LABORATORY SETUP FOR DEIONIZATION
OF
WATER USING RESINS

SEVENTH SEMESTER B.Tech PROJECT

Submitted in partial fulfilment of

The Requirements for the Degree of

BACHELOR OF TECHNOLOGY

in

CHEMICAL ENGINEERING

of

ASSAM SCIENCE AND TECHNOLOGY UNIVERSITY

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CERTIFICATE

This is to certify that **Vivek Gupta (Roll No. - 200610010054), Stuti Choudhury (Roll No. - 200612710017), Bhaswati Deka (Roll No. - 200610010010), Violinaa Borborah (Roll No. - 200610010053)** of B.Tech 7th Semester have jointly carried out the project entitled "**Laboratory Setup for Deionization of Water Using Resins**" under my supervision and submitted the report in partial fulfilment of the requirement for the Degree of Bachelor of Technology in Chemical Engineering, which may be accepted.

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Dr. Bandana Chakrabarty

Head of Department

Department of Chemical Engineering

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Declaration

We declare that this written submission represents our ideas in our own words and where others' ideas or words have been included, we have adequately cited and referenced the original sources. We also declare that we have adhered to all principles of academic honesty and integrity and have not misrepresented or fabricated or falsified any idea/data/fact/source in our submission. We understand that any violation of the above will be cause for disciplinary action by the Institute and can also evoke penal action from the sources which have thus not been properly cited or from whom proper permission has not been taken when needed.

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ABSTRACT

This report provides information about the deionization of water using resins by ion exchange process with the help of a deionization plant setup in a laboratory scale. Since normal tap water contains many impurities and ions in it, this setup helps to deionize the water making it less harmful. Furthermore, the deionized water thus can be used for industrial or medical purposes.

The setup basically consists of two separate tanks; anion and the cation tank where both anionic and cationic resins are kept respectively inside it that helps to deionize the incoming water.

Before deionization the resins need to be regenerated for active participation of the resins which is done by passing 5% w/v solution of HCl into the cation exchange tank and passing 0.1% w/v solution of NaOH through the anion exchange tank. Thus, after regeneration the high TDS or tap water can be passed through both the tanks i.e first through the cation tank followed by the anionic tank where deionization of the water takes place by the process of ion exchange method. Deionization is the process of removing ions from water. It is a chemical process that forms high-purity water by removing all charged particles in raw water using an ion-exchange method. Ions exist as cations (positively charged) and anions (negatively charged).

We prepared cation exchange tank and anion exchange tank with PVC pipes and done all the connections, passes tap water through it giving continuous water connections at a particular flow rate. We obtained results that showed that our setup was effective in removing ions from water from water. Our projects build on previous research by developing a low cost and efficient setup for deionization of water using resin

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CHAPTER 1
INTRODUCTION

Deionization is the process of removing ions from water. It is a chemical process that forms high-purity water by removing all charged particles in raw water using an ion-exchange method. Ions exist as cations (positively charged) and anions (negatively charged). Demineralization or deionization produces water that is similar in quality to distilled water.

Deionization is usually accomplished through an ion exchange process. Resins play their leading role in the ion exchange process. Resins are polymers manufactured with styrene crosslinking with divinylbenzene. Resins have electrostatically bonded ions. Resins with positively charged ions are called cation resins, and resins with negatively charged ions are called anion resins. Deionization is achieved by using ion exchange resins that are made of tiny plastic beads with charged functional group built on it. The process involves running water through a resin bed, where the resin beads grab onto the salts responsible for water's charge, allowing only deionized water to pass through.

Some examples of usage of deionized water are laboratory applications, pharmaceutical industry, petrochemical processes, food & beverages industry, boiler feeding, cooling applications, aquariums, automotive and electronic equipment manufacturing, etc.

1.1) Objective of the Study:

I. To design a small-scale deionization setup/system to produce deionized water.
II. Analysing the performance of the designed system, including efficiency of the ion exchange process and quality of the deionized water produced.

The scope of our project includes exploring practical application in water purification, assessing the efficiency and specificity of the setup in removing targeted ions from water, evaluating scalability factors, such as cost effectiveness and energy consumption.

1.2) Overview of Methodology:

Deionization of water using resin is a method of removing dissolved ions from water by exchanging them with Hydrogen and Hydroxide ion on the surface of the resin bed. The method involves two tanks: one contains cation exchange resin bed, and the other has anion exchange resin beds. The cation resins exchange H^+ ions for the cations (such as Calcium, Magnesium, Sodium) in raw water. The anion resins exchange OH^- ions for the anions, (such as sulphate, chloride and bicarbonate) in natural water. The H^+ and OH^- ions then combine to form pure water. The resin beds need to be regenerated periodically by flushing them with acid and base solutions to restore their ion exchange capacity.

CHAPTER 2
LITERATURE REVIEW

A literature review is an essential component of academic research that involves a systematic examination and evaluation of existing literature, scholarly articles, books, and other sources relevant to a particular research topic or question. It serves multiple purposes within a research project, such as,

- Contextualizing the research
- Identifying gaps and research questions
- Evaluating methodologies
- Supporting theoretical framework

Literature Survey:

A comprehensive literature survey was conducted to explore the existing research studies, technical papers, and articles related to ion exchange deionization of water using resin, types of resin, effect of resin amount, technology and suitable setup for deionization of water. The survey aimed to gain insights into the methodologies, technologies, and approaches employed in previous works, as well as to critically analyse their effectiveness, limitations, and potential areas for improvement.

Through searching for different research paper, studying them we have taken different inputs and insights. Some of them with their works and features and future scope have been discussed below:

i. Ion Exchange Experiments- Water Softening and Deionization. This paper was published in the year of 2016.

Salient features of this paper:

- To create ion exchange experiments to imitate the ion exchange process at the laboratory scale.
- To understand the characteristics of an ion exchange column, to be able to determined breakthrough capacities of an ion exchanger, and to utilize laboratory testing in the design process.

ii. A Comprehensive Method of Ion Exchange Resin Regeneration and its Optimization for Water Treatment. This paper was published in year 2016.

Salient features of this paper:

- Ion exchange deionization and the effect of resin amount as well as concentration of acid and base on the product conductivity.
- Water conductivity, as an indicator of resin regeneration efficiency. Conductivity decreases with time until one point is reached and then starts to increase as a result of resin saturation.

iii) Handbook of industrial water treatment- Ion exchange, water demineralisation and resin testing. This paper was published in year 2005.

Salient features of this paper:

- An ion exchange water treatment system is a specialized technology used in wastewater treatment to remove dissolved ions and contaminants from water.
- This system relies on ion exchange resins that attract undesirable ions in the wastewater and exchange them with more desirable ions, effectively purifying the water before discharge. Ion exchange water treatment systems play a significant role in wastewater treatment and contribute to improving water quality and meeting various industrial and domestic needs.

In the middle 1940's, ion exchange resins were developed based on the copolymerization of styrene cross-linked with divinylbenzene. These resins were very stable and had much greater exchange capacities.

iv) Chemical reviews published on 2022 by Mohammad A Alkhadra, Xiao Su, Mattheww E Suss "Electrochemical Methods for Water Purification, Ion Separations, and Energy Conversion".

Salient features of this paper:

- This review provides a comprehensive description of the principles and applications of electrochemical methods for water purification, ion separations, and energy conversion.
- Electrochemical methods have attractive features such as compact size, chemical selectivity, broad applicability, and reduced generation of secondary waste.

- the greatest advantage of electrochemical methods, however, is that they remove contaminants directly from the water, while other technologies extract the water from the contaminants, which enables efficient removal of trace pollutants.
- The review begins with an overview of conventional electrochemical methods, which drive chemical or physical transformations via Faradaic reactions at electrodes, and proceeds to a detailed examination of the two primary mechanisms by which contaminants are separated in non-destructive electrochemical processes, namely electrokinetic and electro sorption.
- Recent examples of Faradaic platforms for water purification are based on electrochemical reduction of target contaminants, electrochemical switching of ion exchange, and molecularly selective removal of ions, uncharged compounds, and biomolecules.
- Electrochemical systems use applied electrical currents to remove contaminants from the feed by either driving separations in bulk electrolytes, electrochemically trapping them in electric double layers (EDLs), or intercalating them in solid electrodes.

v) Ion exchange for water treatment by Mark Ludwigson

Salient features of this paper:

- Ion exchange is a water treatment process that can remove several contaminants and help to produce high-quality drinking water.
- Ion exchange was first utilized for water treatment in the 1930s.
- The acceptable level of hardness is debatable and often a personal preference. Many public water treatment systems target a hardness of below 60 mg/L.
- a treatment process is commonly used to remove calcium and magnesium and thereby soften the raw water. Ion exchange with cation type resin and lime softening are two common approaches for reducing hardness.
- Ion exchange processes produce deionized water. Partial deionization systems only remove cations or anions, while complete deionization systems remove both cations and anions.
- Deionized water is similar to distilled water. Distillation boils the water and then condenses the steam back into a liquid to remove impurities and minerals. The

distillation process is much more costly than deionization, although it can remove both ionic and non-ionic impurities.

- Cation Resins

  Resin facilitates the exchange of ions. Resin is a collection of small insoluble beads, nodules, or granules. The most common resin is small organic polymer beads (0.25 to 1.43 mm radius) that are yellow or orange. The beads can be porous to provide a greater surface area.

- Chelating Resins

  Chelating resins are cation resins that are manufactured to have a higher-than-normal selectivity towards removing heavy metal cations, including the following:

  • Barium (Ba_2^+), Cadmium (Cd_2^+), Cobalt (CO_2^+), Copper (Cu^+), Chromium (Cr_3^+), Lead (Pb_2^+), Manganese (Mn_2^+), Nickel (Ni_2^+), Zinc (Zn_2^+)

- Anion Exchange resins

  Anion exchange is used to remove a variety of anion contaminants. Anion resins are designed to attract anions, which are contaminants having a negative charge. The resin starts with hydroxide (OH^-) on the surface. When water passes through the resin, anions will attract and adhere to the resin surface, thereby releasing (exchanging) the hydroxide ions.

Overall literature survey serves as a foundation for the present study, providing a comprehensive understanding of ion exchange method for deionization of water, preparation of the setup for it in lab scale, characteristics and uses of resins and the uses of deionized water in different field and work.

Analysing existing work and establishing the context for the current study:

Deionization is the process of removing ionized salts from water using ion exchange resins. Previous research has shown that ion exchange resins can be used to remove a wide range of ions from water including Calcium, Magnesium, Sodium, Sulphate, Chloride. Recent advances in ion selectivity with capacitive deionization have also shown promising results in removing ions from water. However, regeneration of resin is a major challenge in the field of water treatment.

In this study we aimed to develop a setup for deionization of water using resin. We prepared cation exchange tank and anion exchange tank with PVC pipes and done all the connections, passes tap water through it giving continuous water connections at a particular flow rate. We obtained results that showed that our setup was effective in removing ions from water from water. Our projects build on previous research by developing a low cost and efficient setup for deionization of water using resin.

The significance of our projects lies in its potential to provide a low cost and efficient method for deionization of water using resin. Our setup can contribute to the field of water treatment by providing a sustainable and cost-effective solution for deionization of water using resin.

CHAPTER 3

MATERIALS AND METHODS

3.1) *Methods for Deionizing of water:*

The choice of method depends on the specific application, required water purity, and operational considerations. Each method has its advantages and disadvantages, and the selection of a deionization method should consider factors such as cost, maintenance, and the desired level of water purity.

Every method has its own advantages and disadvantages, some of which are listed below:

3.1.1) Ion Exchange Resin Method: - This is one of the most common methods for deionizing water. It involves passing water through a column filled with ion exchange resin beads. Cations and anions in the water are exchanged for hydrogen (H+) and hydroxide (OH-) ions attached to the resin. The resin becomes exhausted over time and needs regeneration or replacement.

Advantages

i. **Effective Deionization:** Ion exchange resin is highly effective at removing both cations and anions from water, making it one of the most efficient methods for producing high-purity deionized water.

ii. **Regenerable:** Ion exchange resins can be regenerated, allowing for multiple cycles of use before replacement is necessary. Regeneration typically involves the use of concentrated acids and bases to strip the ions from the resin and replace them with hydrogen (H^+) and hydroxide (OH^-) ions.

iii. **Consistent Water Quality:** Ion exchange resins can consistently produce water with very low ion concentrations, making them suitable for a wide range of applications where water purity is critical, such as in laboratories and the pharmaceutical industry.

iv. **Scalability:** Ion exchange systems can be designed to meet specific flow rates and water purity requirements, making them adaptable to different applications and industries.

Disadvantages

i. **Limited Capacity:** The capacity of ion exchange resins is finite, and over time, they become exhausted as they exchange ions. This necessitates regeneration or replacement, which can be a labour-intensive process.

ii. **Waste Generation:** Regeneration of ion exchange resins produces chemical waste, which must be managed properly and can be environmentally problematic if not handled correctly.

iii. **Cost:** The initial cost of ion exchange resin systems can be relatively high, and ongoing expenses include the cost of regeneration chemicals and the labor involved in maintenance.

iv. **Continuous Monitoring:** Ion exchange systems require regular monitoring to ensure they are functioning correctly and delivering the desired water quality. If not properly maintained, they can lead to variations in water purity.

3.1.2) Distillation Method: - Distillation involves heating the water to create vapor and then condensing the vapor back into liquid form. Since most ions have higher boiling points than water, they are left behind during the vaporization process. This method is effective but energy-intensive.

Advantages

i. **High Purity**: Distillation is highly effective at producing high-purity water because it separates water molecules from most impurities, including ions, minerals, and contaminants. It can produce water with very low ion concentrations.

ii. **Versatile:** Distillation can be used to purify a wide range of water sources, including tap water, seawater, and industrial wastewater, making it versatile for various applications.

Disadvantages

i. **Slow Process:** Distillation is generally slower compared to some other deionization methods, which can be a drawback for applications that require a high flow rate.

ii. **Equipment Maintenance:** Distillation equipment requires regular maintenance to ensure proper function and prevent fouling of components due to scale or impurities.

iii. **Water Loss:** Distillation results in some water loss as the impurities are left behind in the concentrated brine or reject stream.
iv. **Initial Cost:** The setup of a distillation system can have a relatively high initial cost, including the purchase of specialized distillation equipment.

3.1.3) Reverse Osmosis Method: - Reverse osmosis (RO) is a process that uses a semipermeable membrane to separate ions and other impurities from water. It applies pressure to push water through the membrane while leaving the ions behind. RO is commonly used to produce low-ion-content water.

Advantages

i. **High Purity:** RO is highly effective at removing ions and a wide range of impurities from water, producing water with low ion concentrations.
ii. **Versatility:** RO can be used to treat various water sources, including tap water, well water, and seawater. It is widely employed in both residential and industrial applications.
iii. **Efficiency:** RO is more energy-efficient than distillation, as it does not involve the high heat requirements of distillation.

Disadvantages

i. **Membrane Fouling:** The RO membrane can become fouled or clogged over time, leading to reduced efficiency and the need for regular maintenance and cleaning.
ii. **Waste Disposal:** The concentrate or brine stream generated in RO contains concentrated impurities and may require proper disposal or management.
iii. **Initial Cost:** The initial cost of purchasing and installing an RO system can be relatively high.

3.1.4) Electrodialysis Method: - Electrodialysis uses an electric field to move ions through ion-selective membranes. Positively charged ions migrate toward negatively charged electrodes, and negatively charged ions move toward positively charged electrodes. The process can separate cations and anions into separate streams, effectively deionizing the water.

Advantages

i. **Continuous Operation:** Electrodialysis is a continuous process, making it suitable for applications that require a constant supply of deionized water.
ii. **High Purity:** ED is effective at removing ions from water, resulting in high-purity water with low ion concentrations
iii. **Minimal Chemical Use:** Unlike some other deionization methods, ED typically requires minimal or no chemical reagents for ion removal.

Disadvantages

i. **Complex Equipment:** Electrodialysis systems are relatively complex and require specialized components, including ion-selective membranes and electrodes, which can lead to higher equipment costs.
ii. **Energy Consumption**: ED systems require electrical energy to operate, and the power consumption can be significant.
iii. **Membrane Fouling:** Ion-selective membranes can become fouled or contaminated over time, leading to reduced efficiency, and necessitating regular maintenance and cleaning.
iv. **Initial Cost:** The initial cost of purchasing and installing an electrodialysis system can be relatively high, making it less accessible for some applications.

3.1.5) Chemical Deionization Method: - Chemical deionization involves the addition of chemical reagents that react with ions in the water to form insoluble compounds, which can then be removed by filtration. This method is less common and may involve chemicals like lime or soda ash.

Advantages

i. **Selective Ion Removal:** Chemical deionization can be tailored to selectively remove specific ions by choosing appropriate chemical reagents. This can be advantageous in applications that require the removal of specific ions or contaminants.
ii. **Minimal Energy Use:** Unlike some other deionization methods that require energy for processes like heating or applying electrical fields, chemical deionization generally has lower energy consumption.

Disadvantages

i. **Chemical Handling:** The use of chemicals can be hazardous, and proper safety precautions and waste disposal methods must be followed. This includes the handling of strong acids and bases used in regeneration.
ii. **Waste Generation**: Chemical deionization generates chemical waste, which must be managed properly and can be environmentally problematic if not handled correctly.
iii. **Limited Capacity:** Chemical deionization systems may have a limited capacity before regeneration or replacement is necessary. This makes them less suitable for high-flow applications.
iv. **Lower Water Purity:** Chemical deionization may not achieve the same level of water purity as methods like reverse osmosis, electrodialysis, or ion exchange resin, as it may not remove all ions to the same low concentrations.

3.1.6) Carbon Adsorption Method: - While primarily used for organic contaminant removal, activated carbon can also adsorb some ions, especially organic ions. It is not as effective as other methods for complete deionization but can contribute to overall water quality.

Advantages

i. **Effective Organic Contaminant Removal:** Carbon adsorption is highly effective at removing organic contaminants, such as volatile organic compounds (VOCs), pesticides, and some dissolved solvents, from water.
ii. **No Chemical Regeneration:** Unlike methods that require the use of chemical reagents, carbon adsorption does not involve chemical regeneration, which can simplify the operation.
iii. **Simple and Compact Equipment:** Carbon adsorption systems are relatively simple and compact, making them suitable for smaller-scale applications and easy to install.

Disadvantages

i. **Limited Ion Removal:** While carbon adsorption is effective for removing organic ions and some inorganic ions, it is not highly efficient at deionizing water. It may not reduce the concentration of ions to the same low levels achieved by methods like reverse osmosis or ion exchange.

ii. **Limited Capacity**: The adsorption capacity of carbon decreases as it becomes saturated with contaminants, and it requires periodic replacement or regeneration. This can limit its use in applications requiring continuous deionization.
iii. **Regeneration Challenges:** If regeneration is required, it can be a more complex process compared to other deionization methods, as it often involves the use of chemicals and may require specialized equipment.

3.1.7) Mixed Bed Deionization Method: - Mixed bed deionization combines both cation and anion exchange resins in a single vessel to achieve higher purity levels. It is often used in the final stages of water purification to remove the remaining traces of ions.

Advantages

i. **High Purity:** Mixed bed deionization is capable of producing extremely high-purity water by removing both cations and anions to very low concentrations, often achieving near-total deionization.
ii. **Continuous Operation:** Mixed bed systems can operate continuously without the need for periodic regeneration, as is necessary with separate columns.
iii. **Reduced Chemical Handling:** Mixed bed systems generally require less chemical handling than some other deionization methods, such as chemical deionization or electrodialysis.

Disadvantages

i. **Complex Regeneration:** Regenerating a mixed bed deionization system can be more complex and time-consuming than regenerating separate cation and anion exchange columns. The regeneration process often involves separate regeneration steps for the cation and anion resins.
ii. **Higher Initial Cost:** The equipment for mixed bed deionization is generally more expensive than separate ion exchange columns, and the initial cost can be relatively high.
iii. **Limited Capacity**: Mixed bed resins become exhausted over time, and once their capacity is reached, they must be regenerated or replaced. This can be a limitation in high-flow applications.

3.2) SELECTION OF THE PROCESS

Ion exchange method:

Overviewing all the advantages and disadvantages of various methods for deionizing water and meeting our required requirements Ion Exchange Resin suits the best among all the methods. The choice of method is based on a thorough evaluation of the specific needs and constraints of your water deionization application.

We chose this method because of its high purity water. The chemicals used are safer for the operator to handle and the regeneration of Resins is comparatively easier than other methods. Ion Exchange Resin is a preferred method for applications where consistent, high-purity water is essential, and the advantages of effective ion removal, regeneration of resins and reliability outweigh the associated maintenance and operational costs. The ion exchange process is more cost-effective when treating ground waters, as they are typically a non-carbonate form of water hardness.

The resin used in our experiment:

3.3) ANION EXCHANGE RESINS*:*

Description:

INDION NIP is a Type 2 strong base anion exchange resin in bead form having benzyl dimethyl-ethanol-ammonium groups. These groups are less strongly basic than those in Type 1 resins, resulting in a higher regeneration efficiency with lower operating costs.

INDION NIP is based on cross-linked polystyrene, and has an isoporous structure. INDION NIP has a high capacity for the natural organic matter present in some surface waters and has excellent resistance to poisoning by this organic matter.

Fig 1- : Anion Exchange resin.

TABLE 1 - **Characteristics of Anion Exchange Resin:**

Appearance	Translucent red brown beads
Matrix	Styrene -EDMA copolymer
Functional Group	Benzyl dimethyl ethanol amine
Ionic form as supplied	Chloride
Total exchange capacity	1.2 meq/ml, minimum
Moisture holding capacity	45 - 53 %
Particle size range	0.3 to 1.2 mm
Effective size	0.45 to 0.60 mm
Volume change	Cl to OH, 10-15 % approximately
Maximum operating temperature	40 ^{o}C
Operating pH range	0 to 14

Use of good quality regenerants

All ion exchange resins are subject to fouling and blockage of active groups by precipitated iron. Hence the iron content in the feed water should be low and the regenerant sodium hydroxide must be essentially free from iron and heavy metals. All resins, especially the anion exchangers are prone to oxidative attack resulting in problems such as loss of capacity, resin clumping, etc. Therefore, sodium hydroxide should have as low a chlorate content as possible. Good quality regenerant of technical or chemically pure grade should be used to obtain best result.

Storage:

Ion exchange resins always require proper care. The resin must never be allowed to become dry. Regularly open the plastic bags and check the condition of the resin when in storage. If not moist, add enough clean demineralised water and keep it in completely moist condition. Always keep the resin drum in the shade. Recommended storage temperature is between 20 ^{o}C and 40 ^{o}C.

Safety:

Acid and alkali solutions are corrosive and should be handled in a manner that will prevent eye and skin contact. If any oxidising agents are used, necessary safety precautions should be observed to avoid accidents and damage to the resin.

3.4) CATION EXCHANGE RESINS

Description:

INDION 225 H is a premium grade strong acid cation exchange resin containing sulphonic acid groups. It is baed on cross-linked polystyrene and has a gel structure. The resin has high capacity and excellent kinetics.

INDION 225 H in hydrogen form is used as a first step in de-ionising.

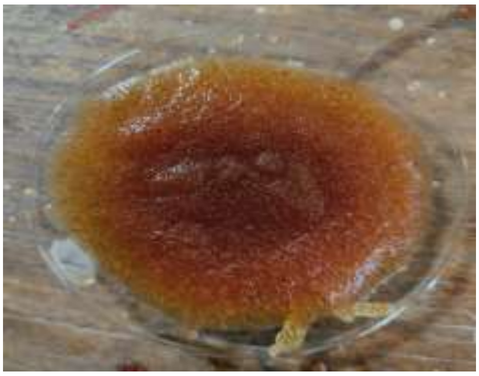
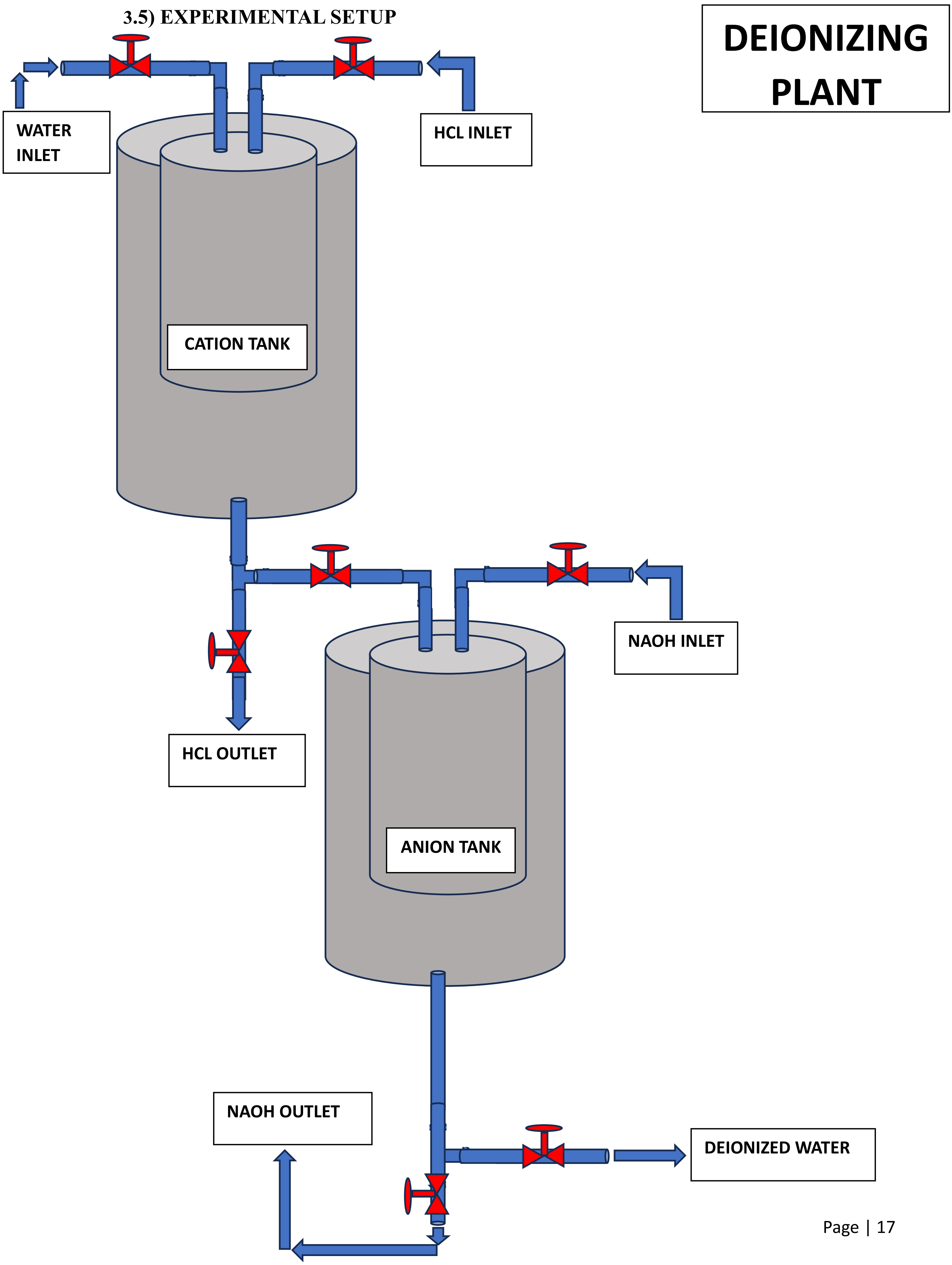


Fig 2- : Cation exchange resin.

Table 2 - **Characteristics of Cation Exchange Resin:**

Appearance	Golden yellow to brown beads
Matrix	Styrene divinylbenzene copolymer
Functional Group	Sulphonic acid
Ionic form as supplied	Hydrogen, H^+
Total exchange capacity	1.8 meq/ml, minimum
Moisture holding capacity	49 -55 %
Particle size range	0.3 to 1.2 mm
Effective size	0.45 to 0.55 mm
Volume change	Na to H, 8 % approximately
Maximum operating temperature	120 ºC
Operating pH range	0 to 14

3.5) EXPERIMENTAL SETUP



3.6) PREPARATION OF THE SETUP:

I. We prepared the Cation and anion exchange resin tank by using two different size of PVC pipes of diameter 5 inch (larger pipe) and 3 inch (smaller pipe).

II. Using PVC pipes keeping the smaller diameter pipe inside the larger diameter pipe, followed by endcap on the larger diameter pipe at the bottom also an endcap on the smaller diameter pipe at the top.

III. We placed a bed (using cloth and net) under the smaller diameter pipe. Resins are placed above it and made it fixed by placing another bed above the resin bed.

IV. We have made following connections with the pipes and valve for continuous flow of water. The pipes connection used for flow of water are of 1 inch diameter.

Fig 3- : Prepared experimental setup

3.7) PROCEDURE FOR BATCH PROCESS:

REGENERATION OF THE RESINS:

The experiment is performed in our chemical department laboratory.

Both the cationic and anionic resins are regenerated before use.

CATIONIC RESIN-

- 5% w/v HCl Solution is prepared by mixing 100ml of distilled water with 50 ml of 37% concentrated HCl.
- We take the cationic resin above a filter paper in a funnel above a 400ml beaker.
- The HCl solution is passed through the resin by pouring continuously for 15mins.
- Ion exchange takes place between the solution and the resin and thus the cationic resin is regenerated.

ANIONIC RESIN-

- 0.1% w/v NaOH solution is prepared for regeneration of anionic resin.
- 0.1g of NaOH flakes is taken in 100ml of distilled water to prepare the solution. The solution is stirred slowly.
- Anionic resin is taken in a filter paper above a 400ml beaker.
- The prepared NaOH solution is passed through the resin continuously once and thus the resin is regenerated.

Deionizing tap water:

- After regeneration of the resins, we take tap water to deionize it with the help of resins.
- We collect about 400ml of tap water and pass it through the cationic resin. The cationic resin contains positively charged ions which exchanges it for any anions that may contain in the water.
- Similarly, the partially deionized water is again passed through the anionic resin which exchanges it for positive charged ions present in the water.
- Parameters like conductivity, pH, TDS etc are thus measured of the collected deionized water with the help of an instrument called water analysis kit.

APPARATUS USED:

- Funnel
- Filter paper
- Beakers (100ml, 400ml)
- Stirrer

CHEMICALS USED:

- HCl
- NaOH flakes

3.8) PROCEDURE FOR CONTINUOUS PROCESSES:

REGENERATION OF RESIN:

Cation Exchange Resin:

- 5% w/v solution of HCl is prepared by mixing 50 ml of HCL in 500 ml of distilled water.
- HCl solution is passed through the cation exchange resin bed continuously for 30 minutes.
- Ion exchange takes place between the solution and the resins and thus cation exchange resins are regenerated.
- The solution passed through the resins are collected below.

Anion Exchange Resin:

- 0.1% w/v solution of NaOH is prepared by mixing 0.5 g of NaOH flakes in 500 ml of distilled water for regeneration of anionic resin.
- NaOH solution is passed through the anion exchange resin bed for once.
- Thus, ion exchange takes place between solution and the resins and the resins are regenerated.

Instruction:

After an amount of 2.5 litre of tap water is passed through the Deionizing plant regeneration is required by following same steps as mention above. The used Solution can be again used for regeneration of resins respectively.

Deionizing *Tap Water:*

- First, introducing tap water to be deionized into the cation exchange resin tank giving continuous flow with a flow rate of 0.5L/min
- The cation exchange resin will replace positively charges ions (cations) in the water with Hydrogen ion (H^+).
- Directing the partially deionized water (now containing H^+) to the anion exchange resin tank.
- The anion exchange resin will replace negatively charged ions (anions) with Hydroxide ions (OH^-).
- Collecting the treated water, now largely deionized, from the outlet of the anion exchange resin tank.

CHAPTER 4
RESULTS AND DISCUSSION

After deionizing we obtain the following results: -

4.1) For Batch Process:

TABLE 3 - ***For Tap Water***

Parameters	Theoretical value	Experimental Value (before deionization)	Experimental Value 1 (after deionization)	Experimental Value 2 (after deionization)
pH	6 – 6.4	7.29	6.17	6.29
Conductivity	0.5-3 µS/cm	325 µS/cm	1.27 µS/cm	2.5 µS/cm
TDS	0-1 ppm	187 ppm	0.808 ppt	0.525 ppt
Salinity	0(approx..)	0.211 ppt	0.132 ppt	0.093 ppt

TABLE 4 - ***For Water from Aqua guard***

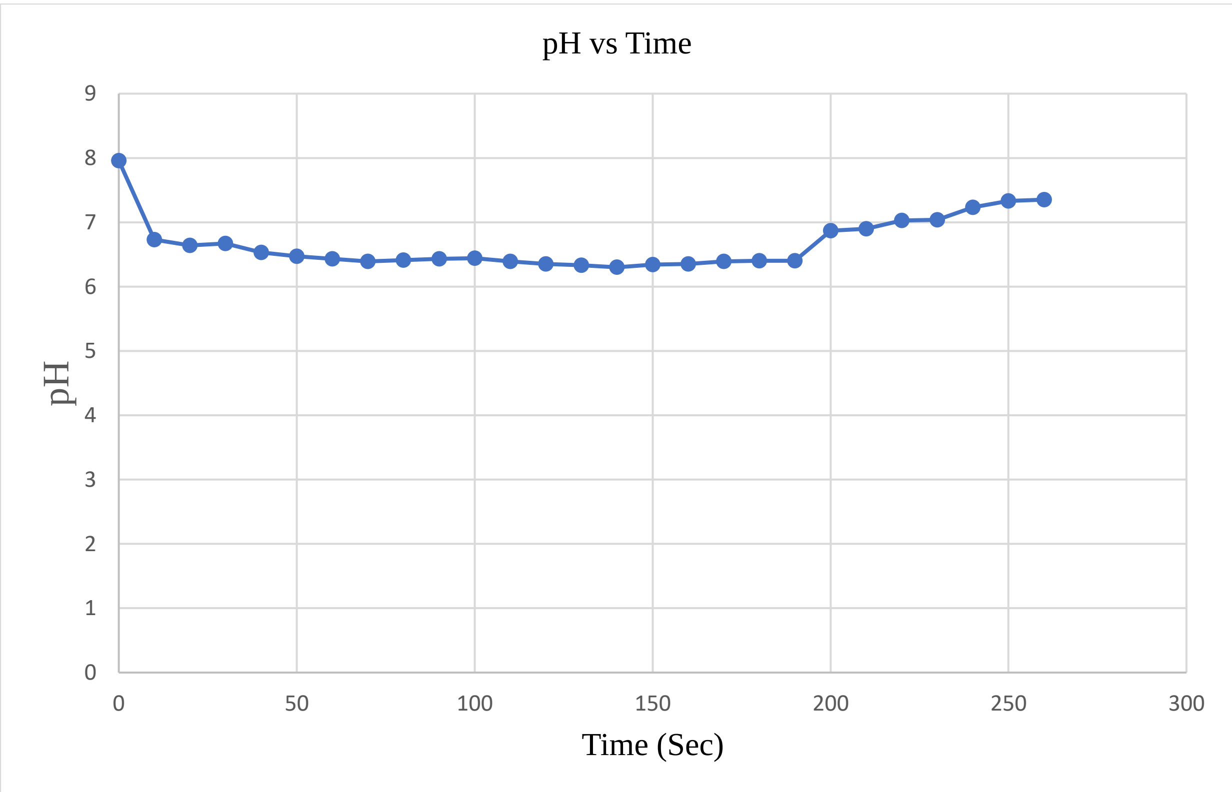
Parameters	Theoretical value	Experimental Value (before deionization)	Experimental Value 1 (after deionization)	Experimental Value 2 (after deionization)
pH	6-6.4	7.05	6.1	6.24
Conductivity	0.5-3 µS/cm	211 µS/cm	1.09 µS/cm	0.124 µS/cm
TDS	<5 ppm	137.4 ppm	0.654 ppm	0.323 ppm
Salinity	0(approx..)	0.144 ppt	0.101 ppt	0.0888 ppt

4.2) For Continuous Process

Capacity of the plant: - 2.5 litres

TABLE – 5: **pH VS TIME**

Time (Sec)	pH	Time (Sec)	pH	Time (Sec)	pH
0	7.96	90	6.43	180	6.4
10	6.73	100	6.44	190	6.4
20	6.64	110	6.39	200	6.87
30	6.67	120	6.35	210	6.90
40	6.53	130	6.33	220	7.03
50	6.47	140	6.30	230	7.04
60	6.43	150	6.34	240	7.23
70	6.39	160	6.35	250	7.33
80	6.41	170	6.39	260	7.35



The time vs pH curve during the deionization of water using resin typically follows a trend where the pH decreases then stabilizes. Initially, as water passes through the resin bed, the acidic ions are removed, causing a drop in pH. This is more noticeable at the beginning of the deionization process. Overtime, as the resin becomes saturated with ions, the pH tends to stabilize and may approach neutral levels. The stabilization occurs because the resin reaches its ion exchange capacity.

Instruction:

During the calculation of pH, we must make sure that accurate amounts of regenerants had been used since if NaOH is used is large amount the deionized water will be basic which is not desirable similarly if HCL is use in large amount the deionized water be more acidic which is also not desirable.

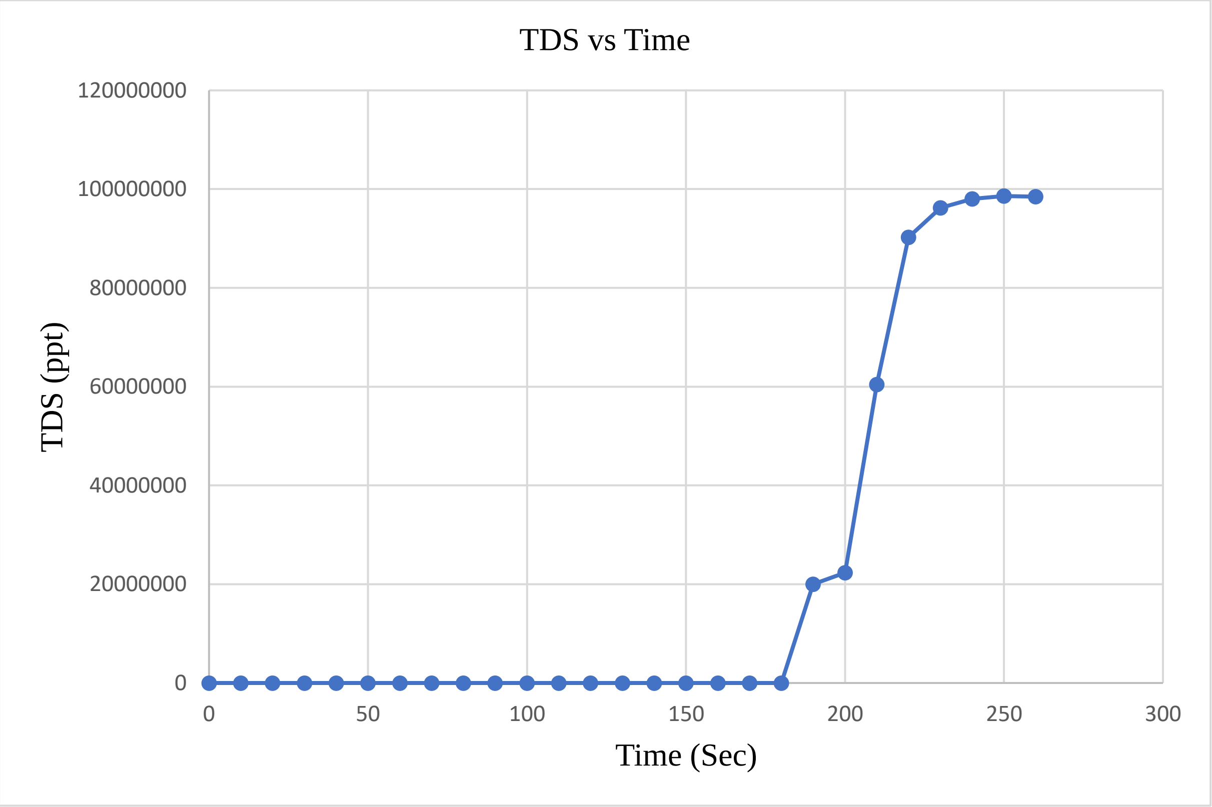
For a perfect deionized water, we should take 5% w/v of HCL and 0.1% w/v of NaOH flakes in same quantity of distilled water, the suggested amount is 500 ml.

Initially the pH will temporarily increase due to the introduction of the concentrated regenerant solution, once the regeneration is complete and excess regenerants is rinsed away, the pH level of the treated water should return to the range of 6-6.4.

Fig 4- Measuring pH with Water Analysis Kit.

TABLE – 4: **TDS VS TIME**

Time (sec)	TDS (ppt)	Time (sec)	TDS (ppt)	Time (sec)	TDS (ppt)
0	2.79	90	5.828	180	6.948
10	0.89	100	5.867	190	20×10^6
20	0.340	110	6.996	200	22.34×10^6
30	0.221	120	6.806	210	60.46×10^6
40	0.220	130	6.809	220	90.23×10^6
50	0.225	140	6.81	230	96.23×10^6
60	0.178	150	6.83	240	98×10^6
70	0.200	160	6.832	250	98.6×10^6
80	3.44	170	6.95	260	98.5×10^6



The time vs. Total Dissolved Solids (TDS) curve during the deionization of water using resin generally exhibits a similar pattern to the pH curve. Initially, TDS levels in the water decrease rapidly as the resin removes ions. This reduction is more prominent during the early stages of the deionization process. As the resin approaches its ion exchange capacity, the rate of TDS reduction slows down, and the curve tends to plateau. Continuous processing of water through the resin will maintain a relatively stable, low TDS level once the system reaches equilibrium.

Instruction:

Similarly for TDS, initially a high value may come the due to the introduction of the concentrated regenerant solution, once the regeneration is complete and excess regenerants is rinsed away, the TDS level of the treated water should return to the range of 0-5 ppm (parts per million).

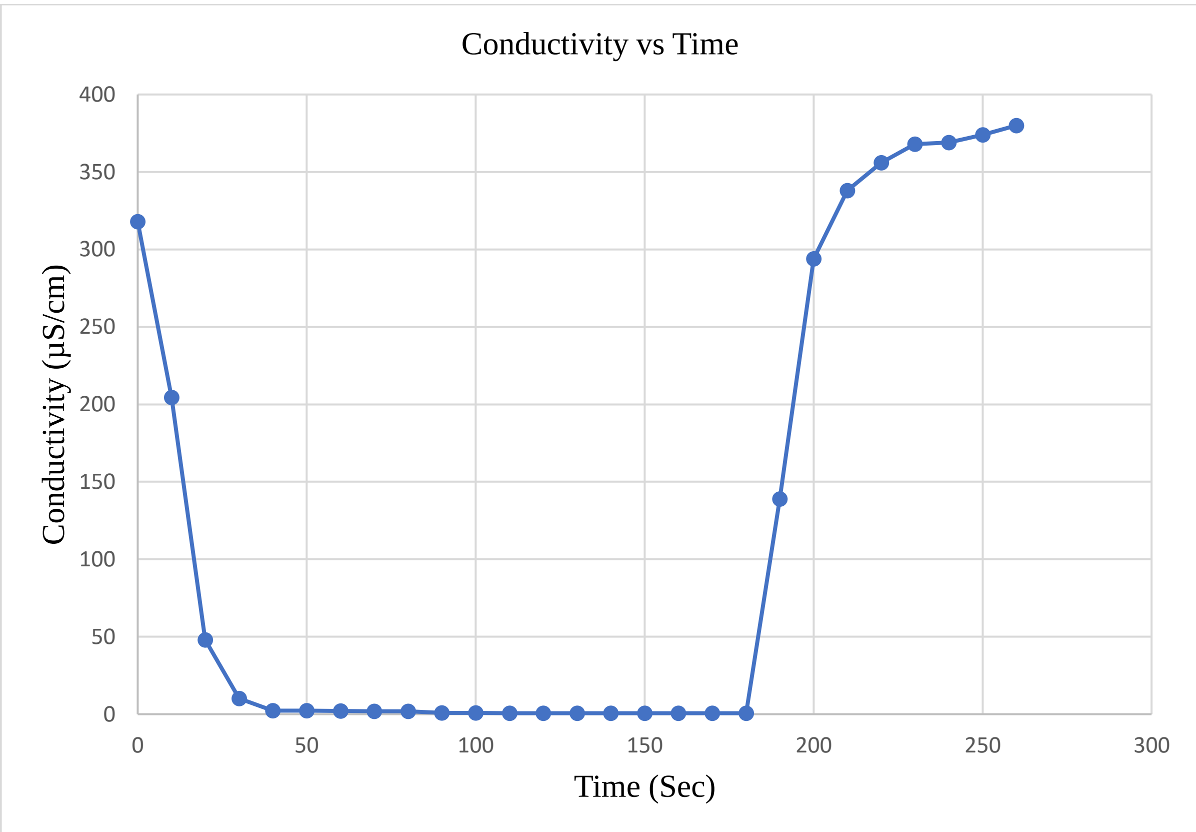
We can collect around 2.5 litre of deionized water have a TDS below 5 ppm (our experimental value has come in parts per trillion unit which is equivalent to 1 x 10^{-6} ppm).

After an amount of 2.5 litre has passed both resin beds, we need to regenerate it again following the steps discussed in 3.8, to get deionized water again for further uses.

Fig 5- Measuring TDS with Water Analysis Kit.

TABLE – 5: **CONDUCTIVITY VS TIME**

Time (sec)	Conductivity (µS/cm)	Time (sec)	Conductivity (µS/cm)	Time (sec)	Conductivity (µS/cm)
0	318	90	0.84	180	0.67
10	204.4	100	0.79	190	139
20	48	110	0.68	200	294
30	10.2	120	0.67	210	338
40	2.3	130	0.65	220	356
50	2.23	140	0.63	230	368
60	2.14	150	0.64	240	369
70	1.78	160	0.64	250	374
80	1.94	170	0.65	260	380



The time vs. conductivity curve in the deionization of water using resin typically follows a trend where conductivity decreases initially and then levels off. At the beginning of the process, as water passes through the resin bed, the conductive ions are removed, leading to a rapid decrease in conductivity. As the resin approaches its ion exchange capacity, the rate of conductivity reduction slows down, and the curve tends to reach the tap water conductivity value. Continuous processing of water through the resin will maintain a relatively constant low conductivity once the system reaches equilibrium.

Instruction:

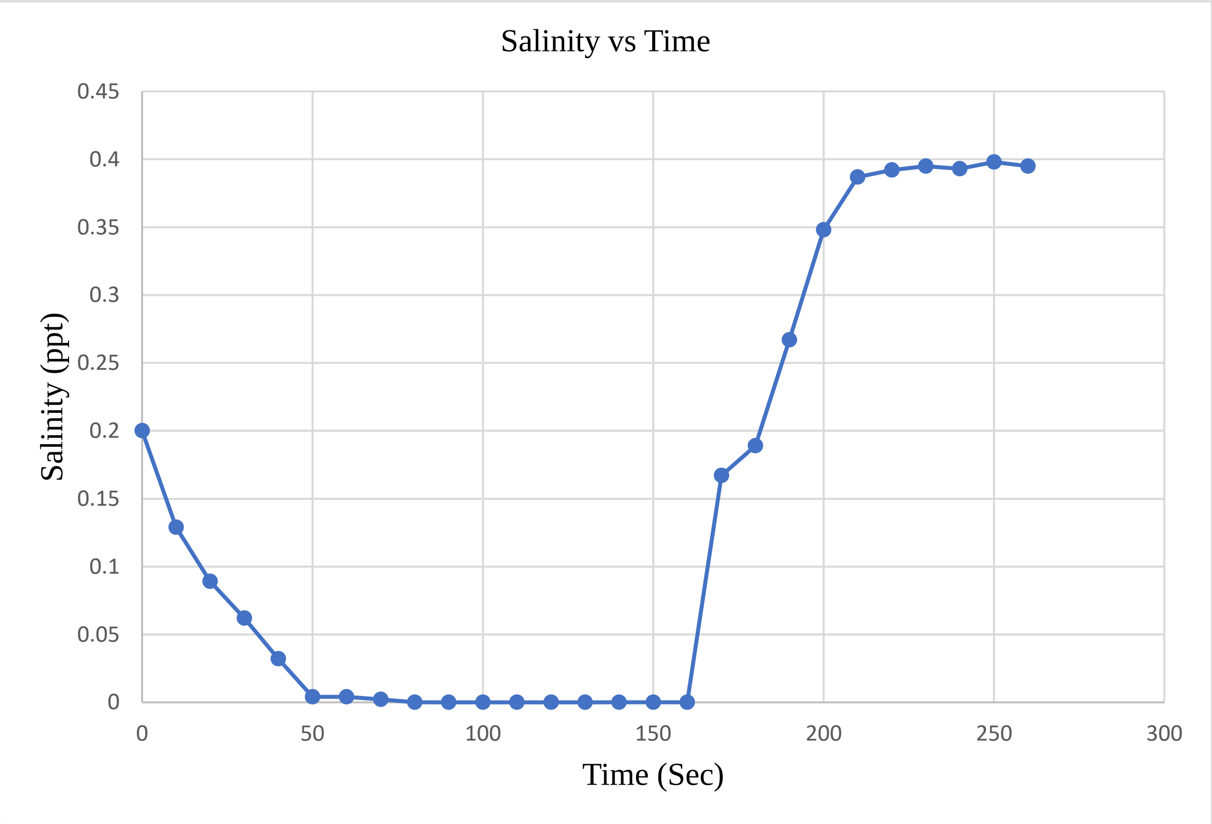
For the measurement of Conductivity, we used Water Analysis Kit, Conductivity also shows a rise due to the introduction of the concentrated regenerant solution, once the regeneration is complete and excess regenerants is rinsed away, the Conductivity level of the treated water should return to the range of 0.5-2 µS/cm.

We have measured the value of pH, TDS, Conductivity, Salinity in an interval of 10 sec for better accuracy and come to an end discussion that our plant is capable to deionize 2.5 litre of deionized water.

Fig 6- Measuring Conductivity with Water Analysis Kit.

TABLE – 6: **SALINITY VS TIME**

Time (sec)	Salinity (ppt)	Time (sec)	Salinity (ppt)	Time (sec)	Salinity (ppt)
0	0.20	90	0	180	0.189
10	0.129	100	0	190	0.267
20	0.089	110	0	200	0.348
30	0.062	120	0	210	0.387
40	0.032	130	0	220	0.392
50	0.004	140	0.0001	230	0.395
60	0.004	150	0.00012	240	0.393
70	0.0021	160	0.00011	250	0.398
80	0.0001	170	0.167	260	0.395



In a deionization process using resin, the time vs. salinity graph typically shows a decreasing trend. Initially, when the resin is introduced to water with high salinity, the ion exchange process begins rapidly, leading to a quick reduction in salinity. As time progresses, the rate of deionization may slow down, approaching a more gradual decline in salinity. The graph might exhibit an asymptotic behaviour, indicating that achieving complete deionization takes more time as the water approaches a state of higher purity.

Fig 7- Measuring Salinity with Water Analysis Kit.

CHAPTER 5

SUGGESTIONS

Energy Efficiency: By looking into ways to make the deionization process more energy efficient, such as using renewable energy or optimizing power use during regeneration.

Waste Management: To reduce environmental impact, develop effective techniques for handling and recycling leftover resin and regeneration chemicals.

Strategies for Cost Reduction: Looking into ways to reduce the overall cost of the deionization system, making it more accessible for broader applications.

Flow Rate Optimization: Determine how different flow rates affect the effectiveness of deionization. Aim for optimal performance by optimizing the flow rate while taking useful applications into account.

Here are some ideas for enhancing our ion exchange deionization project in the future:

By taking these enhancements into account, our deionization project will be improved and advanced, becoming more effective, long-lasting, and suitable for a larger variety of situations.

REMEDIES

Resin selection: To make sure we have selected the appropriate kind of ion exchange resin for the makeup of our water. Resins with strong bases or acids are appropriate for various uses.

Appropriate Regeneration: To keep the resin's efficacy, regenerate it according to the manufacturer's instructions. A longer resin lifespan is ensured by adequate regeneration.

Flow Rate Control: To maximize the efficiency of ion exchange, we must keep the flow rate through our system constant. The efficiency of deionization may be harmed by an excessively high flow rate.

Monitoring: Both before and after the deionization process, keeping an eye on the quality of the water. This makes it easier to determine when resin replacement or regeneration is required.

pH Control: Keeping an eye on and regulating the water's pH since high or low pH levels can affect how well the resin works. For best results, most ion exchange resins operate within a certain pH range.

Temperature Considerations: we must pay attention to the range of temperatures that our resin can operate at. Extreme heat can shorten the lifespan and performance of resin.

Backwashing: To get rid of accumulated contaminants and stop channeling inside the resin bed, we must do a periodic backwashing process.

CHAPTER 5
CONCLUSION

For hospitals, biotech companies, pharmaceutical manufacturers, blenders, or any other facility that needs purified water for their production, deionized water is crucial. Deionization is the process of removing all the charged ions in water except the water molecule (H_2O). This results in a true water "blank" – nothing but water in its absolute purest state. This report provides information on how the water is being deionized with the help of resins by the ion exchange process. The setup was devised proved from the water, showcasing the practicality of this approach.

We obtained results that showed that our setup was effective in removing ions from water upto a capacity of 2.5 litres. Our project is built on previous research by developing a low cost and efficient setup for deionization of water using resin. This projects not only enhances our understanding of deionization processes but also underscores the potential for broader applications in water treatment

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