0	0	0	0
12	DOHAD	5708	0	330	0	237	0	86	0	3	139	105
13	GANDHINAGAR	1813	0	27	7	77	0	38	19	62	12	11
14	GIR SOMNATH	0	0	0	0	0	0	0	0	0	0	0
15	JAMNAGAR	3141	0	24	4	462	0	120	2	591	141	151
16	JUNAGADH	3486	0	3	3	253	0	79	138	145	99	84
17	KACHCHH	2835	1	42	29	4	0	73	0	3	76	78
18	KHEDA	5353	0	191	23	210	0	408	0	839	190	31
19	MAHESANA	1394	0	107	4	228	0	77	0	0	86	19
20	MAHISAGAR	0	0	0	0	0	0	0	0	0	0	0
21	MORBI	0	0	0	0	0	0	0	0	0	0	0
22	NARMADA	2985	0	21	0	134	0	103	0	87	16	93
23	NAVSARI	5066	0	46	4	66	0	358	12	8	49	93
24	PANCH MAHALS	6233	2	298	1	652	0	200	0	1103	164	99
25	PATAN	2487	0	152	14	18	0	73	3	1	117	33
26	PORBANDAR	1559	0	8	1	1	0	53	4	145	11	22
27	RAJKOT	4773	0	5	1	246	0	218	0	302	128	185
28	SABAR KANTHA	3432	0	3	0	145	0	31	0	0	50	5
29	SURAT	7496	0	171	5	421	0	387	1201	7	145	218
30	SURENDRANAGAR	2986	0	47	3	69	0	39	1	0	78	44
31	TAPI	8010	0	2	1	139	1	105	0	22	22	133
32	VADODARA	6529	0	313	9	789	0	346	0	528	360	506
33	VALSAD	11047	0	42	3	14	0	65	3	439	86	137
	Total	**110583**	**3**	**2264**	**157**	**5436**	**1**	**3781**	**1453**	**5176**	**2649**	**2840**

Source: http://indiawater.nic.in

Annexure

Year 2014-15

Ministry of Drinking Water & Sanitation
National Rural Drinking Water Programme
Format E6- District Quality Profile For Lab Testing (2014-2015)

State - GUJARAT District - All District Financial Year - 2014-2015

S.No.	District	Total Sources Tested	No. of Sources with Single Chemical Contaminants						No. of Sources with Bacteriological Contaminants		No. of Sources with Multiple Contaminants	
			Iron	Fluoride	Salinity	Nitrate	Arsenic	Other	E-Coli (MPN /100 ml)	Coliform	In Iron, Fluoride, Salinity, Nitrate & Arsenic	also with Other Contaminants
1	AHMADABAD	6756	0	0	14	29	0	24	73	0	79	13
2	AMRELI	4443	0	9	5	205	0	145	358	421	179	239
3	ANAND	3646	0	46	9	244	0	141	0	8	75	58
4	ARAVALLI	3199	0	5	0	194	0	5	0	21	14	0
5	BANAS KANTHA	4346	0	339	4	506	0	163	77	207	256	44
6	BHARUCH	4208	0	6	3	42	0	31	0	1	89	181
7	BHAVNAGAR	4211	0	0	0	120	0	148	0	471	2	20
8	BOTAD	1332	0	1	0	6	0	21	0	36	8	3
9	CHHOTAUDEPUR	6437	0	525	1	909	0	110	5	5	214	259
10	DANG	3167	0	0	0	35	0	19	41	90	0	0
11	DEVBHOOMI DWARKA	2324	0	4	1	71	0	21	0	514	67	59
12	DOHAD	9927	0	371	2	733	0	102	0	126	149	96
13	GANDHINAGAR	3286	0	9	0	89	0	18	2	258	4	6
14	GIR SOMNATH	1986	0	12	0	123	0	21	0	92	26	13
15	JAMNAGAR	2371	0	7	0	264	0	44	1	1019	28	33
16	JUNAGADH	2191	0	7	1	227	0	32	0	455	27	24
17	KACHCHH	5663	0	42	24	22	0	84	429	431	147	124
18	KHEDA	3266	0	159	17	152	0	169	6	4	111	37
19	MAHESANA	2984	0	132	6	298	0	57	3	24	91	20
20	MAHISAGAR	7508	0	97	1	684	0	152	2	4	212	188
21	MORBI	1810	0	4	1	8	0	100	15	58	17	22
22	NARMADA	3417	0	43	0	229	0	120	0	6	22	45
23	NAVSARI	8699	0	11	3	32	0	37	0	0	55	66
24	PANCH MAHALS	3697	0	13	0	360	0	131	0	14	113	74
25	PATAN	3239	0	135	4	9	0	83	16	31	102	17
26	PORBANDAR	1872	0	20	0	36	0	67	0	294	23	22
27	RAJKOT	5733	0	0	0	150	0	198	2	135	32	71
28	SABAR KANTHA	3480	0	3	1	190	0	47	0	108	33	5
29	SURAT	6175	0	37	0	122	0	113	13	6	59	89
30	SURENDRANAGAR	2434	0	29	1	28	0	20	39	114	37	22
31	TAPI	4826	0	0	0	28	0	28	0	0	7	38
32	VADODARA	3634	1	34	14	275	0	302	23	6	129	271
33	VALSAD	8327	0	7	0	1	0	0	0	3	13	19
	Total	**140594**	**1**	**2107**	**112**	**6421**	**0**	**2753**	**1105**	**4962**	**2420**	**2178**

Source: http://indiawater.nic.in

Year 2015-16

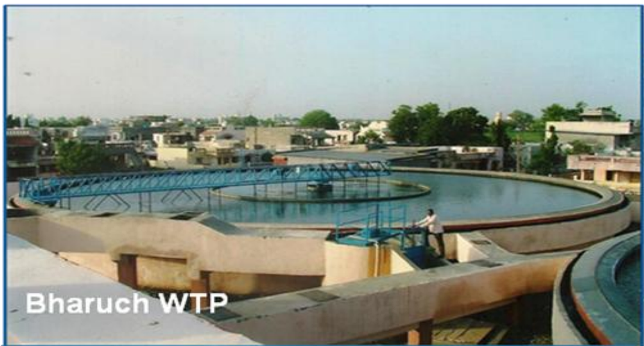
Ministry of Drinking Water & Sanitation
National Rural Drinking Water Programme
Format E6- District Quality Profile For Lab Testing (2015-2016)

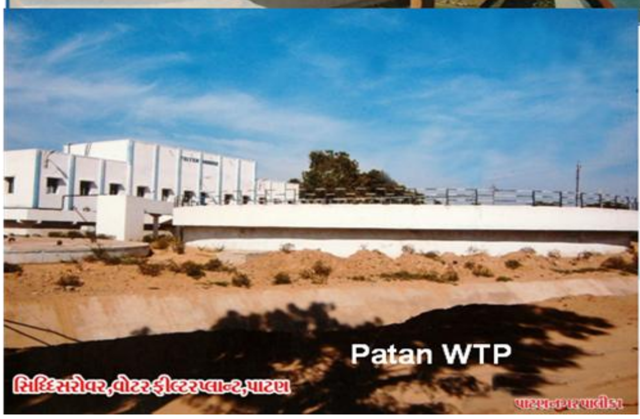
State - GUJARAT District - All District Financial Year - 2015-2016

S.No.	District	Total Sources Tested	No. of Sources with Single Chemical Contaminants						No. of Sources with Bacteriological Contaminants		No. of Sources with Multiple Contaminants	
			Iron	Fluoride	Salinity	Nitrate	Arsenic	Other	E-Coli (MPN /100 ml)	Coliform	In Iron, Fluoride, Salinity, Nitrate & Arsenic	also with Other Contaminants
1	AHMADABAD	5693	0	0	0	0	0	1	0	0	0	0
2	AMRELI	5377	0	0	0	0	0	57	0	53	0	0
3	ANAND	2918	0	0	0	0	0	7	0	5	0	0
4	ARAVALLI	2833	0	0	0	6	0	2	0	0	3	0
5	BANAS KANTHA	3590	0	6	0	10	0	81	0	240	4	1
6	BHARUCH	3978	0	0	0	0	0	0	0	0	0	0
7	BHAVNAGAR	5922	0	0	0	0	0	140	0	147	0	0
8	BOTAD	6246	0	0	0	0	0	63	0	38	0	0
9	CHHOTAUDEPUR	4620	0	2	0	6	0	2	0	0	0	0
10	DANG	2618	0	0	0	0	0	10	27	67	0	0
11	DEVBHOOMI DWARKA	2777	0	0	0	0	0	4	0	830	0	0
12	DOHAD	8563	0	0	0	0	0	17	0	0	0	0
13	GANDHINAGAR	3005	0	0	0	0	0	0	0	3	0	0
14	GIR SOMNATH	3798	0	0	0	0	0	5	0	163	0	0
15	JAMNAGAR	3076	0	0	0	0	0	0	0	854	0	0
16	JUNAGADH	2361	0	0	0	0	0	0	0	378	0	0
17	KACHCHH	7676	0	0	0	0	0	0	0	493	0	0
18	KHEDA	3953	0	0	0	0	0	0	1	10	0	0
19	MAHESANA	2136	0	0	0	0	0	42	1	122	0	0
20	MAHISAGAR	6229	0	0	0	0	0	0	0	0	0	0
21	MORBI	2395	0	0	0	0	0	73	0	316	0	0
22	NARMADA	3335	0	0	0	0	0	1	0	0	0	0
23	NAVSARI	8170	0	0	0	0	0	14	0	0	0	0
24	PANCH MAHALS	3714	0	0	0	0	0	1	0	0	0	0
25	PATAN	2639	0	0	0	0	0	34	0	42	0	0
26	PORBANDAR	1628	0	0	0	0	0	63	0	247	0	0
27	RAJKOT	6944	0	0	0	0	0	33	0	213	0	0
28	SABAR KANTHA	2504	0	0	0	0	0	0	0	0	0	0
29	SURAT	4620	0	0	0	0	0	61	5	8	0	0
30	SURENDRANAGAR	4501	0	0	0	0	0	0	0	214	0	0
31	TAPI	4342	0	0	0	0	0	0	0	0	0	0
32	VADODARA	2635	0	0	0	1	0	20	0	19	1	2
33	VALSAD	6088	0	0	0	0	0	8	1	1	0	0
	Total	**140884**	**0**	**8**	**0**	**23**	**0**	**739**	**35**	**4463**	**8**	**3**

Source: http://indiawater.nic.in

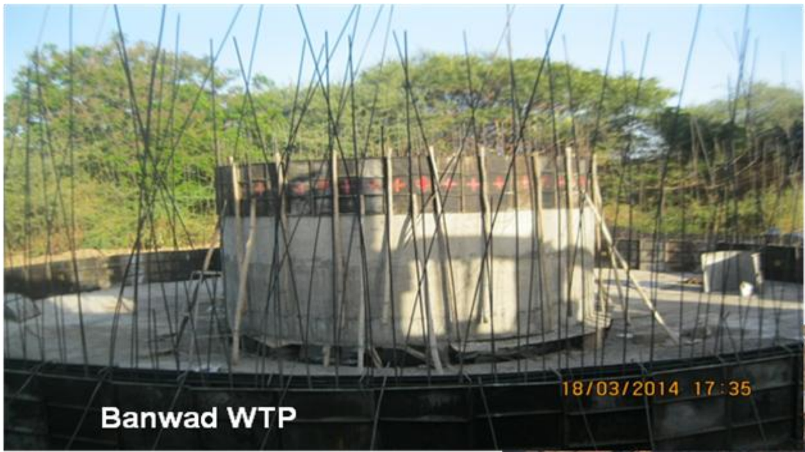
Annexure: 10
Photographs of Water Treatment Plants





WTPs which need up-gradation/repairs

WTPs under construction



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1. Vijay Anadkat & Dr G P Vadodaria, Technological Interventions to improve Quality of Drinking Water in Urban Gujarat, India Water works Association, Ahmedabad , January 2015 (Copy enclosed) Page 33-40
2. Vijay Anadkat, Rajkot RITE project:m-governance beyond e-governance , Shelter Magazine by HUDCO, Vol. 15, No.1 April 2014, ISSN-2347-4912 (copy enclosed), page 48-58 available at_ http://www.hudco.org/writereaddata/shelter-apr14.pdf
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India Water Works Association, Ahmedabad, January 2015

Technological interventions to improve quality of drinking water in Urban Gujarat

By _ Vijay Anadkat and Dr G P Vadodaria[4]

Abstract

This paper provides an overview of quality of water in Urban Gujarat covering all 159 municipalities and 8 Municipal Corporations area. It is intended here to access water parameters of covering all ULBs of the state, interconnected challenges for water supply particularly for quality of water. It is also attempted to present macro aspects and recent developments & studies regarding technical options and methods for water treatments alongside examples of standards, benchmarks, performance assessment, ongoing efforts; it outlines strategies to scale up the use of appropriate methods to improve quality of water in urban Gujarat.

1. **Background:** Over the past three decades Gujarat has emerged as one of India's most urbanised states with a high level of industrialisation. With nearly 38 percent of its population living in urban areas, Gujarat ranks high on the scale of urbanization, next only to Tamil Nadu (43.9%) and Maharashtra (42.4%). Given this pace of urbanisation, the need to augment the investment levels in improving the urban infrastructure levels would be critical. The urban infrastructure levels in Gujarat's cities clearly reveal that past investments levels in the State have not kept up with addressing the needs of the urban population. The direct impact of inadequate investments has been the deterioration in the service levels of core civic infrastructure such as water supply, sewerage and solid waste management.

   The State has an average annual rainfall of 80 cm with a high coefficient of variance over time and space and as a result droughts have been frequent. With depleting ground water resources, more and more cities need to resort to extension of piped network from water sources. Addition to that about one fourth municipalities of Gujarat do not have water treatment plant to cater even present population. This ends with a host of other problems like poor reliability measured in terms of number of hours of supply, poor quality of water etc.

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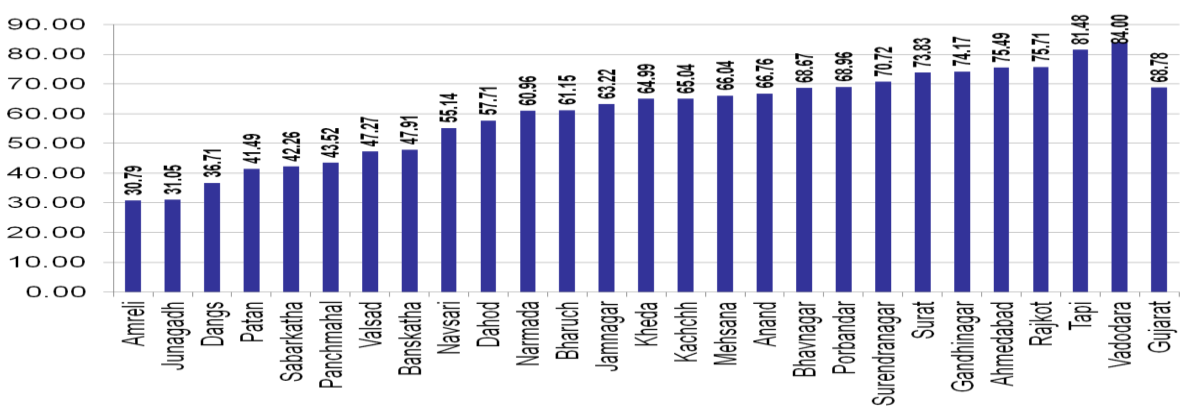
For instant, Groundwater quality deteriorates due to the discharge of untreated industrial effluents, urban wastewater, over use of pesticides by irrigators and seawater intrusion either directly from casual disposal or indirectly as seepage from treatment lagoons or infiltration from surface watercourses or canals. Water quality threat is when water is tapped from sedimentary formation due to water flow in adjacent rock types and mineral compositions of rocks, water quality is affected. Often over-exploitation of groundwater magnifies inherent salts i.e. TDS, fluorides, Chlorides. There are region specific issues and require to identified each one and have to make model provide appropriate type of the technological solution at treatment level as well as at monitor level. Therefore, it is intended to provide correct technological solution by conventional, non-conventional way like adopting various methods like ground water recharging, developing water –barriers, and developing technological intervention on working water treatment plant, involving non-conventional methods like modular sedimentation tanks, use of coconut shells, traditional water treatment plant by non-conventional, advance technology for better performance like membrane, RO, water excursion etc., for appropriate technological solution for particular region.

2. **Assessment of water supply in Urban Gujarat:** Major points of Urban Gujarat water supply can be highlighted as under:
   i. Gujarat falls under semi-arid zone. The long sea coastline along Saurashtra, Kutch and other parts creates the problem of salinity ingress, which affects the ground water quality on coastal belt and because of scanty and uncertain rainfall, the replenishment in dam is also not reliable, hence this areas are always under water deficiency. It has just 2.28% of India's water resources and 6.39% of country's geographical area.[5] The per capita fresh water availability in the State as per the study done in 2001 has been estimated as 1,137 M3 /annum as against the country's per capita renewable freshwater availability of 2000 M3/annum. Out of 185 rivers, the State has only eight perennial rivers and all of them are located in southern part. Around 80% of the State's surface water resources are concentrated in central and southern Gujarat, whereas the remaining three-quarters of the State have only 20%. Water is to be brought from water surplus to water scarce area.

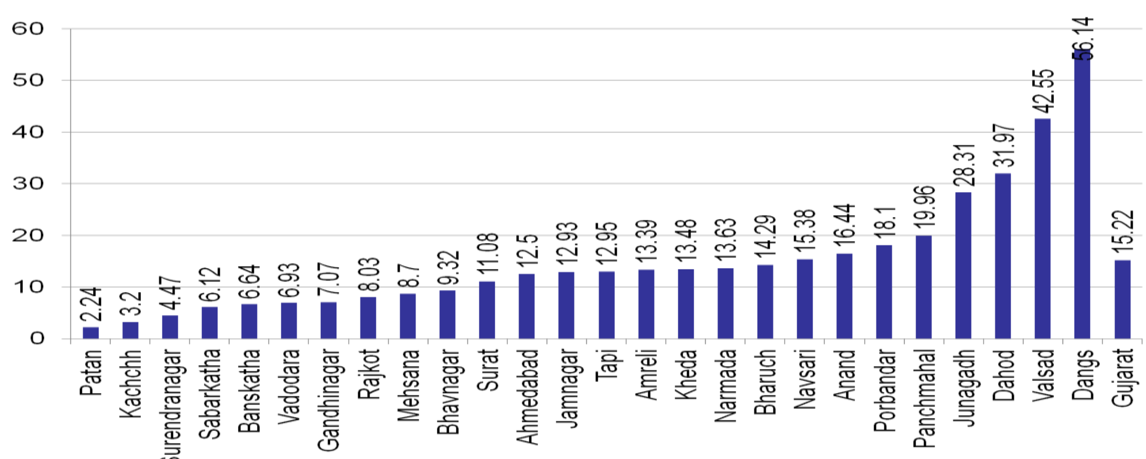
[5] The role of water technology in development: a case study of Gujarat State, India by Dr Rajiv Kumar Gupta, UN water international conference

ii. General practice of water treatment process is similar to other part of the country like Clariflocculator followed by sand filter and chlorination. Largely two types of quality of water test viz., test for turbidity and test for chlorination are practiced. None of municipalities or Municipal Corporations have advance water treatment plant. Only at Surat and part of Ahmedabad have on line quality of water check available, rest does not such facilities[6].

iii. As per census 2011, the HH % coverage of drinking treated & taped water is about 69%. The district wise details are as under:



iv. Large part of the people in Urban Gujarat still depends on sources of ground water. About 56 % of HH in the Dangs with the highest ground water dependency and the least at Patan. The district wise details areas shown below:



[6] Self data collection

v. Overall status of the water supply in urban Gujarat with facility of WTP is as under:

Urban Gujarat_ current status	No of Municipalities	No of Bigger Corporations	No of Smaller Corporations
Source			
No Source / insufficient source	59	0	0
Surface water	43	2	0
Ground Water	49	0	0
Ground + Surface	67	2	4
Distribution			
No network	Nil	0	0
Incomplete coverage	139	4	4
Slums / OG area not covered	139	4	4
Filtration			
No filter plant	44	0	0
Up gradation required	10	4	4

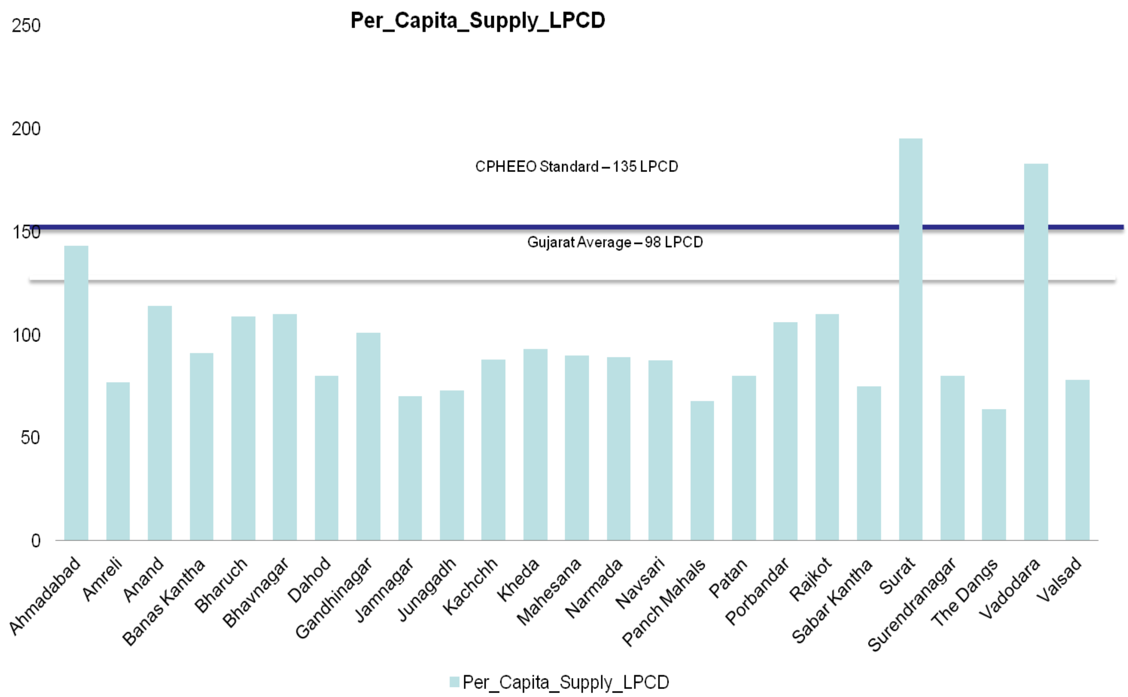
(Source: GUDM, GWSSM January 2014)

vi. The details of water supply in eight corporations which occupy more that 80% of the urban population of Gujarat is as under:

Parameters	Ahmedabad	Surat	Vadodara	Rajkot	Bhavnagar	Jamnagar	Junagadh
Supply- Liter Per Capita Per day (LPCD)	170 Liter	182 liter gross	175 Liter	115 Liter	80 Liter	110 liters	110
Population Coverage	95%	85%	97%	92%	93%	95%	75% old city 50% New City
Area Coverage	85%	56%	86%	90%	85%	82%	60%
Demand of Water Supply	1060 MLD (Domestic)	900 MLD (Domestic)	350 MLD (Domestic)	175 MLD (Domestic)	105 MLD (Domestic)	60 MLD (Domestic)	33 MLD
Distribution of Water Supply	850 MLD	700 MLD	300-330 MLD	165 MLD	75 MLD	90 MLD (JMC+MES+ OG area)	25 MLD
Treatment Capacity in MLD	1314 MLD	1128 MLD	145 MLD	249 MLD	75 MLD	122 MLD	14 MLD
Treatment / Supply capacity in %	146%	161 %	100 %	142%	90%	135%	42%
Storage Capacity in MLD	1200MLD	590 ML	197 MLD	156.67 MLD	22 MLD	55 MLD	21 MLD
Supply / storage in %	108%	118%	56 %	90%	29%	61%	84%
Hours of Supply	120 mins to 150 mins	120 min to 180 min	60 mins	20 minutes	45 mins (5 days in a week)	45 min to 60 mins – Alternate day	45 Min

vii. The duration of water supply in Urban Gujarat varies from 20 minutes per day to 3hrs per day. None has 24x7 water supply system

viii. The average rate of water supply, district wise in urban area is as shown below:



ix. Municipality-wise as well as well city class wise availability of water treatment plant can be summarised as 43 ULB out of 167 urban town have water treatment plant out of which one third are not in functional stage. There are 10 municipalities require modification in the plant, while 3 municipal corporation need augmentation of water treatment plant. Stated reason is that, half of them have ground water supply & WTP for remaining are under construction. However, all ULBs ensure water supply with only after required chlorination,

x. Other aspects for supply and quality of water can be summarised as under:

- Groundwater quality deteriorates due to the discharge of untreated industrial effluents(GWIL report March 2012 for Ahmedabad & Gandhinagar)
- Water quality threat is when water is tapped from sedimentary formation due to water flow in adjacent rock types and mineral compositions of rocks, water quality is affected. Often over-exploitation of groundwater magnifies inherent salts i.e. TDS, fluorides, Chlorides.
- North Gujarat suffers the most by excessive fluoride followed by Saurashtra – Kachchh and Patan suffer from excessive fluoride in their water supply.

- High level TDS and salinity are common scenario across the state
- In Municipalities of Rajkot as well as Junagadh district excessive nitrate are also noted
- In many cities it is observed that, due to low quantity of water supplied, people often go for tapping private water sources and eventually in many cases it turns out to be ground water.

3. **Universal practice and Technology for Water Treatment** In this era of Smart city it is essential to supply quality of water across the state. Therefore, it is attempted here to identify technical options across the globe with minimum intervention to improve the quality of water across the state.

3.1 : Based on sources of water: Universal water treatments have following technological options available for ground for water as well as surface water.

<u>Ground Water</u>

- ❖ Major contaminants – Fluoride , Nitrate, Arsenic, Salinity (TDS) ,iron etc
- ❖ Present treatment technologies
  - Boiling, filtration and chlorination for relatively good source
  - Fluoride - Activated alumina treatment / Alum & Lime treatment
  - High salinity (TDS) – Reverse osmosis
  - NITRATE - Resin based treatment
  - ARSENIC - Activated alumina, oxidation with chlorine

<u>Surface water</u>

- ❖ Aeration in cascade aerators (to remove iron/manganese)
- ❖ Chemicals
  - Alum/lime/polyelectrolyte followed by flocculation and Coagulation
  - Clarifications/sedimentation (Innovations possible in clarifier design)
- ❖ Filtration (Innovations possible in filter bed composition)
- ❖ Chlorination/ UV/others

3.2 Based on Need of upgrading properties of water. It can be summarised as tabulated below.

Property	**Contaminated part**	**Universal Practice**
Physical Property		
Turbidity	Suspended fine sand, clay, other small particles	Use sand filter for large quantities of suspended particulates or use a sediment filter or sedimentation (allowing the particles to settle out of suspension) for smaller quantities of sediment

Colour	Hydrogen Sulphide gas (rotten egg odour)	Remove by using chlorination and a sedimentation filter
Odour	Many odour and taste problems other than rotten egg smells	An oxidizing (i.e. greensand) filter followed by activated carbon filter
Chemical Property		
TDS	Temporary or permanent hardness	Activated carbon filter /RO
Ph	Acidity: pH lower than 7	pH correction using either a tank-type neutralizing filter for respective correction
Radio nucleotides	Very critical property	Radon can be removed with an activated carbon filter
		Radium can be removed with RO, carbon exchange & distillation
Biological Property		
Biological load/ MPAN/Bcoil	Bacteria/ fungus	Chlorination/ UV ray/ Ionisation

4 **Universal practice and Technology for Water Treatment: Methods & Principles of Water Purification:** To describe macro level of water purification. It can be identified with any or combination of three methods viz., Water Purification, Reverse Osmosis & Distillation. Pros and cons of all three macro methods are summarised (Ref: CPHEEO manual) below to choose appropriate methods:

1. Filtration		
Method	**Pros**	**Cons**
• Filtration has evolved from cloth, to the complicated solid block carbon and multimedia water filters	• Water filters are not limited in type or size of contaminants they can remove. • Water filters are able to remove far more contaminates than any other purification method • They use the chemical adsorption process • Water filters also extract from drinking water the chlorine-resistant protozoa • Do not require the costly energy • Rapid water filters allot water inadequate contact time with the inadequate contact time with the filter media. Limiting	• Not remove all minerals • Backwash & continuous maintenance require • Limited control over bacterial load

	the number of contaminants that may be removed • Solid block carbon filters solve both these problems by using both adsorptive and slow filtration processes	
2.Reverse Osmosis (RO)		
Method	**Pros**	**Cons**
• RO process depends upon a semi- permeable membrane through which pressurized water forced • RO is the opposite of thee natural osmosis process of water. Osmosis is the name for the tendency of water to migrate from a weaker saline solution to a strong saline solution • In RO, water is forced to move from a stronger saline solution to water solution again through semi-permeable membrane	• RO is a valuable water purification process when mineral-free water is the desired end product • RO removes some chemical components including fluoride. • RO also removes alkaline mineral as well as acidic water • Remove 95% + bacteriological load	• RO is still incredibly inefficient process. • On average, the RO process wastes three litters of water for every one litre of purified water it produces • Costlier • Trace elements of mineral were intended to be in water ; their removal leaves tasteless unhealthy drinking water
3.Distilliation		
Method	**Pros**	**Cons**
• The distillation process utilizes a heat source to vaporize water. • Evaporated water is captured and guided through a system of tubes to another container. Contaminants having a higher boiling point than water remain in the original container. This process removes most minerals, most bacteria and viruses, and any chemicals that have a higher boiling point than water from drinking water.	• Distillation, similarly to reverse osmosis, provides mineral-free water to be used in science laboratories or for printing purposes, as both functions require mineral-free water. • It removes heavy metal materials like lead, arsenic, and mercury from water and hardening agents like calcium and phosphorous	• Distillation provides mineral-free water that can be quite dangerous to the body's system when ingested, due to its acidity. • Acidic drinking water strips bones and teeth of valuable and essential mineral constituents. • Not suitable for large scale

5 Recommendation: Looking to the international practice and available option quality of water in Urban Gujarat can be improved by any or combination of following points

a. Filtration media up gradation of technology like microfiltration technology which eliminated sand filtration, coagulation and flocculation, filter beds and cartridges can be adopted for bigger Municipal Corporation where more technically qualified staffs are available.

b. Conventional clarifiers with ultra filtration membrane in proposed projects, Refurbishment of existing clarifiers can be adopted where the problem of fluoride and high level of TDS are observed

c. Scope for using multimedia structure in new and existing filter beds can be adopted instead of constructing new water treatment plant

d. High amount of Loss of head and UFW are found at water treatment plant and hence, energy and water audit of WTP is must.

e. Option for U/V against Chlorination can be thought of and adopted at suitable ULBs

f. International trend is to preserve and develop green and natural water infrastructure, suitable analysis for Grey V/S Green Infrastructure Development be made and adopted.

g. Drinking water pre-paid card based kiosk can be installed similar to Dwarka, Delhi (an attempt by MoUD, Govt. of India) at water quality stress area to ensure good quality of drinking water

h. Online quantity and quality check and suitable MIS system can be developed to ensure quantity and quality of water across the Gujarat

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