

**PLANNING POLICIES FOR SAFE DRINKING WATER IN
KOLLAM CORPORATION**

THESIS REPORT

Submitted by

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MUP (2020 - 2022) BATCH

to

*the APJ Abdul Kalam Technological University in partial fulfillment
of the requirements for the award of the
Post Graduate Degree of M. Planning in
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URBAN PLANNING

DEPARTMENT OF ARCHITECTURE

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CERTIFICATE

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Place: Kollam

Date: 12/09/2022

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ABSTRACT

Potable water is one of the major issues faced by many Countries. Safe potable water is essential for public health, drinking water, domestic use, recreational purposes etc. Safe drinking water and sanitation was included under Millennium development goals 2015 under Sustainable development to achieve it by 2030. Globally, around 2 billion people does not have access to safe potable drinking water services and around 3.5 billion people lacks proper sanitation facilities. More than 6% of the Indian population does not have access to safe drinking water, and over 15% of India's population practices open defecation. Several issues regarding the water quality and sanitation are mainly due to urbanization.

In this study, it is about the understanding of different water management methods followed and its issues prevailing in the society along with brief details how it affects the society. It also gives an idea about what are the various methods adopted in the society to improve the water management system. The study was pertaining to Potable water management in Kollam city which has been carried out to evaluate the current status, and to identify the major issues. The study is concluded with few policies which may help in improving the present water management method in Kollam Corporation.

Key words: Potable Water Management, Pollution, Sustainable Development Goal

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CHAPTER 1 INTRODUCTION

This chapter explains the background, needs and aim of the study. The purpose and objectives of the study are also mentioned. The methodology adopted for the research and policies formulated are explained.

1.1 BACKGROUND OF THE STUDY

Safe potable water is essential for public health, drinking water, domestic use, recreational purposes etc. In India, less than half of the population has access to properly managed drinking water. Chemical contamination of water is found in 1.96 million homes, primarily due to fluoride, arsenic due to poor sanitation, improper water management causing pollution and causes diseases like hepatitis A, diarrhea, dysentery cholera, typhoid polio etc. The country that pumps the most groundwater has reached a water and food security crossroads that threatens political and economic stability as well as long-term public health.

State	Proportion of Households Access to Drinking Water			
	Rural		Urban	
	2011	2001	2011	2001
India	82.7	73.2	91.4	90.1
Jammu and Kashmir	70.1	54.9	96.1	95.7
Himachal Pradesh	93.2	87.5	97.8	97.1
Punjab	96.7	96.9	98.9	98.9
Uttarakhand	89.5	83	98.6	97.8
Haryana	92	81.1	96.7	97.3
Rajasthan	72.8	60.5	94.3	93.5
Uttar Pradesh	94.4	85.5	97.8	97.1
Bihar	94	86.1	94.7	91.3
Assam	68.3	56.8	78.2	70.3
West Bengal	91.4	87	93.9	92.3
Jharkhand	54.3	35.5	78.5	68.2
Odisha	74.4	62.9	79.7	72.3
Chhattisgarh	84.1	66.1	93.9	88.8
Madhya Pradesh	73.1	61.6	92.1	88.5
Gujarat	84.9	76.9	97	95.4
Maharashtra	73.1	68.4	95.7	95.4
Andhra Pradesh	88.6	76.9	94.5	90.1
Karnataka	84.4	80.5	92.2	92.1
Kerala	28.4	16.9	39.5	42.9
Tamil Nadu	92.2	85.3	92.9	85.9

Figure 1 Percentage of Households with Access to Safe Drinking Water: 2001–11

(Udaya S. Mishra)

Several issues regarding the water quality and sanitation are mainly due to urbanization. There has been a great improvement in the field of sanitation facilities in last decades, but still there are millions of urban dwellers living without access to proper sanitation facilities. 90% of all waste water in developing countries is discharged untreated, polluting rivers, lakes and seas (Water quality). So, it is clear that human plays an important role in ground water contamination which is a serious issue faced by urban cities. Groundwater is in scarce supply in Delhi. In June, the government-chartered think tank NITI Aayog issued a report warning that Delhi, along with 20 other Indian cities, could face "zero groundwater levels" by 2020.

Safe drinking water, sanitation, and hygiene (WASH) are fundamental to improving standards of living for people (National Library of Medicine.). Safe drinking water and sanitation was included under Millennium development goals 2015 under Sustainable development to achieve it by 2030. The MDG's drinking water target was met in 2010; yet in 2015, the world remained 9 percentage points short of achieving the sanitation target (National Library of Medicine.).

The world's second-largest country and seventh-largest economy is being destabilized by contaminated aquifers and water scarcity. India is losing its ability to protect public health, assure farm production, build the economy, and maintain social stability as its water reserves become dirtier and smaller.

Extreme water scarcity affects two-thirds of India's 718 districts, and the existing lack of planning for water safety and security is a big worry. One of the issues is the rapid depletion of groundwater in India, which is known as the world's greatest user of this resource due to the widespread use of drilling in recent decades. Groundwater from more than 30 million access points provides 85% of drinking water in rural areas and 48% of water needs in urban areas.



Figure 2 Water quality
(Access to sanitation, 2014)

The United Nations estimates that there are **2.5 billion** people who still do not use an improved sanitation facility and a little over **1 billion** practicing open defecation (Access to sanitation, 2014). By 2011, around two third of the population relied on improved sanitation facilities (Access to sanitation, 2014). In Eastern Asia there was a great progress in sanitation coverage (27% to 67%). In the current scenario sub – Sahara Africa and Southern Asia still struggles with low sanitation coverage.

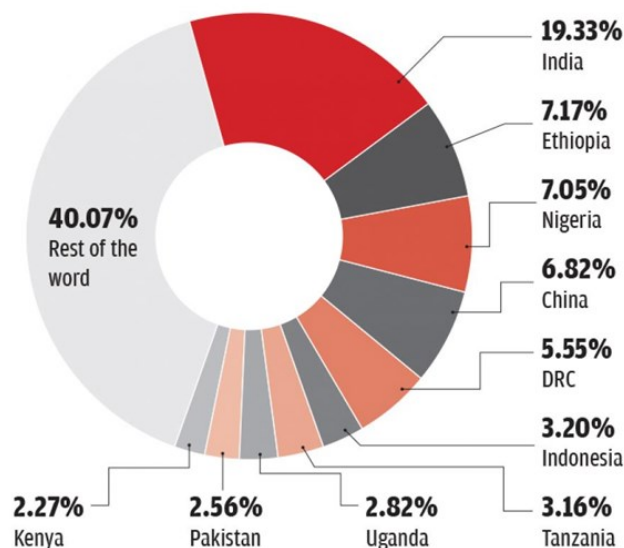


Figure 3 Waterless Countries

1.2 NEED FOR THE STUDY

Globally, around 2 billion people does not have access to safe potable drinking water services and around 3.5 billion people lacks proper sanitation facilities. India is the world's second most populous country, with a population of 1.38 billion people. More than 6% of the population does not have access to safe drinking water, and over 15% of India's population practices open defecation. The impact on child mortality rates is devastating with more than 700 children under five who die every day from diarrheal diseases due to poor sanitation, poor hygiene, or unsafe drinking water (UN World Water Development Report).

Although India contains 4% of the world's water resources, it became water-stressed in 2011. According to a 2019 NITI Aayog report, India is experiencing its biggest water crisis in history, with nearly 600 million people without access to clean water. According to the research, 21 cities, including Bangalore, Delhi, Hyderabad, and Chennai, are likely to run out of groundwater by 2021. (Abraham, 2022)

In low-income countries unsafe water leads to 6% of deaths. People are least aware of hygienic conditions and their role in improving the health conditions. Lack of proper waste management systems and sewerage system contaminates the environment and leads to spread of diseases. Source of drinking water got increased from 76% in 1990 to 90% in 2015 globally. Similarly, sanitation facilities improved from 54% in 1990 to 68% in 2015 but these gains don't meet the Millennium Development Goal target.

The Census of India divided households into three categories based on the distance travelled to get water. Households having 'water within the premises, near the premises, and away from the premises' are included. The availability of water within the premises where households dwell is referred to as "within the premises." Near the premises is defined as a distance of 100 metres in urban areas and 500 metres in rural areas. The category becomes 'away from the premises' if the drinking water source is located beyond 100 metres in urban areas and 500 metres in rural regions. In terms of drinking water availability, India also paints a bleak image. Only 46.6 percent of households have access to drinking water "inside the premises," 35.8% have access "near the premises," and 17.6 percent have access "out from the premises," according to the 2011 census.

1.3 AIM

To formulate effective planning policies to ensure safe drinking water in Kollam corporation.

1.4 OBJECTIVES

- Identify existing sources of water supply along with the quality and quantity of water availability.
- Determine the various drawbacks faced by the existing water management methods through literature case studies.
- Study various technologies that can be adopted to ensure safe drinking water through case studies/ Best practices.
- Identify the study area (Kollam) and study the existing water management methods adopted in Kollam Corporation.
- Identify the issues faced by the existing water management methods in Kollam Corporation.
- Formulate effective strategies and planning policies to ensure safe drinking water supply for Kollam Corporation.

1.5 SCOPE

- The study helps in better management of potable water.
- The study showcases feasible approaches to improve the water quality.

1.6 LIMITATION

- The study of Kollam Corporation was vast so it was limited to selected areas.
- Sample size chosen for the study is 1 in 12 households.

1.7 METHODOLOGY

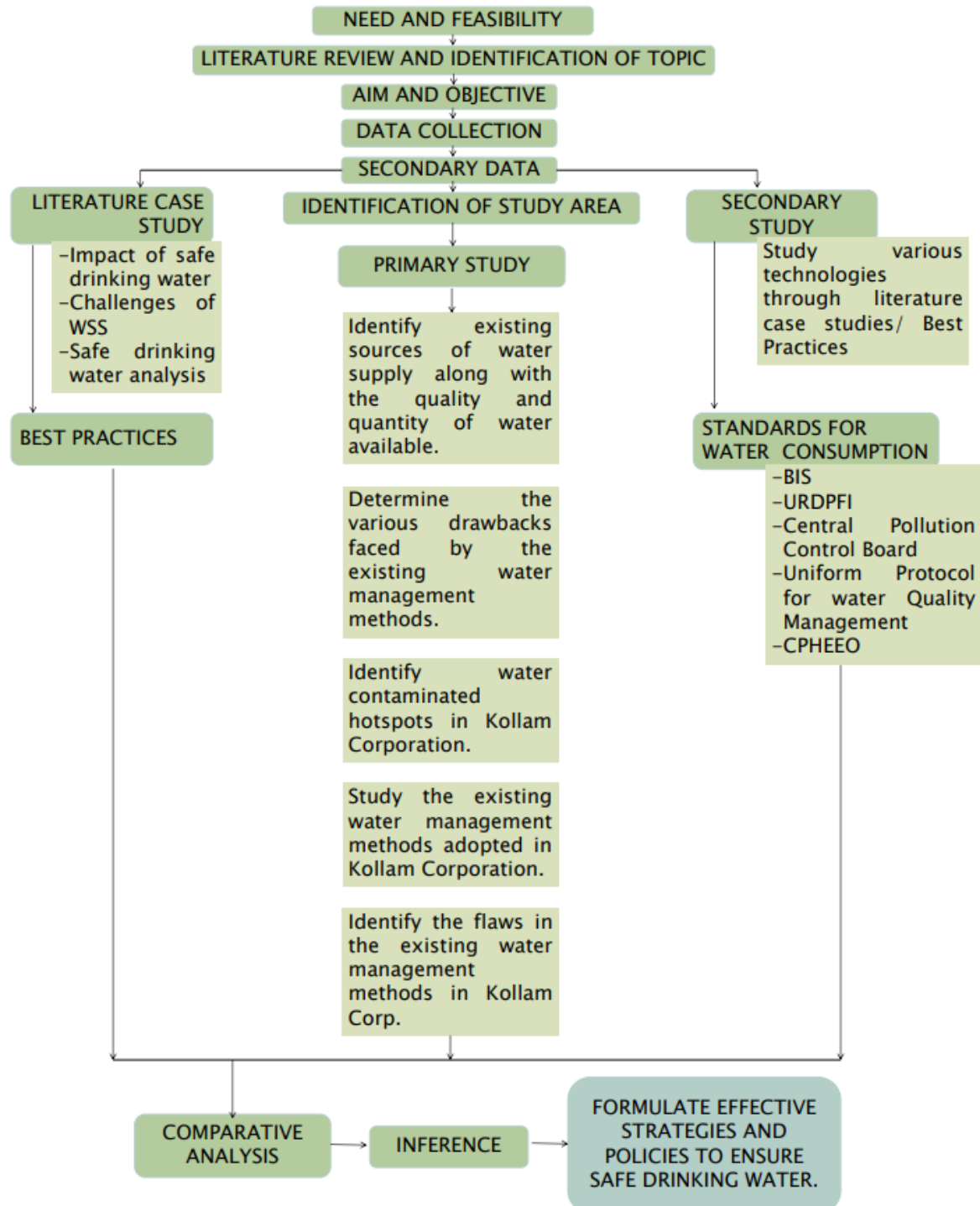


Figure 4 Methodology

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CHAPTER 2 LITERATURE REVIEW

This chapter reviews relevant literature related to definitions & principles of water management. Literature review helps in identifying various methodologies adopted to reach the aim and objectives.

Table 1 Literature Reviews

Journal Author and Date	Aim & Objective	Methodology	Findings
Developing Public Policies for Access to Drinking Water: A Case Study on Environment Friendly and Conventional Technologies. (2016) -Ruxandra Malina, Dacia Crina Petrescu	The main goal of the study is to develop public policy options regarding the supply of safe drinking water in rural areas.	The public policy analysis was a six-steps process: definition of the problem, determination of evaluation criteria, identification of alternative policies, evaluation of alternatives, and their comparison and evaluation.	The technical and economic evaluation of the chlorine and advanced oxidation process with bio-filter treatment solutions reveals higher performances, raising awareness on the existence of technologies, which are, economically efficient, technically, and environmentally friendly.
Assessment of the quality of drinking water in storage tanks and its implication on the safety of urban water supply in developing countries (2017). -Derara Chalchisa, Moa Megersa and	Objective of is to assess physiochemical and bacteriological qualities of tap water stored in water storage tanks.	The study was conducted in Jimma. The study was conducted on piped-water supply before entering the storage tanks and after leaving the water storage tanks.	The study indicated that water samples were bacteriologically contaminated and none of them met the WHO drinking water quality. Detail risk assessment should be conducted from treatment to distribution including storage and safe

<p>Abebe Beyene</p>			<p>handling of water.</p>
<p>A social-ecological analysis of drinking water risks in coastal Bangladesh (2019). -Sharif Tanjim Arif, Robert Hope, Sonia Ferdous Hoque and Tanjila Akhter</p>	<p>Provide basic drinking water services for millions of poor people.</p>	<p>This approach is to examine through hydrogeological mapping, a water infrastructure audit, household surveys, group discussions and interviews to evaluate the risks of drinking water.</p>	<p>Increased private investments in tube wells with new technologies and models to mitigate groundwater salinity. Institutional coordination and hydrogeological monitoring are necessary to mitigate socio-ecological risks.</p>
<p>WHO Sanitary Inspection based Assessment of Contamination Risk in Drinking Water from Community Tube wells with Handpump in Rural India (2019). -Mukul Kulshrestha, Nagendra Parasad Singh</p>	<p>Objectives: Determines the risk associated with contamination of drinking water source and it also determines the extend of risk.</p>	<p>The sanitary surveys were done in 324 communities with tube wells with handpump. The contamination risk posed by the unsafe sources was quantified into 4 categories as recommended by WHO.</p>	<p>28.7% of all sampled community tube wells with handpump were found infested with contamination. The contamination levels were regularly tested and monitored.</p>
<p>Effects of inadequate water supply to the community, with reference to Gidan Kwano in Niger state (2020) -Yusuf Yahaya Miya, Mustapha</p>	<p>Identify problems associated with inadequate water supply to support hygienic living.</p>	<p>Survey research method is used to assess the effects of inadequate water supply on human health by analysing the differential effect on human health.</p>	<p>The occurrence of water borne disease affects the health of people due to consumption of low-quality water obtained from unhygienic sources. So proper water supply facilities</p>

Usman Baba			should be provided.
<p>Modelling the interplay of future changes and wastewater management measures on the microbiological river water quality considering safe drinking water production (2021).</p> <p>-Katalin Demeter, Julia Derx, Jürgen Komma and Juraj Parajka</p>	<p>The aim is to test an integrative approach to improve the water quality through considering the factors climate change and population growth along with enhanced WWTPs prevention of CSO.</p>	<p>It is an integrative modelling approach that combines CO2 emission of the IPCC, a regional climate model, a conceptual hydrological model of the catchment as well as the extended version of the microbial fate, transport and infection risk model QMRACatch.</p>	<p>Climatic and demographic changes had little impact on the microbiological river water quality, where 98% of the pathogen loads stemmed from WWTP discharges. The integrative modelling framework is demonstrated at a large, wastewater impacted river, and is applicable at other catchments and types of pollution sources for long-term water safety planning.</p>

CHAPTER 3 SAFE DRINKING WATER

Water covers more than two-thirds of the earth's surface; however, it is primarily salty and unfit for human consumption. Only 2.7% of the available freshwater on Earth is accessible, and only 1% of the available freshwater (in lakes, rivers, and groundwater) is accessible. The majority of available freshwater resources are inaccessible due to buried parts of the hydrologic cycle (deep aquifers) and glaciers (locked in polar ice), implying that safe drinking water on Earth makes up only 3% of the total freshwater resources. Water supply deficiencies have a negative impact on health both directly and indirectly.

Safe drinking water is defined as water that poses no major health risk over the course of a lifetime of use. Drinking water that is pure, wholesome, healthy, and potable must be given. Safe water is not always pure; it may include contaminants. Salts such as magnesium, calcium, carbonates, bicarbonates, and others can be found in trace amounts. Purity and safety are relative terms that are arguable. There are no minerals in clean/pure water, and it just includes H and O. According to the Monitoring organizations under the supervision of the Joint Monitoring Programme (JMP), "safe drinking water" is defined as water from an "improved water source," which includes household connections, public standpipes, boreholes, protected dug wells, protected springs and rainwater collections (Dinka).

At the point of supply to the consumers, the water must meet the relevant (chemical, biological, and physical) quality requirements. As a result, safe drinking water is a relative phrase that is determined by a country's regulations and guidelines; the requirements set for various quality metrics varies. The phrase "safe" refers to a person's individual resistance capacity. Some African countries' drinking water may not be safe to consume in European countries. Some African countries have already developed resistance to water-borne illnesses. The MDGs and SDGs of the United Nations (UN) programme and vision demonstrate that safe drinking water is anonymously recognized as an international agenda and priority.

3.1 BENEFITS OF SAFE DRINKING WATER

Water of acceptable quality is a key measure of a society's health and well-being, and is thus critical for a country's growth. Contaminated water not only poses a direct threat to

humans, but it can also influence an individual's productivity rate. For humans and the ecosystem, water delivers a variety of advantages and services.

According to the OECD (Organization for Economic Cooperation and Development), the value of water is not adequately documented, resulting in a low political priority for water concerns and insufficient investment in water infrastructure. According to most academics, the benefit-to-cost ratio of access to water is greater than 2, and in some situations, it can reach 7.0. Because water is linked to every aspect of developmental operations. Water supply projects include **technical, environmental, and political benefits** in addition to **economic benefits**. At the local, national, regional, and worldwide levels, the water sector is interwoven with other development sectors (agricultural, energy, industry etc.) and aspects (social, economic, environmental, health, educational, legal, and political). In fact, having access to potable water provides a multitude of immediate and indirect **health, education, poverty, and environmental benefits**. Water and sustainable development are linked, according to the UN World Water Development Report, much beyond their social, economic, and environmental elements. According to the research, access to safe water is critical in addressing developmental concerns such as human health, food and energy security, urbanization and industrial growth, and climate change.

Between 1990 and 2015, the UN's **Millennium Development Goals** aimed to "**halve the people without access to safe drinking water and basic sanitation**". According to a report released by WHO and UNICEF as part of their Joint Monitoring Programme (JMP) for water supply and sanitation, approximately 2.3 billion people now have better drinking water.

3.2 IMPACT ON HEALTH DUE TO UNSAFE DRINKING WATER

Water-borne diseases such as cholera, diarrhea, and dengue fever kill millions of people each year. Water-borne infections kill more than 25,000 people every day around the world, with around 5000 children dying every day. Diarrhea and related disorders claim the lives of around 1.8 million children each year, the majority of whom live in underdeveloped nations. Around 1.8 billion individuals are projected to drink water polluted with *Escherichia coli* (indicator of faecal contamination). Water-borne infections

are the major cause of death in many regions of the world, particularly in impoverished countries. As a result, having access to safe water reduces the number of diseases caused by water. It provides a possibility for better health by reducing the spread of disease.

Table 2 Water related diseases

Water-related disease.		
Category	Description	Example Diseases
Waterborne disease	Enteric infections spread through faecal contamination of drinking water	Typhoid, <i>Campylobacter</i> , giardiasis, <i>Cryptosporidium</i> , cholera, enterohemorrhagic and enterotoxigenic <i>E. coli</i> , norovirus, etc.
Water-washed diseases	Infections that spread in communities that have insufficient water for personal hygiene	Trachoma, scabies, <i>Shigella</i>
Water-based diseases	Diseases where the causative organism requires part of its lifecycle to be spent in water	Schistosomiasis, dracunculiasis
Water-related diseases	Vector-borne diseases where the insect vector requires access to water	Malaria, onchocerciasis, trypanosomiasis

(Paul R. Hunter, 2010)

According to UN-SDG 6 “Water sustains life but safe, clean drinking water defines civilization.” (Dinka). The UN-SDG 6 recommended a dedicated SDG for water under five target areas such as (i) WASH, (ii) water resources, (iii) water governance, (iv) water quality and wastewater management and (v) water-related disasters (Dinka). Improving access to healthy water in underdeveloped nations necessitates the formation of strong governance.

3.3 SUSTAINABLE WATER SUPPLY AND ITS CHALLENGES

To sustain human needs and environmental integrity, sufficient and safe water must be provided for all by 2050, according to the SDG's ambitious ambition. Because water resources are interconnected with other sectors, the world's sustainable development is heavily reliant on water resources. It necessitates improvement in all three aspects of sustainable development (social, economic and environmental). A WSS may confront a variety of obstacles in providing a quality, efficient, dependable, resilient, and sustainable water supply for current and future generations due to a variety of variables. Rural communities have greater financial and technological challenges than urban places.

The SDGs necessitate significant **capital investment** and **effective governance**, both of which are lacking in developing nations. Infrastructure, treatment plant systems, and water recycling all require significant investment. Unsustainable development practices put the amount and quality of renewable freshwater resources under jeopardy. Population growth at an alarming rate, rapid urbanization, considerable land cover and climate change, increasing demand for new energy suppliers, and weak governance are all factors affecting WSS's long-term viability. These driving factors are contributing to an increase in water scarcity, floods and droughts, harmful runoff, coastal hypoxia, and depleted aquifers.

The **lack of adequate policies and initiatives** that reflect rural diversity is another difficulty of sustainable water supply. Water pollution has the greatest impact on small rural populations. Furthermore, they struggle to raise the finances needed to enhance water treatment and delivery systems, and as a result, they fall short of meeting drinking water quality standards. The global trend of providing water to rural regions is known as community management.

In metropolitan settings, there is a pressing need to move toward more **sustainable and resilient smart water infrastructures**. Water leaks, overuse, quality difficulties, and drought and natural disaster response are all issues that urban water delivery systems face. Smart water grids that network and automate monitoring and control devices could help address these issues using information and communications technology.

Water demand and supply modelling is critical in rapidly increasing metropolitan areas. Water service providers need reliable water demand predictions for planning, design, and water utility asset management of drinking water supply systems. Accurate prediction, on the other hand, is always difficult since predicting models necessitate simultaneous consideration of a number of elements impacting water demand and supply patterns.

There are a various factors challenging WSS. Some are aging infrastructure, water service provision thinking horizons, catchment (mountain)-specific issues, climate change, knowledge gaps with respect to present and future hydrology, accurate water demand prediction, land use/cover change, optimal operation of water supply systems, cost

recovery, operating cost, water quality (water pollution), water scarcity, water leaks, low water pressure, over-use, response to drought and natural disasters, rapid urbanization, population growth, migration, demographic changes, economic development, consumer behavioral patterns, efficiency and reliability of a water supply system, self-sufficiency through use of alternative water sources, dynamic and uncertain urban water systems, complex dynamic 170 Water Challenges of an Urbanizing World human-environment coupled systems (non-holistic or siloed management), lack of adaptive capacity indicators to assess sustainability of water systems, scant attention of smart water grids (not supported by information and communications technology), lack of policies and programs that consider rural diversity and cultural differences and neglecting wastewater management are mentioned as challenges to water supply systems for provision of sustainable and reliable water services, which meet acceptable standards for present and future generations (Dinka).

3.4 DRINKING WATER QUALITY

When it comes to human and animal health and disease states, water quality is the most important determining factor. Water is responsible for almost 80% of all human diseases, according to a WHO report.

Water quality can be described by a set of biological, physical, and chemical variables that are directly related to the water's intended usage, depending on the objective of the water quality examination. Drinking water should be devoid of microorganisms and hazardous substances in theory. Contamination of freshwater (particularly groundwater) sources is one of the most pressing issues faced today, particularly in communities that rely nearly entirely on groundwater. In every corner of the globe, groundwater is used for domestic, industrial, and agricultural water supply. As a result, toxins in natural freshwater remain one of the most pressing environmental concerns in many parts of the world, particularly in developing countries. Because the quality of contaminated groundwater cannot be quickly restored, the best option is to protect it.

3.4.1 WATER QUALITY PARAMETERS

Water quality is determined by the intended uses of water for various reasons, which necessitates different standards to be met. It is regarded safe for a specific use if the

quality variables meet the pre-established norms. If water does not meet these standards, it must be treated before use if at all possible.

3.4.1.1 PHYSICAL PARAMETERS

Total solids content, which includes floating matter, settleable matter, colloidal matter, and matter in solution, is related to physical quality characteristics. Following are the parameters:

- a) **Colour:** due to landfill leachate or dissolved organic compounds from rotting vegetation.
- b) **Taste and odour:** Foreign chemicals, such as organic compounds, inorganic salts, or dissolved gases, might cause this.
- c) **Temperatures:** Drinking water that is constantly chilly and does not fluctuate by more than a few degrees is the most preferable. These conditions are frequently met by groundwater.
- d) **Turbidity:** Clay, silt, organic material, plankton, and other suspended solid elements can all be found in water.

3.4.1.2 CHEMICAL PARAMETERS

Chemical constituents are more harmful to human health than physical constituents in drinking water. Some of the chemical ingredients' principal objectionability stems from aesthetic as well as health-related issues. Some chemical compounds have the potential to create health concerns if exposed to them for an extended period of time. Alkalinity, biological oxygen demand (BOD), chemical oxygen demand (COD), dissolved gases, nitrogen compounds, pH, phosphorus, and solids are some of the chemical quality criteria of water (organic).

Some elements and chemical compounds found in water are:

- a) **Arsenic:** appears in various geologic formations spontaneously. It has been related to lung and urinary bladder cancer in drinking water.
- b) **Chloride:** Chloride is present in almost all waters. The amount discovered could be due to industrial or home water leaching. To be pleasant, chloride levels in residential water should not exceed 100 mg/L.

- c) **Fluoride:** Fluoride is a naturally occurring water pollutant. It is one among the substances listed by WHO as having a high priority for human health consequences. Fluorosis of the teeth and skeleton is mainly caused by high F in drinking water. Fluorosis (tooth mottling) is caused by excessive F (>2 mg/L), while bone and skeletal fluorosis can be caused by regular ingestion in excess. F 2 mg/L, on the other hand, causes tooth cavities in youngsters.
- d) **Zinc:** Some natural waters contain zinc, particularly in places where zinc ore deposits have been exploited. Though it is not harmful to one's health, it does give water an unpleasant taste.
- e) **Iron:** Because of the abundance of iron in geologic rocks, minute amounts of iron are regularly found in water. The water will turn a reddish tone.
- f) **Manganese:** Manganese is frequently found in considerable concentrations in natural groundwater. Agricultural products, waste batteries, and steel alloy manufacture are all examples of anthropogenic sources.
- g) **Toxic substances:** Inorganic substances, organic compounds, and heavy metals are the three types of toxic substances. Nitrates (NO₃), cyanides (CN₋), and heavy metals are among the hazardous inorganic compounds. In drinking water, these contaminants pose a serious health risk. In babies, high NO₃ levels can cause Methemoglobinemia (often known as "blue baby syndrome"), while CN can cause oxygen deprivation. Pesticides, insecticides, and solvents are among the more than 120 harmful organic compounds that exist.

3.4.1.3 BIOLOGICAL PARAMETERS

Biological parameters are the most important quality indicators for diseases caused by pathogenic organisms of human origin. Bacteria, fungus, algae, protozoa, plants and animals, and viruses are among the pathogenic species present in surface water. Some of these disease-causing organisms are difficult to identify and can only be seen under a microscope. Microbiological agents are extremely essential in terms of public health, and they may also play a role in changing the physical and chemical properties of water. Water used for drinking and cooking must be pathogen-free. Drinking water that has been contaminated with human or animal excrement poses the greatest microbiological risk. Water-borne infections should be avoided at all costs since they have the potential to infect a large number of individuals at once. While water can be a major source of

infectious organisms, many diseases that are spread by water can also be spread through other means, such as person-to-person contact, droplets and aerosols, and food consumption.

Comprehensive bacteriological testing requires difficult and time-consuming processes. Various assays have been developed to detect the relative degree of bacterial contamination in terms of a quantifiable quantity. To assess the quantity of microorganisms in coliform groups (*Escherichia coli* and *Aerobacter aerogenes*), there are two commonly used test techniques. Total coliforms or *E. coli* are two examples, but the latter is shown to be a stronger diagnostic of biological contamination than the former.

3.5 WATER QUALITY STANDARDS

A standard is a criterion for measuring the quality of something. As a result, a standard for drinking water quality serves as a point of reference to verify that the water delivered is safe for human consumption. The water quality standard is the framework that determines if a water sample is acceptable or safe to use. World Health Organization, Commission for European Union, United States Environmental Protection Agency, Environmental Canada, Russian Standard, Indian Standard, South African National Standard, and Ethiopian Standards are some of the standard drinking standards. The WHO drinking water standards are used by the majority of developing and developed countries.

3.5.1 THE BUREAU OF INDIAN STANDARDS (BIS)

BIS has established drinking water quality standards in India to ensure that people have access to clean drinking water. Drinking water sources must be tested on a regular basis to determine whether the water meets the mandated drinking water standards and, if not, the level of contamination/unacceptability and the necessary follow-up.

Water for drinking should be as pure as possible. The concept of water quality management is becoming as important as water quantity management as the scale of demand for water approaches the available supply.

Table 3 Drinking Water Specifications (IS 10,500:1991)

Characteristics	Desirable limit	Permissible limit
Essential Characteristics		
Colour, Hazen Units, Max	5	25
Odour	Unobjectionable	-
Taste	Agreeable	-
Turbidity, NTU, Max	5	10
PH value	6.5 to 8.5	-
Total Hardness (as CaCO₃), mg/l, Max	300	600
Iron (as Fe), mg/l, Max	0.3	1.0
Chlorides (as Cl), mg/l, Max	250	1,000
Residual free chlorine, mg/l, Max	0.2	-

Desirable Characteristics		
Dissolved solids, mg/l, Max	500	2,000
Calcium as (Ca), mg/l, Max	75	200
Magnesium (as Mg), mg/l, Max	30	75
Copper (as Cu), mg/l, Max	0.05	1.5
Manganese (as Mn), mg/l, Max	0.1	0.3
Sulphate (as So ₄), mg/l, Max	200	400
Nitrate (as No ₃), mg/l, Max	45	100
Flouride (as F0, mg/l, Max	1.0	1.5
Phenolic compounds (as C ₆ H ₅ OH), mg/l, Max	0.001	0.002
Mercury (as Hg), mg/l, Max	0.001	-
Cadmium (as Cd), mg/l, Max	0.01	-
Selenium (as Se), mg/l, Max	0.01	-
Arsenic (as As), mg/l, Max	0.05	-
Cyanide (as CN), mg/l, Max	0.05	-
Lead (as Pb), mg/l, Max	0.05	-
Anionic detergents (as MBAS), mg/l, Max	0.02	1.0
Chromium (as Cr ⁶⁺), mg/l, Max	0.05	-
PAH, mg/l, Max	-	-
Mineral oil, mg/l, Max	0.01	0.03
Pesticides, mg/l, MAX	Absent	0.001
Alkalinity, mg/l, Max	200	600
Aluminum (as Al), mg/l, Max	0.03	0.2
Boron, mg/l, Max	1	5

Hydrology and Water Resources Information System for India

3.5.2 UNIFORM PROTOCOL FOR WATER QUALITY MONITORING

"The most effective way to consistently ensure the safety of a drinking-water supply is to utilize a comprehensive risk assessment and risk management methodology that incorporates all steps in the water supply from catchment to consumer," according to the Guidelines for Drinking-water Quality, Fourth Edition, published by the World Health

Organization (WHO) published in 2011. Such techniques are termed as **Water Safety Plans (WSP)**.

The goal of a Water Safety Plan (WSP) is to assure the safety and acceptability of a drinking-water supply on a consistent basis. This is accomplished by removing or reducing the danger of contamination in raw water sources, water treatment plants, catchments, distribution networks, storage, collection, and handling. WSP is a critical component of all sorts of water supply systems, including major piped drinking water supplies, small community supplies, stand-alone residential systems such as wells, and rainwater harvesting systems.

Water safety plans aim to reduce the risk of contamination by sanitary surveillance and can be combined with water quality monitoring to ensure that communities have safe drinking water. This means that water quality data, in conjunction with Water Safety Plans (WSP), is important for both preventive and curative management. The combined method of integrating WSP with Water Quality Monitoring is a useful tool that goes beyond just creating water quality databases.

Components of a water safety plan include water quality monitoring that leads to the identification of pollution sources, the implementation of corrective activities, and subsequent verification. In this situation, the utility of water quality monitoring is extended to the community's provision of clean water. The following is a framework for water safety in a rural setting:

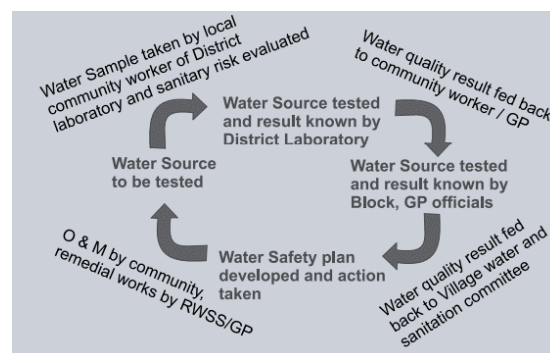


Figure 5 Framework of Water Safety in Rural Context
(Uniform Drinking Water Quality Monitoring Protocol, 2013)

3.5.2.1 DRINKING WATER QUALITY MONITORING

Apart from the BIS specification for drinking water, the Ministry of Water Resources of the Government of India published another water quality guideline in 2005. Uniform Protocol for Water Quality Monitoring is the name for this. In light of the growing risk of geogenic and anthropogenic contamination, a distinct consistent approach for Drinking Water Quality Monitoring has become necessary. If the States judge it necessary, other criteria other than those listed in IS 10500: 2012 may be measured. In the absence of an alternate source, this criterion has two limits: acceptable limits and allowed limits. Water is considered unsuitable for human consumption if any parameter exceeds the limit.

The Drinking Water Quality Monitoring Protocol lays out certain parameters for monitoring drinking water quality in order to ensure that consumers have access to safe drinking water. This document also contains standards for the establishment of laboratories at the state, district, and sub-district levels, as well as quality control for frequent testing and surveillance of drinking water sources. The goal of this paper is to describe many aspects of laboratory management practices in order to ensure that the data provided is comparable and scientifically correct, and that it is in a format that can be utilized to inform water quality interventions.

National Rural Drinking Water Programme (NRDWP), provision for setting up new sub-district level laboratories to test the quality of water and bridge the gaps between water quality testing. The decentralized Water Quality Monitoring and Surveillance Program, which began in 2005-06, calls for preliminary testing of all drinking water sources (public and private) using simple field test kits, with only positively tested samples referred to district and sub-district water testing laboratories for confirmation. This programme also includes a sanitary inspection.

The BIS has established specifications for drinking water in its IS-10500 standards. In the Uniform Drinking Water Quality Monitoring Protocol, the new edition of the IS 10500: 2012 standard must be followed. There are two types of limits in this standard: desired limits and maximum allowed or cause for rejection limits. Water is considered unfit for human consumption if any parameter exceeds the cause for rejection standard. According to the Bureau of Indian Standards, IS-10500-2012, water is considered as unfit for drinking in broad terms.

3.5.3 URDPFI

The goal of a public protected water supply system is to provide safe and clean water in sufficient quantities, in a convenient and cost-effective manner. The increased demand for water as a result of growing urbanization is putting great strain on the system. The Indian Standard Organization has established water quality standards, they are:

Table 4 Water Quality Standards by The Indian Standard Organization

S. No.	Characteristics	Requirement (Acceptable limit)	Permissible limit in the absence of alternate source	Method of Test, ref. to part of IS 3025	Remarks
1	Colour, Hazen units, Max	5	15	Part 4	Extended to 15 only, if toxic substances are not suspected in absence of alternate sources
2	Odour	Agreeable	Agreeable	Part 5	Test cold and when heated Test at several dilutions
3	pH Value	6.5-8.5	No relaxation	Part II	-
4	Taste	Agreeable	Agreeable	Parts 7 and 8	Test to be conducted only after safety has been established
5	Turbidity, NTU, Max	1	5	Part 10	-
6	Total dissolved solids, mg/l, Max	500	2000	Part 16	-

(URDPFI, 2014)

Table 5 Bacteriological Quality of Drinking Water

S. No.	Organisms	Requirements
1	All water intended for drinking:	
(a)	E. Coli or thermotolerant coliform bacteria	Shall not be detectable in any 100 ml. sample
2	Treated water entering the distribution system	
(a)	E-Coli or thermotolerant coliform bacteria	Shall not be detectable in any 100 ml. sample
(b)	Total coliform bacteria	Shall not be detectable in any 100 ml. sample
3	Treated water in the distribution system	
(a)	E-Coli or thermotolerant coliform bacteria	Shall not be detectable in any 100 ml. sample
(b)	Total Coliform bacteria	Shall not be detectable in any 100 ml. sample

(URDPFI, 2014)

Table 6 General parameters amounts in drinking water

S No.	Characteristics	Requirement (Acceptable limit)	Permissible limit in the absence of alternate source	Method of test, Ref. No.	Remarks
1	Aluminium (as Al), mg/l, Max	0.03	0.2	IS 3025 (Part 55)	-
2	Ammonia (as total ammonia-N),mg/l, Max.	0.5	No relaxation	IS 3025 (Part 34)	-
3	Anionic, detergents (as MBAS) mg/l, Max.	0.2	1.0	Annex K of IS 13428	-
4	Barium (as Ba), mg/l, Max.	0.7	No relaxation	Annex F of IS 13428 or IS 15302	-
5	Boron (as B), mg/l, Max	0.5	1.0	IS 3025 (Part 57)	-
6	Calcium (as Ca), mg/l, Max.	75	200	IS 3025 (Part 40)	-
7	Chloramines (as Cl ₂), mg/l, Max.	4.0	No relaxation	IS 3025 (Part 26) or APHA 4500-CLG	-
8	Chloride as (Cl)/mg/l, Max.	250	1000	IS 3025 (Part 32)	-
9	Copper (As Cu), mg/l, Max	0.05	1.5	IS 3025 (Part 42)	-
10	Fluoride (as F) mg/l, Max	1.0	1.5	IS 3025 (Part 60)	-
11	Free residual chlorine, mg/l, Min	0.2	1	IS 3025 (Part 26)	To be applicable only when water is chlorinated. Tested at consumer end. When protection against viral infection is required, it should be minimum 0.5 mg/l.
12	Iron (as Fe), mg/l, Max	0.3	No relaxation	IS 3025 (Part 53)	Total concentration of manganese (as Mn) and iron (as Fe) shall not exceed 0.3 mg/l)
13	Magnesium (as Mg), mg/l, Max	30	100	IS 3025 (Part 46)	-
14	Manganese (as Ms), mg/l, Max	0.1	0.3	IS 3025 (Part 59)	Total concentration of Manganese (as Mn) and iron (as Fe) shall not exceed 0.3 mg/l
15	Mineral Oil, Mg/l, Max	0.5	No relaxation	Clause 6 of IS 3025 (Part 39) Infrared partition method	-
16	Nitrate (as NO ₂), mg/l, Max	45	No relaxation	IS 3025 (Part 34)	-
17	Phenolic compounds (as C ₆ H ₃ OH)	0.001	0.002	IS 3025 (Part 43)	-
18	Selenium (as Se), mg/l, Max	0.01	No relaxation	IS 3025 (Part 56) or IS 15303	-
19	Silver (as Ag), mg/l, Max.	0.1	No relaxation	Annex J of IS 13428	-
20	Sulphate (as SO ₄), mg/l, Max	200	400	IS 3025 (Part 24)	May be extended to 400 provided that Magnesium dos not exceed 30
21	Sulphide (as H ₂ S), mg/l, Max	0.05	No relaxation	IS 3025 (Part 29)	-
22	Total alkalinity as Calcium, Carbonate, mg/l, Max.	200	600	IS 3025 (Part 21)	-
23	Total hardness (as CaCO ₃), mg/l, Max	200	600	IS 3025 (Part 21)	-
24	Zinc (as Zn), mg/lr, Max	5	15	IS 3025 (Part 49)	-

(URDPFI, 2014)

3.5.4 DRINKING WATER QUALITY MONITORING AND SURVEILLANCE BY CPHEEO

The Government of India's Ministry of Housing and Urban Affairs (formerly the Ministry of Urban Development) is the nodal ministry in charge of various aspects of urban development, including urban water supply and sanitation, as well as municipal solid waste management, and formulates policies and strategies pertaining to various aspects of urban development in the country. The Ministry also assists the States with technical and financial assistance. Since its establishment under the Ministry of Health in 1954, in response to the recommendations of the Environmental Hygiene Committee, the Central Public Health and Environmental Engineering Organization (CPHEEO) has been involved in all major sanitation programs for the country. The CPHEEO was linked with the Ministry of Urban Development in 1973-74.

CPHEEO is in charge of the country's urban water supply and sanitation, as well as solid waste management. CPHEEO is critical in the processing of schemes submitted to bilateral and multilateral financial organizations such as the World Bank, JICA, ADB, KW.h, and AfD, as well as other external funding agencies.

The Central Public Health and Environmental Engineering Organization (CPHEEO), a Ministry of Urban Development (MoUD) office, has established a guidebook that serves as a standard aide in general wellbeing building by providing a code of everyday practice for general wellbeing designers to follow. The Central Public Health and Environmental Engineering Organization (CPHEEO), a Ministry of Urban Development (MoUD) office, has established a guidebook that serves as a standard aide in general wellbeing building by providing a code of everyday practice for general wellbeing designers to follow.

The manual aims to unify these practices and teaches a rationale for the design and administrative decisions, as well as providing guidance to general health engineers in achieving the goal of providing clean water to all groups in a cost-effective and timely manner. The manual has been updated on a regular basis to reflect new technological advancements and trends in the expansion of protected water supply systems.

CPHEEO Water Quality Standards:

1. Drinking water source that has not been treated conventionally but has been disinfected

Total Coliforms Organism MPN/100ml must be fewer than 50.

Dissolved Oxygen between 6.5 and 8.5 pH 6mg/l or higher

Oxygen Demand in Biochemistry 2mg/l or less after 5 days at 20°C

2. Outdoor Bathing (Organised)

Coliforms in Total The MPN/100ml of the organism must be 500 or less.

Dissolved Oxygen between 6.5 and 8.5 pH 5mg/l or higher

Oxygen Demand in Biochemistry 3mg/l or less after 5 days at 20°C

3. Drinking water source after conventional treatment and disinfection

Total Coliforms Organism MPN/100ml shall be 5000 or less pH between 6 to 9

Dissolved Oxygen 4mg/l or more

Biochemical Oxygen Demand 5 days 20°C 3mg/l or less

4. Propagation of Wild life and Fisheries

pH between 6.5 to 8.5 Dissolved Oxygen 4mg/l or more

Free Ammonia (as N) 1.2 mg/l or less

5. Irrigation, Industrial Cooling, Controlled Waste disposal

pH between 6.0 to 8.5

Electrical Conductivity at 25°C micro mhos/cm Max.2250

Sodium absorption Ratio Max. 26

Boron Max. 2mg/l (CPHEEO, 2005)

3.5.5 CENTRAL POLLUTION CONTROL BOARD

Under the Water (Prevention and Control of Pollution) Act, 1974, the Central Pollution Control Board (CPCB) was established as a legislative body in September 1974. The Air (Prevention and Control of Pollution) Act of 1981 also gave the CPCB powers and responsibilities. It functions as a field formation and also provides technical support to the

Ministry of Environment and Forests under the 1986 Environment Act. The Water Act of 1974 and the Air Act of 1981 establish the CPCB's primary functions as (i) promoting the cleanliness of streams and wells in various areas of the States through water pollution prevention, control, and abatement, and (ii) improving the quality of air and preventing, controlling, or abating air pollution in the country. Monitoring water quality is an important element of water quality management.

Each water usage has distinct quality requirements. As a result, identifying the uses of water in a water body is critical to setting the criteria for the desired quality of that water body. **The Central Pollution Control Board (CPCB)** in India has created the idea of designated best use. According to this, among a body's several uses of water, the one that requires the highest quality is referred to as its designated best use. There are five top uses that have been discovered are:

Table 7 Designated Best Uses of Water

Designated Best Use	Class	Criteria
Drinking Water Source without conventional treatment but after disinfection	A	1.Total Coliforms Organism MPN/100ml shall be 50 or less 2. pH between 6.5 and 8.5 3. Dissolved Oxygen 6mg/l or more 4. Biochemical Oxygen Demand 5 days 20 °C, 2mg/l or less
Outdoor bathing (Organised)	B	1.Total Coliforms Organism MPN/100ml shall be 500 or less 2. pH between 6.5 and 8.5 3. Dissolved Oxygen 5mg/l or more 4. Biochemical Oxygen Demand 5 days 20 °C, 3mg/l or less
Drinking water source after conventional treatment and disinfection	C	1. Total Coliforms Organism MPN/100ml shall be 5000 or less 2. pH between 6 and 9 3. Dissolved Oxygen 4mg/l or more 4. Biochemical Oxygen Demand 5 days 20 °C, 3mg/l or less
Propagation of Wild life and Fisheries	D	1. pH between 6.5 and 8.5 2. Dissolved Oxygen 4mg/l or more 3. Free Ammonia (as N) 4. Biochemical Oxygen Demand 5 days 20 °C, 2mg/l or less
Irrigation, Industrial Cooling, Controlled Waste disposal	E	1. pH between 6.0 and 8.5 2. Electrical Conductivity at 25 °C micro mhos/cm, maximum 2250 3. Sodium absorption Ratio Max. 26 4. Boron Max. 2mg/l
	Below-E	Not meeting any of the A, B, C, D & E criteria

CPCB

3.6 SAFE DRINKING WATER ANALYSIS

3.6.1 GLOBAL ANALYSIS

Diseases connected with insufficient water and sanitation continue to be a major public health concern around the world, particularly in developing countries. In 2003, it was estimated that hazardous water supply and sanitation, including lack of cleanliness, were responsible for 4% of the worldwide burden of illness and 1.6 million fatalities each year. By the end of 2011, 2.5 billion people still lacked access to improved sanitation, and 768 million lacked improved drinking water sources. While access in Asia and Latin America has vastly improved in recent decades, many African countries are still far from meeting the Millennium Development Goals.

Water scarcity affects almost two billion people worldwide, and it is likely to worsen in some areas as a result of climate change and population expansion. At least 2 billion people worldwide use feces-contaminated drinking water. Microbial contamination of drinking water as a result of faecal pollution provides the greatest threat to water safety.

Microbiologically contaminated drinking water can spread diseases such as diarrhea, cholera, dysentery, typhoid, and polio, and is projected to kill 485 000 people every year. In 2020, 74 percent of the world's population (5.8 billion people) had access to a safe drinking-water service. Improved water supply and sanitation, as well as better management of water resources, can help countries thrive economically and reduce poverty.

5.8 billion people used properly managed drinking-water services in 2020, which means they used improved on-premises water sources that were available when needed and were free of contaminants. In 2020, the remaining 2 billion individuals without access to safe services included:

- 1.2 billion people with basic services, which means an improved water source within a 30-minute round trip;
- 282 million people with limited services, which means an improved water source that requires more than 30 minutes to gather water;
- 368 million people using unprotected wells and springs; and

- 122 million people collecting untreated surface water from lakes, ponds, rivers, and streams.

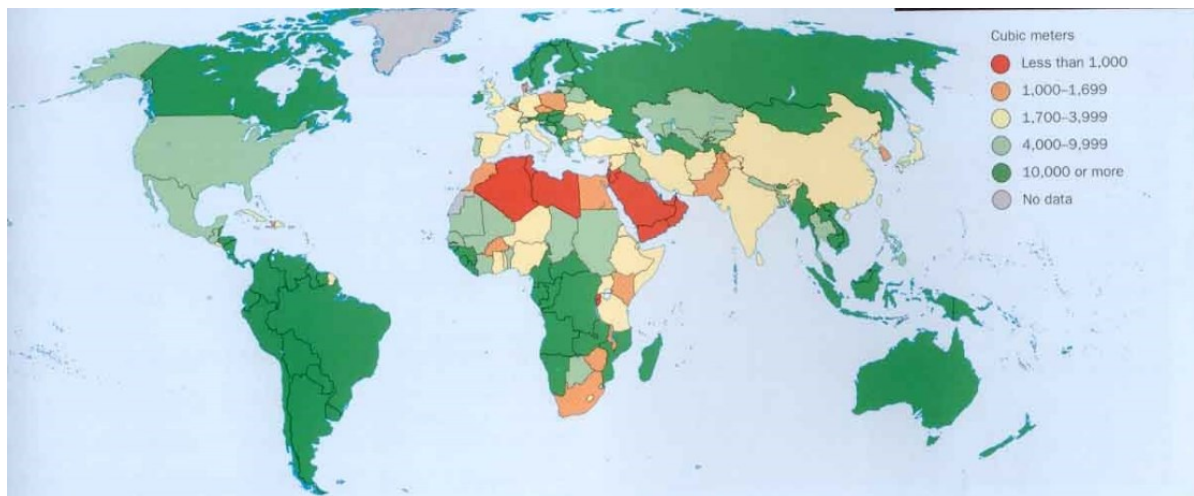


Figure 6 World Map showing Per Capita Availability of Freshwater
(Keller, 2014)

3.6.2 NATIONAL ANALYSIS

Despite having 1.3 billion people, India possesses only 4% of the world's freshwater resources. For a substantial portion of the population, the lack of piped water and the paucity of drinkable water exacerbates the issue. In recent years, India has made considerable progress in providing safe drinking water to both urban and rural populations. Until November 4, 2021, the government's flagship Jal Jeevan Mission has supplied piped water connections to nearly 8.45 crore **rural** homes, or 44 percent of the total 19.22 crore. Six states and union territories have already achieved 100 percent coverage of rural homes with tap water connections. Goa, Telangana, Haryana, Dadra and Nagar Haveli, Andaman and Nicobar Islands, and Puducherry are the states and union territories in question (Mission Pani, 2021).

According to the NSSO (National Sample Survey Office) 69th round, 85.8% of rural Indian families have enough drinking water, compared to 89.6% in urban India. Uttar Pradesh (97.1%) has the greatest number of rural families with access to safe drinking water, while Jharkhand has the lowest (70.3 per cent). Punjab (99.5%) and Kerala (29.5%) have the largest and lowest proportions of families in rural areas with improved source drinking water, respectively.

India is the world's third-largest user of groundwater, ranking 120th out of 122 countries in the Water Quality Index 2019. When it comes to access to safe drinking water in India, the problem is made worse by depleting groundwater, contamination of resources, and ageing supply infrastructure. Rivers, which are one of India's key sources of water, are also diminishing or becoming contaminated as the country's population, industry, and pollution levels rise (Mission Pani, 2021).

The **Jal Jeevan Mission**, aims to give tap water connections to all **rural** families by 2024, has made tremendous headway, the scheme's poor pace in some states is a major source of concern. Uttar Pradesh, the largest state, has only covered 12.4% of its total rural households. Rajasthan, a state known for its water scarcity, only has 20.91% of its over one crore rural households covered. Similarly, Assam (22 percent), Ladakh (16.62 percent), Jharkhand (15.16 percent), West Bengal (13.48 percent), and Chhattisgarh (13.23 percent) have lesser Jal Jeevan Scheme coverage.

Water shortages are also a severe problem in **urban areas**, particularly in slums and unauthorized colonies. According to research released by the World-Wide Fund for Nature (WWF) in 2012, over 30 Indian towns could experience serious water shortages by 2050 due to rapid population growth. According to a recent assessment conducted by the Delhi government, approximately 44 percent of inhabitants in Delhi slums rely on bottled water for drinking. News18 and Harpic India's **Mission Paani** raises awareness about water conservation and amplifies efforts to ensure that everyone has access to safe drinking water, sanitation, and hygiene.

The Department of Drinking Water and Sanitation provides states with technical and financial assistance to ensure that rural India has safe and adequate drinking water, with a focus on service delivery. **The Department's Centrally Sponsored Scheme, the National Rural Drinking Water Programme (NRDWP)**, was reformed and absorbed into the **Jal Jeevan Mission (JJM)** in order to offer Functional Family Tap Connection (FHTC) to every rural household, or Har Ghar Jal, by 2024. The works/schemes proposed to be undertaken under JJM include: in-village water supply (PWS) infrastructure for tap water connection to every household; reliable drinking water source development/augmentation of existing sources; water transfer (multi-village scheme; where quantity and quality issues exist in local water sources); technological intervention

for treatment to make water potable (where water quality is an issue, but quantity is sufficient); and technological intervention for treatment to make water potable (where water quality is an issue, but quantity is sufficient)(Ministry of Jal Shakthi/ Department of Drinking water and Sanitation)

3.6.3 DRINKING WATER ANALYSIS STATE WISE - KERALA

Kerala is known for its abundant water resources, which include rivers, backwaters, lakes, and numerous streams. Kerala, on the other hand, routinely experiences drought and severe water scarcity in many districts. The majority of inhabitants in rural areas of the state get their water from unprotected wells, tanks, rivers, and streams. Protected water supply systems are also not totally available in metropolitan areas. Though water delivery plans have received top priority in Kerala's Five-Year Plans, the availability of potable water across the state remains a severe challenge.

The 13th Five-Year Plan's objective is to ensure drinking water supply to the entire population, with a special emphasis on drinking water supply for scarce metropolitan areas, special attention to well protection, and appropriate measures to reduce distributional loss.

In the drinking water sector, the **Kerala Water Authority (KWA)** and **KRWSA (Kerala Rural Water and Sanitation Agency)** are the main implementing bodies. In this regard, the work of local level institutions is also critical. The Government of India aids States in the implementation of urban and rural water delivery programs as part of its commitment to providing clean drinking water to all citizens. Similarly, the state conducts water supply improvement programs in both rural and urban areas.

The Western Ghats give rise to 41 west-flowing rivers and three east-flowing rivers in Kerala. Kerala has only four medium and forty minor rivers, and the state does not have a single big river according to national standards. A multitude of lakes and backwater lagoons dot the landscape of the state. However, in many regions of the state, there is a major lack of drinking water. Rainfall shortages, which are the primary source of our water resources, have impacted the supply of drinking water in the state. The lack of rain will have an impact on all areas of the economy, including agriculture.

Every year, Kerala receives two monsoons. The state's average rainfall is 3,055 mm, which is twice as much as the national average. In Kerala, the Southwest Monsoon (June to September) receives 69 percent of yearly rainfall, the Northeast Monsoon (16 percent) receives 16 percent, and the Summer Rains receive the remaining ten percent. The water drains quickly into the sea due to Kerala's physiographical layout. During the non-monsoon season, this results in water scarcity in several sections of the state. The rainfall obtained during the 2017 monsoon season was below average.

Kerala has the lowest percentage of people with access to safe drinking water in urban areas (56.8 per cent). As of March 31, 2017, there were 1,073 KWA water supply systems in operation in the state, with a total installed capacity of 3,367.13 MLD (Million liters per day), implying that the average per capita availability of piped water is 104.20 liters per day 989 rural and 84 urban water supply projects are among the 1,073 total.

The number of water supply schemes in operation in the state has decreased, with 1,078 systems in operation the previous year. The city of Thrissur has the most water supply schemes (119), followed by Ernakulam (98). Wayanad is the district with the least coverage under KWA's water supply programs (27). However, in all districts, the LPCD (liters per capita per day) varies with habitation. As of March 31, 2017, Ernakulam had the highest LPCD (201.35) and Kasargod had the lowest (35.77).



Figure 7 District wise coverage of Drinking water
 State Planning Board, Thiruvananthapuram, 2017

House Service Connections (HSC) and street taps are how KWA delivers water. Kerala Water Authority's water supply projects serve 1.81 crore people in the state, accounting for 54% of the population. Piped water is available to 54.19 percent of the rural population and 54.36 percent of the urban population. KWA wants to reach 100% of the population by using 100 LPCD in rural areas and 150 LPCD in urban areas.

In terms of drinking water delivery in **rural regions**, Kollam district has the highest coverage (75%), followed by Ernakulam (74%), Thrissur (68%), and Alappuzha (68%). (68 per cent). Due to its unique natural geographic features, Idukki (29%) has the lowest coverage, followed by Kasargod (29%). (28 per cent). The state's average rural coverage is 54 percent. (State Planning Board, Thiruvananthapuram)

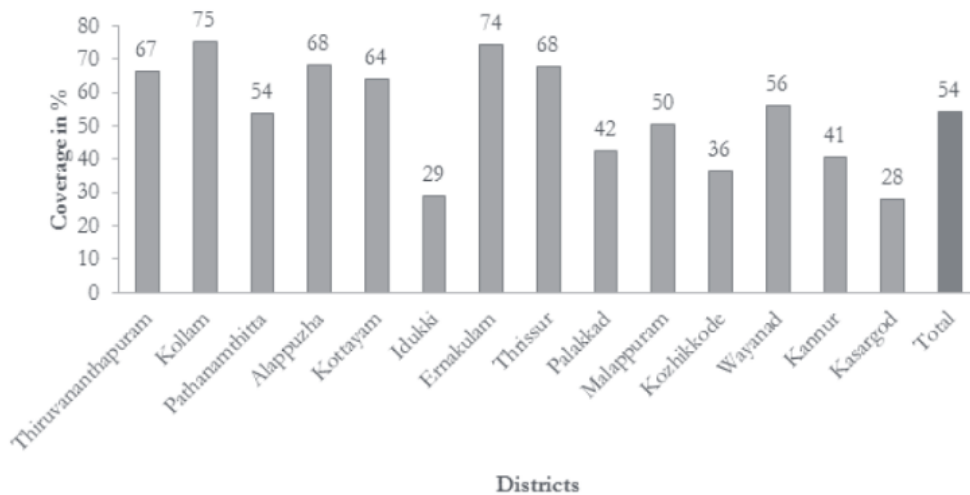


Figure 8 District wise Rural Drinking water coverage

State Planning Board, Thiruvananthapuram, 2017

Kasargod has the lowest coverage of drinking water delivery in **urban Kerala**, at barely 10%. Thiruvananthapuram (76%) is the city with the highest urban water supply coverage, followed by Thrissur (72%), and Palakkad (72%). (State Planning Board, Thiruvananthapuram)

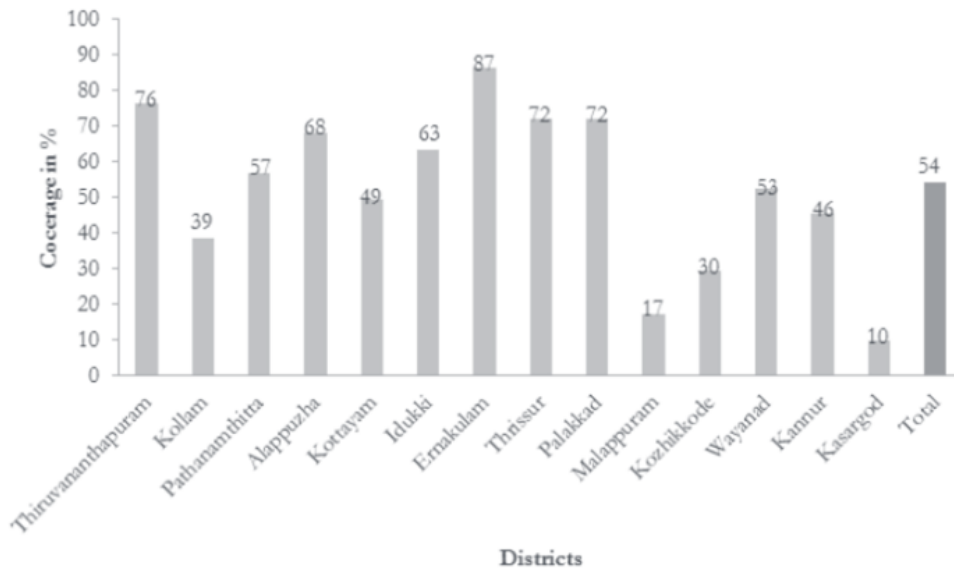


Figure 9 District wise Urban Drinking water coverage
State Planning Board, Thiruvananthapuram, 2017

KWA's total water supply connections, including household, non-domestic, and industrial, increased by 283496 from the previous year to March 31, 2017. Only 1,623 people have access to water for industrial usage. The total number of street taps is 214,097, up 6,063 from the previous year. Panchayats have 159,463 street taps, Corporations have 20239, and Municipalities have 34,395. (State Planning Board, Thiruvananthapuram)

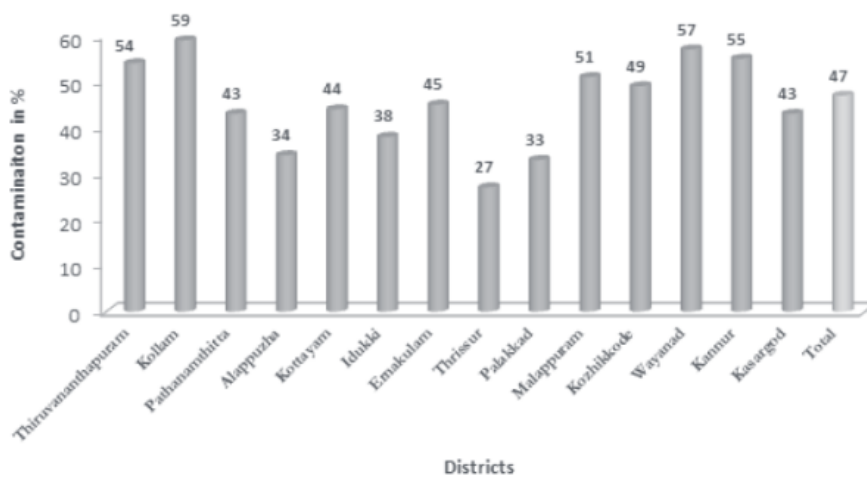


Figure 10 District-wise Contamination Tested, in per cent (as on November 11, 2017)
(State Planning Board, Thiruvananthapuram)

Unscientific sanitation techniques and indiscriminate garbage disposal have damaged the majority of drinking water sources in our state. These supply sources are polluted bacteriologically and chemically. Though Kerala has made progress in many areas, its performance in water quality management is appalling, with negative consequences for both health and the economy.

Waterborne infections are on the rise due to rising population density, indiscriminate use, and widespread pollution of water bodies. The use of dirty water can lead to a variety of waterborne infections, some of which are fatal. Data on the number of waterborne diseases has shown an upward trend over time. In 2012 and 2015, 366,463 and 470,863 cases were reported, respectively. In 2016, this number grew to 497,027. The numbers for the first quarter of 2017 show a total of 97,089.

With the backing of the Kerala Government's Water Resources Department, the Centre for Water Resources Development and Management (CWRDM) is implementing a project called "Establishment of Mobile Testing Laboratory for the Quality Assurance of Water Resources in Kerala." This mobile laboratory aims to enhance community awareness about the importance of protecting water sources. The mobile laboratory's services were extended to about 120 Panchayaths, 15 Municipalities, and three Corporations. Following the testing, consumers were given a drinking water card, and this exercise helped local residents become more conscious of their water quality.

3.7 POTABLE WATER TREATMENT METHODS

The raw water contains numerous contaminants. These contaminants are divided into three groups:

Physical: things that do not dissolve in water and appear to make the water "filthy"

Chemical: compounds dissolved in water as a result of both natural and artificial processes

Biological: organisms include viruses, bacteria, algae, and other microscopic species.

In nature, there is no such thing as "chemically pure" water that is free of all other components. Few people prefer drinking distilled water since it is usually flat and

tasteless. Purifying our entire water supply to that level would be prohibitively expensive and probably unhealthy. "Natural water," which includes no artificial additives, contains concentrations of minerals including calcium, magnesium, and iron, which are good to human health in modest amounts.

Water treatment uses physical, chemical, and biological techniques to eliminate all impurities from the water. Chemical and physical techniques are the most popular treatment methods for drinking water. The biological method is solely for the treatment of wastewater. Slow sand filtering to remove infections and biologically activated carbon process to remove organic pollutants are both viable options.

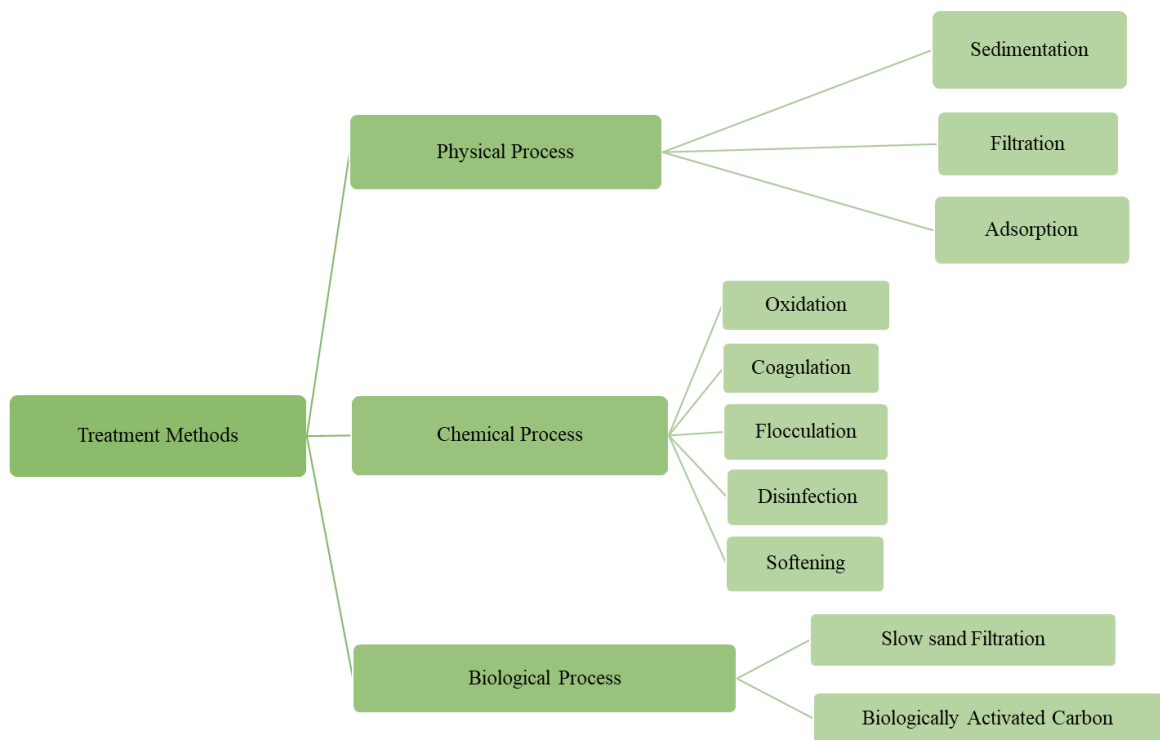


Figure 11 Water Treatment Classification Methods

Author Generated

3.7.1 PHYSICAL PROCESS

Larger creatures, such as fish, and plant items, like as branches and logs, will be screened out of the raw water entering the treatment plant.

1. SEDIMENTATION:

- Water quality is improved by storing it undisturbed and without mixing it for long enough for larger particles to settle out/sediment by gravity.
- Decanting, ladling, or other gentle ways are used to remove the settled water.
- Particles sink to the bottom in calm conditions, when flow velocities and turbulence are low.
- Decanting, ladling, or other procedures will be used to remove the collected solid at the bottom, known as sludge.
- Large, dense particles such as sands and silt, as well as larger microorganisms and smaller particles associated with large particles, will sediment after a few hours of storage.
- Larger microorganisms, as well as some nuisance bacteria like algae and clay particles, will be removed by settling times of more than 24 hours to 1- 2 days.
- Sedimentation efficacy for viruses and bacteria rarely exceeds 90%, but helminth ova and some protozoans do, especially when stored for prolonged periods of time.
- The density, size, drag, buoyancy, temperature, and viscosity of water all affect sedimentation.
- Sedimentation is excellent in reducing turbidity in water, but not always at reducing microbiological contamination.
- Sedimentation also increases the aesthetic quality of the environment.

2. FILTRATION:

- Particles and at least some bacteria are removed from the water using an ancient and commonly used method.
- It is the process of filtering water to remove suspended and colloidal particles.
- Straining, Settling, and Adsorption are some of the physical processes involved.
- Water and particles (floc) settle, adsorb, and gather on the upper area of the filter media when they enter the filter. This raises the pressure above the particles, which causes them to fall into the media.
- Backwashing removes the clogged area of the filter bed.

Filter Media

- Silica sand, greensand, anthracite coal, and activated carbon make up this mixture.
- Each material can be used as a stand-alone filter or combined to produce better filtering.
- Dual media (anthracite coal + silica sand) and single media (anthracite coal + silica sand) are the two most prevalent granular media filters.
- Filters made of anthracite coal, silica sand, and fine garnet
- In mixed filter media, the most typical filter arrangements are
 - Anthracite(top) + green media – to remove inorganic pollutants such as Mn and Fe
 - To adsorb organic pollutants known as contactors, activated carbon and silica sand are used.

3. ADSORPTION

- The adsorption technique can remove both organic and inorganic pollutants from water. Adsorption is the accumulation of a material on the surface of a solid called adsorbent.
- Adsorbents include activated carbon, ion exchange resins, and metal oxide, as well as aluminium or ferric chloride floc that forms during flocculation. This floc has the ability to absorb organic carbon as well as inorganics like arsenic.
- Metal oxide, ion exchange, and activated carbon are examples of stationary media.
- Activated carbon assists in the removal of a wide range of organic pollutants.
 - **Organic Adsorption:**
 - Activated carbon can remove a wide range of organic pollutants.
 - It can either be injected into the water as a powder (PAC) or placed in a vessel as granules (GAC) for the water to pass through.
 - **Inorganic Adsorption:**
 - The adsorption technique can be used to remove some inorganic pollutants.
 - Adsorption might take place on the media's surface or on the floc's surface.

- Ferric oxide or activated alumina are common adsorption media.
- Arsenic, manganese, fluoride, and other inorganic chemicals can be eliminated via adsorption.

3.7.2 CHEMICAL TREATMENT PROCESS

1. COAGULATION

- If given enough time, most organic and inorganic particles suspended in water but not dissolved will settle away.
- The principal components of colour and turbidity, on the other hand, are either dissolved or too tiny to settle.
- Colloidal material, which is less than one micrometre in size (0.001 mm), is the source of the problem.
- Electrical charges on the surface of colloids prevent them from settling in an acceptable amount of time.
- The influence of the surface charges offsets gravity at one micrometre (sometimes described as 1 μm) in size, and the particles remain suspended.
- A particle 0.01 mm in diameter, for example, will settle one foot in 33 minutes, but a particle 0.0001 mm in diameter (a colloid) will take 230 days to settle one foot.

Colloidal material is divided into two categories:

- Hydrophobic - Hydrophobic refers to a person who is afraid of water. Hydrophobic colloidal substance is generally inorganic and has a negative electrical surface charge, which adds to turbidity.
- Hydrophilic - Hydrophilic is a word that implies "love of water." Organic material, which is the most prevalent source of colour in water, makes up the majority of hydrophilic colloidal material. Because hydrophilic substances are surrounded by water molecules, they tend to be negatively charged.
- Organic substance that passes through a membrane filter with a 0.45 micrometre pore size is considered dissolved.

- Humic and fulvic acids, which can generate colour in water and are quantified as organic carbon, are among these compounds (both TOC and DOC).

Coagulants:

The clearance of colloidal particles is influenced by two competing forces:

- Stability factors - those that aid in the dispersion of colloids.
- Instability factors - those that contribute to colloids being naturally removed.

Coagulation:

Coagulation is the process of lowering the stability of colloids in water. Coagulation occurs when iron, aluminum, or cationic polymer²⁸ salts are added to water.

The following are some examples of common coagulants:

- Aluminium Sulphate
 - Sodium Aluminate.
 - Ferric Sulphate
 - Ferrous Sulphate
 - Ferric Chloride.
 - Polyaluminum Chloride (PAC)
 - Cationic Polymers
- Coagulation can occur when metal salts or polymers are added to water that contains negatively charged impurities.
 - The most straightforward coagulation procedure involves alum and water. When alum is dissolved in water, it undergoes a chemical reaction that produces positive-charged aluminium ions.
 - The negatively charged aluminium ions are subsequently linked to the negatively charged colloid's surface.
 - The total outcome is a decrease in negative surface charges, which leads to the formation of agglomerate (floc).
 - Coagulation's main contribution to the removal of turbidity, colour, and microbes is this destabilising factor.

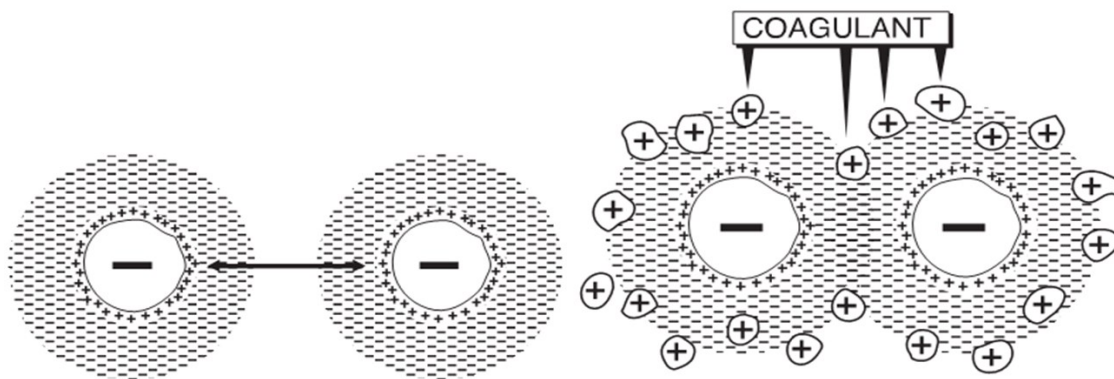


Figure 12 Hydrophobic Particles, Hydrophobic Particles after Coagulation

(Basumatary, 2021)

The process of coagulation is influenced by

- pH
 - Turbidity
 - Temperature
 - Alkalinity
- The extent to which these parameters have an impact is determined by the type of coagulant utilised.
 - The procedure is more influenced when metal salts are utilised as the principal coagulant than when polymer cations are used.
 - There are three types of polymers that are commonly used:
 - Cationic polymers are positively charged polymeric compounds.
 - Anionic polymers are negatively charged polymeric compounds.
 - Non-ionic polymers are polymeric compounds that have no charge.

2. FLOCCULATION

Flocculation is a physical process that involves slowly mixing coagulated water in order to improve the likelihood of particle contact. The floc is formed as a result of this process. Floc is a substance that resembles a snowflake and is made up of colloidal particles, bacteria, and precipitate.

Flocculants:

- Flocculation can occur even if only the primary coagulant is used.

- Additional chemicals can be added to improve the coagulated materials' settling or filtering properties, known as floc. Anionic polymers are the most common flocculants.
- Anionic polymers boost the speed of floc production, as well as the floc's strength and weight.
- Depending on the temperature, the flocculation process takes 15-45 minutes.

3. OXIDATION

- Chemical oxidation is used in water treatment to help remove inorganic contaminants like iron (Fe²⁺), manganese (Mn²⁺), and arsenic (As), enhance particle removals through coagulation, and eliminate taste- and odour-causing chemicals.
- To increase the removal of inorganics, particles, taste, and odour, oxidation can be employed before coagulation, filtering, adsorption, or sedimentation.
- Chlorine and potassium permanganate (KMnO₄) are the most prevalent oxidants in tiny systems. Ozone and chlorine dioxide can be employed to a lesser extent.
- Process requirements, operating cost, chemical safety, and operational complexity all play a role in determining which oxidant is the most desirable.
- Oxidants are given as a gas or a liquid injection. The gas or liquid mixes or diffuses into the water stream very quickly.
- The pace of the reaction is determined by the type of oxidant, the type of pollutant, pH, and the temperature of the water. In general, a lower pH or lower water temperature slows the rate of oxidation.
- The addition of other pollutants, such as organic carbon, ammonia, manganese, or sulphur, might delay the oxidation rate or raise the oxidant demand.

Table 8 Oxidant Demands for Chlorine and Potassium Permanganate

Oxidant	Contaminant	Demand
Chlorine	Fe ²⁺	0.64 mg Cl ₂ /mg Fe ²⁺
	Mn ²⁺	1.29 mg Cl ₂ /mg Mn ²⁺
	As ³⁺	0.95 mg Cl ₂ /mg As ³⁺
Potassium Permanganate	Fe ²⁺	0.94 mg KMnO ₄ /mg Fe ²⁺
	Mn ²⁺	1.92 mg KMnO ₄ /mg Mn ²⁺
	As ³⁺	1.26 mg KMnO ₄ /mg As ³⁺

4. DISINFECTION

- Disinfection is the process of controlling waterborne pathogenic organisms and, as a result, preventing waterborne disease.
- The purpose of water disinfection is to render all disease-causing organisms inactive.
- Inactivation is performed by changing or eliminating the microbe's key structures or functions.

Denaturation is one of the inactivation processes which includes:

- proteins (structural proteins, enzymes, transport proteins)
- nucleic acids (genomic DNA or RNA, mRNA, tRNA, etc)
- lipids (lipid bilayer membranes, other lipids)

An Ideal Disinfectant's Characteristics:

- Broad range activity: effective against all bacteria.
- Effective in the presence of organic matter, suspended particles, and other matrix or sample ingredients.
- Fast acting: induces fast inactivation.
- Nontoxic, soluble, non-flammable, and non-explosive;
- compatible with a wide range of materials and surfaces.
- For the duration of the desired exposure period, stable or persistent.
- Ensures that there is a residue (sometimes this is undesirable)
- It's simple to create and use.
- Economical.

Disinfectants Methods in Water Treatments are:

- Free Chlorine
- Monochloramine
- Ozone
- Chlorine Dioxide
- UV Lights
 - Mercury lamp with low pressure (monochromatic)
 - Mercury lamp with a medium pressure (polychromatic)

- Broadband radiation in pulses
- Boiling - Used in many nations at the household level and in crises.
- Iodine -Short-term use of iodine is safe; long-term use poses a health risk.

Properties of Water Disinfectants:

- Free chlorine: HOCl (hypochlorous) acid and OCl⁻ (hypochlorite ion) HOCl (hypochlorous) acid at low pH and OCl⁻ (hypochlorite ion) at high pH HOCl is a more powerful germicide than OCl⁻ at high pH. In water, it's a strong oxidant that's relatively stable (provides a disinfectant residual).
- Chloramines (mainly NH₂Cl) are a weak oxidant that leave a stable residue.
- Ozone (O₃) is a powerful oxidant that leaves no behind (too volatile, reactive).
- ClO₂ (chlorine dioxide) is a potent oxidant that is also unstable (dissolved gas). Concerns about chemical disinfectants and their by-products (DBPs), particularly free chlorine and its DBPs, posing a health concern.
- UV radiation: low pressure mercury lamp (low intensity; monochromatic at 254 nm; medium pressure mercury lamp (high intensity; polychromatic at 220-280 nm) pyrimidine dimers and other changes are the most common reactions with nucleic acids.
- Boiling: effective kill; no residual protection; high fuel and environmental costs

5. SOFTENING

- The process of eliminating the dissolved calcium and magnesium salts that produce hardness in water is known as water softening.
- Ion exchange or adding compounds that generate insoluble precipitates are two methods for softening water. Ammonia, borax, calcium hydroxide (slaked lime), or trisodium phosphate are some of the chemicals used for softening on a modest scale, frequently in combination with sodium carbonate (soda ash).
- To eliminate the precipitates, the lime-soda method of water softening must be followed by sedimentation and filtering.
- On a wide scale, water can be chemically softened by adding just enough lime to precipitate the calcium as carbonate and the magnesium as hydroxide, followed by the addition of sodium carbonate to eliminate the leftover calcium salts.

- Water softening by ion exchange is a typical industrial practise.
- Water is passed through columns of a natural or synthetic resin that exchanges sodium ions for calcium and magnesium ions.
- Calcium and magnesium begin to appear in the water leaving the column after it has been in use for a while.

3.7.3 BIOLOGICAL PROCESS

Microbial biomass has been utilized to decompose pollutants, fertilizers, and organics in wastewater since the early 1900s. Drinking water biological treatment is restricted, but recent discoveries may indicate that biological drinking water treatment is becoming more viable and likely to be accepted by the general population.

(1)The emergence cost and increased complexities of residue treatment; (2) The emergence of new contaminants that are particularly amenable to biological degradation (e.g., perchlorate); (3) the push for green technologies (i.e., processes that efficiently destroy contaminants instead of concentrating them); (4) regulations limiting the formation of disinfection by-products (DBPs); and (5) the emergence of new contaminants that are particularly amenable to biological degradation (e.g., perchlorate).

PROCESS:

Bacteria obtain energy and reproduce by facilitating the flow of electrons from reduced to oxidized substances. When a reduced chemical donates electrons, they go back and forth across the mitochondrial membrane of a cell in a series of internal oxidation-reduction reactions. The electrons are eventually given to the terminal electron-accepting molecule. This set of processes, together referred to as the electron-transport chain, provides an electrochemical gradient across the cell membrane that bacteria exploit to produce adenosine triphosphate, or energy. When a compound gains or loses electrons, it is transformed to a new, typically harmless, form that is thermodynamically more stable than the original complex. (BROWN, 2007)

The establishment of bacterial communities capable of mediating oxidation-reduction reactions involving at least one target pollutant is the basis of biological drinking water

treatment techniques. Organic electron donors are used in heterotrophic biological activities (e.g., acetic acid).

1. SLOW SAND FILTRATION

Slow sand filtration is a sort of water purification system that is either centrally or semi-centrally located. Through a combination of biological, physical, and chemical processes, a well-designed and well-maintained slow sand filter (SSF) successfully removes turbidity and harmful organisms in a single treatment step. Only when a sufficient amount of turbidity or algal pollution is present can pre-treatment steps become necessary. Slow sand filtering systems have a high level of dependability and relatively moderate lifecycle costs. Slow sand filtration is a viable filtration method for small to medium-sized rural settlements with rather good surface water quality. Slow sand filtration, according to the WHO, is a basic yet highly effective and very inexpensive method that can contribute to a sustainable water management system.

PROCESS

- Freshwater that has been contaminated passes through a layer of sand, where it is not only physically filtered but also biologically treated.
- Both sediments and pathogens are eliminated in this way. This method is based on organisms' ability to eliminate infections.
- It's critical to distinguish between slow and fast sand filtration.
- The distinction between the two isn't only an issue of filtration speed; it's also a matter of the treatment process's core principle.
- Rapid sand filtration is a physical treatment method, whereas slow sand filtration is basically a biological process.
- Although physical sediment removal is an important part of the purification process, biological filtration is the most critical aspect.
- The creation of a microbial community on the top layer of the sand substrate, also known as 'schmutzdecke,' makes the top layers of the sand biologically active.
- These microorganisms normally enter the system through the source water and form a community within a few days.

- The fine sand and modest filtration rate make it easier for this microbial community to grow.
- Predatory bacteria make up the majority of the community, feeding on waterborne germs that pass through the filter.
- As a result, the SSF's core concept is the same as bio-sand filtration. The former is used in semi-centralised water treatment, whereas the latter is primarily used in households.

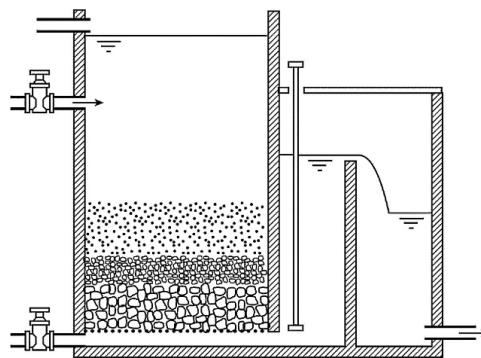


Figure 13 Slow Sand Filter

(Marco A. Bruni)

STRUCTURE

- The framework is pretty simple. Only the filter chamber, a reservoir of some sort, and pipelines are necessary.
- The filter chamber can be built as either an open or closed box.
- The one or the other is more reasonable depending on climatic and other conditions (e.g., cold climate requires a closed box since low temperatures decrease the performance of the process).
- Once an SSF is constructed, only clean sand has to be replaced on a regular basis. The sand layers are added in layers, with coarse grains at the bottom and fine grains at the top, according to grain size.
- One metre of supernatant water normally covers the sand-bed. Because biological filtration takes a long time to sufficiently filter water, SSFs typically operate at sluggish flow rates of 0.1–0.3 m³/h per square metre of surface.

- As a result, the water stays in the region above the medium for several hours, allowing larger particles to separate and settle (see also sedimentation). It then travels into the sand-bed, where it undergoes a series of purifying procedures.
- To pass the drag generated by the sand layers, the water requires some type of physical pressure. In terms of construction, two options are available. Pumps or gravity can be used to increase the pressure.

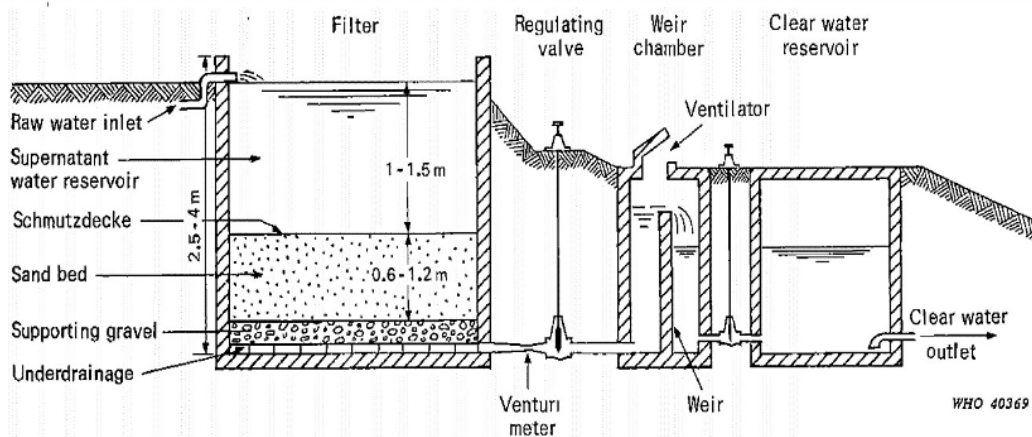


Figure 14 Slow Sand Filter with A Regulating Valve and A Subsequent Reservoir
(Marco A. Bruni)

Slow sand filtration is a highly effective method for eliminating microbial contamination, with no indicator bacteria often present at the outflow. Protozoa and viruses are also effectively removed by SSFs. If the effluent turbidity is less than 1.0 nephelometric turbidity units (NTU), bacteria and viruses are reduced by 90 to 99 percent. However, for the vast majority of chemicals, slow sand filtration is ineffective (WHO). Chemical requirements for drinking water, on the other hand, may be argued to be of secondary importance in water supplies with high bacterial contamination (WHO).

Although SSFs are quite successful at removing microbiological pathogens, disinfectants (e.g., chlorination) are frequently utilized as a step after the SSF unit in treatment facilities. First, as a final unit of treatment, to inactivate any remaining bacteria, and second, to provide a residual disinfectant that will eradicate any germs introduced during storage and/or distribution. To avoid interfering with the biological process, chlorine is usually injected after the filter unit. Chlorination should be avoided if the water includes a lot of natural organic matter (NOMs) since it can cause disinfection by-products (DBPs).

NOMs produce trihalomethane (THM) and other organic DBPs when damaged by chlorine radicals, which are known to be carcinogenic.

Highly effective for	Somewhat effective for	Not effective for
- Bacteria	- Odour, Taste	- Salts
- Protozoa	- Iron, Manganese	- Fluoride
- Viruses	- Organic Matter	- Trihalomethane (THM) Precursors
- Turbidity	- Arsenic	- Majority of chemicals
- Heavy metals (Zn, Cu, Cd, Pb)		

Figure 15 Treatment Performance of Slow Sand Filters.

(Marco A. Bruni)

2. BIOLOGICALLY ACTIVATED CARBON

Many water utilities are considering the biologically enhanced active carbon method. GAC (granular activated carbon) has long been used to remove dissolved organics from drinking water. Bacteria that thrive in GAC filters may be responsible for a fraction of the net organic's removal in the filter, according to research published in the early 1970s. Following this discovery, it was shown that pre-ozonation dramatically increased the biological activity of GAC. The biological activated carbon (BAC) process, also known as the **biologically enhanced active carbon process**, is a mix of ozonation and GAC.

The Biological Activated Carbon process is based on activated carbon technology, which purifies raw water using the synergistic impact of adsorption on activated carbon and biodegradation. Because activated carbon has a large specific surface area and a well-developed pore structure, it has a strong absorption capacity for dissolved oxygen and organics in raw water. In Biological Activated Carbon technology, activated carbon is used as a carrier, and microorganisms are accumulated or artificially immobilized on the surface of the activated carbon, where they reproduce and eventually form BAC, which can perform both adsorption and biodegradation functions simultaneously.

The interaction of activated carbon particles, bacteria, pollutants, and dissolved oxygen in aqueous solution is the basis of Biological Activated Carbon technology. The interaction between activated carbon and pollutants is simply the result of activated carbon

adsorption, and the reaction is determined by the activated carbon and contaminants' characteristics. Meanwhile, activated carbon can absorb DO, and microorganisms that have affixed themselves to the activated carbon's surface and feed on DO will destroy pollutants. In summary, by combining these four criteria, the goal of eliminating contaminants from raw water can be accomplished by using biological activated carbon.

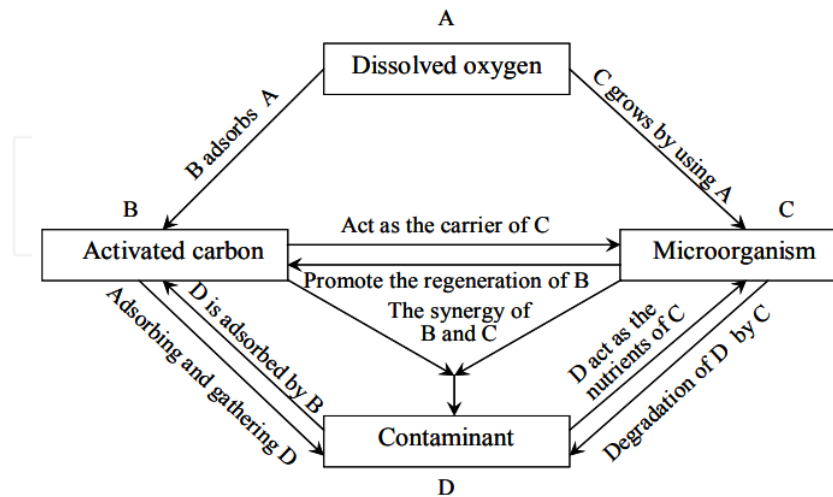


Figure 16 Simplified Interaction Model of Factors in BAC Process

(Pengkang Jin, 2021)

The use of BAC technology is primarily focused on three aspects: advanced water treatment, industrial waste water treatment, and advanced water treatment. The standard advanced treatment procedure for drinking water and sewage reuse.

All three methods are based on the traditional coagulation-sedimentation-filtration method. They are distinct from the two processing points for importing ozone and activated carbon, which are located at different locations. The activated carbon technique is sandwiched between sedimentation and filtration in Process A. The activated carbon layer's outflow will carry some microscopic carbon particles and bacteria, which will eventually be removed by a sand filter. Prior to this treatment, chlorination and improved coagulation were performed to improve filtration efficiency. The purity of the outflow is ensured in this procedure by using a higher ozone dosage.

While in Process B, ozonation and activated carbon are applied after filtration, removing ozone-depleting chemicals and resulting in a lower ozone dosage than in Process A.

Micro carbon particles and microorganisms that leap out of the activated carbon layer, on the other hand, will have a negative impact on the outflow quality, necessitating frequent backwashing of the activated carbon layer.

The only difference between Process c and Process b is that Process c uses a two-level ozone technique, which means that ozone is added separately before and after sand filtering. The rest of the operations are the same. To boost filtering efficiency, a lower ozone dosage is employed before sand filtration. It's also commonly utilized in the treatment of industrial waste water, including printing and dyeing wastewater, food processing wastewater, pharmaceutical wastewater, and so on.

These three technological steps are clearly linked to oxidation-BAC technology throughout the normal BAC treatment process. Contact oxidation-BAC has its own set of properties as compared to traditional biochemical technology. To begin with, contact oxidation can eliminate organics and ammonia-nitrogen, reduce odours and the amount of DBPs precursor, and reduce the chance of bacteria regrowth in the pipeline, all of which contribute to increased biological stability. Second, contact oxidation can reduce the BAC treatment processing load and, to some extent, extend the working life and capacity of residual filtration and BAC, resulting in a safer, more dependable outflow.

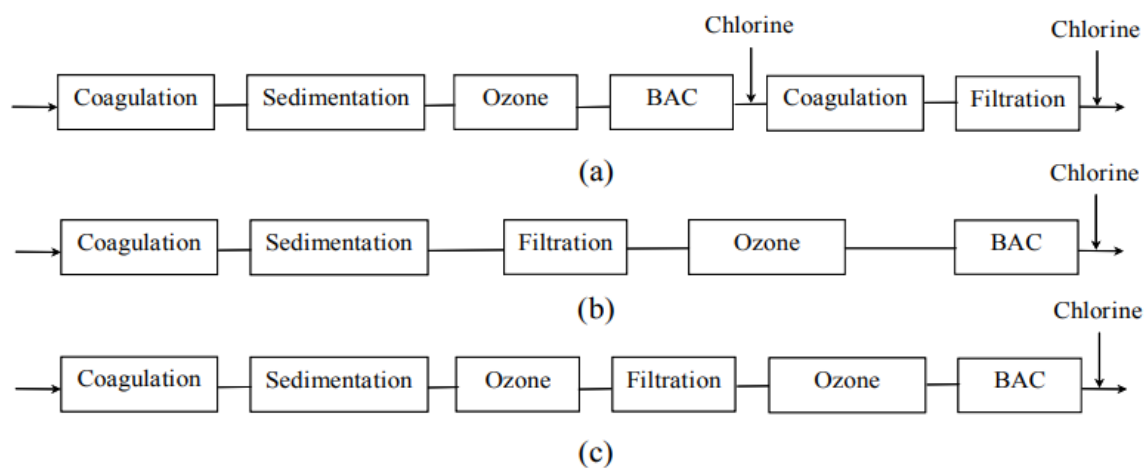


Figure 17 Typical processes of BAC
(Pengkang Jin, 2021)

CHAPTER 4 CASE STUDY

4.1 DESIGN OF 24X7 WATER SUPPLY SYSTEMS, A CASE STUDY: AHMEDABAD CITY

One of the most critical environmental challenges that various countries are addressing is the declining availability of water supplies. 24 hours Intermittent service, in which individuals receive water for a restricted number of hours each day, is common in many urban areas. There are two major benefits to continuous supply. One advantage is that people can draw water whenever they need it. The second benefit is that pollution is not retained. Contamination can leak in through cracks and holes while pipes are mostly empty. The water pressure in a pipe carrying water 24 hours a day, on the other hand, will not allow this because it is operating centrifugally. One of the most crucial requirements for smart cities is continuous water supply.

4.1.1 STUDY AND FINDING

The Local Body is responsible for providing 125-150 litres of water per head per day per household, 24 hours a day, with acceptable pressure, and for keeping up with the metropolitan areas' demographic increase. As a result, local governments devised a strategy of limiting the supply time. Almost all municipal governments now cut supply for their city supplies to the tune of a few hours or even minutes. Despite the availability of sufficient raw water and treatment plants, there is a lack of an effective water supply system, resulting in low user satisfaction. Currently, the water supply department supplies water based on time of supply rather than user demand, as per the CPHEEO manual's guidelines (Gov. of India). As a result of the government's practise of limiting water supplies, residents try to conserve as much water as possible throughout the supply period. As a result, every household's taps are left fully open during the supply time, resulting in excessive consumption of water. During a limited supply phase, water storage is simply transferred from municipal storage to individual households.

According to the Ministry of Urban Development, Government of India's guideline for continuous water supply, the area has been divided into small District Metering Areas (DMA). The essential building blocks (Wards) of the zones distribution system are District Metering Areas, which give a controllable unit through which distribution

consumers and performance information may be achieved. West Zone has the largest proportion of population and area covered by water distribution network among the 6 zones of Ahmedabad city, while Sabarmati and old Wadaj have the highest coverage of population with treated tap water within premises among all wards of the west zone. As a result, these two wards have been chosen for a detailed examination of the 24x7 water project. WaterGEMS was used to create a hydraulic model of a 24-hour water supply system. "WaterGEMS is a water distribution system hydraulic modelling solution with advanced interoperability, GIS model construction, optimization, and asset management facilities." ArcGIS and AutoCAD are included in WaterGEMS."



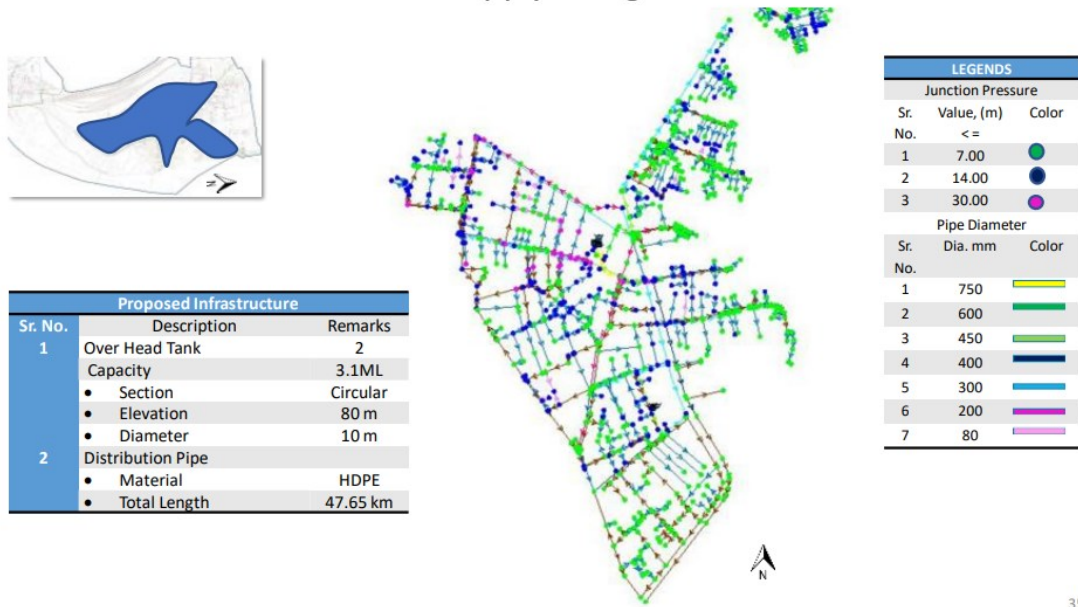
Figure 18 Design Process in WaterGEMS

(Shah, 2018)

4.1.2 DATA COLLECTION AND DESIGN

For chosen DMAs, data was collected from census data and the local government's water supply department. Based on the design, it was determined that 85 percent of the existing network would need to be replaced in order to convert intermittent to 24x7 water delivery. There are three technological options for implementing a 24x7 water delivery system, each with its own material and construction technology.

Sabarmati Ward – 24x7 water supply Design



35

Figure 19 24x 7 Water Supplies Design for Sabarmati Ward

(Shah, 2018)

Wadaj Ward – 24x7 water supply Design

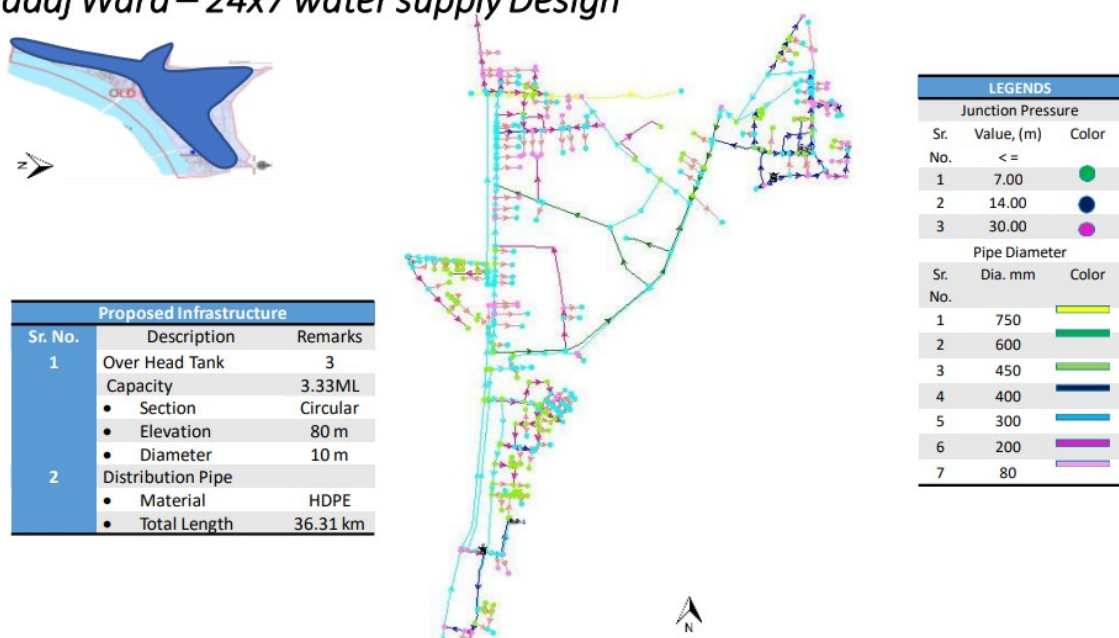


Figure 20 24 X7 Water Supply Design for Old Wadaj Ward

(Shah, 2018)

4.1.3 COST ANALYSIS SCENARIO

Three scenarios were chosen for cost analysis based on the available options. Each has its own set of advantages in terms of cost, technology, the environment, and social and economic factors.

1. 85 percent distribution system replacement with existing material and traditional excavation method (The total project cost is 54 crores).
2. Trenchless Technology was used to replace 85 percent of the distribution system using existing material (Total Project cost is fifty-seven cr.).
3. Trenchless Technology and High-Density Polyethylene HDPE Pipes are used in a new distribution system (The total project cost is 72 crores.).

Option 3 for the 24x7 water delivery system in both wards was chosen after analysing the project's social, environmental, and long-term viability.

Table 9 Total cost of the Project

Sr. No.	Description	Total Cost, Cr. Rs
1	Total Cost of the Project in Sabarmati Ward	38.87
2	Total Cost of the Project in Old Wadaj Ward	32.77
TOTAL PROJECT COST Rs.		72.00

(Shah, 2018)

4.1.4 ECONOMIC FEASIBILITY

Water and sewerage service revenues in India often cover less than 30% of operational costs. As a result, the government must extensively subsidize water and sewerage services. The main focus should be on better infrastructure, which is directly linked to better service delivery to people. As a result, the Indian government has implemented the AMRUT and Smart City schemes. In the financial year 2016-17, Ahmedabad received Rs. 115 crores under the AMRUT Scheme for water augmentation and water projects.

It is advised that projects be implemented on a PPP basis with 90% government shares and 10% public shares for better finance and project success. According to the calculations and research, the cost of installing a water metre for each dwelling is Rs. 2,300, with a monthly operating and maintenance price of Rs. 200. The telescoping tariff for water usage has been designed in four slabs based on water usage in different premises such as residential and commercial.

Telescopic tariffs are:

- a) Rs.7.5/kilo litre when water usage is between 13.5 and 20.25 kilo litre (KL) per month;
- b) Rs.10/KL when water usage is between 20.25 and 27KL per month;
- c) Rs.15/KL when water usage is between 27 and 33.75 KL per month; and
- d) Rs.30/KL when water usage is higher than 33.75 KL per month.

Revenue generated from the connection, operation & maintenance charge and water tariff helps to recover the expense incurred in the project:

Table 10 Total Revenue generate from the project

Sr. No.	Description	Unite No.	Rate Rs.	Total Cost in Cr. Rs.
1	One time connection charge	30,531 households	2,300.00	70.22
2	O & M cost	30,531 households	2,400.00	73.27
3	Average water usage charge	30,531 households	21,972.00	16.77
TOTAL REVENUE COST Rs.				31.12

(Shah, 2018)

E/R ratio = $31.12 / 64.80 \times 100 = 48.05\%$ which is less than 100

(10% of total project cost is 7.2cr will be from the public, remaing 64.80 cr from GoI)

E/R ratio which is less than 100 shows that the project is economically viable to execute and the project recovery is short term.

4.1.5 CONCLUSION

1. To meet service level benchmarks, Ahmedabad city has the greatest need to change its water distribution system from intermittent to 24x7 water deliveries.
2. Among Ahmedabad's six zones, the West Zone has the highest coverage of area and population by water distribution network; Sabarmati and old Wadaj are two of the ten wards in the west zone with the highest percentage of population covered by water distribution network, and the majority of households have treated tap water within their premises.
3. The design of a water distribution network for Sabarmati and old Wadaj wards using WaterGEMS demonstrates that to convert an intermittent to a 24x7 water delivery system, approximately **85 percent of the present network must be replaced.**

4. For the 24x7 water supply system, there is need for constructing more elevated storage reservoir in both wards,
 - Sabarmati Ward: Total 3.1 ML capacity
 - Old Wadaj: Total 3.33ML capacity
5. There are three technological options for implementing a 24x7 water delivery system, each with its own material and construction technology.

Table 11 Scenario wise project cost

Sr. No.	Ward	Scenario 1	Scenario 2	% Increase	Scenario 3	% Increase
1	Sabarmati	29.12	30.92	6.18	38.87	33.44
2	Old Wadaj	24.94	26.30	5.45	32.76	31.34

(Shah, 2018)

6. Scenario 3 has been chosen for the 24x7 water supply system in both wards, taking into account the project's social, environmental, and long-term viability.
7. The money is split between the government and the general public (90:10).
8. The cost of installing a water metre is Rs. 2,300 per property, with a monthly operating and maintenance price of Rs. 200 per dwelling.
9. The telescoping tariff has been designed in four slabs for water usage.

Table 12 Telescoping Tariff

Sr. No.	LPCD	Kilo Liter	Charge Rs /Kilo Liter	Range Rs / Month
1	100-150	13.50-20.25	7.50	102-152
2	150-200	20.25-27.00	10.00	202-270
3	200-250	27.00-33.75	15.00	405-507
4	>250	33.75 & More	30.00	>1012

(Shah, 2018)

10. Since E/R ratio of the project is 48.05% shows that this project is economically viable to execute and it is a short-term recovery project.

4.1.6 CONCLUSION

Issues faced are:

- Interrupted water supply
- Polluted drinking water
- Lack of an effective water supply system

Measures taken are:

- Ministry of Urban Development, formulated some guideline for continuous water supply - the area has been divided into small District Metering Areas (DMA).
- Hydraulic modelling solution known as WaterGEMS distribution system was formed.
- The project was implemented on a PPP basis - 90% government shares and 10% public shares for better finance and project success.
- Better infrastructure was developed to improve the service delivery to people.
- Tariff has been designed in four slabs based on water usage.
- Public awareness

4.2 A SOCIAL-ECOLOGICAL ANALYSIS OF DRINKING WATER RISKS IN COASTAL BANGLADESH

More than 25 million coastal residents in the lowest portions of the Ganges Brahmaputra-Meghna (GBM) delta in South Asia, salinity causes substantial drinking water concerns. The Sustainable Development Goals (SDGs) face significant challenges in reaching the excluded pockets of unserved populations, enhancing service levels for those with basic access, and maintaining current and future water infrastructure. Inadequate and unplanned investments in water supply infrastructure, are a major cause of governments' inability to provide basic services. Water security is characterized by four intersecting risks - environmental, institutional, financial and social.

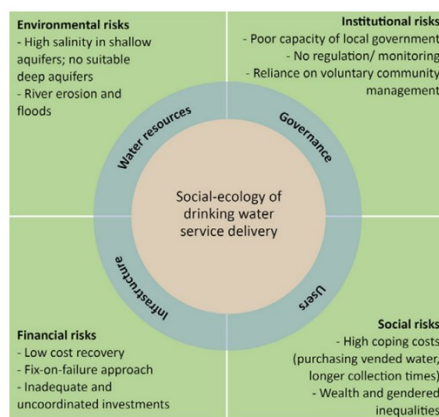


Figure 21 Water Security Characterization

A social-ecological analysis of drinking water risks in coastal Bangladesh, 2019

4.2.1 SOCIAL-ECOLOGICAL FRAMEWORK OF DRINKING WATER SECURITY

Water security, comprises a ‘provision’ and a ‘risk’ aspect. Provision aspect, aiming to increase coverage of technologically improved sources through infrastructure development.

In Bangladesh, where 97% of the population has access to an improved source but only 39% has safely-managed drinking water services, the challenge is to ensure that the water is free from contaminants. Environmental risks are particularly high in coastal Bangladesh. The region is highly susceptible to tropical cyclones and tidal surges, particularly in the pre- and post-monsoon periods. Intrusion of saline water from the Bay of Bengal poses significant challenges in the dry season when lack of rainfall decreases upstream river flows. Infrastructure encompasses public and private water supply technologies. Development and management of these infrastructures are prone to financial risks like inadequate investments, low-cost recovery, and inequitable pricing structures. Rural water infrastructure development is financed through publicly and donor-funded projects and implemented by the Department of Public Health and Engineering ((DPHE) – support from World Bank), as well as NGOs.

In Bangladesh, the provision and maintenance of rural water supplies lies with the Union Parishads, the lowest administrative tier, that often lack the capacity and financial resources to fulfil the mandate set by DPHE at the national level.

4.2.2 RESEARCH DESIGN

The Study conducted in Polder 29 – an embanked area of 80 km² covering five unions across Dumuria and Batiaghata upazilas (sub-districts) of Khulna district in southwestern coastal Bangladesh. The polder is further sub-divided into 77 mouzas with a total population of 58,000 and 17,000 households.

4.2.2.1 WATER AUDIT

Data on water resources and infrastructure were collected through a water audit that involved recording the locations, installation dates, technical specifications, ownership, maintenance, and usage patterns of all tube wells, pond sand filters and piped water taps in the south and central regions of the polder. The audit covered 2805 tube wells and 19

pond sand filters, of which 87% and 58% were functional, respectively. Water salinity was measured in-situ for all functional tube wells and pond sand filters.

4.2.2.2 ARCMAP

ArcMap was used to illustrate the spatial variation in groundwater salinity. Based on the standard practice in coastal Bangladesh, the aquifer system in polder 29 was categorized as:

- (i) the shallow (or 1st) aquifer extending up to 100 m below the surface;
- (ii) the main (or 2nd) aquifer ranging from 100 to 300 m and
- (iii) the deep (or 3rd) aquifer extending to depths N300 m.

4.2.2.3 INTERVIEWS

Key informant interviews with owners, managers or representatives of the different drinking water infrastructure were conducted to understand the governance system and institutions, which helped to identify the technical design, institutional and management structure, and financing model of key community drinking water interventions in the polder. Focus group discussions (FGDs) and household surveys provided data on the users, that is, the households and individuals. The household survey collected quantitative data on various indicators of multidimensional poverty and the state of drinking/domestic water services. The survey was done to 2103 households in two stages: phase 1 involved 978 households, while phase 2 involved 1125 households with relatively higher risk profiles. A stratified random sampling method was used.

4.2.2.4 INTERVENTIONS

These interventions included:

- three small piped water systems;
- water vending through truck and vans;
- pond sand filters;
- one public rainwater harvesting tank, and
- one privately funded reverse osmosis plant.

4.2.3 RESULTS

There is a high degree of socio-spatial variation in access to drinking water services in the polder, owing to differences in the availability of good aquifers, infrastructure investments, institutions and management systems, and socio-demographic profiles of the users.

Water resources

- Despite the presence of good shallow aquifers, availability of drinking water was severely constrained due to high levels of salinity.

Infrastructure

- There has been a significant growth in infrastructure in polder, which includes piped water systems, aquifer recharge units, community rainwater harvesting tank, formal water vendor, one private reverse osmosis plant, and pond sand filters in the polder.
- These interventions involved four types of funding mechanisms – 1) direct provision by local government with funds from annual development budgets or donor funded projects; 2) NGO supported investments using grants from international development partners; 3) self-supply by households and 4) water markets.

Government-led interventions

- Water audit data
- Piped-systems (2014) in Union-3 run on solar energy automatically, with no user tariffs and ad hoc repair costs.
- The local government in Union 4 established a water vending system in 2015 through funds from the Upazila Governance and Development Project (UGDP).
- The vending system sourced water from a pumphouse beside DTW1 and used a pick-up truck to deliver one 20l container six days a week to registered households in Union 4.
- The project started operation with 115 households; however, within the first six months, additional households signed up, increasing the total to 350.



Figure 22 Location Map

A social-ecological analysis of drinking water risks in coastal Bangladesh, 2019

NGO and donor-funded projects

- Electricity-powered pipe system in Union-3 provides water to households covering two thirds of the mouza (300 households).
- Households used tap water mainly for drinking and sometimes cooking and relied on private shallow tube wells for other domestic purposes.
- NGOs provided critical services where public investments were inadequate.

Private investments and self-supply

- The number of privately-funded tube wells increased four times in the past decade.

Water markets

- In the southern part more than half of the households purchases water from informal vendors, where these vendors sourced water from DTW1 and DTW3 for charges.

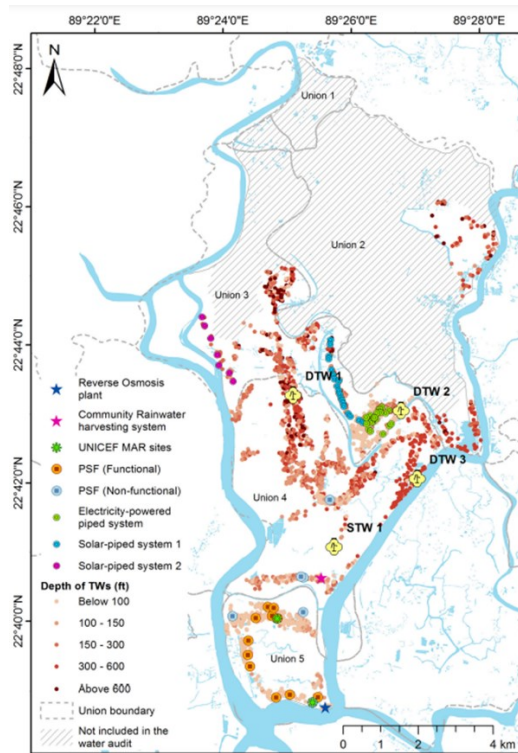


Figure 23 Water supply infrastructure in Polder 29.

A social-ecological analysis of drinking water risks in coastal Bangladesh, 2019

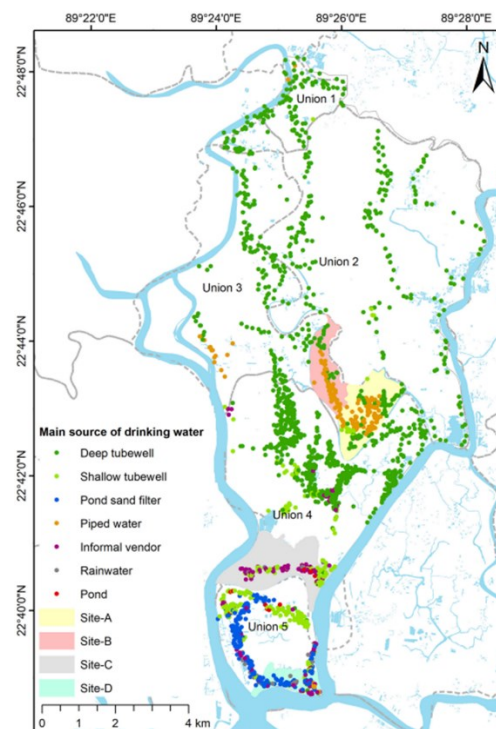


Figure 24 Main sources of drinking water used in polder 29.

A social-ecological analysis of drinking water risks in coastal Bangladesh, 2019

4.2.4 CONCLUSION

Issues faced:

- Salinity in drinking water.
- Inadequate infrastructure facilities.
- High Environmental in coastal Bangladesh.
- High financial risks
- Improper maintenance of rural water supplies
- High Institutional and Social risks

Measures taken:

- Improved infrastructure development technologically.
- Data on water resources and infrastructure were collected through a water audit.
- ArcMap was used to illustrate the spatial variation in groundwater salinity.
- Focus group discussions (FGDs) and household surveys.
- Mixed interventions like piped water systems; water vending through truck and vans; pond sand filters; rainwater harvesting tank, and reverse osmosis plant.
- Electricity-powered pipe system.
- Increased the number of privately-funded tube wells.
- Households purchased water from informal vendors.
- NGOs provided critical services where public investments were inadequate.

4.3 NEMMELI SEAWATER DESALINATION PLANT

It is India's Second Largest Sea Water Reverse Osmosis Plant. The CMWSS (Chennai Metropolitan Water Supply and Sewerage) Board has established a 100MLD capacity Seawater Desalination Plant on an Engineering, Procurement and Contract (EPC) basis as a drought-proofing mechanism and to increase water supply to the Southern areas of Chennai City.

The Government of Tamil Nadu granted administrative approval for the project, "Construction of 100 MLD SWRO Desalination plant at Nemmeli," which was funded by a grant from the Government of India worth Rs. 871.24 crores and money from GoTN worth Rs. 43.18 crores. The "Construction of 100MLD SWRO Desalination Plant at

Nemmeli and O&M Period of 7 Years" project was awarded to M/s by the CMWSS Board. IDE Technologies, Israel and VA Tech Wabag Ltd., Chennai February 2013 saw the commissioning of this plant. In comparison to the current traditional Surface Water Treatment Plants, the Sea Water Reverse Osmosis Desalination Plant uses a completely different technique. Surface water TDS ranges from 150 to 300 ppm, whereas the Total Dissolved Solids (TDS) in sea water ranges from 28000 to 41000 ppm, necessitating the use of a reverse osmosis (R.O.) procedure in order to meet potable water standards. 100MLD of product water is created after 265MLD of raw seawater has been taken.

Characteristics	Sea Water Quality (Avg)	Product Water Quality (Avg)	Desirable Limit (IS-3025)
pH	8.17	8.27	6.5 - 8.5
Total Dissolved Solids in ppm	28000 - 41000	480	< 500
Free Residual Chlorine in ppm	0.5	0.5	0.2 - 1.0
Chlorides in ppm	16695	217	< 250

Figure 25 Water quality after treatment
Chennai metropolitan water supply and sewerage board

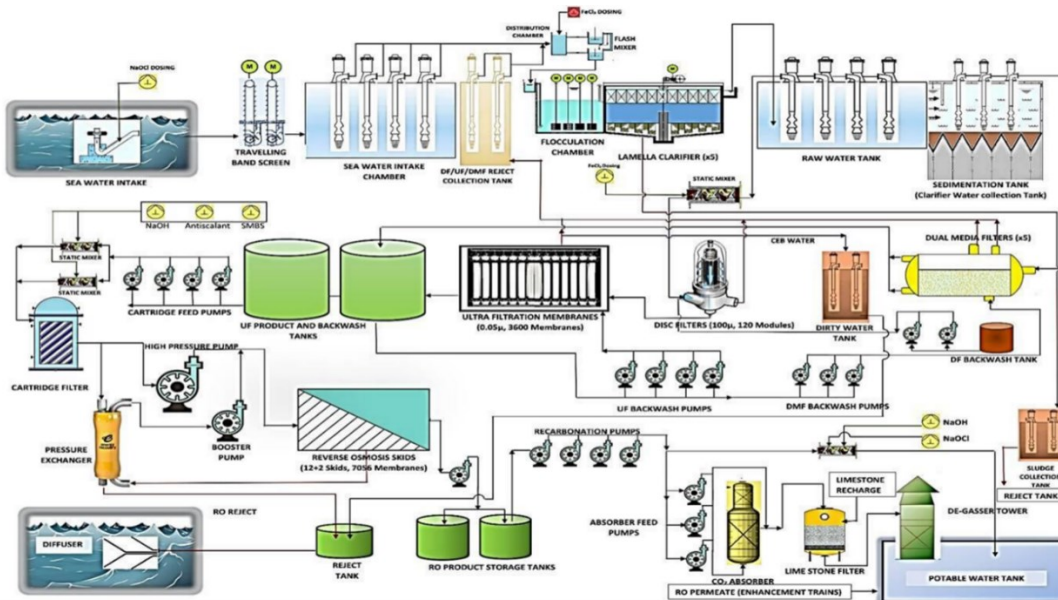


Figure 26 100 MLD SWRO Nemmeli Desalination Plant Process Flow Diagram
Chennai metropolitan water supply and sewerage board

PRE-TREATMENT PROCEDURE: To remove suspended materials up to 0.05 microns in size, the pre-treatment process includes a coagulation and flocculation chamber, a lamella clarifier, disc filters, ultra-filters, and cartridge filters. This procedure eliminates germs, viruses, and colloidal particles.

REVERSE OSMOSIS PROCESS: The UF permeate is routed through high pressure pumps to reverse osmosis membranes. The dissolved particles with a size of up to 0.001 microns are removed using R.O. Membranes. Energy Recovery Instruments are fitted to reduce the power cost, which is a major cost issue in the SWRO treatment process.

POST-TREATMENT PROCESS: To achieve the necessary alkalinity and hardness, the water is Remineralised by adding chemicals like lime and carbon dioxide. Then, to disinfect, sodium hypochlorite solution is applied.

Rejected water from R.O. and other plant processes is discharged into the sea using a 1200mm HDPE pipe line in accordance with environmental regulations.

4.3.1 CONCLUSION

Issues faced:

- Potable water scarcity

Measures taken:

- Desalination plant installation

CHAPTER 5 BEST PRACTICES

5.1 SUCCESSFUL IMPLEMENTATION OF WATER SUPPLY CONCEPT IN MALKAPUR WATER SUPPLY SCHEME

Malkapur town is located along NH-4, near to the 'Historical Agashiv Hills' on the outskirts of town Karad in Maharashtra's Sarata district. Malkapur is a rapidly expanding town due to a lack of suitable land in the neighbouring Karad metropolis. Malkapur also has industrial and commercial facilities such as Krishna Hospital, Emerson Industries, Educational Institutes, a few large hotels, co-operative organisations, and so on.

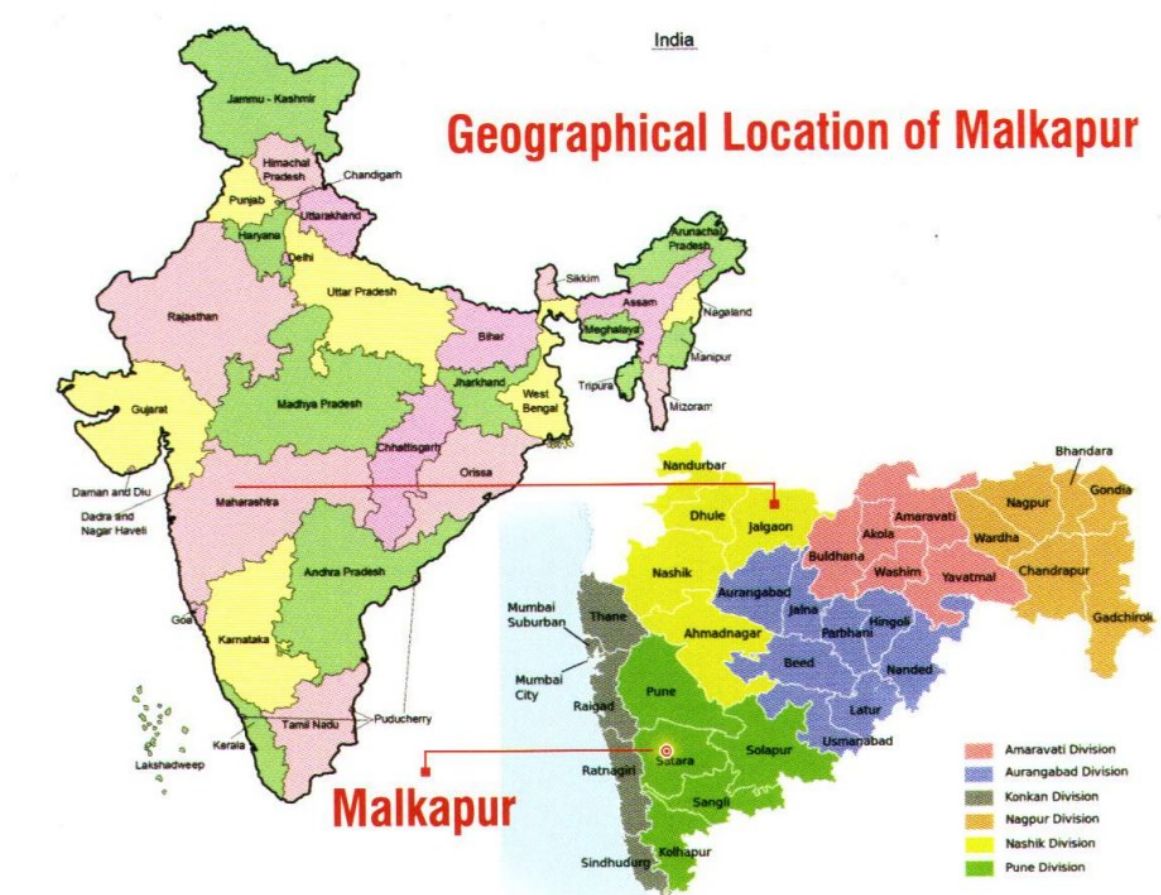


Figure 27 Location of Malkapur Town

(Success Story of Malkapur 24X7 Water Supply System)

By using Koyana River as perennial source, the first integrated water supply plan for Malkapur and Nandlapur village was completed in 1988, with a predicted population of

14000 by 2010. In addition, 11 borewells were used to provide water to the Malkapur town area. The water delivery rate was 40 LPCD.

However, the present water supply infrastructure was determined to be insufficient to meet the growing demand for water. As a result, in response to the people of Malkapur Grampanchayat's demand, it was decided to plan and implement a 24x7 Water Supply Scheme using the Koyana River as a perennial source, and a proposal was drafted for a projected population of 67196 for the year 2037 and submitted to the government for approval.

Table 13 Scheme Details

Scheme Details		
1	Cost	
	Original	Rs 947.54 lakh (Adm. Approval dt. 9/6/1999)
	Revise	Rs. 1225.13 lakh (Adm. Approval dt. 3/8/2008)
	Re-revise	Rs. 1402.92 lakh (with Govt.)
2	Financial Pattern	
	Govt. share	90%
	Popular contribution	10% (122.00 lakh collected till date)
3	Population	
	Year 2011	31713
	Year 2037	67196 (ultimate)
4	Rate of water supply	70 LPCD
5	Pumping hours	12 (daily)
6	Work executed	
	A)Head works	
	Intake well	3.00 m dia (RCC)
	Inspection well	3.00 m dia (RCC)
	Connecting Pipe	750 mm dia (CI) L - 55 m
	Approach Bridge	45 m. Length (RCC)
	B) Pumping Machinery	
	Raw water	150 HP (VT) Discharge- 3.25 Lakh Ltr./Hr
	Pure water	75 HP (VT) Discharge- 3.08 Lakh Ltr./Hr
	C) Rising main	
	Raw water	400 m.m. DI L- 1840 m.
	Pure water	400 m.m. DI L - 155 m
	D) Water Treatment Plant	Capacity - 8.00 MLD
	E) Gravity Main	400 to 250 mm DI L- 3520 m
	F) ESR/ GSR	Total - 06 nos, Cap- 36.75 Lakh Ltrs.
	G) Distribution System	
	300 To 150 mm D.I.	L - 8.06 km
	140 To 75 mm HDPE	L - 67.17 km
	Domestic water connection (MDPE pipe & with AMR water meter)	Nos - 5997
7	Total expenditure incurred	Rs. 1398.45 Lakh

(Success Story of Malkapur 24X7 Water Supply System)



Figure 28 Zonal Division of the Town
(Success Story of Malkapur 24X7 Water Supply System)

5.1.1 STRATEGY ADOPTED

The Malkapur water supply distribution system was planned, designed, built, and is being operated in accordance with the following strategy:

1. **The consumer shall get the water whenever he opens the tap:** This technique ensures that customers can get service whenever they want it. Water is required by customers in various trades at various times of the day. The intermittent system delivers water at set or variable times (if the scheme is in chaos like Malkapur). This necessitates citizens adjusting their schedules to coincide with the availability of water. It results in the loss of economic or other opportunities within that time period. As a result, it was proposed to make water available at the consumer's tap

24 hours a day, seven days a week. The policy also aims to eliminate the concept of keeping water and discarding it the next day when fresh water is delivered, as well as the investment in storage vessels/tanks.

2. **Provide good health to the citizens through good quality potable water:** Every piped water delivery system strives to deliver high-quality drinking water. Outside pollutants enter the pipes from the areas where leaks have occurred when the intermittent systems are depressurized during non-supply hours. Because the pressurised systems are operational 24 hours a day, 7 days a week, the quality of the water delivered is guaranteed at all times.
3. **Consumer pay as they use** - The notion of consumers paying according to their usage incentivizes resource conservation. Unlike unmetered flat rates, where amount consumed is not a criterion, the metered water delivery system allows for charging based on the volume of water consumed. As a result, consumers in metered systems aim to reduce their usage by closing their taps as soon as their needs are addressed.
4. **Pay at higher rate when using higher per capita water** - The use of telescopic rates necessitates the payment of higher charges for increasing per capita water demand. The bare minimum of water is given at a reasonable cost. As a result, the poor are looked after, and they also have access to water 24 hours a day, seven days a week. This transfers wealth from the wealthy to the poor. The micro mapping of the number of people in each dwelling, as well as the AMR metres given in the system, make this plan a reality.
5. **The service to work on no loss basis** - It was recommended that the water supply service not be conducted at a loss. The rates were to be set in accordance with this. It was also necessary to use extreme caution in order to limit operational costs to a bare minimum.

5.1.2 IMPACT OF INITIATIVES

On June 9, 1999, a RS.947.54 lakhs expansion to the water supply system was approved. However, due to a lack of money, the work could not begin until December 2002. In the year 2037, the system is expected to provide 55 LPCD of water to a population of 67196 people. The bulk water system involved drawing water from the perennial river Koyana and pumping it to a water treatment facility at a rate of 3.25 lakh litres per hour (8 MLD).

The pumps have a horsepower of 150. The W.T.P. is used, which includes alum dosage, flocculation, coagulation, sedimentation, filtering, and chlorine disinfection. The cleaned water is pumped up the hill to the Master Balancing Reservoir. This tank's treated and disinfected water is distributed to six distribution zones through five service reservoirs. The 75-horsepower treated water pumps By January 2005, the system had been completed up to ESR, and water was being delivered via the existing distribution system.

The service delivery distribution network was the last but most critical piece of work. The project was approved, and it included a PVC and HDPE pipe distribution system. The distribution network was then created with the "Water Gems" software. Apart from designing for steady state flow, this programme also simulates the system according to the stated pattern of water demand at various times of the day in the 24 x 7 availability. The software is based on Darwin. A generic algorithm is designed. It has a multi-criteria optimization feature. Performance and cost are the two criteria. The software's solutions are graded. The user is now able to Choose the greatest solution for his pressing needs and financial resources.

Following the design and estimate, a thorough tender for a distribution network in HDPEpipe, house service connection in MDPEpipe with AMR metre, and bulk water metres of AMR type was requested from large scale manufacturers of HDPEpipes who worked with the AMR metre maker. The performance criterion was also kept in mind in terms of distribution network leakage. The incentive penalty provision was preserved, with a benchmark leakage threshold of 5%. The system must be managed by the manufacturer for a period of two years after completion, and the leakage level must be recorded every month.

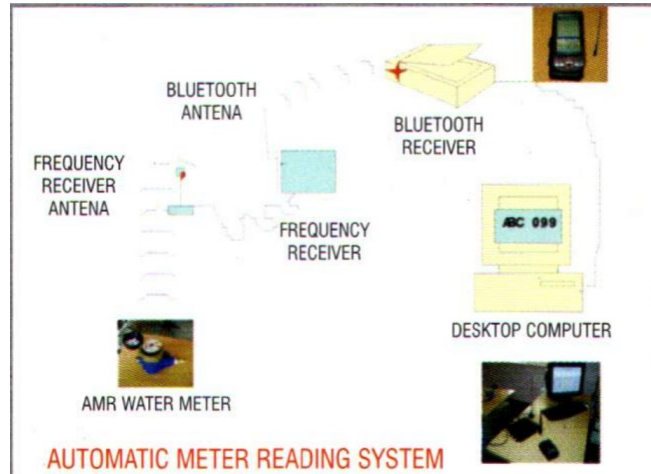


Figure 29 Automatic Meter Reading

(Success Story of Malkapur 24X7 Water Supply System)

The work order was issued on the 7th of October, 2007, and the real work began on the 8th of March, 2008. Each water connection has been equipped with automatic metre readers (AMRs), which use radio frequency to take metre readings within a 200-meter radius. It is not essential to visit the metre in order to obtain readings. The information is entered into a computer, and the water bill is generated as a result. The billing is accurate because there is no manual interference when taking readings.

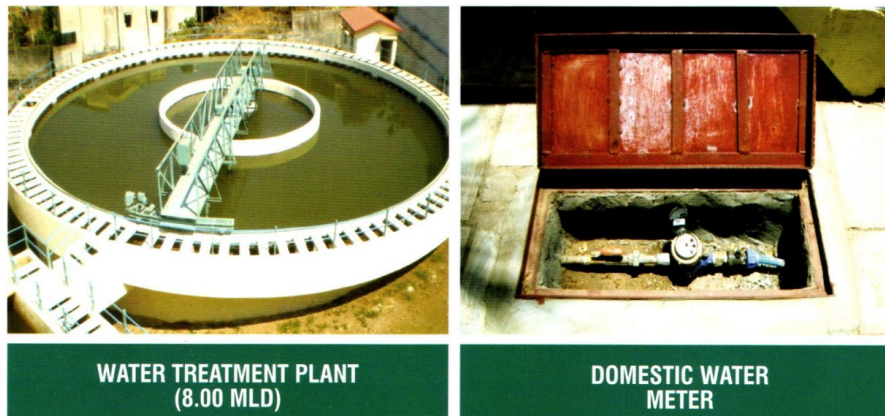


Figure 30 Water treatment Plant and Domestic Water Meter

(Success Story of Malkapur 24X7 Water Supply System)

The actual work in Malkapur town began in March 2008, and a plan was drawn out to complete each zone in every way. As a result, the pipelines were laid and the system was commissioned zone by zone, as shown below.

Zone No.5 (Part)	- Aug 2008
Zone No.5 (complete) and Zone No. 6	- Dec 2008
Zone No.2 and Zone No. 3	- Mar 2009
Zone No.1 and Zone No. 4	- May 2009

The predicted demand for Malkapur city in 2037 was assessed at 70 LPCD, and the scheme was framed, designed, and authorised by the Maharashtra government. The distribution system network was hydraulically built using the 'Water Gems' software to meet the needs of the intended distribution nodes. The distribution system was topographically separated into six zones, and a scheme was implemented and commissioned in August 2008. Role of Various Stake Holders also played an important role.

5.1.3 VARIOUS DIFFICULTIES WERE FACED DURING THE IMPLEMENTATION OF THE PROJECT WHICH INCLUDED FOLLOWING MAJOR DIFFICULTIES.

1. The elected body was dissolved when the Gram Panchayat was raised to a Nagar Panchayat. As a result, people's representatives were unavailable to coordinate.
2. 37 customers refused to fix the metres during the election of the newly created Nagar Panchayat.
3. Before beginning the project, there were 2950 consumers in the system, and the project comprised transferring these connections to new pipelines using AMR metres, MDPE pipes tapping tee, ferrule, and other components. However, the Panchayat provided 222 more connections and roughly 450 new connections over the project term, necessitating the expenditure of additional funds for these metres.
4. When the system was running 24 hours a day, seven days a week in commissioned zones but the flat rate tariff was still in effect, the number of hours of pumping grew. The people began Page No. 11 with a lot of water. The lack of suitable float stop cocks for overhead tanks, among other things, resulted in water overflow and waste. Even when the water supply was overflowing or being

abused by the public, it was kept running. This was necessary to reassure them that "now there will be no water shortage." The ongoing experience may persuade them that installing adequate stop cocks on the overhead tanks is critical. They persuaded them not to use the overhead tanks at all, because the quality of water provided by the 24 x 7 system is far superior, and the overhead tanks may become contaminated if they are not properly covered, or if children playing on the terrace may introduce dust, or if birds attempt to use the water if they are not covered. They were also warned about the overhead tank washing, among other things.

5. Then there was the question of determining an appropriate water rate to prevent consumers from overusing water.

5.1.4 CURRENT TELESCOPIC TARIFF

Domestic

- | | | |
|--|---|---------------------|
| 1) Monthly consumption up to 12600 lit | - | Rs 04 = 50/1000 Lit |
| 2) 12601 to 22500 lit | - | Rs 07 = 00/1000 Lit |
| 3) Above 22500Lit | - | Rs 10= 00/1000 Lit |
- (Consumers who use less than 9900 litres of water per month are entitled for a 15% rebate.)

Commercial

- | | | |
|-------------------------------|---|---------------------|
| 1)Only Hotels | - | Rs 09 = 00/1000 Lit |
| 2)Hotels with dining | - | Rs 14 = 00/1000 Lit |
| 3)Star Hotels, Hospitals etc. | - | Rs 20 = 00/1000 Lit |

The combination of a public awareness campaign and a telescopic price lowered consumption to the point that 19-20 hours of pumping were cut to 13 hours and a 24-hour water supply was possible at an average LPCD of 110.

5.1.5 BENEFITS RESULTING FROM THE PROJECT

1. Improvement in delivery time and services

2. Improved Quality of Water
3. Decrease in water borne illnesses in children
4. Reduction in wastage of water
5. Shifting control of the distribution system from Valve man to the Consumer
6. Simplification of billing procedure
7. Saving in Electricity & helping clean development initiatives
8. Increased prestige & pride for Citizens leading to increase in revenue recovery
9. Reduction in operation cost
10. Reduction in NRW

Table 14 Impacts of the Project

Sr.No.	Result Area	Pre Project	Post Project
01	Timeliness of service delivery.	No definite time. Water supply 2-3 days alternate.	Water supply available 24 hrs. a day 7 days a week to the citizens.
02	Water Quality	Water quality could not be guaranteed.	Guaranteed water quality with 100% samples potable.
03	Time management of consumer	Wastage of time of consumer.	Consumer can utilize his time as per their will since water is available 24 x 7.
04	Saving in water	After 24x7 but before charging on metered basis, the water was required to be pumped for 19-20 hrs. People used to overuse & waste large quantity of water and the flow from gutters used to be high which was getting into one of the private land making it like a pool of waste water.	Post 24x7 complete commissioning with demand management efforts water to the extent of 30% is conserved. Now 13-14 hrs. pumping is sufficient to keep 24 x 7 operational. Now the land where the pool was; has become dry.
05	Reduction in electricity consumption	11 bore wells with power pumps of M.C. and many power pumps, small pumps for lifting water from ground to terrace was working.	Now these pumps are totally stopped with reduction in electricity consumption by 27528 KWH per month.
06	Reduction in cost of operation.	i) For operating pumps at head works separate operators were required.	i) With automation using GSM technology pumps are operated from WTP & the Head works is un-manned. Reduction in cost by Rs. 9000 per month
		ii) 22 valve men used to operate the valves in distribution network & the bore well valves so as to provide water to the consumer at different times of day and night by zoning method.	ii) There is no need of valve man as the water is available 24 x 7 throughout the town and no valves are to be operated. Reduction in cost by Rs. 66000 per month
			Valve actuators have been installed near service reservoirs which are fed by gravity through MBR. When water level in the tank reaches full tank level, the water supply through gravity main is cut off and when it is empty water supply is restarted. This maintains water supply 24x7 available in distribution network.
			Electronic Pressure sensors have been installed in MBR to control the water levels. As soon as the water levels in the tanks get reduced to the level of 30 % of total height, the pumps installed in pure water pump are started automatically. As soon as water reaches to full capacity of tank, the pumping is stopped. Because of this the water supply in the distribution system is maintained 24x7.

Sr.No.	Result Area	Pre Project	Post Project
		<p>iii) Ordinary meters would have required 3 meter readers to collect the meter readings.</p> <p>Leakage level in India varies from 25-40%</p>	<p>iii) Due to use of AMR no meter reader is required. The data handling error are also not there.</p> <p>Measured leakage level in Malkapur is 8-12%</p> <p>As per the sanctioned scheme, it was proposed to install 2950 water connections with AMR water meters. The same were executed at cost Rs. 6560/- per no. and the expenditure was done through Govt grant. After commissioning of the scheme, new consumers were given water connections including AMR water meter at Rs. 14600/- per no.. The rate included the cost of AMR meter, ferrule, MDPE pipe, brick chamber. The complete rate as above includes the cost of AMR meter at Rs. 9300/-, the 50% of which is borne by Malkapur Nagar Panchayat & 50% by consumers. The above rate of Rs.14600/- is fixed by Malkapur Nagar Panchayat by inviting annual rate contract.</p>
07	System leakage level		20 no of pressure sensors are installed at various node points on distribution system, which record loss in the pressure, due to leakages. This control is done by GSM network system with remote wireless operation, with the help of computer installed @ WTP.
08	Recovery of water tariff	60% recovery	Now 94% recovery and still improving targeted to be 100%.

This programme received the "Prime Ministers Award for Excellence in Public Administration" for 2009-10 for successfully planning, designing, and implementing the Malkapur water delivery scheme 24 hours a day, seven days a week. The National Urban Award for the year 2010 was also given to this.



Figure 31 National Urban Award for year 2010
(*Success Story of Malkapur 24X7 Water Supply System*)



Figure 32 Prime Ministers Excellence Award year 2009-2010
(*Success Story of Malkapur 24X7 Water Supply System*)

The use of latest modern technology has been effectively incorporated to run the Malkapur Water Supply Scheme 24 hours a day, seven days a week, and the scheme has been tested to its 100 percent efficiency and satisfaction of the people. Water bills will be paid in the future using SMS systems on consumer mobile phones.

The proper & effective combination of high political will power, successful government machinery, and public contribution has yielded an excellent and successful 24x7 Water Supply Scheme, such as Malkapur & Malkapur Only, which serves as a pathfinder and mile stone for all future water supply schemes.

5.1.6 CONCLUSION

Issues faced are:

- Water supply was insufficient to meet the growing demand for water.
- Interrupted water supply.
- Polluted drinking water.

Measures taken are:

- The area has been divided into small District Metering Areas (DMA).
- The distribution network "Water Gems" software was designed for steady flow based on water demand.
- Water connection has been equipped with automatic meter readers (AMRs),
- Village Panchayat, Nagar Panchayat elected representatives played an important role to implement the idea.
- The project was implemented on a PPP basis - 90% government shares and 10% public shares for better finance and project success.
- Tariff has been designed in four slabs based on water usage.
- Public awareness
- Better infrastructure was developed to improve the service delivery to people

5.2 MAZHAPOLIMA INITIATIVE - THRISSUR DISTRICT, KERALA

In the Thrissur district, the Kerala government launched Mazhapolima in 2008 as a cooperative programme for addressing climate change. The initiative aims to address the issue of water scarcity by collecting rainwater from rooftops and placing it into open drilled wells, which have historically acted as the state's water security measures.

More than 4.5 lakh open wells, which supply 70% of the domestic water supply in the Thrissur district alone, make up a significant portion of the state's water supply. The majority of these wells dry up in the summer. Another one is the issue of groundwater exploitation. Four semi-critical blocks and one overexploited block (Kodungallur) are located within the Thrissur district itself (Mala, Mathilakam, Ollukkara and Thalikulam). The district spends approximately Rs. 100,000 annually on tankers.

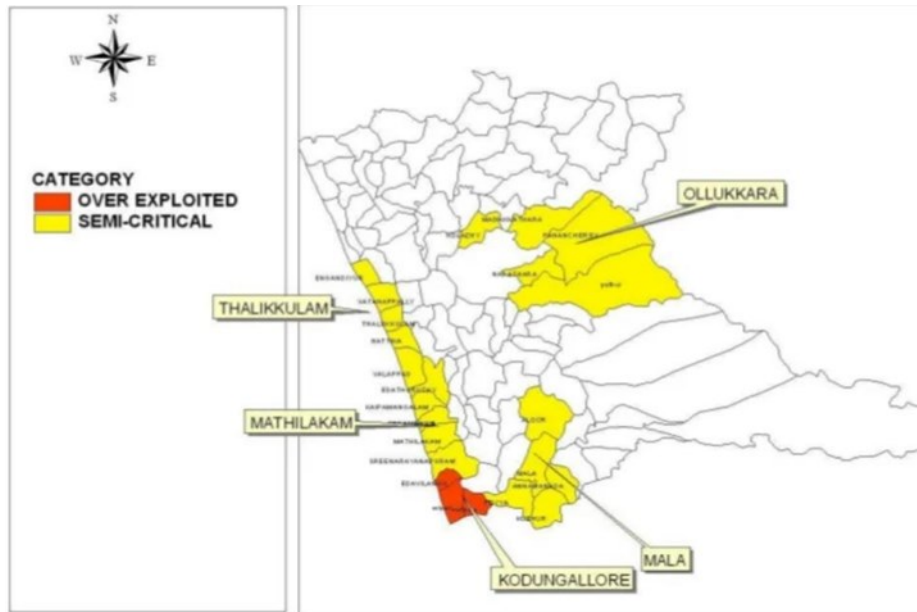


Figure 33 Trissur District

The proposal took into account the region's specific geohydrological features:

- On average, the area receives 3,000 mm of rain annually.
- Per square kilometre, there are 200 household open-dug wells; Unrestrained aquifers are created by open-cut wells;
- The water table falls in the summer when 75% of the 4.5 lakh wells dry out.
- The coastal belt becomes more salinized



Figure 34 Mazhapolima Initiative - Thrissur District

NITI Aayog, 2017

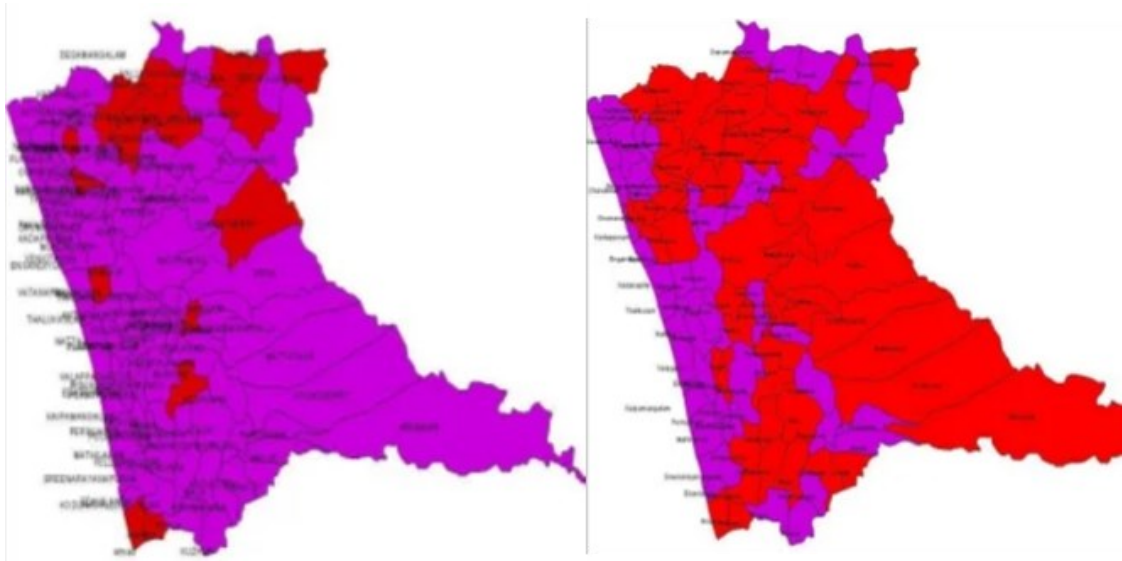


Figure 35 Water supply by Tanker Lorry – 2004, Water supply by Tanker Lorry – 2006

NITI Aayog, 2017



Figure 36 Salinity Intrusion in Thrissur

NITI Aayog, 2017

5.2.1 TECHNIQUE USED

The Mazhapolima employed two distinct types of tactics:

- The use of PVC gutters to collect rainwater from the roof and pipe it to the filter is one technique known as "roof-top harvesting with sand filter." Sand, metal, and charcoal make up the filter. This approach has a price range of Rs. 2,500 to 3,750 per unit.
- The second method, roof-top harvesting with a typical nylon filter, costs between Rs. 1,250 and 2,500 per unit and diverts roof-top water to the well through a nylon or cloth filter using a PVC pipe.

5.2.2 IMPACTS

Strong public support for the establishment of Mazhapolima units: By December 2012, 58 GPs had implemented about 8,056 Mazhapolima units thanks to the active involvement of GPs, private organizations, and beneficiaries.

Enhancements to the water's quality: According to a Centre for Water Resources Development and Management impact assessment research, bacterial infestation increased although pH and salinity levels decreased.

The GOK approved Rs. 1 crore for the programme, while additional organizations like KWA and NABARD also contributed financially. The total amount of money Mazhapolima had access to in Phase I was Rs. 2,10,32,000

5.2.3 CONCLUSION

Issues faced are:

- Fall in water table during summer
- Water scarcity
- No infrastructure providing uninterrupted water Supply
- Ground water Exploitation
- Saline Intrusion

Measures taken are:

- Roof-top harvesting with sand filter to filter
- Roof-top harvesting with Nylon to Wells
- Awareness among people about Rainwater harvesting Techniques
- Strong Public Involvement leading to the success story which can be adopted everywhere.

CHAPTER 6 STUDY AREA - KOLLAM

6.1 HISTORY

Kollam, one of the oldest settlements is the fourth largest city in Kerala. Thangasery and Neendakara ports triggered the development activities in the region and led to the growth of settlements around these ports and thus Kollam developed as an important commercial center in the southern part of Kerala. During the colonial period it was known as Quilon and was famous for its trade linkages and industrial potential from the ancient period. One theory has it that the name Kollam derives from the Sanskrit “Kollam,” which means pepper, because the place had been an ancient trading and exporting centre for pepper.

In the earlier days (8th century AD), Kollam was called Desinganadu. In those days, Kollam was the capital of the Venad kingdom. Chinese traders were one of the oldest foreign communities to settle in Kollam. During that period, Kollam evolved as a major trade center of spices and an important port in the Malabar Coast. In 1502, the Portuguese were the first Europeans to establish a trading center and later came the Dutch followed by the British in 1795. On 1 July 1949, Quilon became one of the four districts in newly formed Travancore–Cochin state. In 1 November 1956 following the formation of State of Kerala through States Reorganization Act, 1956 Quilon district comprising parts of present day Pathanamthitta district became a part of Kerala.

The city is situated 72 km north of Thiruvananthapuram, the state capital, and 150 km south of Kochi. The city has strong physical connectivity with important towns in Kerala as well as the neighboring state of Tamil Nadu both by road and railways. As per the Integrated District Development Plan (IDDP), the settlements in the districts are divided into groups based on their density and activity pattern. The city is also the district headquarter. Kollam is the first order settlement in the district. Being the district headquarters, the city accommodates many administrative institutions such as the District Collector's office and District Court.

6.2 KOLLAM CORPORATION

Kollam city is the 4th largest city in the state with a population of 3.49 lakhs (Census 2011). Also, the city has the 2nd highest density in the state. The city accounts for 1% of the Kerala states total population and around 2% of its urban population. The Kollam Municipal Corporation population accounted for 29% of the district’s urban population and 13% of the district’s total population.

Population of Kollam city increased moderately from 2.43 lakhs in the year 1971 to 3.61 lakhs in the year 2001. During the period 1991 to 2001, four Panchayats, namely, Vadakkevila, Kilikolloor, Shaktikulangara and Eravipuram were merged with KMC. As a result, the area of KMC increased from 18.48 sq. km to 57.31 sq. km. The gross population density of planning area is 5156 persons per square kilometer (pp.sq.km) which is nearby than 5 times the district average (1038 sq.km). The reason for this high density is that the planning area falls within the coastal belt of the district where the density is rather high compared to rest of the district. Gross population density of Kollam Corporation is the highest among LSGs in the planning area (6259 pp.sq.km).

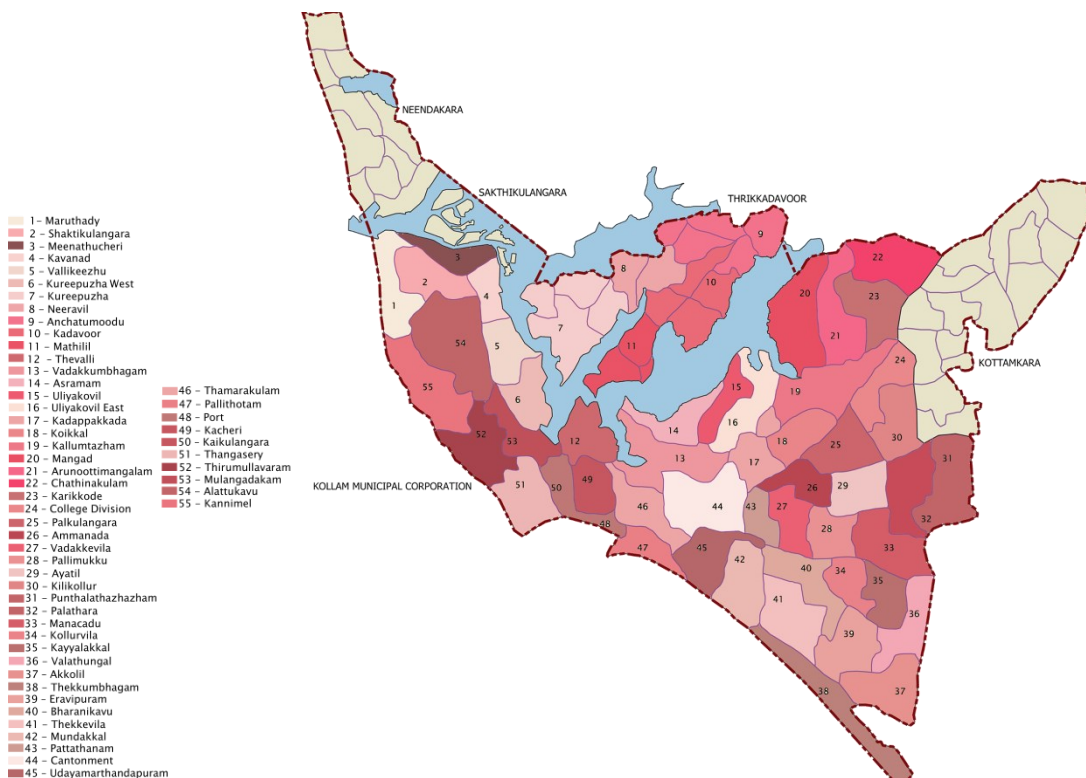


Figure 39 Kollam Corporation

Author generated with reference to Municipality Map

The urban population of Kollam district is 7% of the state's urban population, or 1 crore 59 lakhs, with Kollam accounting for over 29% of the district's urban population. Kollam's demographic profile is characterized by a low growth rate due to its unique geographical location. Kollam has progressed from a Nagar palinka with a population of 312,521 in 1991 to a Class I city with a population of more than 3 lakhs now. Another demographic trait of the city, given its unusual environment, is its large floating population, which was believed to be 500 people every day (on average) in 2011.

6.2.1 POPULATION DISTRIBUTION AND GROWTH PATTERN

Except for the decade 1951-1961, which saw an unusual decennial increase in population (86%) because Kollam was declared a municipality with an area of 27.55 sq km, Kollam has experienced historically and consistently modest population growth.

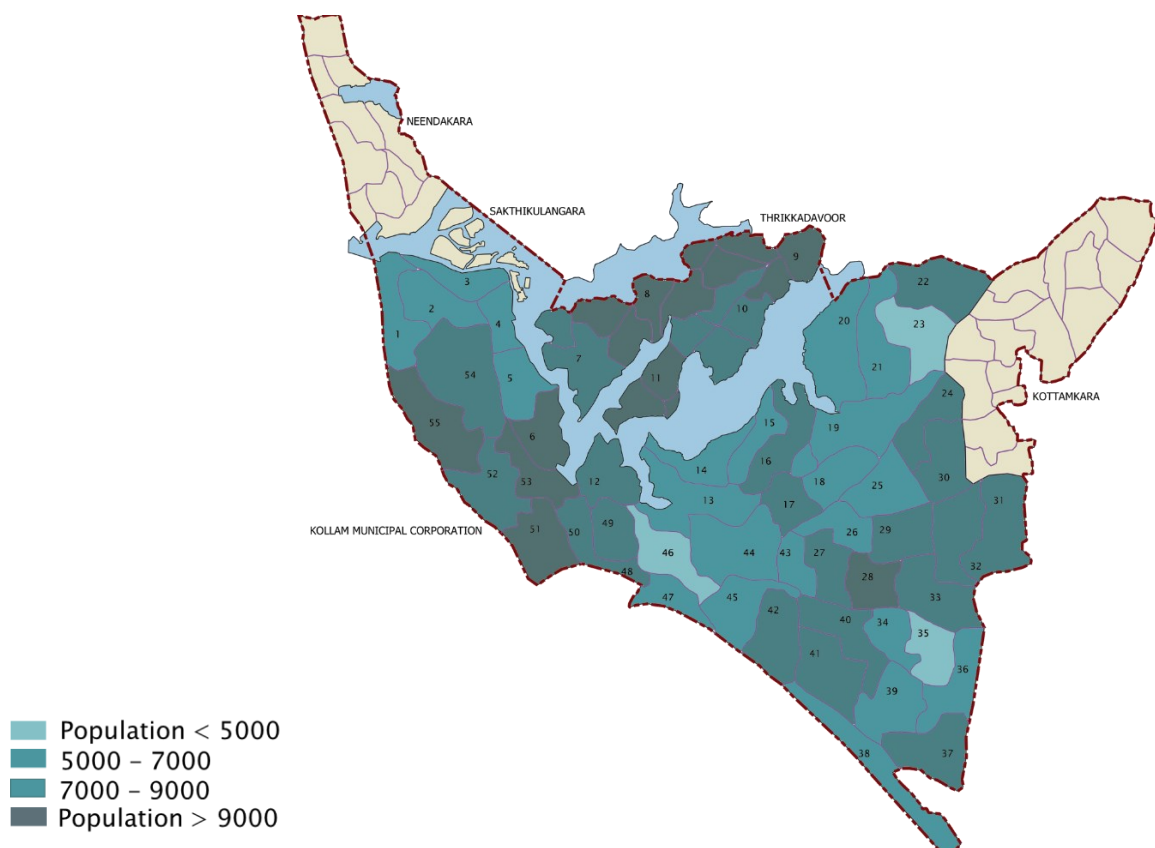


Figure 40 Population Map

Author Generated Population Map with reference to Corporation Map

Kollam is one of Kerala's most beautiful regions. On October 1, 2001, the Kollam Municipal Corporation was founded. The city's urban growth rate of 154.59 percent,

according to the 2011 census, was the second highest in the state. Kollam has been designated as a "Port City of Kerala" by the Kerala government. The project will include the regeneration of the Maruthadi-Eravipuram area, as well as the installation of fishing facilities, tourism, and entertainment initiatives.

Kollam is Kerala's fourth most populated city (new population is considered city agglomeration) and fifth largest in terms of incorporated area. It is well-known for its cashew processing and coir production. Ashtamudi Lake is a popular tourist spot in Kollam and is regarded the southern gateway to Kerala's backwaters. Suburban towns such as Paravur in the south, Kundra in the east, and Karunagappally in the north make up the Kollam urban area. Eravipuram, Kottiyam, Kannanalloor, and Chavara are other prominent towns in the city's outskirts. Kollam is still a prominent business and commercial centre in Kerala's southern region.

Kollam, being an important port city, had to accommodate administrative offices and labour, as well as a lot of investment and development, resulting in an economic boom in the city, with people coming to Kollam in quest of better employment prospects. Because of out-migration, population growth in the following decade was negative (-0.35%).

Table 15 Population Distribution in Kollam (KMC+OG)

Year	Kollam	CAGR
1951	66126	
1961	123291	6.43%
1971	166079	3.02%
1981	211278	2.44%
1991	327945	4.49%
2001	380091	1.49%
2011	367107	-0.35%

(Census of India, 2011)

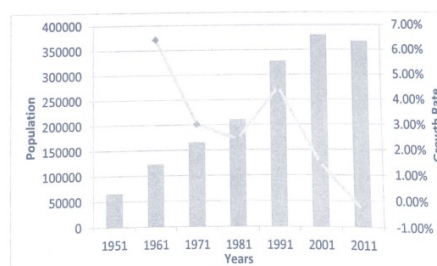


Figure 41 Pattern of Population Growth in Kollam (KMC+OG)

(Census of India, 2011)

6.2.2 POPULATION DENSITY

In 2011, the area under Kollam's authority, including KMC and the extension, was 62.36 square kilometers, with an average density of 5,887 people per square kilometer. The population of the Kollam Municipal Corporation is divided into 55 wards, with ward no. 9 (an extension) having the largest population of 10357, followed by ward no. 53 (9668), and ward no. 6 (9576). Ward 46, known as Pattathanam, has the smallest population.

6.2.3 LAND USE

Residential areas are increased from 73% to 80% and most of the mixed-use buildings diminished and paddy fields also decreased from 5% to 1% and also decline in water body to 4% (mainly Ashtamudi lake), its due to increase in residential areas and other human activity.

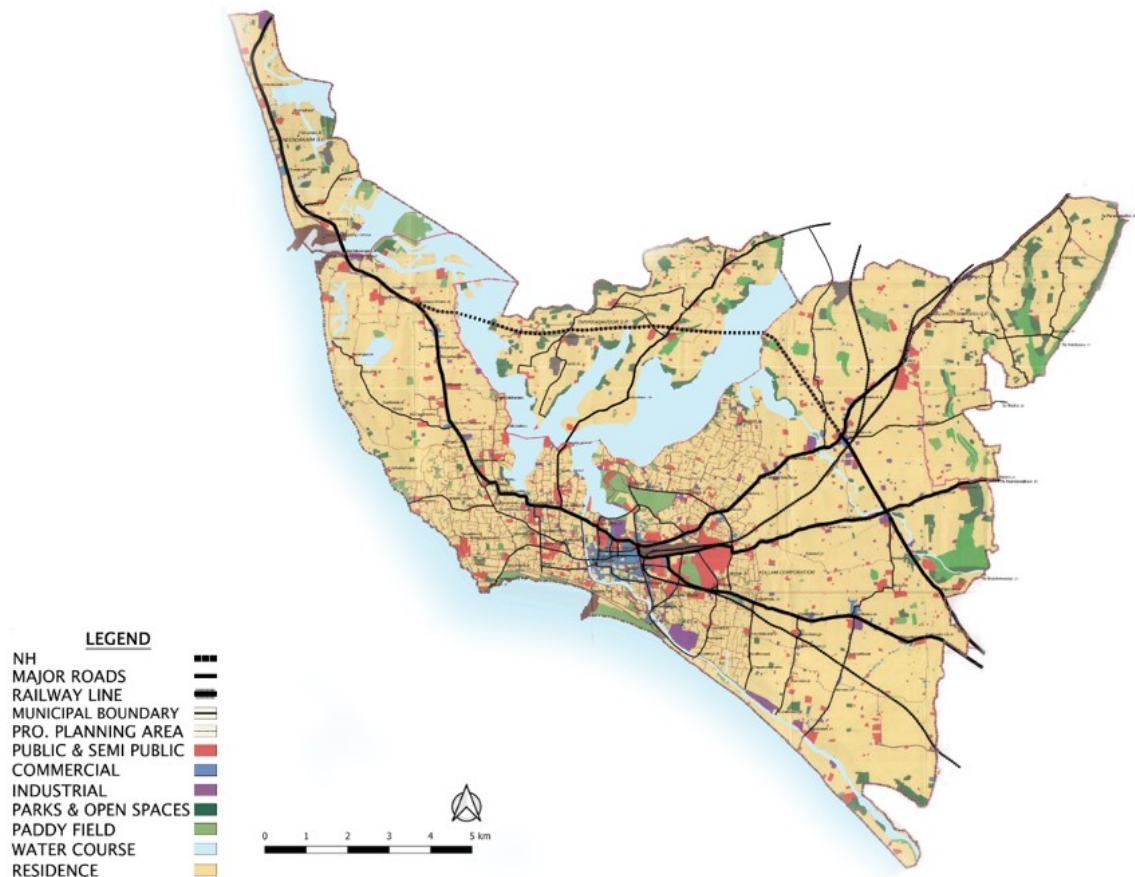


Figure 42 Land Use Map

Greater Kollam, 2015

6.2.4 GROUND WATER STATUS

The porous granular formations such as (i) alluvium, (ii) laterite, (iii) tertiary sediments, (iv) weathered and degraded crystalline rocks, and (v) fissures, joints, and fractures of crystalline rocks in the Kollam district have significant ground water supplies. Alluvial aquifers, laterite aquifers, tertiary sedimentary rock aquifers, and crystalline rock aquifers are the four different geological formations that exist in the district.

The tertiary sedimentary rock aquifers that recharge Kollam city and its surrounding region contain ground water that is phreatic in the shallow zone and restricted in the deeper zones. The deeper restricted aquifers are widely developed by submersible or vertical turbine pumps and have been substantially developed for the drinking water supply schemes designed for Kollam city and its bordering rural areas.

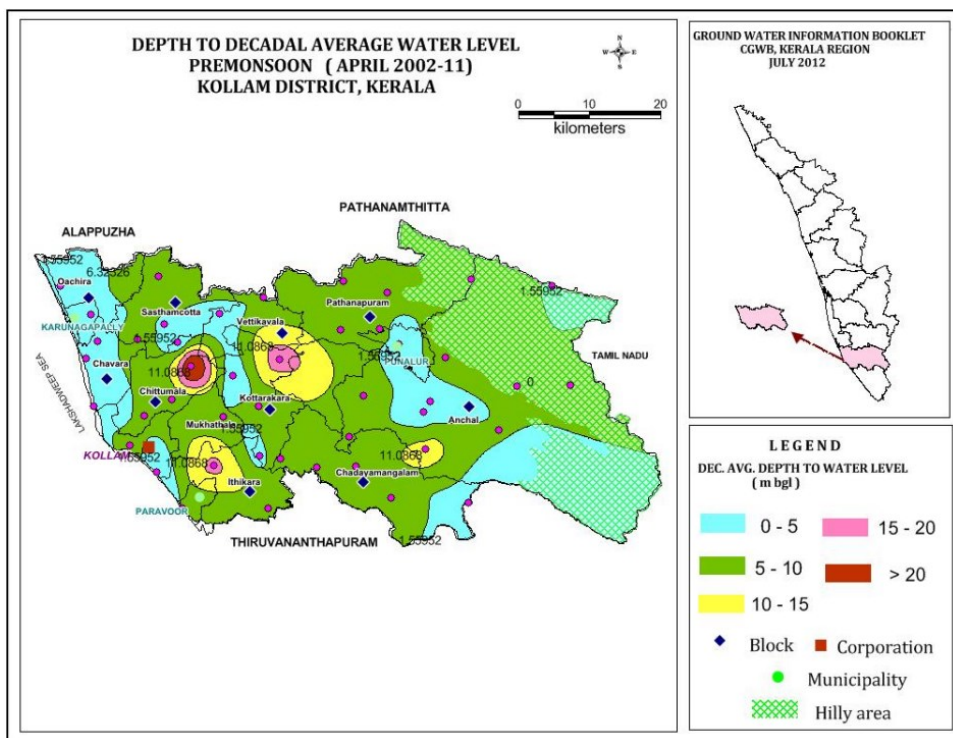


Figure 43 Depth to Decadal Average Water Level (Pre-monsoon April 2002-11)

(Chandran, 2013)

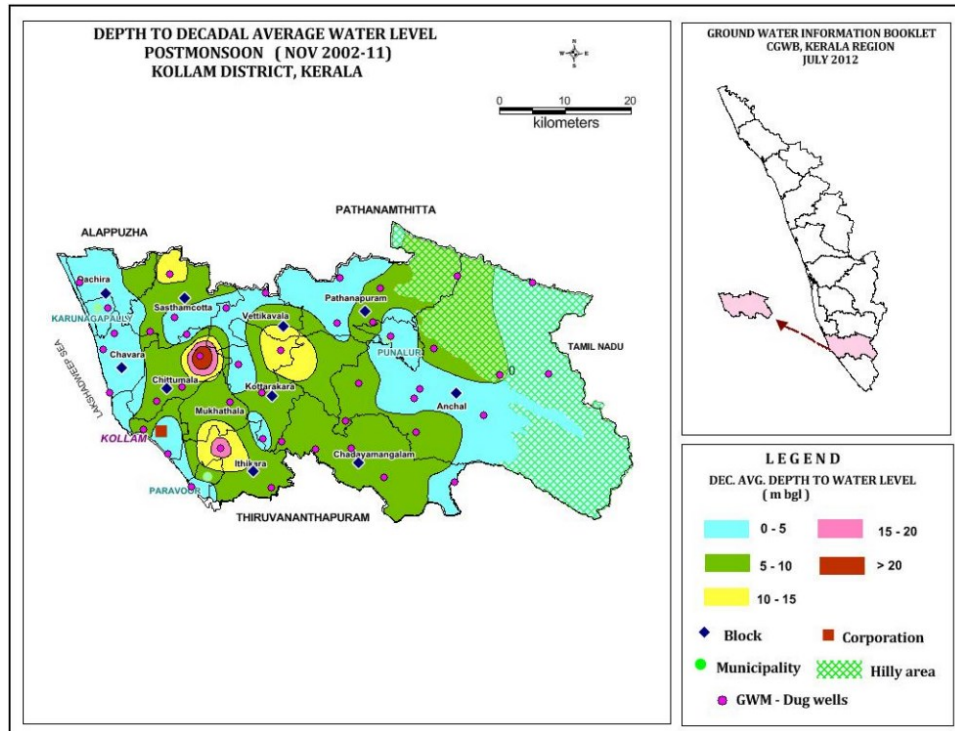


Figure 44 Depth to Decadal Average Water Level – Post monsoon-(Nov-2002-2011)
(Chandran, 2013)

The availability of groundwater at relatively shallow depths ranging from 1.50m to 6.20m below ground determines the variation in water table across Kollam district. Because of concerns about contamination of domestic supplies based on groundwater or the inability to leach out wastewater into the soil matrix, shallow water table conditions are typically not conducive to the adoption of on-site sanitation systems. In addition to the aforementioned issues, saline water incursion and contamination from industrial effluents have been recorded in several locations of the city.

6.2.5 SURFACE WATER BODIES

Water bodies border Kollam on the north, north-west, and west sides. The scenic Ashtamudi Lake lies to the north and north-west, while the Lakshadweep Sea defines the margin on its west. The city is spanned by two ferry canals, the T S canal on the west and south-west, and the Kollam bypass canal on the north-east, both of which are backwater waterways and connect the city to other villages, towns, and cities. Numerous ponds/fresh water bodies dot the cityscape, most of which are found within temple complexes.

After Vembanad Lake in Alappuzha district, Ashtamudi Lake is one of Kerala's largest and deepest wetland ecosystems. The palm-leaf-shaped lake that borders Kollam on its north and north-west boundaries is used for interior travel between the city and neighboring villages. The estuarine system, which is also a Ramsar site, is home to a wide range of mangrove species, birds, fish, edible crabs, and other wildlife. Next to the Vembanad estuary, it is the second largest fish market centre, and thousands of fishermen rely on the estuary for their living. However, the wetland system has been deteriorating as a result of the dumping of solid wastes, animal wastes, biological wastes, and other pollutants into it at random.

The TS Canal, also known as the Kollam Canal, is a section of the **National Waterway-3** and the 78-kilometer-long Kollam-Kovalam State Waterway Project, which includes a 7.7-kilometer-long canal system that runs through Kollam and runs from Ashtamudi Lake to Paravoor Lake in the south.

6.2.6 SURFACE DRAINAGE PATTERN

Ashtamudi Lake to the north and the Lakshadweep Sea to the south naturally drain Kollam. The city is split into two drainage zones by NH 47, which runs through it. The city region west of NH 47, which is positioned between the sea and the national highway, drains naturally into the sea, but the city area east of the highway drains from west to east, primarily towards the Ashtamudi Lake. Waterlogging occurrences have been observed in a few low-lying regions of the city, mostly in slums and densely populated neighborhoods. Chathinakulam, Mundakkeri, Pattathanam, and Manayil Kulangari are few of these areas, which are located in the centre of the city and experience localized flooding during periods of sustained high intensity rains. In these places, the greatest time of water stagnation is roughly 2-3 days. Various natural canals also drain the city, acting as principal drains and receiving the majority of the city's storm runoff.

The main causes of waterlogging are:

- a) reduced carrying capacity of existing canals/drains due to heavy silt deposition, discharge of solid wastes in the canals/drains, and growth of vegetation in the canals/drains;

- b) unplanned reclamation of water bodies and haphazard development in low-lying areas without due consideration of the drainage system;
- c) insufficient or no drainage facilities in certain areas; and
- d) irregular and inadequacy of Natural drainage systems discharge into the sea, the T.S. Canal, or Ashtamudi Lake.

6.3 MAJOR WATERBODIES IN KOLLAM

The Kallada river, which runs for 151 kilometers, the Ittikara river, which runs for 56 kilometers, and the Pallikal River, which runs for 42 kilometers, are the three major rivers in the district.



Figure 45 Location of Major Water bodies

Google Map

➤ PALLIKAL RIVER

The Pallikal River having a length of 42 kilometers flows through Kollam district and joins the Kallada River. This river is used for irrigation and fishing by many people. Pallikal River separates it from Thodiyoor panchayath on its western side. Here is where the Pallikal River begins. Permissible values: DO > 4.0 mg/l, pH: 6.5-8.5, BOD < 3, TC: MPN/100ml shall be 5000

Table 16 Pallikal River Monitoring Report
AT PALLIKAL - 2016

	pH	DO	BOD	TC
Units		mg/l	mg/l	no/100ml
Max	7.7	7	2.1	560
Min	6.7	5.8	1.2	300
Mean	7.12	6.59	1.51	438.33
2017				
Max	7.5	7.1	2	420
Min	6.9	5.4	1	320
Mean	7.26	6.38	1.23	393
2018				
Max	7.2	6.8	1.4	410
Min	6.7	6	0.2	140
Mean	7.05	6.4	1.6	284

Pollution Control Board

➤ KALLADA RIVER

Kallada River originates from the Kulathurpuzha Section of Western Ghats near Ponnudi in Thiruvananthapuram District. It flows through Kollam District. The North Mynagappally - Somavilasam, Anoor kavu - branch of the Kallada Irrigation Project canal finishes in the Pallikal River. It is the longest river in Kerala, India's Kollam District. The Kallada river rises in the Kollam district's south-eastern corner. The Kallada Irrigation Project (KIP) is Kerala's biggest irrigation project. This 121-kilometer-long river flows into the Ashtamudi Lake in the Kollam District. Another attraction of this river is the Palaruvi Waterfalls. Permissible values: DO > 4.0 mg/l, pH: 6.5-8.5, BOD < 3, TC: MPN/100ml shall be 5000

Table 17 Kallada River Monitoring Report

AT KALLADA RIVER - 2016

	pH	DO	BOD	TC
Units		mg/l	mg/l	no/100ml
Max	7.4	7.7	2.8	1700
Min	6.8	4.2	1	310
Mean	7.13	6.73	1.61	738
2018				
Max	7.5	7.1	2	420
Min	6.9	5.4	1	320
Mean	7.26	6.38	1.23	393

Pollution Control Board

Table 18 Pallikal and Kallada River

	PALLIKKAL	KALLADA
Basin area, km ²	220	1699
Basin area in Kerala State, km ²	220	1699
District of Kerala in which basin are located	Pathanamthitta,Kollam , Thiruvananthapuram	Pathanamthitta, Kollam , Thiruvananthapuram
Origin of River		Karimalai, Kadakkal Elevation.m : 1524
Length of main stream, km	42	121
Main tributaries		Kulathupuzha, Chendurni, Kalthuruthi
Average annual rainfall, mm	2800	2800
Average annual streamflow, Mm ³	3374.86	3374.86
Water requirement for domestic use (2021 AD), Mm ³	244.5	244.5
Existing major/medium irrigation projects under construction(Commissioned/Partially Commissioned)		Kallada
Proposed Hydroelectric project		Kallada
Water requirement for industrial use (2021 AD), Mm ³	400	400
Navigable length of river, km	2	40

(ENVIS Hub: Kerala, 2022)

➤ **ITTIKKARA RIVER**

The Ittikkara River runs for 56 kilometers in Kerala, India. It rises in the Western Ghats' Kulathurpuzha and runs through the Kollam district before emptying into Paravur Lake. Ittikkara is a riverside community located 15 kilometers from Kollam's port. It rises in Thiruvananthapuram District's Ponnudi and runs through Kollam District before emptying into Paravur Kayal. Chathannoor and Pooyappally are two settlements along the river. Permissible values: DO > 4.0 mg/l, pH: 6.5-8.5, BOD < 3, TC: MPN/100ml shall be 5000

Table 19 Ittikkara River Monitoring Report

AT ITHIKKARA - 2016

	pH	DO	BOD	TC
Units		mg/l	mg/l	no/100ml
Max	8	7.7	2.4	1100
Min	6.8	6.1	1	320
2018				
Mean	7.49	6.68	1.4	680.83
Max	7.8	7.1	1.6	410
Min	7	4.5	1	180
Mean	7.33	6.5	1.1	293

Pollution Control Board

Table 20 Ittikkara River

Basin area, km ²	:	642
Basin area in Kerala State, km ²	:	642
District of Kerala in which basin are located	:	Kollam , Thiruvananthapuram
Origin of River	:	Madathurikunnu Elevation.m : 240
Length of main stream, km	:	56
Main tributaries	:	Vattaparambu,Kundumanthodu, Vattamthodu, Kulanjethodu
Average annual rainfall, mm	:	2400
Average annual streamflow, Mm ³	:	489
Water requirement for wetland for three crops, Mm ³	:	343
Water requirement for gardenland , Mm ³	:	150
Water requirement for domestic use (2021 AD), Mm ³	:	103.5
Water requirement for industrial use (2021 AD), Mm ³	:	45
Navigable length of river, km	:	16

(ENVIS Hub: Kerala, 2022)

➤ ASHTAMUDI LAKE

The Ashtamudi Lake in Kerala's Kollam district is one of the world's largest and deepest wetland ecosystems. It is one of the deepest estuaries in the state. The lake stretches northwards from Kollam town. The lake is fashioned like a palm tree or, as the locals prefer to call it, an octopus. The Ramsar Convention for the conservation and sustainable use of wetlands put Ashtamudi Wetland on its list of wetlands of international importance. People living near the lake rely on fishing, coconut husk retting for coir manufacture, and inland transportation services to make a living.

There are 43 different species of mangrove in the Ashtamudi Estuary. These species have a lot of potential for developing a marine bioreserve to enhance eco-tourism in the lake's estuary. There are 57 species of avifauna in the lake, 6 of which are migratory and 51 of which are resident. Around 40 species of wetland-dependent birds have been observed in the lake, with 45 percent of them being long-distance migrants. The most common birds in the lake are terns, plovers, cormorants, and herons.

The water quality of Ashtamudi Lake is decreasing, particularly in the area connecting the lake to Kollam city's built-up area, the TS Canal, and the Kallada River. It currently

receives all untreated sewage from the city of Kollam, as well as direct human excreta disposal from hanging latrines and domestic garbage. In some areas, particularly around the port and in the Kallada River zone, microbiological pollution is high. The use of chemical/organic fertilizers and insecticides/pesticides is justified by agricultural practices, and the residual discharge into the lake causes pollution and water eutrophication. Waste disposal from the coconut husk retting, ceramic, paper, and palm oil industries, tourism, cashew manufacturers, and hospitals has harmed the southern half of Ashtamudi Lake, resulting in increased bioaccumulation of sediments and heavy metals. The problem is made worse by untreated effluents from small-scale companies, poor fishing methods, food processing facilities, boat building yards, oil spills, and slaughterhouses.

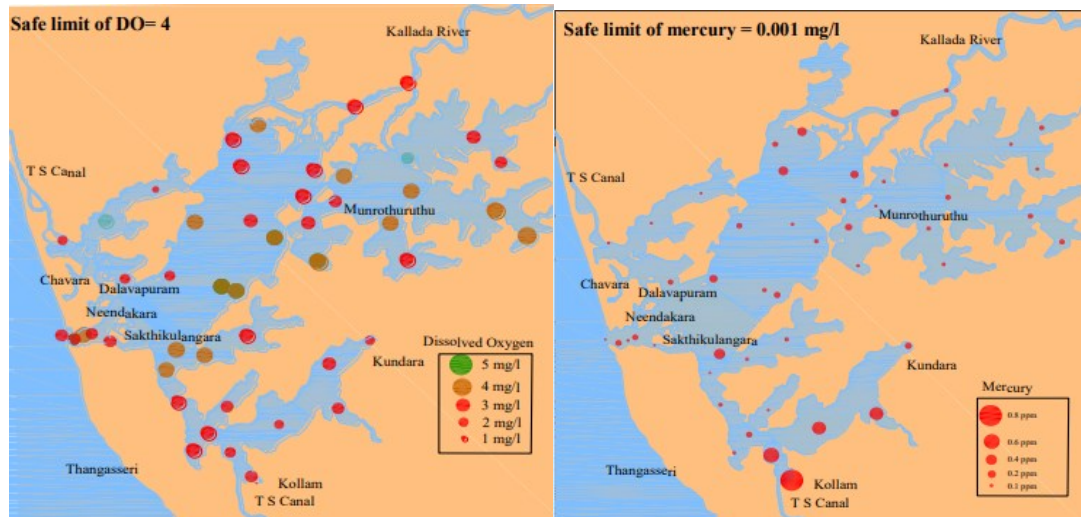


Figure 46 Dissolved Oxygen Levels and Mercury Levels

(Sitaram, 2014)

Table 21 Variations of Water Quality Parameter in Ashtamudi Lake

Year	Water Quality Parameter (DO,pH and Heavy Metals)			
	Permissible values : DO > 4.0 mg/l, pH : 6-8.5, Mercury <0.001mg/l, Cd<0.01mg/l			
	DO	pH	Mercury	Cadmium
1999	3.8	7.8	0.16	0.225
2003	3.4	8.1	0.23	0.230
2006	2.5	8.1	0.29	0.260

(Sitaram, 2014)

Over a seven-year period, the water quality parameters of DO, pH, and heavy metals were analyzed, and it was discovered that the water quality in Ashtamudi Lake is decreasing at

a quicker rate. Kerala State Council for Science, Technology, and Environment (Kerala State Council for Science, Technology, and Environment). The Korean Society for the Conservation of Science, Technology, and the Environment (KSCSTE) has proposed a comprehensive plan to increase Ashtamudi water quality and long-term viability Lake.

Agricultural growth, aquaculture techniques, coir retting, harbor construction, urban development, and other public and private uses are among the many reasons for which the lake is reclaimed. Dumping of urban rubbish is also reclaiming the Ashtamudi Lake's southern end near the Asramam district (Sitaram, 2014).

Table 22 Ashtamudi Lake Monitoring Report

AT ASHTAMUDI - 2016

	pH	DO	BOD	TC
Units		mg/l	mg/l	no/100ml
Max	7.8	6.8	4.8	680
Min	6.9	5.5	1.4	480
Mean	7.5	6.12	2.92	605.45
2017				
Max	7.6	6.8	2.4	680
Min	6.8	5.7	1.4	480
Mean	7.28	6.53	19.3	612
2018				
Max	7.8	6.6	2.4	580
Min	6.8	5.4	1.2	210
Mean	7.20	6	1.7	408

PCB

COMPARATIVE STUDY OF RIVERS

Table 23 Comparative analysis

NAME OF THE RIVER	pH		DO (mg/l)		BOD (mg/l)		TC (no./100ml)		Permissible values
	2016	2018	2016	2018	2016	2018	2016	2018	
PALLIKAL RIVER	7.12	7.05	6.59	6.4	1.51	1.6	438.33	284	DO > 4.0 mg/l, pH: 6.5-8.5, BOD < 3, TC: MPN/100ml shall be 5000
KALLADA RIVER	7.13	7.26	6.73	6.38	1.16	1.23	738	393	DO > 4.0 mg/l, pH: 6.5-8.5, BOD < 3, TC: MPN/100ml shall be 5000
ITTIKKARA RIVER	7.4	7.33	6.9	6.5	1.7	1.1	710	293	DO > 4.0 mg/l, pH: 6.5-8.5, BOD < 3, TC: MPN/100ml shall be 5000
ASHTAMUDI LAKE	7.5	7.20	6.12	6	2.92	1.7	605.45	408	DO > 4.0 mg/l, pH: 6.5-8.5, BOD < 3, TC: MPN/100ml shall be 5000

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CHAPTER 7 WATER SUPPLY IN KOLLAM CORPORATION

7.1 EXISTING WATER SUPPLY FACILITIES

The main source of water for Kollam Corporation is Sasthamcotta Lake. The lake lies 16 kilometers from the city. The lake has a maximum capacity of 60 MLD of water that can be extracted. Within the Corporation Area, there are additional 33 tube wells that provide 5 MLD of water. There are two water treatment plants, one with a capacity of 22.5 MLD and the other with a capacity of 37.5 MLD. Only the 37.5 MLD water plant is operational, while the other is not. This plant produces 18 million liters of purified water.

The state government department, Kerala Water Authority, is responsible for water supply, including operation and maintenance activities within the Kollam corporation jurisdiction area (KWA). It delivers water to the city from a variety of sources, including Sasthamcotta Lake and tube wells/bore wells, among others.

Because the Kollam Corporation is bordered by the Arabian Sea and Ashtamudi Lake, open wells are not practicable in most areas, particularly along the coastal strip, due to salt. The Kollam Corporation's residents rely on piped water for their daily requirements. Residents of the Kollam Corporation rely on piped water provided by Kerala Water Authority through the **Quilon Water Supply Scheme**.

7.1.1 QUILON WATER SUPPLY SCHEME

Comprehensive Water Supply Scheme that was commissioned in 1958 with Norwegian funding and upgraded in 1997 with World Bank aid. The project gets its fresh water from Sasthamcotta, which is around 25 kilometers from the Corporation boundary. The lake's raw water is piped into a water treatment plant in Sasthamcotta, and then sent to Kollam Corporation via 750mm dia cast iron pipes laid over a distance of around 26 kilometers.

Water that reaches Kollam Corporation is collected in a sump with a capacity of 20 lakh liters, which is located within the Corporation's boundaries near Ananthavalleeswaram. Water is piped from this sump to twelve Overhead Service Reservoirs positioned across the organization for distribution. KWA now operates the OWSS (Quillon Water Supply

Scheme) facility, which has a total capacity of 37.5 MLD. About 16 MLD of treated water is sourced from this water treatment plant and given to the city, with the remainder being diverted to the nearby gramme panchayats. As previously mentioned, 35 tube-wells provide approximately 2 MLD of water, which is piped straight into the distribution network after chlorination. The existing water supply system was installed in 1958, and since then, augmentation and maintenance work has been carried out on a regular basis between the 1990s and 1999.

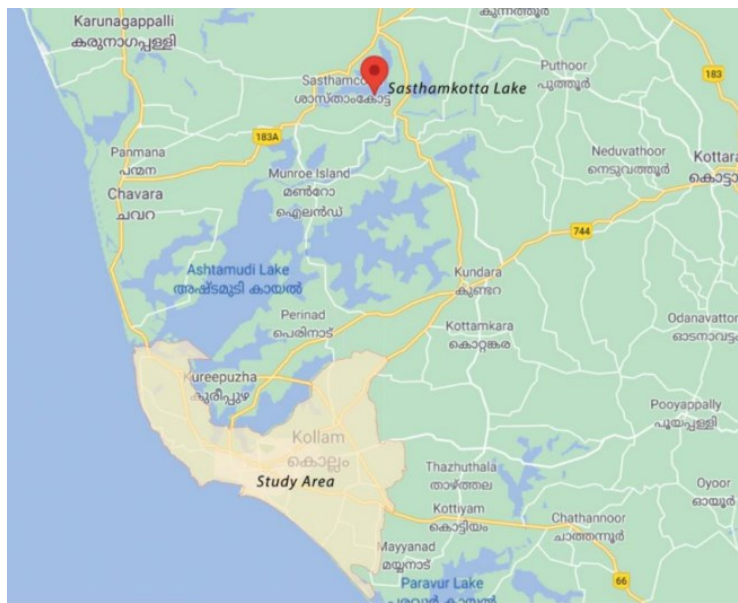


Figure 47 Map showing the location of study area and Sasthamcotta Lake

Google Map

The water comes from Lake Sasthamcotta and is processed at a quick sand filtration plant. According to KWA, there are currently two water treatment facilities with capacities of 37.5 MLD and 22 MLD, and a third WTP is being considered. However, the WTP, which has a capacity of 37.5 MLD, is only operational, and Kollam receives about 13-15 MLD from it. Water is then piped to the main sump at Ananthavalleeswaram Collectorate campus. Water is chlorinated at this stage before being sent to ERS and the distribution network.

According to service providers, Sasthamcotta Lake will not be viable in the future due to significant water level decline. This, combined with the expansion of municipal boundaries and, most all, the city's population (including the floating population), has put persistent strain on the city's fresh water supply.

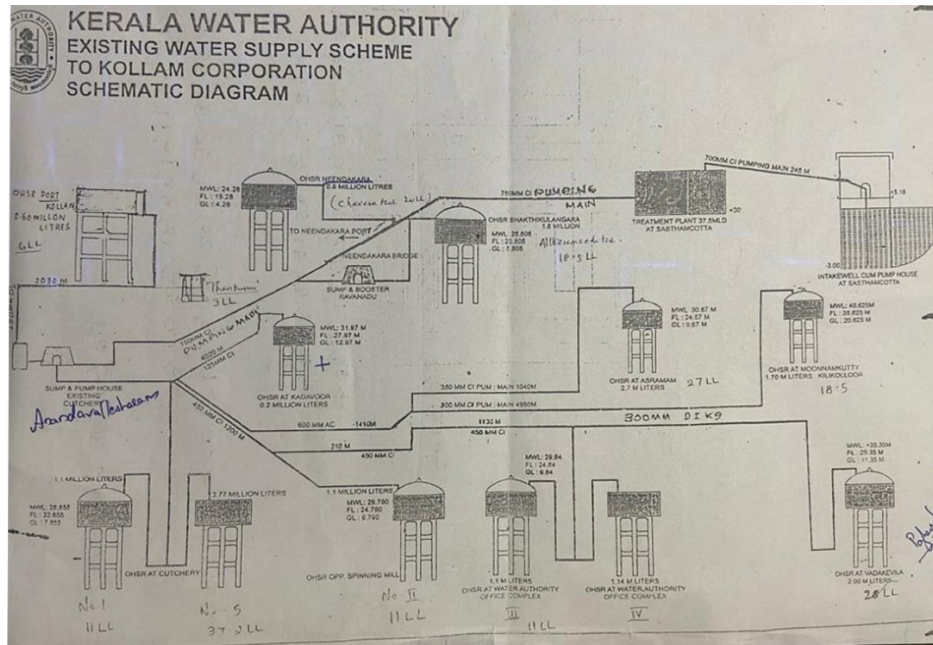


Figure 48 Existing Water Supply Scheme
Kerala Water Authority

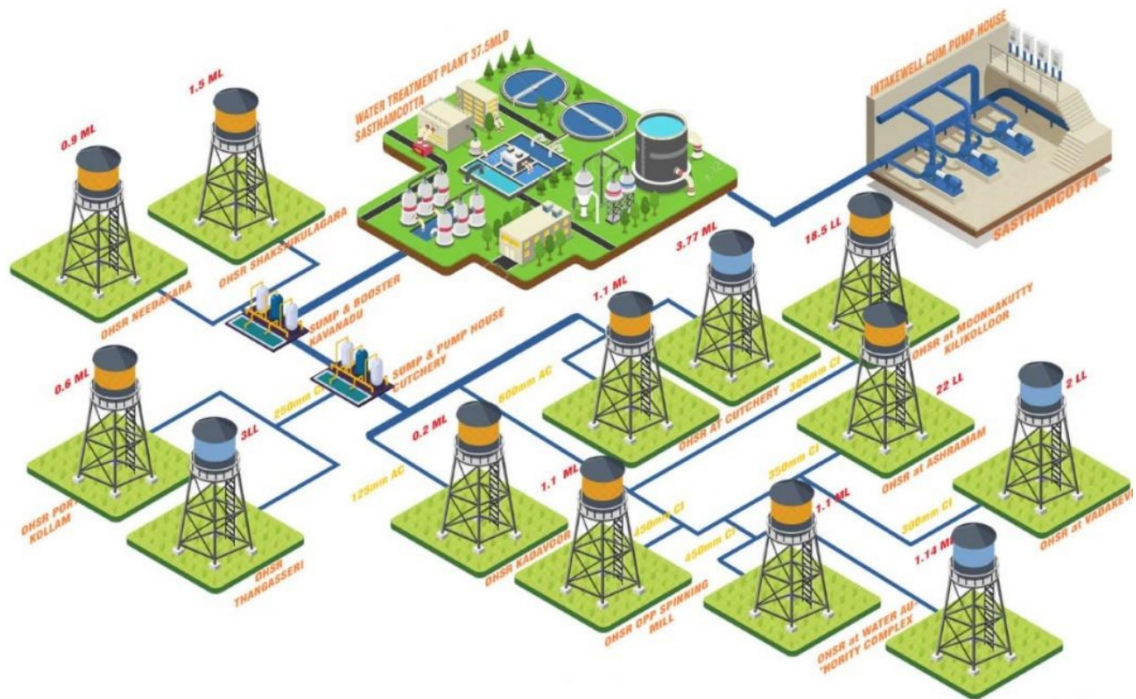


Figure 49 Schematic Diagram showing Main Water Supply System in Kollam Corporation
(KOVOR, 2021)

7.1.2 JAPAN INTERNATIONAL CORPORATION AGENCY(JICA) PROJECT FOR WATER SUPPLY:

Meenad Scheme is a JICA-funded water delivery project. KWA is currently implementing five projects as part of the much bigger "Kerala Water Supply Project." Intake (Pump house), water treatment plant, transmission main line, overhead service reservoirs, and water distribution lines are the four components of the project. One of the primary difficulties facing the city is that the city's current source of water, Sasthamcotta Lake, has reached its capacity limit, necessitating the search for a new source of water.

The Kallada River, which is around 50 kilometers from Kollam, has been identified as a new water source under the JICA project. It is intended to relieve major strain on the Sasthamcotta fresh water lake, which is rapidly dwindling. The Kollam District receives 73 MLD of water from this project, with 4 MLD going to the Kollam Corporation region. The project entails connecting the Meenad system to the Kollam WTP by a 250 mm diameter pipe running from the Kottiyam Reservoir to the Pazhayattinkuzhy Reservoir. Water is provided to 21 wards in the Kollam corporation region under this system.

Table 24 Citywide Household Level Water Supply Status

No. Of Households	Sources Of Drinking Water						
	Tap Water from Treated Source	Tap Water from Untreated Source	Covered Well	Uncovered Well	Hand Pump	Tube Well/Bore Well	Other Sources
88,522 (Excludes Institutional Households)	31,104	4899	19416	31265	73	1146	619
9734 (Newly Incorporated Area Thrikkadavoor)	2080	854	1766	4706	53	85	187
100%	33.77%	5.86%	21.56%	36.61%	0.13%	1.25%	0.82%

(Final City Sanitation Plan - Kollam, 2020)

7.2 SOURCES OF WATER AND ITS ADEQUACY

The city is divided into 55 wards; however, there are no water supply zones, and water is supplied to families, commercial establishments, and institutional establishments through a linked distribution network of service reservoirs (ESRs) throughout the city. At this

time, the Kollam Corporation is not involved in any operations relating to water delivery; nevertheless, the KMC has begun a scheme in which they distribute free water to impoverished parts of society including slum dwellers. KWA presently supplies tap water connections at the household level in the newly added Thrikkadavoor; nevertheless, coverage is limited.

To supply the Municipality's industrial, commercial, and institutional water demands, Kollam mostly relies on ground water. The existing sources of water supply to Kollam Corporation are local wells in residential residences, ground water bore wells controlled by the corporation, and the largest fresh water lake at Sasthamcotta. Only roughly 34% of the population has access to clean drinking water at this time. Kerala Water Authority will need to expand its distribution network as well as identify other fresh-water sources in order to improve service levels. With a similar aim, KWA has identified a new plan at River Kallada that is likely to meet the city's water supply needs in the future.

KWA is the company that owns and operates Kollam Water Works. A system of 48 ground water tube wells and Sasthamcotta Lake, which is stored by ground water springs, are the sources of Kollam's drinking water. The water extracted from these sources is supplied to the general public via a 453-kilometer distribution network with ten service reservoirs with a total capacity of 1.2 billion gallons.

The river then travels north-west till it reaches Pathanapuram, where it flows west to Enath. In other terms, the river runs south-west till it reaches Ashtamudi Lake. The river is roughly 121 kilometers long. A dam was built by the irrigation department for the Kallada irrigation project downstream of the confluence of the three streams at Parappan. This dam has a gross storage capacity of 504 m³ and a live storage capacity of 484.92 m³. The Kallada irrigation project's irrigation canals begin at Ottakkal weir, 5 kilometers downstream of Thenmala dam. A hydroelectric project is also housed within the dam. The Kallada River is an important source of water for Kerala Water Authority's various water supply programs.

7.3 WATER DISTRIBUTION NETWORK

Raw water is provided after treatment through elevated service reservoirs that are nearly at the same height, allowing for a hydraulically feasible integrated distribution network.

Direct pumping is used to distribute water from tube wells/borewells (about 2 MLD, according to KWA). The existing water distribution network is approximately 363 kilometers long, with pipes ranging in diameter from 50 to 450 millimeters that were installed in the 1970s and 1990s and periodically rebuilt. In addition, the city has 3248 stand-posts/public taps, which are frequently shared by three to four homes. KMC, according to KMC, bears the cost of providing water to underprivileged and poor individuals. These stand-posts are delivered to low-income homes, particularly those living in slums, and provide as their primary supply of drinking water.

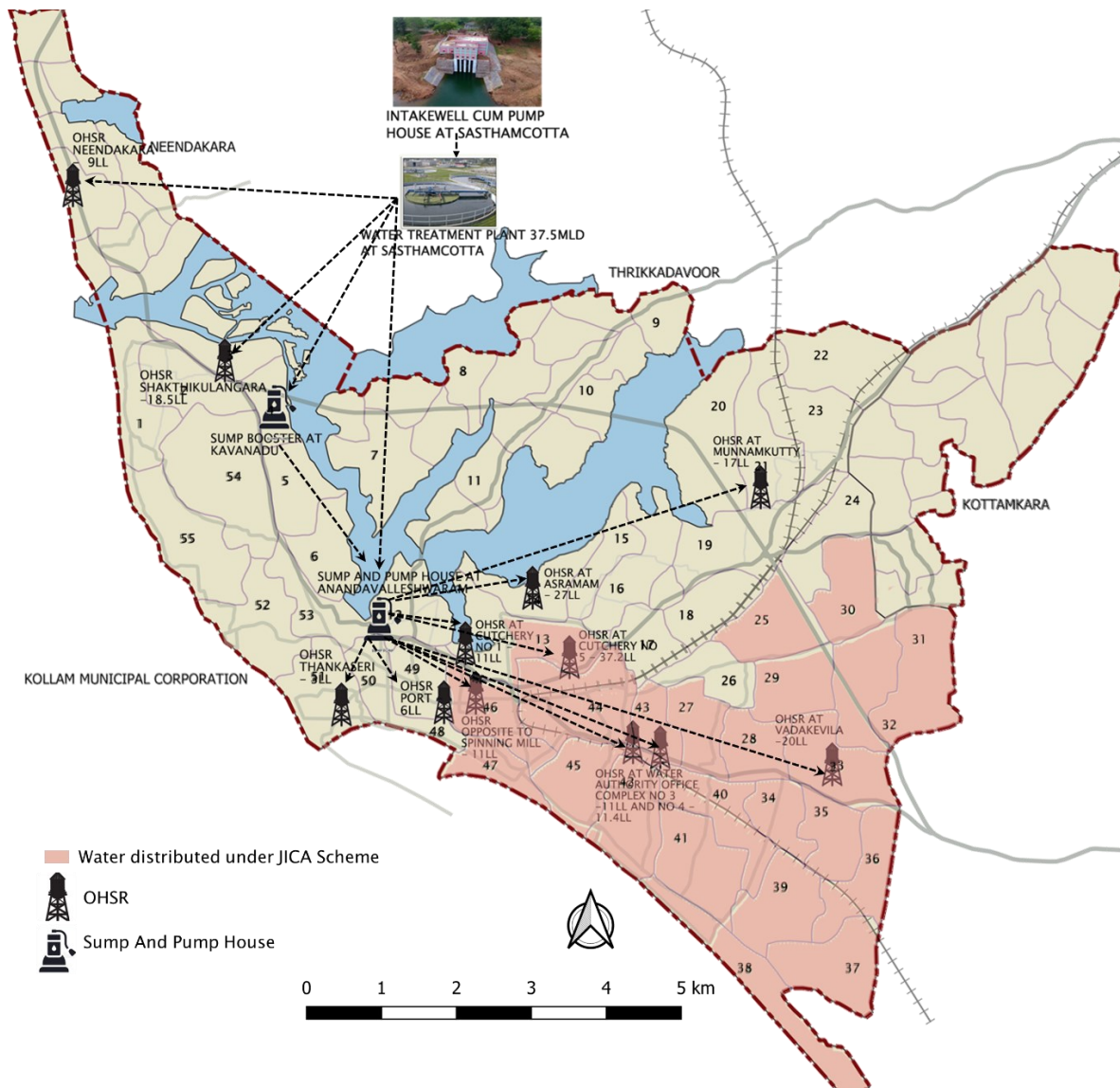


Figure 50 Locations of Overhead Water Tanks

Author Generated with reference to KWA Data

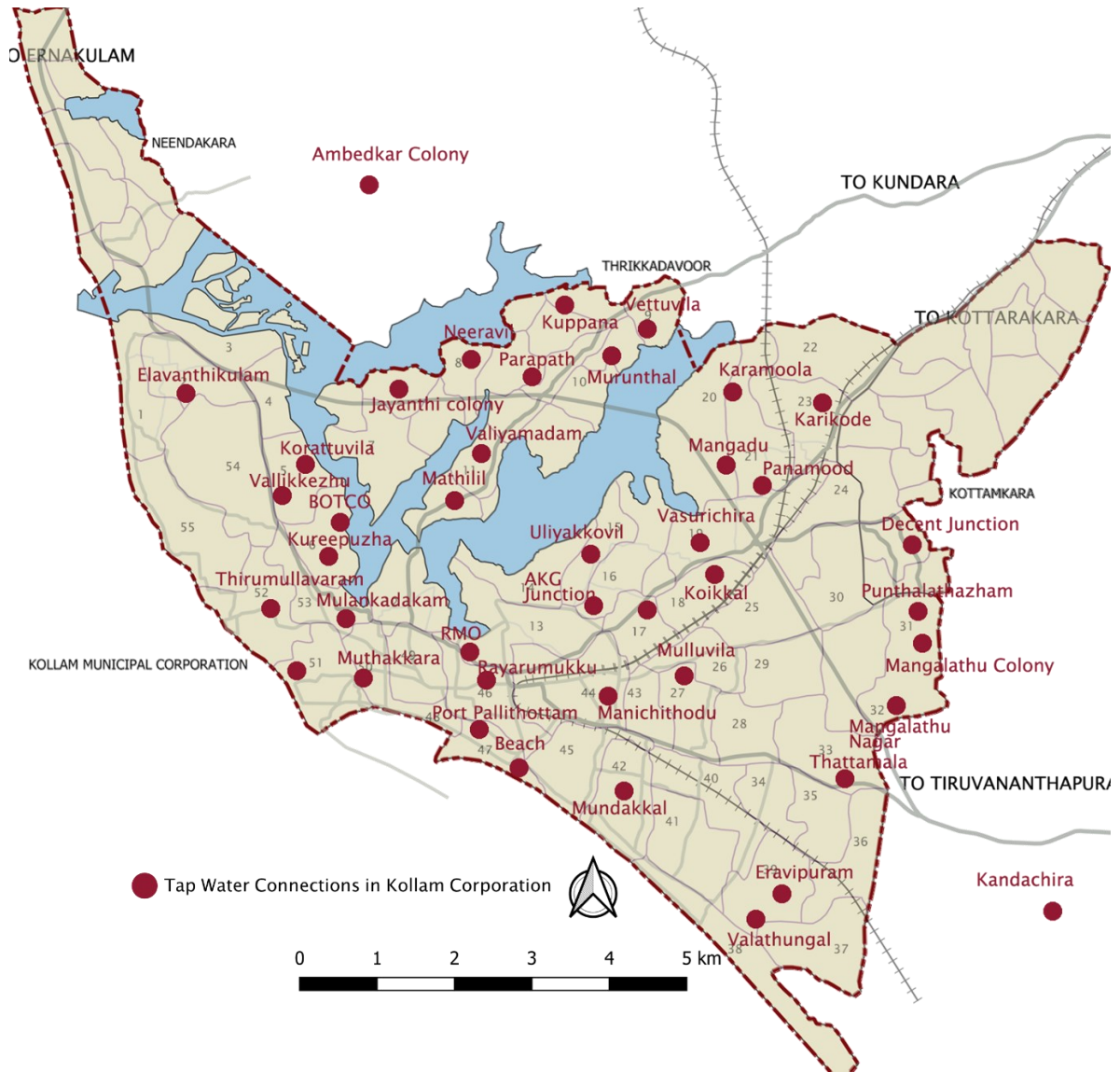


Figure 51 Tap Water Connections in Kollam Corporation

Author Generated from Kerala Water Authority Data

Table 25 Water Reservoirs and their Capacities in KMC

Location of Reservoirs	Capacity (Lakh Liters)	Location of Reservoirs	Capacity (Lakh Liters)
Shaktikulangara	18.5 LL	Parvathi Mills - No. 2	11 LL
Neendakara	9 LL	Water Authority Complex - No. 3	11LL
Port	6 LL	Water Authority Complex - No. 4	11.4 LL
Thangasery	3 LL	Vadakkevila	20 LL
Cutchery - No. 1	11LL	Asramam	27 LL
Cutchery - No. 5	37.2 LL	Moonnamkutty	18.5 LL
Total Storage Capacity		183.6 LL	

Kerala Water Authority

Table 26 Capacity of The Tank and Source

Wards	No. Of Overhead Tanks/ Reservoirs and Capacity	Source And Capacity of Wtps	Treated Supply As% Of Total Water Supplied
1 - 6	1 overhead tank / 20 Lakh litre	Sasthamcotta lake (20MLD)	75.00%
7 - 11	2 OHT / 4 Lakh litre	Tube Well	
12 - 13	1 OHT / 11 Lakh litre	Sasthamcotta Lake (20 MLD)	
14 - 17	1 OHT / 20 Lakh litre		
18 - 24	1 OHT / 20 Lakh litre		
25 - 26	Tube well / 10000 Litre	Tube Well	
27 - 41	2 OHT / 20 Lakh litre	Sasthamcotta Lake (20 MLD) and Kallada river(4MLD)	
42 - 47	2 OHT / 22 Lakh litre		
48 - 55	2 OHT / 48.5 Lakh litre	Sasthamcotta lake (20MLD)	

Kerala Water Authority

Table 27 Water Tariff in Kollam

Category	Monthly Consumption	Rate from 1/09/2008	Rate from 1/3/2009
Domestic	0 - 5 kilo litre	Rs.20/- Minimum	Rs.20/- Minimum
	5 - 10 kilo litre	Rs.20 + @ Rs.4/KL	Rs.20 + @ Rs.4/KL
	10 - 20 kilo litre	Rs.40 + @ Rs.5/KL	Rs.40 + @ Rs.5/KL
	20-30 kilo litre	Rs.90 + @ Rs.6/KL	Rs.90 + @ Rs.6/KL
	30-40 kilo litre	Rs.150 + @Rs.14/KL	Rs.150 +@. Rs.10/KL
	40-50 kilo litre	Rs.290 + @ Rs.14/KL	Rs.250 +@. Rs.14/KL
	Above 50 kilo liters	Rs.430 + @ Rs.25/KL	Rs.390 + @ Rs.25/KL
Non – Domestic	Upto15KL	@Rs.10 per KL and Rs.125/- Minimum	@Rs.10 per KL and Rs.125/- Minimum
	15 - 50 kilo litre	Rs.150+@ Rs. 14/KL	Rs.150+ @ Rs. 14/KL
	Above 50 kilo liters	Rs.640+@ Rs. 25/KL	Rs.640+@ Rs. 25/KL
Industrial	For the whole month consumption	@ Rs.25 per KL and Rs.250/ minimum	@Rs.25per KL and Rs.250/- Minimum

(Final City Sanitation Plan - Kollam, 2020)

Treated water is delivered to houses / tap connections via ductile iron, asbestos-cement, or polyvinyl chloride pipes of various sizes depending on their intended purpose and distances in the distribution network. According to KWA, there are currently 32,184 home connections and 1,730 commercial connections within KMC.

KWA also provides water to industrial customers, with 31 such customers now receiving water from the KWA. KWA requires all customers to apply for new connections, which is usually completed within 10 days. A new water supply connection rate for home consumers is Rs. 500/-, while it is around Rs. 1000/- for non-domestic consumers. The current water tariff implemented since 2008 – 09.

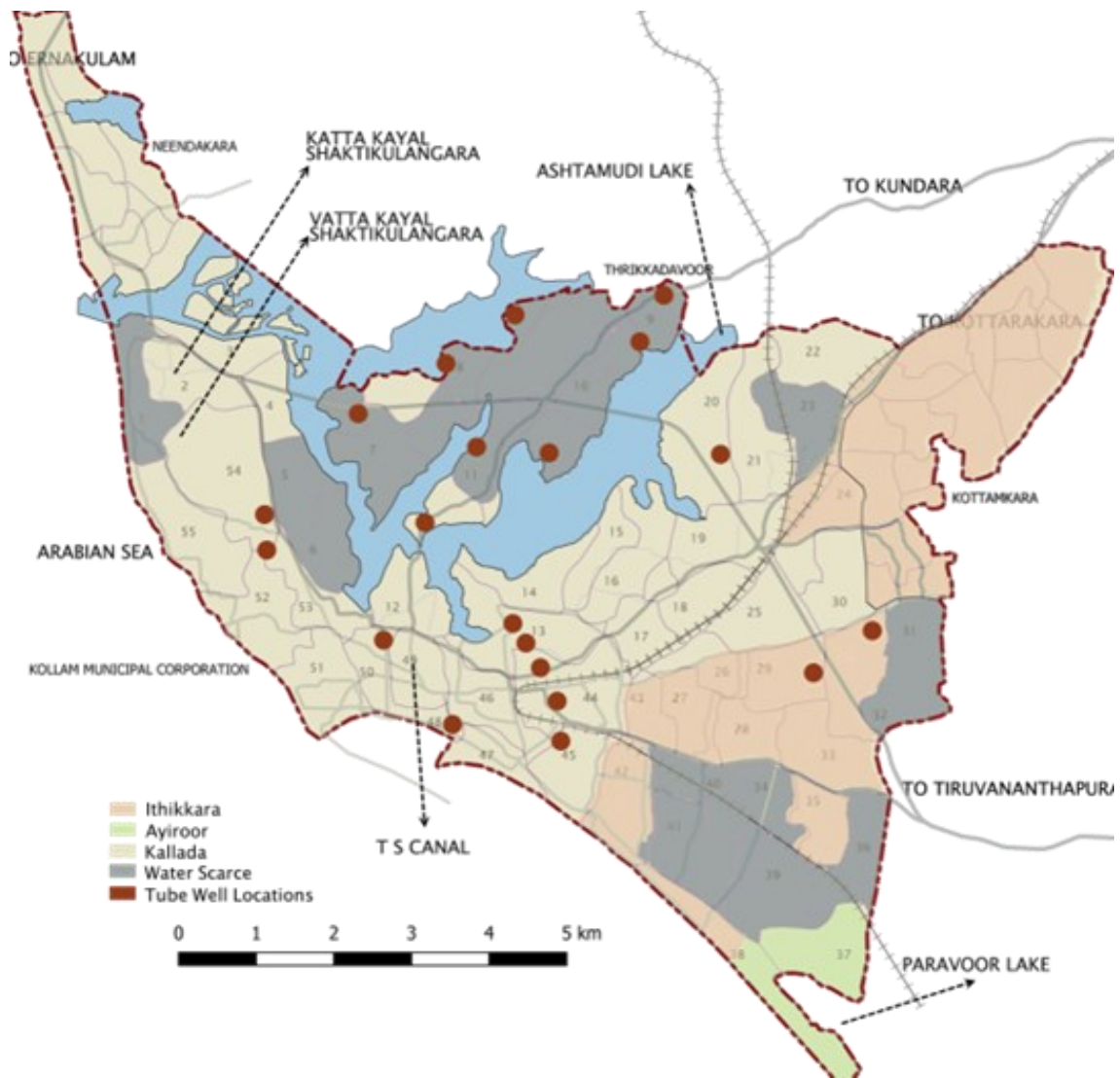


Figure 52 Map Locating the Tube wells and Water Scarcity

Author Generated with reference to KWA, Kollam

7.4 WATER QUALITY

It was impossible to determine the water's quality in terms of bacterial contamination and the presence of any chemicals or heavy metals in the city's supply. During stakeholder interactions, it was discovered that the city does not have any water quality issues in general, though water quality is an issue at a few locations during public interaction, such as infiltration of drainage water into the pipes during off-peak hours, which then gets mixed with potable water during peak hours. Residents in some areas have also reported receiving water that is yellowish in colour due to rust from ancient pipes.

Despite the fact that the chloride concentration at the intake point is well within permitted limits. During drought seasons, when a high amount of water for the project is extracted from the river, there is a potential that salinity will invade. As a result, a weir is recommended downstream of the intake point to prevent saline intrusion and to provide adequate water during dry seasons.

The 'BLUE BRIGADE' squad of KWA has been tasked with **detecting leaks** in the existing water supply infrastructure. As a result of the emergency, the leak in the pumping line was repaired within hours. The maintenance companies have been in charge of the water supply system's annual maintenance.

Table 28 Water Supply Service Levels in Kollam
Parameters Baseline Present Status

Parameters	Baseline	Present Status
Coverage of water supply connections	100%	38%
Per capita supply of water (net)	135 lpcd	51 lpcd
Extent of metering of water	100%	NA
Extent of non-revenue water	20%	20%
Continuity of water supply	24X 7	2-3 Hr./day
Quality of water supplied	100%	95%
Cost Recovery	100%	70%
Efficiency in collection of water related charges	90%	80%

Final City Sanitation Plan – Kollam, 2021

The amount of water delivered to consumers varies slightly depending on the area of town, ranging from 51 to 86 lpcd. It is found to be inconsistent in terms of continuity and duration, with an average supply of 2 to 3 hours.

7.5 FREQUENCY OF SUPPLY

KWA can provide roughly 32 MLD of water. As a result, the Kollam Corporation area receives daily water supply for two to three hours every morning. The area coverage of the Kollam Municipal Corporation is only 44%, and the per capita supply (57.5 lpcd) needs to be enhanced. Water supply is only available for a few hours every day, and the extra adequacy of drinking water during the summer season is /increases.

According to the AMRUT project, water supply is one of the mission's primary trust areas, so the Kollam Municipal Corporation must rehabilitate the sector's standards and current facilities.

7.6 WATER SCARCITY

According to the socio-economic survey, 7% of wards have severe water scarcity, 40% have medium scarcity, and 53% have water availability. Arunoottimangalam, College Division, Chathinakuiarn, Vallikeezhu, and other wards have significant scarcity.

7.7 DEMAND SUPPLY ANALYSIS

The water demand in Kollam city in 2041 is expected to be around 98 MLD, based on a combined population of 612300 in 2041 and a floating population of 15975 at a rate of 7% per year increase. These calculations also take into account the newly added Thrikkadavoor panchayat. According to the data, the existing water delivery capacity of roughly 16 MLD in the KMC area needs to be increased to satisfy future water demand. Furthermore, water supply requirements for the Kollam Municipal Corporation (KMC) over the next 30 years have been determined based on population predictions and MoUD recommended criteria for water provision.

According to the calculations, the current water supply is insufficient in terms of quantity within the city. To satisfy the city's needs for the next 30 years, KWA must find additional water supply source and expand its distribution network to serve the entire city. Aside from that, KWA must closely monitor losses and non-revenue water.

Population as per 2011 Census – 349033

Rate of Supply in lpcd in Corporation – 150lpcd

Sl.No	Name of the Village	Popn. as per 2011 census	Projected population in 1.72% decennial increase				Water demand @ 150 lpcd in mld				Institutional & Industrial demand @4%				Floating Population @5%		Floating Population Water demand @ 45 lpcd in mld		Design demand including 20% NRW		
			2016	2020	2035	2050	2016	2020	2035	2050	2016	2020	2035	2050	2035	2050	2035	2050	2016	2035	2050
1	Kollam Corporation	349033	352035	354436	363633	373041	52.805	53.165	54.545	55.956	2.112	2.127	2.182	2.238	18182	18652	0.818	0.839	68.646	71.931	73.791
2	Thikkadavoor panchayath	35859	36167	36414	37359	38325	5.425	5.462	5.604	5.749	0.217	0.218	0.224	0.230	1868	1916	0.084	0.086	7.053	7.390	7.581
3	TOTAL	384892	388202	390850	400992	411366	58.23	58.627	60.149	61.705	2.329	2.345	2.406	2.468	20050	20568	0.902	0.925	75.699	79.321	81.373

Design demand is taken as 88 MLD for a design period of 30 years from 2020 (Base year)

Table 29 Demand Supply Gap Analysis
Kerala Water Authority

7.7.1 BACK LOG IN WATER DEMAND AND SUPPLY

Water availability in the piped water supply lasts roughly 2-3 hours on average. The current water demand in Kollam is calculated as follows, based on a daily water supply demand of 384892 people (2011 census data):

Water demand (domestic use) = 135/lpcd

Other users (ice-related industries, institutions and firefighting) = 25 lpcd

Projected population:

Method	2021	2031	2041
Arithmetic Increase Method	4,14,125	4,78,052	5,44,201
Incremental Increase Method	5,28,254	8,21,284	12,28,245

Current population for the year 2021 = 4,14,125Nos (projected from census 2011) = **A**

Treated water supplied to the city = 32MLD = **B**

Quilon Water Supply System = 20 MLD

From tube wells = 8 MLD

JICA Project For Water Supply = 4 MLD

Water losses 25% (Assume) = C

Actual water supplied to the city = **D = (B – (B*C))**

$$= (32 - (32 * 25/100))$$

$$= 32 - 8$$

$$= 24$$

Per capita supply = **D/A = E**

$$= 24 / 414125 = 57.95 \text{ lpcd}$$

Water requirement of the city = 185vlpcd = **F**

Current water demand @102.8 MLD = **(F * A / (1-C)) = G**

$$= 103 \text{ MLD}$$

Backlog = **G - B**

$$= 103 - 32$$

$$= 71 \text{ MLD (Calculated with reference to Water Authority Data)}$$

7.8 NEED FOR NJANKADAVU PADHATHI

The Quilon Water Supply Scheme currently has a distribution network that covers the whole Kollam corporation region. However, the system can only offer 23 MLD of drinking water to the current population of 3.91 lakh, a poor average of 65 lpcd, although the CPHEEO-required per capita supply for urban population is 150 lpcd. The current population of Kollam Corporation is predicted to be 3.91 lakhs, with a projected population of 4.11 lakhs for the year 2050. At 150 lpcd, the water demand for the

predicted population of 2050 will be 62 MLD. The amount of raw water required, after accounting for industrial demand, floating population demand, NRW, and other factors, is 82 MLD. After deducting the current supply of 23 MLD, another 59 MLD is required to meet Kollam Corporation's water requirement.

The current water extraction from Sasthamcotta Lake for QWSS is around 14 MLD. In addition, the Chavara - Panmana Panchayaths are drawing 6 MLD of water from the lake as part of a water delivery project (Water demand is 11.5 MLD). WSS to Sasthamcotta, Sooranad (S), West Kallada and WSS to Thevalakkara - Thekkumbhagam are two other systems that are drawing 8MLD. Neendakara Panchayath receives an additional 4 MLD of water. Thus, even if the demand and total installed capacity of treatment plants for the above projects is 71 MLD, the total current extraction of water from the lake is only 32 MLD.

The disparity between demand and supply is attributable to the lake's fast depletion over the last few years. During a severe draught in 2015, the lake's water level dropped to 153cm below MSL, causing pumping to cease numerous times during the summer. The intake of water from the lake for QWSS has been cut short due to alarmingly low water levels, and as a result, water delivery to Kollam Corporation has been reduced to alternate days for 2-3 hours throughout the last three drought seasons. Furthermore, in 2002, Sasthamcotta Lake was designated as a RAMSAR site, a natural wetland area recognized internationally as environmentally significant, emphasizing the need to safeguard the lake by lowering current water extraction.

Given these circumstances, extracting an additional 59 MLD of water from Sasthamcotta Lake to meet Kollam Corporation's anticipated need is impossible. As a result, it is preferable for Kollam Corporation to find a new source to cover the whole demand of 82 MLD.

Because the Kallada River is the only stable source of water in Kottamkara Panchayath, and the panchayath is next to the Kollam Corporation area, the water demand of Kottamkara Panchayath is included in the planned scheme alongside the demand of Kollam Corporation. Furthermore, it is planned that the Raw Water Gravity Main and the Clear Water Pumping Main to Kilikollur be aligned through Kottamkara Panchayath. As

a result, it is proposed that the water demand of Kottamkara Panchayath be factored into the WSS expansion for Kollam Corporation. In this project, the allotted cost of Kottamkara panchayath is split and included in phase II.

This project is being implemented to meet the rising water demand in the Kollam Municipal Corporation area. The Kallada River is the source of the water. This concept is expected to result in a 100 MLD Ultimate Plant Demand Capacity. **Kollam Corporation and Kottamkara Panchayat** are the recipients. The project is being carried out by AMRUT and KIIFB contributing 78 crore and 235 crores respectively. This project is divided into two phases: Phase 1 is under the auspices of AMRUT, while Phase 2 is under the auspices of KIIFB.

1. AMRUT - Design, building, and completion of a 100 MLD water treatment plant at Vasoorchira as part of the WSS to Kollam Corporation Phase I.
2. KIIFB - Supplying, laying, commissioning, and maintaining 1016 mm diameter 8.8 mm thick mild steel clear water pumping main from treatment plant at Vasoorchira to overhead service reservoir at Manichithodu and from Manichithodu to Ananthavalleeswaram, as well as construction of 54 lakh litre overhead service reservoir at Manichithodu.

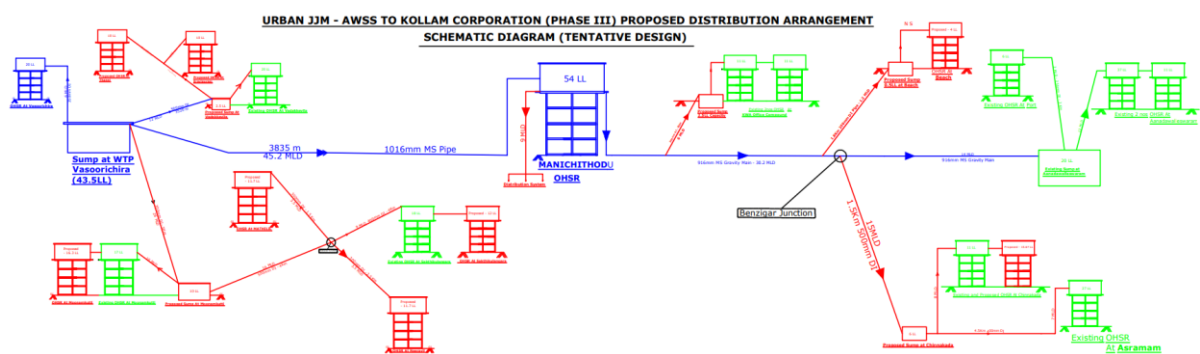


Figure 53 Schematic diagram of Njankadavu project

Kerala Water Authority

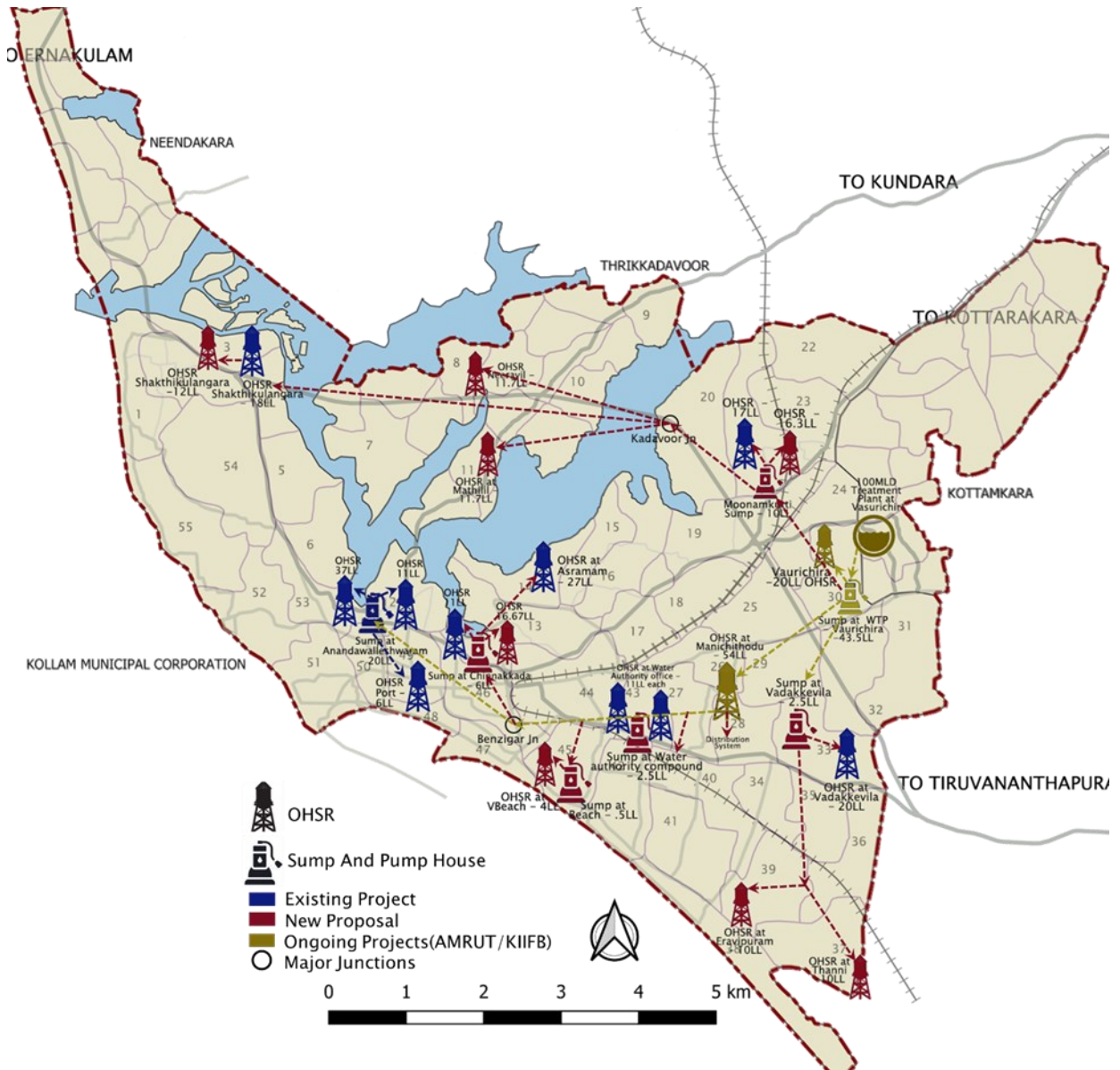


Figure 54 Njankadavu Project

Author Generated with reference to KWA data

7.9 NJANKADAVU PADHATI

The system will be implemented in three stages. AMRUT has done with Phase I of the project. In the three "State Annual Action Plans" of AMRUT from 2015-16 to 2017-18, a total of Rs. 78.35 crores are set aside for this scheme. The project's Phase II is suggested in the State Plan 2016-17, with funding from the "Kerala Infrastructure Investment Fund Board." The proposed Phase-II budget is Rs.235 crores, with Rs. 218.40 crores going to

Kollam Corporation. The current idea is for a new source other than Sasthamcotta Lake to supply the 82MLD of water required for the population of 411366 estimated for the year 2050 in the entire Kollam Corporation region.

The design period is 30 years from 2020, and the per capita water requirement for the corporation is 150 liters per day. The proposed pumping period is 23 hours, and the components are built to handle maximum water demand.

Water will be drawn from the Kallada river, with an intake point at the Njankadavu Bridge in the Pavithreswaram Panchayath. At Njankadavu, a 12m diameter intake open well cum pump house is proposed. In addition, a weir is suggested downstream of the intake.

7.10 ISSUES AFFECTING WATER SUPPLY





1. More than 60% of the HHs in the Kollam Corporation area get their water from shallow wells, however the water from open wells and tube wells is untreated. As a result, during the monsoon season, waterborne infections are common.
2. HHs have been deterred from using private wells due to a lack of confidence in the quality of water supplied by KWA and a low frequency of water deliveries.
3. Within the Kollam corporation borders, water supply lasted anywhere from 2 hours to 3 hour every day. It implies a massive demand/supply discrepancy, which is only expected to worsen in the future.
4. The current water supply system was installed in 1960 and is in a state of repair.
5. Another issue is water contamination caused by pipe leaks and the subsequent infiltration of storm water and groundwater, which occurs regularly during the monsoon.

6. Water pressures are low, and water distribution is irregular. The Corporation's water demand is around 92 MLD, however the existing infrastructure can only supply about 32 MLD.
7. Present source of water' the Sasthamcotta, is on the verge of drying up and cannot meet future demand for water supply (Kollam Corporation).
8. The regulatory structure in place to regulate the sector's operation and set service standards as well as tariffs in order to satisfy capital and operating expenditures is currently locked.

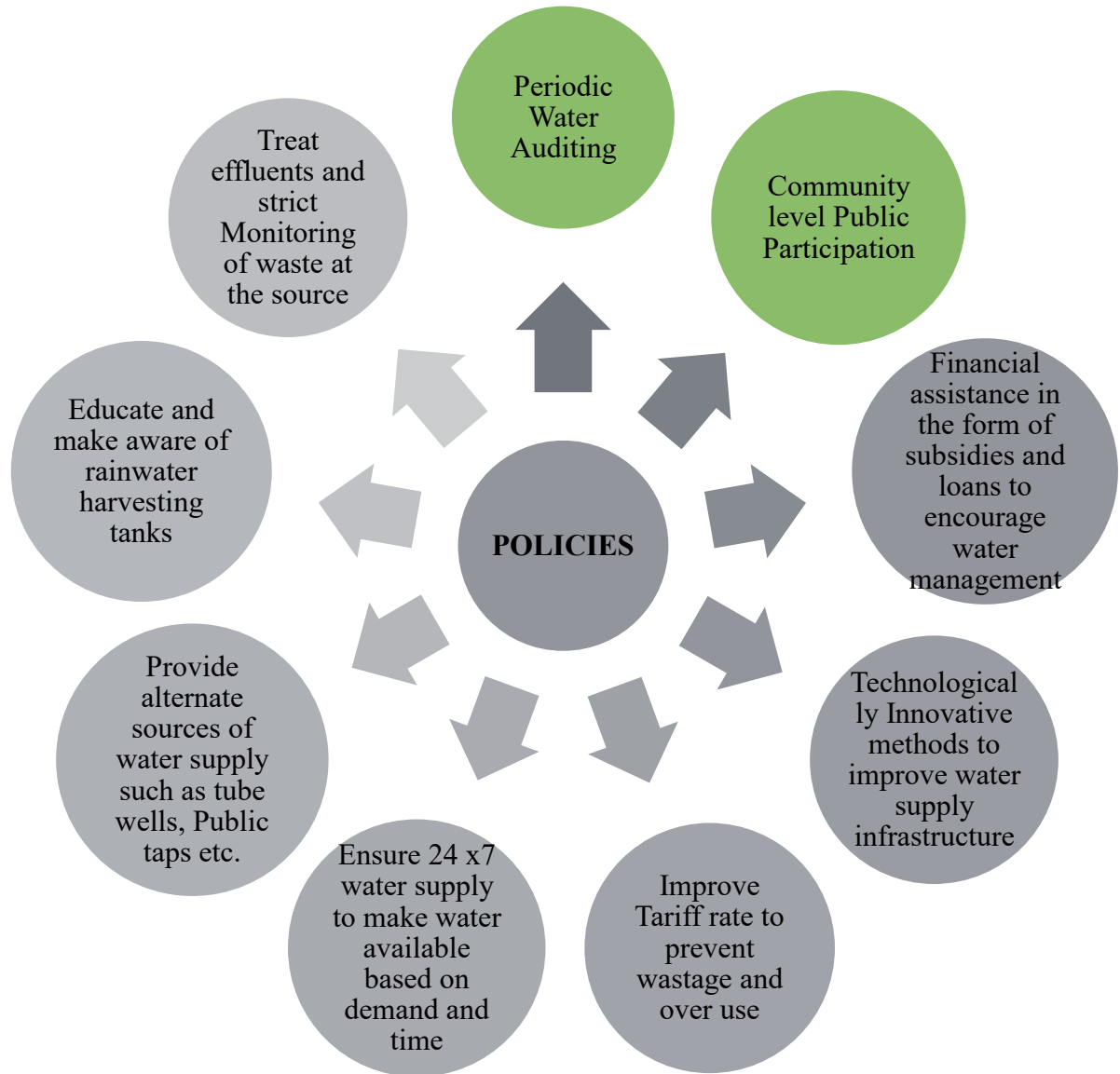
Table 30 Issues Affecting Water Supply Services in Kollam

Issues	Effects
Old distribution Network	Undetectable leakages, Loss of water, results in bad quality of water (due to rusting)
Absence of zones	Problems in monitoring & Inspection in distribution system
Illegal tapping, old pipelines, leakages, drain crossings, etc. especially in slums	Higher unaccounted for water losses and risk of contamination of public supply
Unavailability / Partial metering system	Difficulty in providing sustainable water supply scheme
Intermittent water supply in all the distribution networks.	Risk of Infiltration of contaminants/sewage and adverse effect on public health
Need for identification of alternate source	Insufficient water availability at present source, resulting in not meeting future water demand

CHAPTER 8 SWOT ANALYSIS

SWOT ANALYSIS	
<p>S T R E N G T H</p> 	<ul style="list-style-type: none"> • Kollam corporation have large sources of water bodies. (Kallada river, Sasthamcotta, Ittikara, Ashtamudi etc.) • Well water is most widely used than public taps and Municipal water. • Municipal water is free for BPL consumers up to 15kl/ month.
<p>W E A K N E S S</p> 	<ul style="list-style-type: none"> • Municipal water supply doesn't satisfy their need. • Many localities in Mangad area, Karikkode area, Thamarakulam area still don't have municipal water connection. • Interrupted water supply (2-3 hours daily morning or on alternate days). • Near to coastal areas saline intrusion is more. • In the Karikkode areas and nearby study areas the well water is acidic in nature which can be used only after treatment. • No alternate source of water supply. • During summer many areas of Kollam corporation (Karikkode, Coastal area, Mangad area etc.) faces water shortage. • Lack of maintenance leads to water loss. • Lack of infrastructure facilities. • Illegal pumping of water to overhead tanks leading to water shortage.
<p>O P P U R T U N I T Y</p> 	<ul style="list-style-type: none"> • Alternate source of water supply can be identified. • Community level public participation for conserving water can help to reduce water shortage. • Improved infrastructure facilities help to reduce water loss. • Awareness programs should be given to people regarding rainwater harvesting, RO etc. • Technologically innovate methods should be adopted to improve water supply infrastructure facility and to meet future demand. • New governmental schemes and programs should be implemented to encourage water management methods.
<p>T H R E A T</p> 	<ul style="list-style-type: none"> • Open well waters which are directly used are prone to contamination. • Many areas of Kollam corporation face water scarcity during summer.

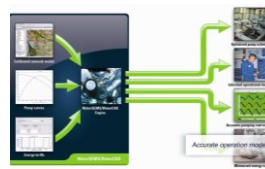
CHAPTER 9 POLICIES AND PLANNING RECOMMENDATIONS



Water Auditing



Community level Public Participation



Water GEMS



Educate and make aware



Periodic Water Auditing

- Periodic water auditing helps to improve the water supply services in Kollam Corporation.
- It helps to identify the water leakages, water loss, theft, seepage, illegal withdrawal of water etc there by improves the efficiency of water supply system and conserve water.
- Water Auditing should be done annually or on a periodic basis.



Community level Participation

- It helps in empowering participation on a community basis.
- It brings together all the people to implement techniques to conserve water.
- It helps in participating the local people including women and children.
- It gives opportunity for them to make decisions and choices of their own.



Subsidies / Loans

- Financial assistance in the form of subsidies and loans to encourage water management methods, i.e., by promoting use of artificial conservation methods (rainwater harvesting, RO etc.)



Tariff

- Tariff rates in Kollam Corporation is very less that rounds to paise for 1L of water. Due to this people are very careless about the use of water.
- They neglect even if these is any leakage.
- No strict rules are not followed for unauthorised or illegal tapping.
- Tariff rates should be increase so that revenue generated from the connection, operation & maintenance charge and water tariff helps to recover the expense incurred in the project.
- This helps in reducing over usage and wastage of water



Water GEMS software

- Water availability in Kollam Corporation is Interrupted (2- 3 hours on daily or alternative day basis.
- Technologically Innovative methods to improve water supply infrastructure through Water GEMS Software.
- It helps in providing 24 x 7 water supply based on demand.
- Water meters are located at each junction to monitor the flow and incur the charges based on Tariff slab.
- Coastal ward is selected to show how this software works on that ward.

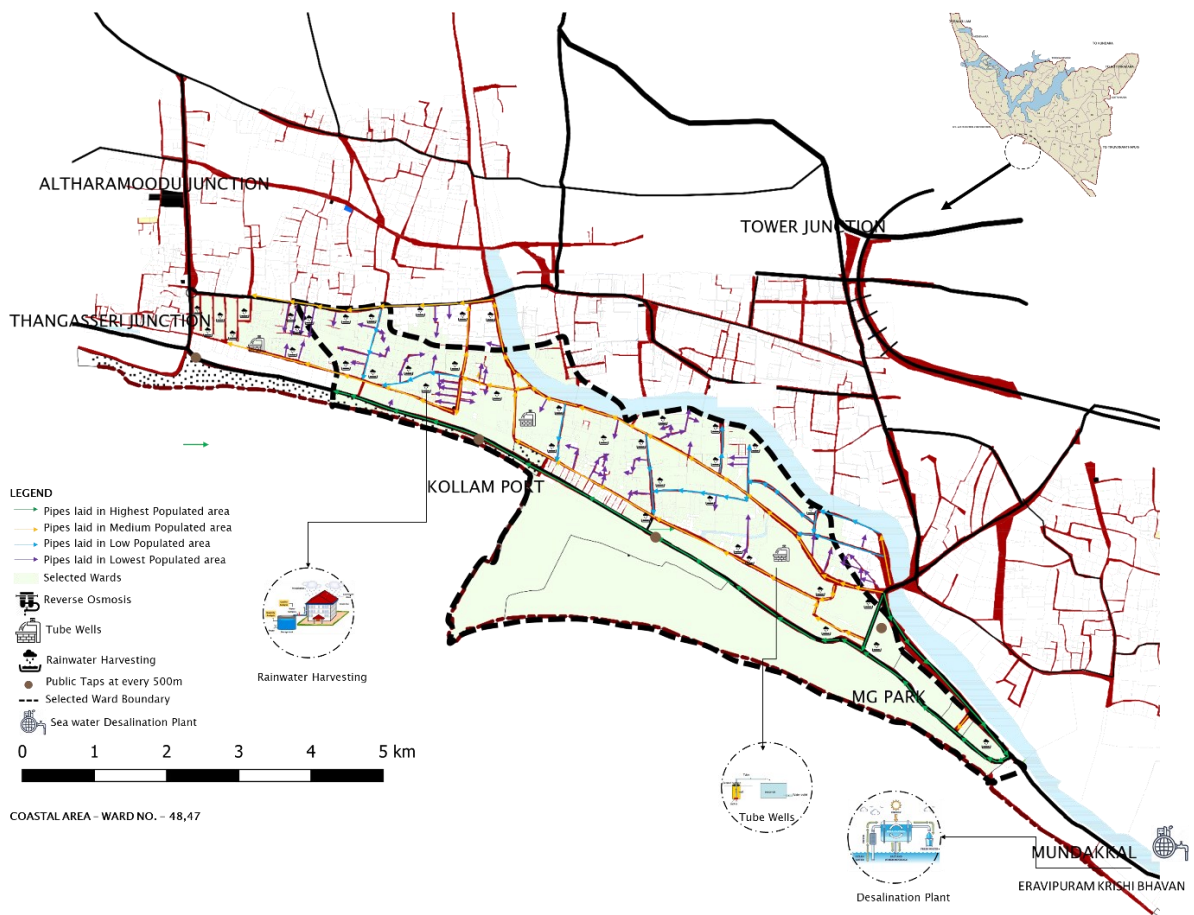


Figure 55 Coastal Area – Ward No. - 48,47

Author generated



24 x 7 Water Supply

- Interrupted water supply is the main issue faced by Kollam Corporation.
- Water supply is either available during morning or evening or morning on alternate days.
- 24 x 7 water supply solve the issues faced due to interrupted water supply.



Alternate Sources

- Alternate sources of water supply such as tube wells, public taps, RO system etc. helps to reduce water scarcity.
- Water Scarcity is found in ward no. 24,21,22,5,6,9,11,15; It is mainly during summer.
- In Kollam Corporation the most populated area is the coastal area and living here lack potable water.
- Saline Intrusion is also high.
- Tube Well can be preferred in Coastal areas.
- Bore Well can be used as a source of water in Rough rocky areas and Filter Point wells in Clay soil areas.



Rainwater Harvesting

- Rainwater harvesting for drinking water effectively meets the water shortage problem.
- Once the people are aware about how rainwater harvesting is done, it can be adopted anywhere.
- It is best method of water conservation.
- In Kollam Corporation Rain Water harvesting is rarely practiced (identified from survey).
- In coastal areas especially Tsunami Rehabilitation houses have huge un used rainwater harvesting tanks of capacity 5000L.
- People are least aware about its use and how it must be done.
- Rain water harvesting tanks can be made in order to protect ground water and this water can be used as potable water.

CAPACITY OF RAIN WATER TANK IN COASTAL AREA

Total Population in ward no. 47 – 5279

Total Population in ward no. 48 – 5438

Considering household size 4

Total h/h in ward no. 47 – 1320

Total h/h in ward no. 48 – 1360

In ward no. 47 and 48 the size of the plot is less than 5 cents and is approx. 500sq ft./ 50msq.

1m2 built up area – 25L (KMBR Rule).

If 50msq is the built-up area,

Total capacity of the tank should be 1250.

- Capacity of the tank for each h/h should be around 1250 as the built-up area of the houses in the coastal area will be approximately 50m sq / 500 sq ft.
- As per KMBR rule rainwater harvesting tanks are not compulsory for less than 5 cents / less than 750 sq ft built-up area.
- In Coastal area, Tsunami rehabilitation houses already have 5000l capacity tanks near each house which is not functional or properly used.
- Governmental subsidy schemes and programs should be implemented.

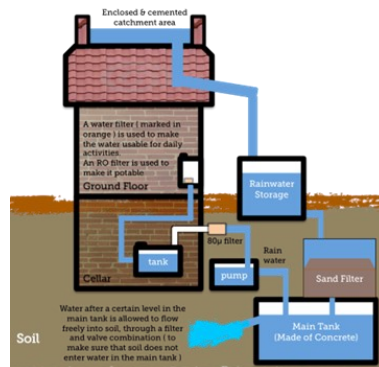


Figure 56 Stages of Rain water Harvesting



**Sea Water
Desalination Plant**

- It can be used as an alternate source of water.
- Seawater is drawn from the Sea via an underground or undersea tunnel.
- This water can be used as potable water in Kollam District and can be supplied to neighbouring districts.

CHAPTER 10 CONCLUSION

Potable water contamination is a main issue faced by India as well as international countries. As the population increases contamination as well as water shortage increases. It can be also said that contamination and water shortage is mainly due to Urbanization.

In this project we are identifying the existing sources of water supply that can be used along with quality of water. The quality of water is understood by various standards. Various existing technologies are identified and along with its drawbacks. It is also studied that whether the existing technology helps in satisfying the present need. Some case studies and best practices are identified and studied which can be adopted in the study area – Kollam Corporation.

In Kollam corporation the present water supply from Sasthamcotta lake doesn't meet the requirement. Kerala Water Authority, is responsible for water supply, including operation and maintenance activities within the Kollam corporation jurisdiction area (KWA). The present water supply scheme in Kollam corporation is Quilon water supply scheme (1958) and JICA (2012) which is not satisfactory. The frequency of water supply in Kollam corporation is 2-3 hours everyday morning either daily or on alternate days. There are places in Kollam corporation where the water scarcity during summer is very high.

Government has come up with a new proposal known as Njankadavu project where the source of water is from Kallada river which helps the serve the total Kollam population. The Kallada River is the only stable source of water in Kottamkara Panchayath, and the panchayath is next to the Kollam Corporation area. Main aim under Njankadavu is to provide water supply to Kottamkara panchayath and to satisfy the future water demand of Kollam corporation. It also aims in providing 24x7 water tap connections to all the households in Kollam Corporation. The project is being carried out by AMRUT and KIIFB contributing 78 crore and 235 crores respectively. This project is divided into two phases: Phase 1 is under the auspices of AMRUT, while Phase 2 is under the auspices of KIIFB. This design is done for a period of 30 years

Along with the new proposal, some water management methods should be done adopted to improve the potable water availability:

- Financial aid through governmental policies and programs and awareness to people through community level participation in Kollam about rainwater harvesting and artificial recharge methods, protects ground water from over exploitation.
- Technologically innovative methods like water GEMS mechanism helps to improve the water supply system and helps in improving infrastructure facilities which makes water available for all the households 24 x 7 based on demand and there by achieving Sustainable Development Goal.
- Sea Water Desalination process in coastal area of Kollam acts as another source of water supply which helps to solve water issues and helps to meet the future demand sufficiently.

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APPENDIX

HOUSE HOLD SURVEY FORM

1. Name of the Family member:

2. Ward no: _____ House No: _____

3. Household size:

2 3 4 5 More than 5

4. Plot Size

Less than 3 cents Between 3 – 10cents More 10 cents

5. Type of Housing

Single Storied Double Storied Government Schemes
 Rental Others

6. Source of drinking available in your neighbourhood?

well borewell municipality water supply public tap
 others.....

7. Sources of drinking water your household use?

well borewell municipality water supply public tap
 others.....

BORE WELL/ HAND PUMP

8. How far (in meters) is the **bore well/ hand pump**?

9. How long (in minutes) does it take to fetch water and back home?

10. Has the bore well / hand pump broken down in the past years?

Yes No

11. How frequent does the bore well/ hand pump broke down?

Once a wee Once a fortnight Once a quarter
 Once in six months Once a year

PUBLIC TAP

12. How far (in meters) is the public tap from your location?

13. Frequency of water supply?

More than once a day

Once a day 3

Once in two days

Once in three days

Once a week 6- Other

14. Is this frequency sufficient for your needs?

Yes No

15. How often would you want to get water?

More than once a day

Once a day 3

Once in two days

Once in three days

Once a week 6- Other

16. Has the public tap broken down in the past years?

Yes No

17. How frequently has it broken down?

Once a week

Once a fortnight

Once a quarter

Once in six months

Once a year

OPEN WELL

18. How far (in meters) is the open well from which you get water?

19. How long (in minutes) does it take to fetch water and return home?

20. What is the frequency of cleaning the well?

Once in a quarter

Once in six months

Once a year 4

Not cleaned in the last year

HOUSEHOLD / MUNICIPALITY WATER SUPPLY (PIPED)

21. What is the frequency of water supply?

24-hour supply

More than once a day

Once a day

Once in two days

Once in three days

Other

22. Is this frequency sufficient for your needs?

Yes No

23. How often would you like to get water?

More than once a day

Once a day

Other

24. On the days that you get water, how many hours do you usually get water for?

COMMON QUESTIONS

25. Is the quantity of water that you receive (from your main source of water) adequate?
 Yes No
26. Is water available (from your main source) throughout the year?
 Yes No
27. Do you face water scarcity?
 Yes No
28. Which months do you face scarcity?
29. How does the water smell?
 No smell Foul smell
30. Does the water have a taste?
 Yes No
31. What does the water look like?
 Clear Cloudy/Dirty
32. Do you pay for water?
 Yes No
33. How much do you pay a month?
34. Have you made a complaint related to your drinking water service in the past one year?
 Yes No
35. To whom did you complain?
36. What was the result of the complaint?
 Prompt action taken Delayed action taken No action taken
37. Do you face any waterborne diseases?
 Yes No
38. Are you satisfied with your drinking water service?
 Yes No
39. What is the extent of your satisfaction?
 Complete Partial
40. What are the reasons for your dissatisfaction?