Design and Cost Analysis of RO Plant for Bullayya College

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https://doi.org/10.55041/ijsmt.v2i4.258

Cite this Article: Satyanarayana, D., Bhavana, Y., Chandana, P., Yasaswini, R. S., Sindhuja, Y. & Srinivas, T. (2026). Design and Cost Analysis of RO Plant for Bullayya College. International Journal of Science, Strategic Management and Technology, *02*(04). https://doi.org/10.55041/ijsmt.v2i4.258

ABSTRACT

Water is an essential requirement for maintaining health and hygiene in institutional environments. The main objective of this project is to understand the design of an appropriate Reverse Osmosis (RO) plant, prepare detailed layout drawings by using AutoCAD and to perform cost analysis for institutional water supply.

Detailed layout drawings of the RO plant and water distribution system for each floor are prepared using AutoCAD software to ensure proper installation planning and efficient water supply management.

KEY WORDS: Reverse osmosis plant, pressure sand filter, activated carbon filter, softeners, brackish water.

INTRODUCTION

Water plays a vital role in sustaining life and supporting daily activities in educational institutions. Many groundwater and other sources contain excessive dissolved salts, hardness, and contaminants that affect water quality. Therefore, implementing an effective water purification system is essential to provide safe drinking water. Among the available purification technologies, Reverse Osmosis (RO) is widely recognized for its ability to remove dissolved salts, impurities, microorganisms, and chemical contaminants.

This project focuses on calculating total water demand based on population and understanding the design of RO plant that meets the required capacity. The design process includes preparation of process flow diagrams and detailed AutoCAD drawings showing the placement of RO plant & water distribution pipelines for each floor of the building. These drawings ensure systematic installation, proper piping layout, and efficient distribution of purified water.

LITERATURE REVIEW

Mona A. Abdel-Fatah et al. (Feb 2016) made an attempt to evaluate the design and performance of an RO desalination plant for treating brackish water. They found that proper design, suitable membranes, and a 50% recovery rate improve efficiency and reduce costs, making RO a reliable solution for water scarcity.

J. Feo – Garcia et al. (Mar 2024) they analyse RO desalination plants and highlights that efficient system design, proper pretreatment, and suitable membrane selection are essential for effective salt removal. They conclude that energy-saving measures improve performance and reduce operational costs.

Y. Kamala Raju et al. made an attempt to design and evaluate the performance of an RO plant, highlighting its effectiveness in improving water quality by removing dissolved impurities. They emphasize that proper design, pretreatment, and operating conditions are essential for efficient and reliable performance.

OBJECTIVES OF RO WATER

To Remove Dissolved Impurities: Eliminate dissolved salts, heavy metals and contaminants using Reverse Osmosis technology.

To Improve Water Quality: Enhance taste, odor, and clarity of water to make it suitable for drinking.

To Reduce Total Dissolved Solids (TDS): Bring TDS levels within acceptable limits as per Bureau of Indian Standards guidelines.

To Remove Harmful Microorganisms: Minimize bacteria, viruses, and other pathogens when combined with proper pre- and post-treatment.

To Provide Safe Drinking Water: Ensure a continuous supply of potable water for institutional use.

To Protect Health: Reduce risks associated with contaminated water such as waterborne diseases and long-term health issues.

To Ensure Efficient Water Treatment: Achieve high purification efficiency with minimum wastage and optimal recovery.

METHODOLOGY

Institution Data Collection: Basic data is collected that includes number of students, staff, and others, existing water sources (bore well /municipal supply), current water consumption patterns etc.

Water Quality Assessment: Collect raw water samples from the institutional source (borewell/municipal) and Conduct laboratory tests for:

a) pH

b) Total Dissolved Solids (TDS)

c) Hardness

d) Alkalinity

e) Acidity

Estimation of Daily Water Demand: Water demand is calculated based on **population × Per capita water requirement** for drinking. This gives the required output capacity (LPH or KLD) of the RO plant.

Design of RO Plant Capacity: Based on the water demand, by consideration of operating hours and future expansion, to ensure the plant meets peak demand efficiently.

Design of Ro plant components: The RO system components are designed that includes raw water tank, pressure sand filter, activated carbon filter, cartridge filter, high pressure pump, feed pump, RO membranes and storage tank etc.

Preparation of Plant Layout: A complete layout is prepared showing pre-treatment units, RO unit, storage tanks and pipelines and floor plans by using AutoCAD.

Capital Cost Estimation: Initial investment cost is calculated including equipment cost, installation cost, piping and fittings, electrical components and softeners etc.

Operating & Maintenance Cost Analysis: Recurring expenses are calculated such as electricity cost, membrane replacement cost, chemical cost, labor cost and maintenance cost.

Cost per Liter Calculation: Cost per liter is calculated using:

[Cost per Liter=Total Annual Cost/Total Annual Water Production]

TESTING OF COLLECTED SAMPLES

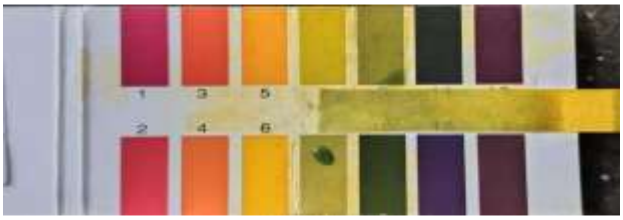
TDS (Total Dissolved Solids): Total Dissolved Solids (TDS) refers to the amount of dissolved substances such as salts, minerals, and impurities present in water. It is an important parameter for determining water quality, as high TDS levels can affect taste and may indicate the presence of harmful contaminants. Measuring TDS helps in assessing the suitability of water for drinking and in designing appropriate treatment methods.

International Journal of Science, Strategic Management and Technology
Volume **02** Issue **04** April-**2026** | ISSN: **3108-1762 (Online)** | Impact Factor: 3.8
An International, Peer-Reviewed, Open Access Scholarly Journal Indexed in recognized academic databases

Hardness: Water hardness is due to the presence of dissolved minerals, mainly calcium and magnesium salts, in water. It is an important parameter that affects water quality, as high hardness can cause scaling in pipes and reduce the effectiveness of soaps and detergents. Measuring hardness helps in evaluating water suitability and determining the need for treatment methods in purification systems.

pH (Potential of hydrogen): pH is a measure of the acidity or alkalinity of water, indicating the concentration of hydrogen ions present. It is measured on a scale from 0 to 14, where 7 is neutral, values below 7 are acidic, and values above 7 are alkaline. Maintaining an appropriate pH level is important for water quality, as extreme values can affect taste, corrode pipes and impact the effectiveness of water treatment process.

TESTS	**SAMPLE 1**	**SAMPLE 2**	**SAMPLE 3**
TDS	310 mg/l	275 mg/l	260 mg/l
Hardness	320 mg/l	290 mg/l	310 mg/l
pH	7.5	7	7.5
Alkalinity	150 mg/l	140 mg/l	125 mg/l
Acidity	250 mg/l	180 mg/l	160 mg/l



ALKALINITY: Alkalinity is the capacity of water to neutralize acids, mainly due to the presence of bicarbonates, carbonates, and hydroxides. It is an important parameter for water quality, as it helps maintain a stable pH and prevents sudden changes in acidity. Proper alkalinity is essential for effective water treatment and ensures the water is less corrosive and more suitable for consumption.

ACIDITY: The acidity of water is determined using a titration method, where a water sample is treated with a standard alkaline solution (usually sodium hydroxide). An indicator such as phenolphthalein or methyl orange is added to detect the endpoint of the reaction. The alkaline solution is slowly added from a burette to the sample until a color change occurs, indicating neutralization of acids present in the water. The volume of alkali used helps calculate the acidity of the sample, which is expressed in terms of mg/L of calcium carbonate ($CaCO_3$).

Table I: Test Results of Samples 1,2,3

SAMPLE-1 (BLOCK 1) , SAMPLE-2 (BLOCK 2) , SAMPLE-3 (BLOCK 3)

Table II: Test Results of Samples 4,5,6

SAMPLE-4 (BLOCK 4) , SAMPLE-5 (BLOCK 5) , SAMPLE-6 (BLOCK 6)

International Journal of Science, Strategic Management and Technology
Volume 02 Issue 04 April-2026 | ISSN: 3108-1762 (Online) | Impact Factor: 3.8
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TESTS	SAMPLE 4	SAMPLE 5	SAMPLE 6
TDS	305 mg/l	292 mg/l	285 mg/l
Hardness	280 mg/l	300 mg/l	305 mg/l
pH	6.5	7	7.5
Alkalinity	138 mg/l	150 mg/l	130 mg/l
Acidity	200 mg/l	250 mg/l	175 mg/l

Table III: Test Results of Samples 7,8,9

SAMPLE-7 (BLOCK 7) , SAMPLE-8 (BLOCK 8) , SAMPLE-9 (BLOCK 9)

TESTS	SAMPLE 7	SAMPLE 8	SAMPLE 9
TDS	197 mg/l	183 mg/l	298 mg/l
Hardness	325 mg/l	353 mg/l	315 mg/l
pH	8	8	6.5-85
Alkalinity	253 mg/l	300 mg/l	132 mg/l
Acidity	325 mg/l	350 mg/l	190 mg/l

Table IV: Standard Values/ Ranges

DESIGN OF RO PLANT

DESIGN CALCULATIONS

PER CAPITA DEMAND : To calculate the per capita demand of an RO plant for 15,000 people for drinking purpose, we use standard water consumption norms.

Standard Per Capita Requirement: According to Bureau of Indian Standards (IS 1172: 1993) Drinking water: 3–5 liters per person per day

So total water demand per person for drinking = 3 - 5 liters/day

Total Water Demand for 15,000 People =Total demand = Number of people × Per capita demand = 15,000 × 5 = 75,000 liters/day

Daily Requirement: Total daily water requirement: 75,000 liters/day.

Plant Capacity: RO plants are usually designed with a factor of safety of 10 – 20% for peak demand.

Design capacity: Capacity = 75,000 × 1.2 = 90,000 liters/day ≈ 90 kl/day

Operating hours 10 hrs per day

Designing in liters per hour (LPH) for 10 - hour operation:

Capacity (LPH) = 90,000/10 = 9000 LPH

RO RECOVERY AND FEED WATER CALCULATION:

Recovery: Typical RO recovery = 60% (for brackish water)

Feed water required: Feed = Product / Recovery = 9 / 0.6 = 15 m^3/hr

Reject water: Feed – Product = 15 – 9 = 6 m^3/hr

STORAGE TANK DESIGN:

Raw Water Tank: Storage required = 8.2 hours of feed water = 15 × 6 = 123 m^3

(provide 125 m^3 capacity tank)

Treated Water Tank: Storage = 1 day demand

= 90 m^3

(

S.NO	TESTS	VALUES
1.	TDS	50 - 150 mg/l
2.	Hardness	150 – 300 mg/l
3.	pH	6.5 – 8.5
4.	Alkalinity	80 – 120 mg/l
5.	Acidity	< 50 mg/l

provide 95 m^3 tank)

PRE-TREATMENT UNIT DESIGN:

(a) Pressure Sand Filter (PSF):

Design data: Filtration rate = 10 m/hr

Flow = 15 m^3/hr

Area $(A) = Q/Rate$ = 15/10 = 1.5 m^2

Diameter $(D) = \sqrt{4A/\pi}$ = √4 × 1.5 / 3.14 = 0.95 m

(Provide 950 –1000 mm diameter PSF)

(b) Activated Carbon Filter (ACF):

Design data: Filtration rate = 10 m/hr

Flow = 15 m^3/hr

Area $(A) = Q/Rate$ = 15/10 = 1.5 m^2

Diameter (D) = $\sqrt{4A/\pi} = \sqrt{4 \times 1.5 / 3.14} = 0.95$ m

(Provide 950 – 1000 mm diameter ACF)

(c) Cartridge Filter:

Design: Flow = 15 m^3/hr

To handle 15 m^3/ hr use standard 20” cartridges

(Provide 20” or 30” cartridge filter housing)

RO Membrane Design :

Type: 8040 membrane (for 9000 LPH) - Brackish water membrane - 8040

Capacity = 1.15 m^3/hr per membrane

Number of membranes required = 9/1.15 = 7.8 ≈ 8 no’s

(Provide 8 membranes - 8040 type)

(Arrangement 2 pressure vessels × 4 membranes each)

High Pressure Pump Design:

Design data: Flow = 15 m^3/hr

Pressure = 10 – 20 bar

(provide a pump capacity of 15 - 16 m^3/hr @ 16 bar)

(power of 7.5 – 15 HP)

Feed Pump Design:

Function:Transfers water from raw tank to filters.

(Provide flow of 15 m^3/hr & power of 2 – 5 HP)

Chemical Dosing System:

Required chemicals

(a) Anti-scalant: Prevents scaling on membranes

(b) Chlorination: Disinfection (before ACF)

(c) SMBS (Sodium Metabisulfite): Removes chlorine before RO

Power Requirement:

Total = 14HP (1HP = 0.7457) = 14 × 0.7457 = 10.44Kw

Reject Water Management:

Quantity: 6 m^3/hr = 60,000 L/day

Reuse options: Toilet, flushing, gardening, cleaning.

This helps in improving efficiency.

FINAL DESIGN SUMMARY

Table III: Design Summary

PARAMETERS	VALUE
Population	15,000 persons
Demand	90,000 liters/day
RO capacity	9000 LPH
Feed water	15,000 LPH
Recovery	60%
Reject	6000 LPH
Membranes	8 (8040)
PSF/ACF	950–1000 mm dia
Raw tank	125 m^3
Treated tank	95 m^3
Power	14 HP

COST ANALYSIS

1 Capital Cost :

Table IV: Capital Cost

COMPONENT	COST (₹)
Civil works (tanks)	8,00,000
RO plant (9000 LPH)	12,00,000
Pumps & motors	2,50,000
Filters (PSF + ACF) & softener	4,00,000
Electrical & control panel	1,50,000
Conveyance of pipelines & Installation	2,00,000
Miscellaneous	1,00,000

Total Capital Cost = ₹ 30,50,000 = 31 lakhs

2 Operating & Maintenance Cost:

Power Cost: 14HP = 10.4kW

Daily energy = 10.4 × 10 = 104 kWh/day

Monthly = 104×30=3120kWh

If ₹8 per unit: = 3120×8=₹24,960/month

Chemicals & Consumables:

Table VI: Cost of Chemicals

ITEM	MONTHLY COST (₹)
Antiscalant	5,000
Chlorine	2,000
Cartridge filters	3,000

Total = ₹ 13,000/month

Labor Cost:

Operator salary = ₹ 15,000/month

Maintenance Cost:

Membrane replacement (every 2–3 years)

Approx monthly equivalent = ₹ 10,000

Total Monthly O&M Cost

= 24,960+13,000+15,000+10,000

= ₹62,960 = ₹63,000/month

Cost Per Liter Calculation:

Monthly production = 90,000×30 = 27,00,000 L

Cost per liter = 63,000 / 27,00,000 = 0.023₹/L

Cost per liter = ₹ 0.02 – 0.03

Final Summary

Table VI: Final Summary of Cost Analysis

PARAMETER	VALUE
Capital Cost	₹ 31 Lakhs
Monthly O&M Cost	₹ 63,000
Cost per Liter	₹ 0.02–0.03
Plant Capacity	90,000 L/day
Annual cost	₹ 10.66 Lakhs

RESULTS AND DISCUSSION

Discussion:

The design of the RO plant for 15,000 people shows that it is both efficient and practical for supplying safe drinking water. Based on 3–5 L/person/day and 10 hours of operation, the system meets the required demand. Proper selection of components like filters, pumps, and membranes helps in achieving good performance and longer lifespan. Pretreatment plays an important role in protecting membranes and improving efficiency.

The cost per litre (₹0.02–₹0.03) is very economical compared to other water sources. Reject water reuse for activities like cleaning and gardening improves overall water efficiency. However, energy use and membrane maintenance are key factors affecting operating cost.

CONCLUSION

The study proves that the RO plant design for 15,000 people is technically feasible and cost-effective. It can supply drinking water efficiently at a low cost while maintaining good quality. With proper maintenance and reject water management, the system becomes more sustainable.

Overall, this project shows that RO technology is a reliable and affordable solution for institutional water supply and can be applied in similar places with minor changes.

ACKNOWLEDGMENT

I am profoundly thankful to Mr. D.V.V.Satyanarayana, Assistant Professor in the Department of Civil Engineering, Dr.Lankapalli Bullayya College of Engineering,Visakhapatnam, India,who has served as my mentor and guide,advising me on how to accomplish my goals.

RECOMMENDATIONS

Provide proper pre-treatment units (softener, filters) to reduce fouling and scaling.

Ensure regular maintenance and membrane cleaning (CIP) for efficient operation.

Use skilled operators and monitoring systems for consistent performance.

Install TDS and pressure sensors for continuous quality control.

Adopt energy-efficient pumps to reduce operating cost.

Plan reject water management systems to minimize wastage.

Design system considering variation in feed water quality.

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