FORWARD OSMOSIS SYSTEM

Internship Report

Submitted for the partial fulfillment of the degree of

Bachelor of Technology

In

CHEMICAL ENGINEERING

Submitted By

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0901CM201007

UNDER THE SUPERVISION AND GUIDANCE OF

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MADHAV INSTITUTE OF TECHNOLOGY & SCIENCE, GWALIOR (M.P.), INDIA

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January – May 2024

DECLARATION BY THE CANDIDATE

I hereby declare that the work entitled **"Forward Osmosis System"** is my work, conducted under the supervision of **Prof. Anish P. Jacob, Assistant Professor & Coordinator,** during the session Jan-May 2024. The report submitted by me is a record of bonafide work carried out by me.

I further declare that the work reported in this report has not been submitted and will not be submitted, either in part or in full, for the award of any other degree or diploma in this institute or any other institute or university.

Aniket Sharma

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TO WHOM IT MAY CONCERN,

This is to certify that Mr. Aniket Sharma, son of Shri Rajiv Sharma, a final year B.Tech student in Chemical Engineering at Madhav Institute of Technology & Science, Gwalior, has successfully completed a four-month internship at our organization, at Dew Projects And Chemicals Private Limited. This internship was undertaken as a part of his Industrial Training Program from December 25, 2023, to April 25, 2024.

During his tenure with us, Mr. Sharma worked diligently on the Forward Osmosis Project. His dedication and enthusiasm towards his work were evident throughout the internship period. Mr. Sharma's contributions were highly valued, and his efforts significantly benefited our organization.

Mr. Sharma demonstrated a strong work ethic, a keen interest in learning, and an ability to adapt quickly to new challenges. He effectively collaborated with team members and consistently met project deadlines. His problem-solving skills and innovative approach to tasks were particularly noteworthy.

We believe that Mr. Sharma possesses the potential to achieve great success in his future endeavors. We extend our best wishes for his bright and prosperous career.

For Dew Projects And Chemicals Private Limited,

AbThakur.

Mr. Abhishek Thakur

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PLAGIARISM CHECK CERTIFICATE

This is to certify that I, a student of B.Tech. in **Chemical Engineering Department** have checked my complete report entitled **"Forward Osmosis System"** for similarity/plagiarism using the "Turnitin" software available in the institute.

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ABSTRACT

A greater emphasis has been placed on forward osmosis (FO), a promising membrane-based separation technique and process with several applications in water treatment. This thesis presents a compendious overview of the principles, applications, challenges, and future prospects of osmosis in forward motion. One effective and natural method of purifying water is through the process of forward osmosis.In this process, water flows through a special membrane from a low-concentration region to a high-concentration region, diluting the concentrated solution. This helps to remove impurities and contaminants from the water, leaving it clean and safe to use. Forward osmosis is gaining popularity for water treatment due to its effectiveness and environmental friendliness. It offers a promising solution for addressing water scarcity and pollution challenges around the world. Instead of using fancy machines or lots of energy, it relies on the Water's inherent ability to flow from place where there's less stuff dissolved in it to where there's more stuff. By doing this, forward osmosis can make dirty water clean without needing too much energy or expensive equipment. The good thing about forward osmosis is that it can remove all sorts of stuff from water, not just salt. It can take out things like bacteria, viruses, and even tiny particles that make water look cloudy. This makes it really versatile for cleaning up all kinds of water, from seawater to wastewater. It has a lot of potential. Despite its potential, challenges such as membrane performance, draw solution recovery and regeneration, and scale-up remain to be resolved.

Keywords: Membrane Technology, Osmosis, Osmotic Pressure, Water Scarcity, Water-Purification.

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Aniket Sharma

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ACRONYMS

COD – Chemical Oxygen Demand

FO – Forward Osmosis

RO – Reverse Osmosis

WTP – Watse Water Treatment

TDS – Total Dissolved Solids

TSS – Total Suspended Solids

ICP – Interfacial concentration Polymerization

WHO – World Health Organization

BOQ – Bill Of Quantity

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CHAPTER 1 :

INTRODUCTION

The water crisis, has increased by increasing population and economic growth, has become a significant issue in the 21st century. Reverse osmosis, ultrafiltration, microfiltration and nanofiltration, are pressure-driven membrane technologies that have drawn interest because wastewater treatment and seawater desalination. Researchers are exploring various technologies to increase the production of freshwater from seawater and other sources for domestic use, including challenges like excessive energy consumption, rigorous pretreatment, and significant membrane fouling..

Forward osmosis has garnered significant interest in the past few years due to its application in water purification. It is a membrane process driven by osmotic pressure which offers cost savings by reducing energy consumption. Forward Osmosis (FO) is a separation process that relies on the osmotic pressure disparity across a membrane. This emerging technology is known for its efficient water recovery capabilities to its high retention capacity. Pressure driven membrane processes use high amount of external pressure which is evident that the desalination process results in high energy consumption and low water recovery. It consumes large amount of energy and the rising demand is nearly about 60 million m^3/d [3]. There is a need for a more sustainable method of water production that makes use of alternative energy sources, despite the high electricity consumption of reverse osmosis membranes commonly used in desalination. It is crucial to emphasize the connection between water and energy production, which is known as the “water-energy nexus”. Forward Osmosis is one of the most suitable technologies as because it does not need any external pressure. It is an osmotic pressure driven membrane technology.

1.1 What is Forward Osmosis?

Forward osmosis involves the passage of water molecules across a semi-permeable membrane, separating solutions of varying concentrations. The higher concentration of solutes serves as an energy reservoir, driving the movement of water from the side with lower concentration towards the side with higher concentration. This process aims to equalize the concentration levels in both regions. The osmotic pressure in the solution being drawn is greater than that of the feed solution, prompting the flow of water due to the disparity in osmotic pressure between the two regions.

1.2 What's all includes Forward Osmosis System?

A FO system includes:

Semipermeable membrane: Also called as heart of the system. Semipermeable membrane describes a membrane permitting the passage of small molecules and ions while obstructing larger molecules or dissolved substances.

Feed Solution: The solution which is need to be treated or concentrated

Draw Solution: This refers to a solution with a greater osmotic pressure compared to the feed solution, capable of pulling water molecules from the feed solution side to the drawing side..

Membrane Module: It contains the semipermeable membrane and facilitates the separation process.

Separation Mechanism: It employs the osmotic pressure produced by a high concentration of solutes to drive the movement of water from the feed side to the draw side.

Pumps and Controls: Used to control the flow of solutions and maintain operating conditions.

Pretreatment and Post Treatment: FO has limitations so pretreatment and postreatment is required, pretreatment is based on the effluent and post treatment could be Reverse Osmosis to recover purewater and draw solution.

CHAPTER 2:

LITERATURE SURVEY

The promise of forward osmosis (FO) for water purification applications has captured significant interest. The challenges of low water flux in FO processes necessitate the development of improved membrane supports with reduced internal concentration polarization, especially for hollow fiber configurations. The draw solute diffusivity can also influence ICP levels. Research was done to establish accurate methods for estimating ICP and enhancing support design. While support morphology has minimal impact on performance, efforts were prioritized for formulation of thinner yet mechanically robust supports. Optimal support thickness was crucial for reducing ICP and enhancing FO efficiency. Advancements in support design and selective layer quality are essential for maximizing FO membrane performance in various applications.[1]

The potential of forward osmosis (FO) membranes for water purification and wastewater treatment are widely acknowledged for their effectiveness in achieving high rejection rates and exhibiting low fouling characteristics. However, challenges persist in developing novel membrane materials that can effectively mitigate fouling, reverse solute flux, concentration polarization, and enhance permeate flux. Key areas for improvement include the development of membrane materials, optimization of draw solutions, addressing salinity build-up, and successful implementation of FO processes. Recent literature reviews have focused on advancements in membrane materials, the effects of draw solutes, applications in wastewater treatment, fouling mechanisms, and cleaning strategies. The analysis underscores research barriers and opportunities for improvement, emphasizing the significance of novel membrane materials and process optimization.[2]

A growing interest in various aspects of FO technology, including draw solutions, membrane fabrication, Hybrid system setup, energy usage, mathematical modeling and economic assessments are key considerations that has been covered. Recent research has focused on FO desalination processes as an alternative to conventional methods, with a notable emphasis on mitigating fouling, optimizing draw solutions, enhancing membrane fabrication, and reducing energy consumption. Continued advancements in FO technology are crucial for addressing challenges such as draw solution recycling, energy efficiency, and organic contaminant treatment to enable wider industrial adoption.[3]

The forward osmosis (FO) membrane, employed in desalination, has seen continuous advancements, presenting several benefits as a process driven by osmosis. Various factors influencing FO membrane efficiency, such as internal concentration polarization (ICP), external concentration polarization (ECP), and structural parameters (S), have been identified and studied. To tackle these challenges, different membrane fabrication techniques like interfacial polymerization (IP), layer-by-layer (LbL) deposition, and incorporation of inorganic fillers have been employed. Careful selection of draw solution and FO mode orientations are critical measures for mitigation. FO utilizes osmosis to pull water from the less concentrated side to the more concentrated solute, thereby equalizing concentration levels. Incorporating a freshwater recovery unit is indispensable for achieving comprehensive desalination using FO, positioning it as an ideal pre-treatment step for other desalination methods such as reverse osmosis (RO), among others..[4]

The discussion has been made on the need for sustainable desalination technologies due to increasing freshwater demand and dwindling water sources. Forward osmosis (FO) is presented as a promising solution compared to traditional methods like reverse osmosis, multieffect distillation, and multistage flash distillation. FO offers lower energy consumption, reduced environmental impact, and high-quality product water. The study evaluates the feasibility of implementing FO in India, highlighting its cost-effectiveness and potential to meet water demands. While FO shows promise, challenges such as the need for trained personnel must be addressed for widespread adoption. Overall, FO emerges as a sustainable and economically viable option for seawater desalination.[5]

CHAPTER 3:

COMPANY PROFILE

3.1 About The Company

Dew was incorporated in 1994 and is fully integrated water and wastewater treatment company with complete range of plants, chemicals and operation services. Dew is headquartered with its manufacturing and warehouse plants in Greater Noida and marketing office in supernova Astralis tower Noida sector 94, U.P, India. The core principles were well established for the growth of the company. Understanding the need for quality service, they have assembled one of the most experienced personnel in sales and services team in today's water and waste water treatment industry. Unlike the majority of the companies present in the water treatment business, which copy products and technology, Dew is responsible for developing original treatment products and innovative service techniques.

Dew has been working in India for 26 years with providing the Services and Chemicals as the primary focus. The average Dew employees have more than ten decades of water treatment experience. Significant customers bases include municipalities, utility companies, Pharma, Food manufacturers, Pulp and Paper, to treat water systems. There corporate technical staff is another key to their service excellence. They provide the top level of professional support in the industries. This experience allows Dew to be able to provide with the highest level of value addition to their customers.

Their expertise includes: -

- Turnkey water and waste-water treatment
- Membrane technology and desalination
- Total water management
- Packaged and customized plants
- Speciality Chemicals for water and wastewater

Fig. No. 3.1: Dew Logo Source: dewindia.com

Here are some pics of Dew Warehouse and Manufacturing Unit.

Fig. No. 3.2: Manufacturing unit Source: Self-Shoot

Fig. No. 3.3: Greater Noida Unit Source: Self-Shoot

3.2 Objectives

The Basic Objectives of the Project can be enlisted as:

- The conventional WTP plants are lare, the primary purpose will be to make it compact.
- As learned from the literature review that was being done, the conventional model requires a significant amount of energy for operations, so I would like to decrease the energy consumption.
- Many industries which have been using the WTP plants from the past have not been upgraded to the recent development that has been in the taking place. They are using the past technolog which has low efficiency as compared to the current technologies.
- The capital cost of the FO system along with other conventional methods is a big issue that the industries are taking a step back to implementing it. I would also tend to decrease the capital cost by replacing the current complicated process by more straightforward and more advanced methods.

CHAPTER 4:

METHODOLOGY & EXPERIMENTAL WORK

4.1 Water Analysis

- It is a process of measuring the chemical, physical and biological characteristic of water.
- The physical parameters encompass characteristics such as color, odor, taste, temperature, turbidity, dissolved solids, and conductivity.
- Chemical parameters encompass factors such as pH, acidity, alkalinity, chlorine hardness, and dissolved oxygen.
- The biological parameters encompass indicators such as Chemical Oxygen Demand (COD), Biological Oxygen Demand (BOD), Total Bacterial Count (TBC), and Sulfate-Reducing Bacteria (SRB).

1. pH

- pH is potential of hydrogen; it signifies the basicity or acidity.
- The pH scale spans from 0 to 14, with 7 representing neutrality.[6]
- pH values below 7 indicate acidity, whereas pH values above 7 indicate alkalinity..
- At 7 pH is neutral because at this point, it denotes that the concentration of hydrogen ions (H+) equals that of hydroxide ions (OH-) in the solution..

Apparatus required: pH Paper or pH Meter, Beaker, Stirrer, Gloves.

Procedure to test:

1. Take sample which is being tested.
2. Then, rinse the electrode with distilled water, then immerse it into the sample.
3. Note down the reading after pH reading being stable.

2. TDS (Total Dissolved Solids)

- Total Dissolved Solids (TDS) refers to the collective measurement of both inorganic and organic substances found within water. This encompasses minerals, salts, metals, and various other impurities capable of dissolving in water.

- TDS is typically quantified in either parts per million (PPM) or milligrams per liter (mg/L).
- High TDS in water indicates the presence of harmful contaminants. Low TDS in water can indicate that the water lacks essential minerals that are important for human health.

3. TDS Levels

- ❖ 50-300 mg/L considered as excellent safe for drinking. (WHO says 300mg/L is safest).
- ❖ 300-600 mg/L is good.
- ❖ 600-900 mg/L is fair.
- ❖ 900-1200 mg/L is poor.
- ❖ 1200-2000 mg/L is very poor.
- ❖ Above 2000 mg/L is unacceptable.

Apparatus required: TDS meter, Beaker, Stirrer, Gloves.

Procedure to test:

1. Take sample which is being tested.
2. Rinse electrode with distilled water then, dip into the sample.
3. Note down the reading after TDS reading being stable.

Note: It is measured in mg/L.

4. CONDUCTIVITY

- Water conductivity is a gauge of its capacity to conduct electrical current, directly influenced by the concentration of conductive ions dissolved in the water.

Apparatus required: Conductivity Meter, Beaker, Stirrer, Gloves.

Procedure to test:

1. Take sample which is being tested.
2. Rinse the electrode with distilled water, then immerse it into the sample.
3. Note down reading after conductivity reading being stable.

Note: It is measured in µS/cm.

5. TURBIDITY

- Turbidity is a metric indicating the clarity of a liquid. It reflects the optical properties of water and gauges the extent of light scattering by substances within the water when illuminated.
- Greater intensity of scattered light corresponds to increased turbidity. Limit of Turbidity, ideally 1 NTU and shouldn't be more than 5 NTU (NTU – Nephelometric turbidity unit).[6]

Apparatus required: Turbidity Meter Kit, Gloves.

Procedure to test:

1. Take sample and fill in bottle provided with the meter.
2. Clean properly outer surface of bottle.
3. Note down the reading displayed on the screen of meter.

Note: It is measured in NTU – Nephelometric Turbidity Unit.

6. TOTAL HARDNESS

- Total hardness represents the combined concentrations of calcium and magnesium, typically measured in mg/L.

Apparatus required: The laboratory equipment includes a beaker, burette, burette stand, stirrer, conical flask, funnel, gloves, and measuring cylinder.

Chemicals required: Ammonia Buffer, Eriochrome Black T Indicator, Ethylenediaminetetraacetic Acid Solution of Normality 0.02.

Procedure to test: [6]

1. Take sample 30 ml in a beaker.
2. Use ammonia buffer 5 drops (to maintain pH level), mix in a sample properly.
3. Then transfer it into the conical flask.
4. Then use indicator EBT (Eriochrome Black T).
5. Titrate with EDTA solution of normality 0.02.

Initial point: Purple in color.

End Point: Blue in color.

Calculation Formula:

$$\frac{\text{Burette Reading*Normality of Solution*50*1000}}{\text{Volume of Sample Used}} = \_\_\_\_\_ \text{mg/L}$$

7. CALCIUM HARDNESS

- Calcium Hardness is the measurement of how much calcium is present in water solution.

Apparatus required: Beaker, Burette, Burette Stand, Stirrer, Conical Flask, Funnel, Gloves, Measuring Cylinder.

Chemicals required: 1 Sodium hydroxide pellet, Patton Reeder Indicator, Ethylenediaminetetraacetic Acid solution of normality 0.02.

Procedure to test:

1. Take 30 ml sample in a beaker.
2. Dissolve one sodium hydroxide pellet in sample.
3. Transfer it in the conical flask.
4. Then use Patton Reeder Indicator.
5. Titrate with EDTA (Ethylenediaminetetraacetic Acid).

Initial Point: Purple in color.

End Point: Blue in color.

Calculation Formula:

$$\frac{\text{Burette Reading*Normality of Solution*50*1000}}{\text{Volume of Sample Used}} = \_\_\_\_\_ \text{mg/L}$$

8. P-ALKALINITY

- It is known as Phenolphthalein alkalinity and is established by titration until reaching the phenolphthalein endpoint.
- If pH is higher than 8.3 then P-Alkalinity test is done. [6]

Apparatus required: pH Meter, Burette, Burette Stand, Stirrer, Gloves, Conical Flask, Funnel, Measuring Cylinder.

Chemicals required: Phenolphthalein Indicator, Sulfuric Acid of Normality 0.02.

Procedure to test:

1. Take solution 30 ml in a beaker.
2. Use 2 drop of Phenolphthalein as indicator.
3. Titrate with sulfuric acid with normality 0.02N.

Final Point: Color less.

Calculation Formula:

$$\frac{\text{Burette Reading*Normality of Solution*50*1000}}{\text{Volume of Sample Used}} = \_\_\_\_\_\text{mg/L}$$

10. M-ALKALINITY

- M Alkalinity is the alkalinity that is determined by using methyl orange indicator.

Apparatus required: The laboratory equipment includes a beaker, burette, burette stand, stirrer, conical flask, funnel, gloves, and measuring cylinder.

Chemicals required: Methyl Orange Indicator, Sulfuric Acid of Normality 0.02.

Procedure to test:

1. Take sample 30 ml in a beaker.
2. **Use** Methyl orange Indicator (mix well).
3. Then titrate with sulfuric acid of normality 0.02.

Initial Point: Orange in color.

End Point: Brick red in color.

Calculation Formula:

$$\frac{\text{Burette Reading*Normality of Solution*50*1000}}{\text{Volume of Sample Used}} = \_\_\_\_\_ \text{mg/L}$$

11. CHLORIDE ANALYSIS

Apparatus required: The laboratory equipment includes a beaker, burette, burette stand, stirrer, conical flask, funnel, gloves, and measuring cylinder.

Chemicals required: Potassium Chloride Indicator, Silver Nitrate Solution of Normality 0.02.

Procedure to test:

1. Take 30 ml sample in beaker
2. Add two drops of potassium chloride indicator solution.
3. Then mix them well.
4. Then transfer this solution in a conical flask
5. Then titrate with silver nitrate solution of normality 0.02

Initial Point: Yellow in color.

Final Point: Orange in color.

Calculation Formula:

$$\frac{\text{Burette Reading*Normality of Solution*35.45*1000}}{\text{Volume of Sample Used}} = \_\_\_\_\_ \text{mg/L}$$

13. COD (Chemical Oxygen Demand)

- Frequently employed for assessing organic content in liquid waste, both BOD (Biochemical Oxygen Demand) and COD (Chemical Oxygen Demand) serve as measures of organic pollution in water.[6]
- BOD measures the organic pollutants that are biodegradable while COD measures the whole organic matter either biodegradable or non-biodegradable.

Apparatus required: Beaker, Burette, Burette Stand, Stirrer, Conical Flask, Funnel, Gloves, Safety Glasses, Measuring Cylinder, COD Digester, COD Digester Bottle, Condenser, Pipette, Weighing Machine.

Chemicals required: Mercuric Sulphate, Potassium Dichromate, Sulfuric Acid, Distilled Water, Ferroin Indicator, FAS Solution (Ferrous Ammonium sulfate).

Procedure to test:

1. Weigh 0.2g of mercuric sulphate for 10 ml solution.
2. Put in a COD digester bottle.
3. Then add 5ml $k_2Cr_2O_7$ Potassium dichromate (for oxidation that's an oxidizing agent).
4. Add distilled water before sample (sample quantity varies on the basis of sample quality).

(Quantity of distilled water is according to the sample taken, for example if 2 ml of sample is used then 8 ml of distilled water is used)

5. Carefully add 15 ml sulfuric acid.
6. Fix the condenser on top of the COD bottle.
7. Turn on COD digester and wait for temperature to reach 150° Celsius.
8. Note down the time when it reaches to 150° Celsius and keep digester ON for 2 hrs.
9. After two hrs. turn off the COD digester and wait till bottle's temperature cooled down and reaches to the room temperature.
10. Then add 40 ml distilled water in COD bottle and shake it properly.
11. Then transfer it into the conical flask.
12. Use ferroin indicator.
13. Titrate with FAS solution of normality 0.1.[6]

Initial point: Yellow in color.

Final point: Wine red in color.

Calculation Formula:

$$\frac{\text{(Blank Burette Reading – Sample Burette Reading) *Normality of FAS Solution*8*1000}}{\text{Volume of Sample Used}}$$

NOTE:

- 8 is an equivalent weight of oxygen.
- Mercuric sulphate is used to convert chlorides into poorly ionized mercuric chlorides.

- For acidification Sulfuric acid is used.
- The organic content within the water sample undergoes oxidation by potassium dichromate in the presence of sulfuric acid.
- It is measured in mg/L.

4.2 Module Specification

The module which is used for a lab trial:

Fig. No. 4.1: Membrane Source: Self-Shoot

Aquaporin Inside Hollow Fiber Forward Osmosis Membrane. It has high rejection of difficult compounds, high recovery of water. It is a biomimetic hollow fiber module with integrated aquaporin proteins. **Biomimetic membrane** is a membrane with a certain permeability that divides a cell's interior from its surroundings or forms intracellular compartments by acting as a partition between two areas of the cell. The use of Hollow Fiber allows for a very high packing density. This membrane has an active area of 2.3 m^2 or 752.85 cm.[9]

Water Flux

Permeate flux refers to the volume of permeate generated per unit membrane area per unit time, whereas the salt rejection rate pertains to the concentration of salt in the permeate relative to that in the feed.For this module water flux is 11 ± 1.5 LMH.[9]

Reverse Salt Flux

Reverse salt flux poses a natural challenge in Forward osmosis, characterized by the diffusion of salt ions in the opposite direction, moving from the draw solution back into the treated water.For this module RSF is 0.15 ± 0.05.[9]

Pressure

Feed inlet pressure less or equal to 4 bar and Draw inlet pressure less or equal to 2 bar.[9]

Transmembrane pressure less or equal to 4 bar.

Other things

Maximum particle size less or equal to 50 µm, and free chlorine tolerance less or equal to 0.1 mg/L.[9]

pH range 2-11.[9]

Membrane can be operated vertical and horizontal positions.

4.3 Bill Of Quantity

S.No.	Description	Specification	Make	Quantity	Rate in INR.	Final Price
1.	FO Membrane	Module HFF02	Aquaporin Biomimetic Membrane	1	41806/-	41,800/-
2.	Pump	100GPD, Pressure 140 PSI, 1.5 V	Aqua	2	1430/-	2,400/-
3.	Pump Adapter	AC to DC convertor		2	580/-	1,000/-
3.	Ball valve	3/8 inch.	KRPLUS	2	100/-	200/-
4.	Beaker 5L	5L 2L	PolyLab PolyLab	4 4	500/- 250/-	3,000/-
5.	Pressure Gauge	100 PSI, 7 kg/cm^2, fluid filled.	DropX	4	250/-	1,000/-
6.	Rotameter	100 LPH	DropX	4	450/-	1,800/-
7.	Pipe	3/8 Inch.		10 Meters pipe	380/-	380/-
8.	Fittings	3/8 Inch.			2210/-	2,210/-
9.	Aluminum setup	-		1	3000/-	3000/-
10.	Sodium Chloride	5kg	Rankem	-	900/-	900/-

Table No. 4.3: Bill Of Quantity

4.4 Draw Solution Preparation

For preparing Draw solution I have taken reference from video which is uploaded by Aquaporin Team, Singapore []. And got relevant information from Mr. Mayur Joshi Ahmedabad, Director of Fluid Sep Technologies [].

In Forward Osmosis (FO), the draw solution plays a pivotal role by creating the primary driving force for water transport across the membrane. An effective draw solution is one that can be readily generated or recovered. It should have a strong affinity for water molecules, achieved through hydration or ionization, to generate significant osmotic pressure. Additionally, the draw solution must not harm or damage the FO membrane and should possess attributes like low viscosity, low toxicity, high diffusivity, and affordability.

Maintaining high osmotic pressure requires highly diffusive draw solutes, but this heightened diffusivity can lead to leakage into the feed solution. Conversely, employing draw solutes with low diffusivity can decrease osmotic pressure, impacting water flux. Draw solutes are typically classified into responsive and non-responsive categories. Non-responsive draw solutes are characterized by their consistent affinity for water molecules, unaffected by variations in temperature, pH levels, or exposure to light. This category encompasses inorganic salts, polymers, and organic molecules.

NaCl stands out as a highly desirable draw solute for FO membranes, owing to its small ion size and remarkable diffusivity into the support, particularly when the membrane features a defect-free and exceptionally selective layer.

Responsive draw solutes are characterized by their ability to undergo significant changes in affinity in reaction to various factors like temperature, pH, light exposure, or electric and magnetic fields. This adaptability renders a responsive draw solution more readily recoverable. Examples of such solutes include nanoparticles and hydrogels.

I had prepared Draw solution of 1M Nacl, and used for lab trials.

4.5 Basic Principles and Working

a. Osmosis: It is the process wherein water molecules move from an area of higher concentration to an area of lower concentration across a semipermeable membrane. Such a membrane permits the passage of tiny molecules and ions while hindering larger molecules or dissolved substances.

b. Osmotic Pressure: The osmotic pressure contrast between the feed and draw solutions serves as the driving force for Forward Osmosis (FO).

c. Working:

1. Feed solution flows from one side and from the second end of the membrane draw is presented, they both are in counter current mode.
2. Water permeates from the feed side to the draw side as a result of the osmotic pressure gradient.
3. The membrane retains solutes from the feed solution, leading to the concentration of solutes in the outlet feed solution.

d. Recovery and Regeneration:

Post-treatment is necessary to recover the diluted draw solution and obtain pure water. this could be achieved by several processes such as RO, distillation, thermal separation.

4.6 Challenges and Consideration

1. Membrane fouling
2. Draw-Solution selection
3. Economic feasibility

4.7 Application Of Forward Osmosis

Forward Osmosis (FO) finds extensive application due to its numerous advantages. It is employed in wastewater treatment, desalination, power generation, and various industrial processes. Additionally, FO serves as a pre-treatment method for commercial-scale reverse osmosis desalination processes.

4.8 Advantage

There is a belief that forward osmosis has an advantage over any pressure-driven membrane process as its energy consumption is comparatively less. Because it does not require any external pressure. But the forward osmosis process consumes a comparable amount of energy; however, the key distinction lies in the energy source utilized by FO, which can be selected from inexpensive sources. The lack of applied pressure results in reduced fouling of FO membranes and greater reversibility of fouling. This reduced fouling behavior is attributed to the lower fluxes. Employing an externally applied pressure induces convective flow towards the membrane surface, resulting in elevated local concentrations and consequently increased fouling. Convective flows are also observed in FO membranes, yet there exists a critical threshold flux specific to each type of FO membrane, beyond which fouling initiates. However, the impact of fouling on FO performance is comparatively less severe due to the denser nature of fouling layers, rendering fouling more reversible. FO has a lower fouling tendency, so without any extensive pretreatment, clean water can be recovered from challenging and highly fouling sources. FO can also be utilized in various fields like treatment of wastewater, seawater desalination, and the removal of dissolved metals. Lower fouling tendency enhances membrane lifetime and makes cleaning easier.

4.9 Disadvantage

In contrast to other water purification processes, the end product of forward osmosis (FO) is not clean water but a diluted solution. Often, FO needs to be supplemented with a secondary separation step, typically reverse osmosis (RO), to recover the draw solution and yield clean water. The challenge lies in finding a suitable draw solute capable of generating high osmotic pressure with high solubility in water, and which is easy to recover or regenerate. The true energy efficiency of FO hinges on eliminating the need to regenerate the draw solution. Selecting the draw solution is particularly challenging because highly diffusive draw solutes are essential for maintaining high osmotic pressure within the support. However, excessive diffusivity can lead to leakage of the feed solution. Conversely, employing low diffusive draw solutes results in decreased osmotic pressure within the support, consequently affecting water flux in FO.

4.10 Design of The System

For Lab Trial setup I have taken reference from the organization named Pure-water enterprises Pune, Maharashtra, India.

Steps mentioned below is used to establish setup

1. A Iron stand is fabricated of size approx 2 feet.
2. An aluminium sheet is used as frame of size 2 feet wide and 1.5 feet long.
3. Wholes for pipe and fitting is drilled on aluminuim sheet.

4. Pumps are fixed beside the aluminium sheet.
5. Valves are installed to control the flow.
6. Pressure gauge and rotameter are also installed on the sheet.

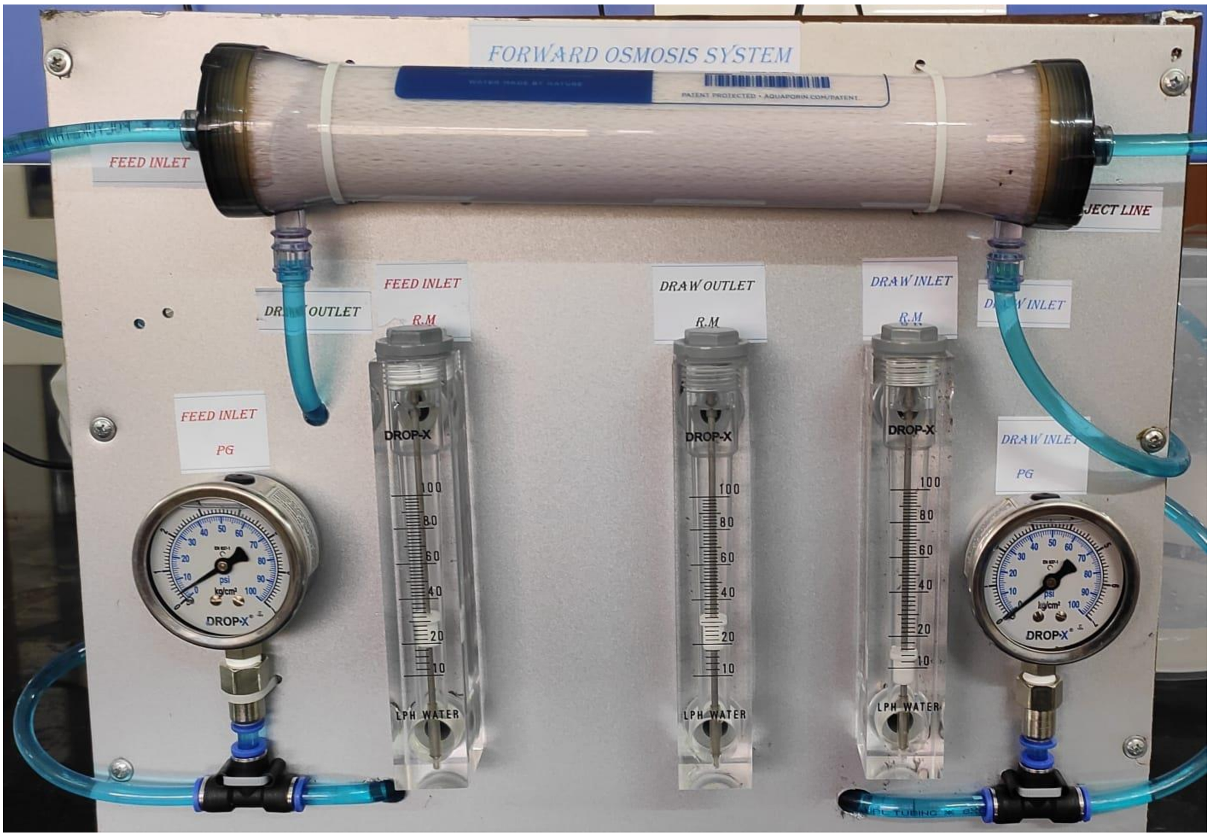

Fig. No. 4.2: Forward Osmosis Setup

Fig. No. 4.3: Membrane

Fig. No. 4.4: Pumps

CHAPTER 5:

RESULT AND DISCUSSION

Report of the sample which was concentrated by using above mentioned methodology and FO membrane. The client demanded enhanced Aroma in less amount of water.

Ref.: DEW/FO/2024/042024 Date: 10/04/2024

SUBJECT: REPORT OF FORWARD OSMOSIS TRIAL

Sample Description:

Sample Collection Date: 04-04-2024

Sample Process : Aroma water (Agar)

Sample Quantity : 5Ltr

Sample Analysis Date : 09-04-2024 to 9-04-2024

S. No	Parameters	Unit	Sample Value
1.	pH	-	3.22
2.	TDS	mg/L	270
3.	Turbidity	NTU	3.94

Table 5.1: Inlet Parameters

Methodology:

Forward Osmosis: It's a membrane separation process primarily driven by osmosis for water separation, it is regarded as less energy consuming technology.

The purpose of the Forward osmosis (FO) is to separate water from dissolved solutes by utilizing osmotic pressure to drive water through the membrane, while simultaneously retaining all dissolved solutes on the opposite side.

Draw Solution:

The draw solution plays a crucial role as it generates the primary driving force for water transport across the membrane.. 1M NaCl solution is used as draw solution for this test.

Apparatus Required:

Forward Osmosis membrane, 100GPD Pump, Pump Adapter, 8 mm Pipe (10m) and 8mm Fittings, Ball valve, Rotameter 100LPH, Pressure Gauge 7kg/cm^2, TDS Meter (high range), Beaker 5L, Stirrer.

Procedure:

I had taken 1L of sample water and passed it from FO membrane

Fig. No. 5.1: First Circulation

After 1st pass of the sample through FO membrane, the volume of the concentrated sample is nearly about 700ml.

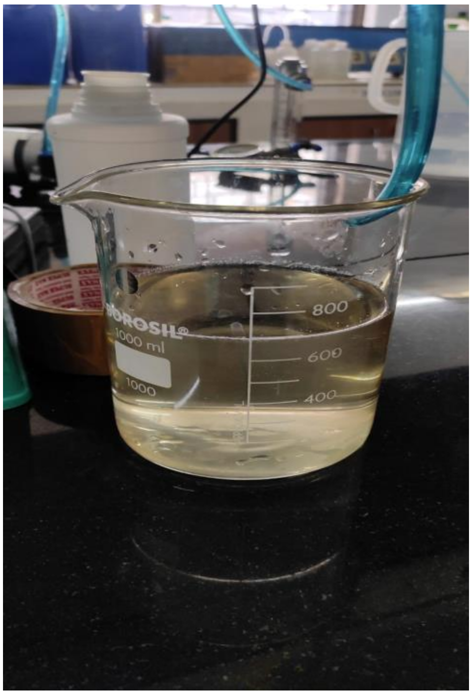

Fig. No. 5.2: Second Circulation

After 2nd pass of the sample through FO membrane, the volume of the concentrated sample is nearly about 340ml.

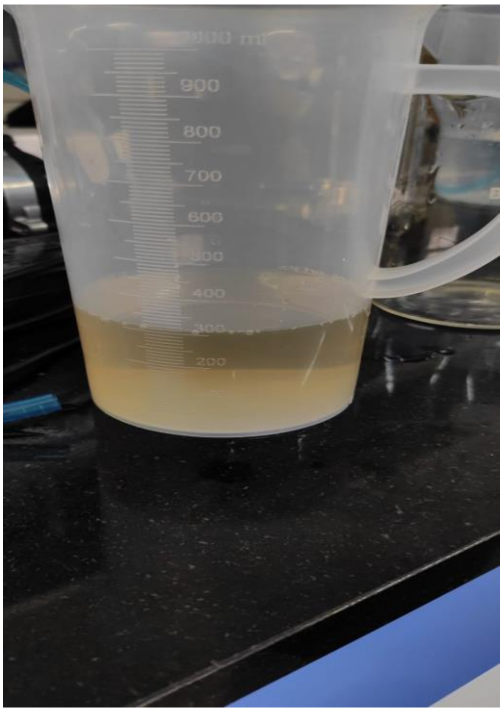

Fig. No. 5.3: Third Circulation

After 3rd pass of the sample through FO membrane, the volume of the concentrated sample is nearly about 175ml. The parameters of final concentrated water is mentioned below, during this trial I found enhanced aroma in less amount of water and also recovered pure water which is diluted with draw solution, which requires post treatment.

Fig. No. 5.4: Final Concentrated Water

This is the final analysis of concentrated water.

S.No	Parameters	Unit	Sample Value
1	pH	-	3.22
2	TDS	mg/L	1020
3	Turbidity	NTU	25.44

Table No. 5.2: Concentrated Water Parameters

The flow rates during this trial was in a ratio of 2:1, 30 LPH for feed and 15 LPH for draw respectively.

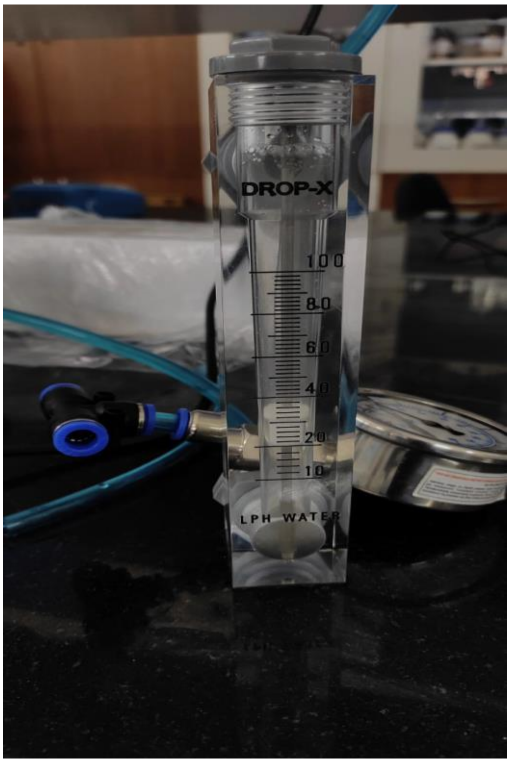

Fig. No. 5.5: Feed flow-rate

Fig. No. 5.6: Draw flow-rate

Comments:

1. By this test recovery of water in % is 83.
2. Flow rates was 2:1, Feed flow rate-30 LPH and Draw flow rate-15 LPH.
3. After recirculating three times we left with 170ml of feed solution. Initial volume of feed solution was 1000ml.
4. Permeate was not a pure water but a diluted solution and has high TDS because of draw solution but that can be removed by simple RO process and draw solution can be reused.
5. This technology can be used according to the requirements either we need to recover pure water from wastewater or to enhance any kind of aroma in less amount of water**.**

CHAPTER 6:

CONCLUSION

Forward osmosis is good technology to keep up with the demand of more fresh water production. FO can be employed in several applications; the result may differ from the expected value. The cost and energy consumptions are comparatively less than any other membrane separation technology. In FO process there is no external pressure is applied which leads to less energy consumption in filtration. It is believed that FO and RO combination consumes more amount of energy than stand alone RO process and although it is true, but this could be minimized only if the draw solution is easily recovered or regenerated than that would be energy efficient process. The result may differ from the literature and expected value.

6.1 Societal Relevance:

1. Water Purification: FO is efficient and can recover more water & reject several species, which can give steady supply of pure water.
2. Environmental Impact**:** FO can reduce water pollution, can help to give a beautiful environment.
3. Resource Conservation: FO gives high recovery of wastewater, and utilizes wastewater to be reused.
4. Technological Innovations: FO gives advancements in membrane technology which leads to development and stimulate growth in technical field.

6.2 Achieved Outcomes

1. Examine water quality parameters such as – pH, TDS, TSS, Turbidity, Total Hardness, Chloride, Iron, Silica, COD, Alkalinity.
2. Apply process design principles for various water-treatment processes.
3. Construct piping and instrumentation diagram.
4. Design RO system and FO system.

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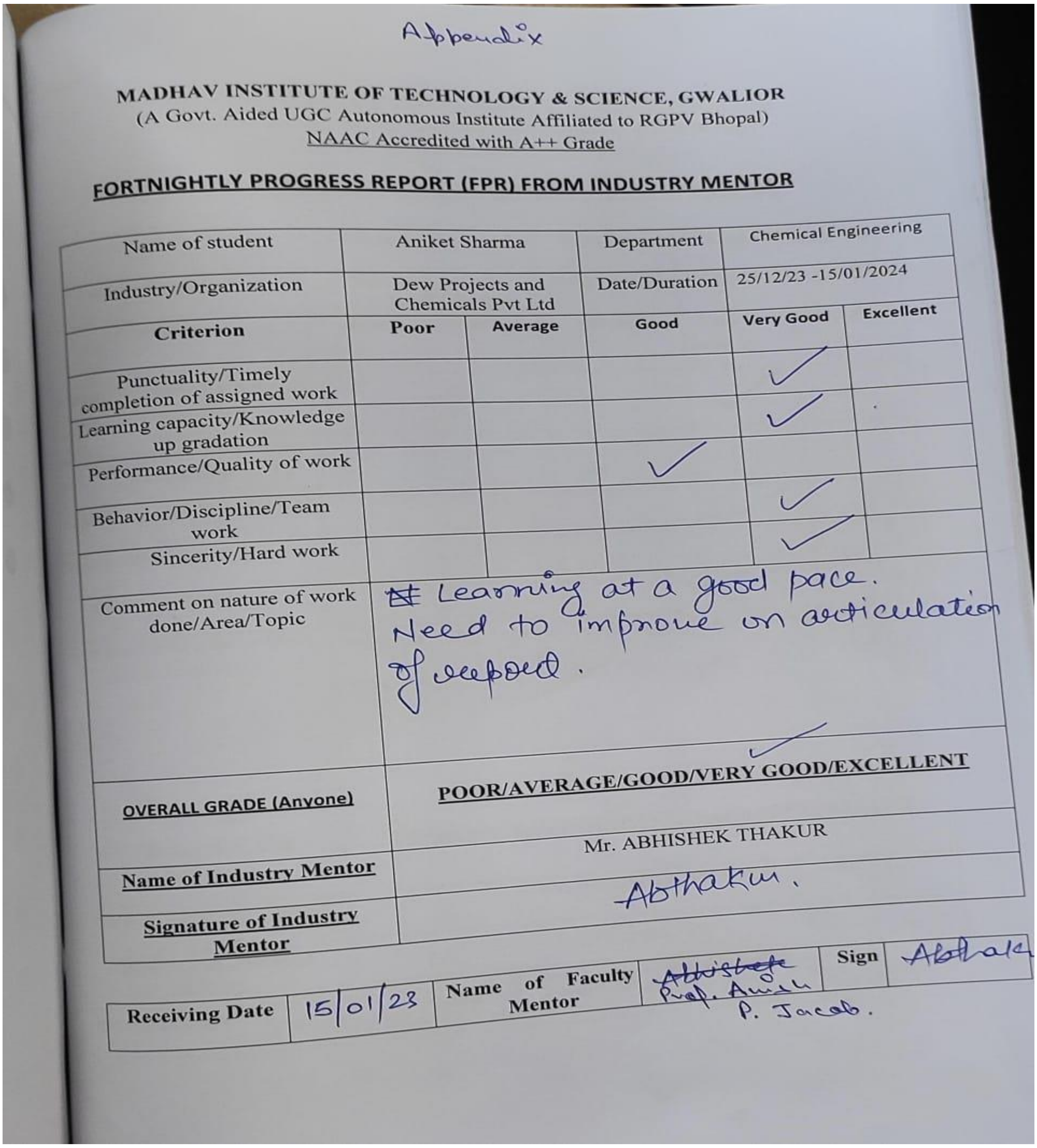

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Industry/Organization	Dew Projects and Chemicals Pvt Ltd	Date/Duration	25/12/23 -15/01/2024

Criterion	Poor	Average	Good	Very Good	Excellent
Punctuality/Timely completion of assigned work				✓	
Learning capacity/Knowledge up gradation				✓	
Performance/Quality of work			✓		
Behavior/Discipline/Team work				✓	
Sincerity/Hard work				✓	

Comment on nature of work done/Area/Topic	~~At~~ Learning at a good pace. Need to improve on articulation of report.
OVERALL GRADE (Anyone)	POOR/AVERAGE/GOOD/✓VERY GOOD/EXCELLENT
Name of Industry Mentor	Mr. ABHISHEK THAKUR
Signature of Industry Mentor	Abthakur.

Receiving Date	15/01/23	Name of Faculty Mentor	~~Abhishek~~ Prof. Anish P. Jacob.	Sign	Abthakur

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Name of Student	Aniket Sharma		Department	Chemical Engineering	
Industry/Organization	Dew Projects and Chemicals Pvt Ltd		Date/Duration	16/01/24 - 04/02/2024	
Criterion	**Poor**	**Average**	**Good**	**Very Good**	**Excellent**
Punctuality/Timely Completion of Assigned Work				✓	
Learning capacity/Knowledge Up Gradation			✓		
Performance/Quality of Work				✓	
Behavior/Discipline/Teamwork				✓	
Sincerity/Hard work				✓	
Comment on Nature of Work Done/Area/Topic	Need to give more attention & effort on learning the concepts.				
OVERALL GRADE (Anyone)	**POOR/AVERAGE/GOOD/VERY GOOD/EXCELLENT** (✓ GOOD)				
Name of Industry Mentor	Mr. ABHISHEK THAKUR				
Signature of Industry Mentor	Abthakur.				

Receiving Date	04/02/2024	**Name of Faculty Mentor**	Prof. Anish P. Jacob	**Sign**	[signature]

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Industry/Organization	Dew Projects and Chemicals Pvt Ltd	Date/Duration	05/02/24 - 20/02/2024

Criterion	Poor	Average	Good	Very Good	Excellent
Punctuality/Timely Completion of Assigned Work			✓		
Learning capacity/Knowledge Up Gradation			✓		
Performance/Quality of Work			✓		
Behavior/Discipline/Teamwork				✓	
Sincerity/Hard work				✓	

Comment on Nature of Work Done/Area/Topic	Too slow in completing regular task. Need to improve on the speed.
OVERALL GRADE (Anyone)	**POOR/AVERAGE/GOOD/VERY GOOD/EXCELLENT** (✓ GOOD)
Name of Industry Mentor	Mr. ABHISHEK THAKUR
Signature of Industry Mentor	Abthakur.

Receiving Date	21/02/2024	**Name of Faculty Mentor**	Prof. Anish P. Jacob	**Sign**	[signature]

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Industry/Organization	Dew Projects and Chemicals Pvt Ltd		Date/Duration	21/02/24 - 11/03/2024	
Criterion	**Poor**	**Average**	**Good**	**Very Good**	**Excellent**
Punctuality/Timely Completion of Assigned Work				✓	
Learning capacity/Knowledge Up Gradation				✓	
Performance/Quality of Work				✓	
Behavior/Discipline/Teamwork				✓	
Sincerity/Hard work				✓	
Comment on Nature of Work Done/Area/Topic	Good presentation & conduct. Need to improve on clarity of concepts.				
OVERALL GRADE (Anyone)	**POOR/AVERAGE/GOOD/VERY GOOD/EXCELLENT** ✓				
Name of Industry Mentor	Mr. ABHISHEK THAKUR				
Signature of Industry Mentor	Abthakur.				

Receiving Date	12/03/2024	**Name of Faculty Mentor**	Prof. Anish P. Jacob	**Sign**	[signature]

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Name of Student	Aniket Sharma		Department	Chemical Engineering	
Industry/Organization	Dew Projects and Chemicals Pvt Ltd		Date/Duration	12/03/2024 - 01/04/2024	
Criterion	**Poor**	**Average**	**Good**	**Very Good**	**Excellent**
Punctuality/Timely Completion of Assigned Work		✓			
Learning capacity/Knowledge Up Gradation				✓	
Performance/Quality of Work			✓		
Behavior/Discipline/Teamwork			✓		
Sincerity/Hard work		✓			
Comment on Nature of Work Done/Area/Topic	Need to be more sincere about the work opportunity provided to him.				
OVERALL GRADE (Anyone)	**POOR/AVERAGE/GOOD/VERY GOOD/EXCELLENT** (✓ GOOD)				
Name of Industry Mentor	Mr. ABHISHEK THAKUR				
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Name of Student	Aniket Sharma		Department	Chemical Engineering	
Industry/Organization	Dew Projects and Chemicals Pvt Ltd		Date/Duration	02/04/2024 - 21/04/2024	
Criterion	**Poor**	**Average**	**Good**	**Very Good**	**Excellent**
Punctuality/Timely Completion of Assigned Work		✓			
Learning capacity/Knowledge Up Gradation				✓	
Performance/Quality of Work				✓	
Behavior/Discipline/Teamwork					
Sincerity/Hard work			✓		
Comment on Nature of Work Done/Area/Topic	Showed good efforts in completing the demo-version of the RO plant.				
OVERALL GRADE (Anyone)	**POOR/AVERAGE/GOOD/VERY GOOD/EXCELLENT** (✓ VERY GOOD)				
Name of Industry Mentor	Mr. ABHISHEK THAKUR				
Signature of Industry Mentor	AbThakur.				

Receiving Date	22/04/2024	**Name of Faculty Mentor**	Prof. Anish P. Jacob	**Sign**	[signature]