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WASHING MACHINE WASTE WATER RECYCLING UNIT

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ABSTRACT

In the recent times, the society as a whole is facing rising concerns about water scarcity and environment sustainability. Washing machines have become a part of our day-to-day life, to provide clean clothing for everyday use. However, they consume a significant amount of water to do so. According to our preliminary findings, most households tend to use top loading washing machines, which on an average consume about 100 liters of water per load. We aim to recycle the outlet water and thus reduce the water required to flush out the chemical detergents. This is to be done by evaluating the following parameters: pH, temperature, TDS, TSS, turbidity, colour, total hardness of the outlet water against freshwater. The water is to be recycled in an energy efficient and cost-effective method. We did a study of various water purification methods. We aim to use solar energy to carry out evaporative distillation for recycling the waste water. This is because the solar energy is a renewable energy resource which is abundantly available at earth's surface. As per studies, the solar insolation; that is solar radiation available at earth's surface, is around 21.6 MJ/m^2 on a regular day. Thus, we aim to design a system using solar energy to recycle the wastewater.

I. INTRODUCTION

1. Study of existing problems/systems:

- In response to increasing concerns about water scarcity and environmental sustainability, there is a pressing need to develop solutions that reduce water consumption in daily household activities.
- Traditional washing machines consume significant amount of water. On a daily basis around 100 liters of water is consumed per load of washing machine.
- This means on an average a single household uses about 35,000 liters of water per year for washing purposes.
- Water resources are abundant, but they are unevenly distributed: 97% of water available on earth is related to the seas and oceans, 2.97% as polar ice caps while the remaining 0.03% is the surface water/freshwater.
- This contributes to depletion of freshwater resources and generates substantial waste water.
- The wastewater contains chemical detergents which contains surfactants.
- The entirety of wastewater goes down the drain which, firstly pollutes the local rivers and subsequently contributes to the overall water pollution problem.
- Direct and indirect release of the surfactants in the environment in large amounts poses serious health and environmental problems.
- Secondly this water cannot be reused, thus requiring more freshwater for subsequent cleaning cycles.
- According to our survey, currently there are no existing systems which can help achieve solutions for both of these issues.

2. Identification of the problem:

The existing problem can be divided into 3 factors:

Firstly, as mentioned earlier there is an issue of wastewater being directly discharged into drainage systems which finally leads to rivers in most of the major cities. As we are aware, the cities are rapidly expanding which further worsens the problem. Wastewater not only contains the impurities from clothes like dirt, dust, oils or paints from stains, to name a few, but also it contains chemical substances such as surfactants from the soapy water. This causes pollution of the water bodies into which the wastewater is finally discharged. This poses a threat to the water-based ecosystems and thus it creates environmental issues.

Secondly, the amount of water utilised for every washing cycle is staggering. Currently there are on-going developments to conserve water per cycle; such as the front-loading machine layout, it is still not very common across the households.

Also, it may seem that around 150 litres of water per cycle is not intensive in terms of water utilization; it does become significant when we take into consideration that washing machines are almost used on a daily basis. This means that around 100 litres of water are being used everyday round the year, which means that 35000 litres of water are being used per year for a single household. When we consider that there are thousands of households across multiple cities, it becomes a point of concern.

Thirdly, creating a solution for conserving water should not be energy and cost intensive. There are multiple water purification systems available which can purify water to the level of water being potable. However, firstly these systems are costly. Also, they consume some form of energy which again brings us to the first point of environmental sustainability. Secondly, these systems are made to handle lesser quantities of water. The scale of the project suggests that the system should be able to handle a lot of wastewaters without the requirement of replacing the filtration medium frequently.

3. Project problem statement:

The project problem is of primarily three aspects, as mentioned in the previous module. Firstly, the concern is about wastewater causing the environmental issue. Secondly, it is about large amount of water utilization, which is responsible for water scarcity.

Thirdly, the issue of energy utilization for the task of water recycling.

We can thus conclude that there are three main aspects of the problem.

The first issue can be tackled by using any available method of water filtration. However, the problem lies in the fact, that these methods; even though they are very efficient at cleaning water, they are energy and cost intensive. Also, these methods, if used for such a large scale will be very costly in terms of initial as well as operating costs. Similarly, the maintenance cost will be significant. This is because the filtration medium generally needs frequent cleaning or replacement due to handling such large quantities of wastewater.

The second issue is that the surfactants need to be removed as effectively as possible. This means that the amount of water required to discharge the surfactant out along with the dirt should be as low as possible. This simply means that the concentration of the surfactant in the wastewater should be as high as possible. This is because the concentration of surfactant will be the ratio of mass of surfactant to the volume of water. Thus, by increasing the concentration of surfactant, we aim to reduce the water required per cycle of washing.

One of the key aspects which we have considered is that, environmental sustainability can be achieved by means of using abundantly available form of energy that is Solar energy for carrying out the filtration process. The total amount of solar energy incident on Earth is vastly in excess of the world's current and anticipated energy requirements.

The solar energy that is received on earth's surface is evaluated by a parameter known as solar irradiance. Solar irradiance is the power per unit area (surface power density) received from the Sun in the form of electromagnetic radiation in the wavelength range of the measuring instrument. Solar irradiance is measured in watts per square meter (W/m^2) in SI units.

Average annual solar radiation arriving at the top of the Earth's atmosphere is roughly 1361 W/m^2. The Sun's rays are attenuated as they pass through the atmosphere, leaving maximum normal surface irradiance at approximately 1000 W/m^2 at sea level on a clear day. Ignoring clouds, the daily average insolation for the Earth is approximately 6 kWh/m^2 = 21.6 MJ/m^2.

This suggests that a very large amount of energy from the sun is readily available at the earth's surface which can be harnessed for use in our project.

The project problem statement can thus be summarized as "To develop a means of reducing the amount of water required for each cycle of washing machine by up to 50%. This is to be done by recycling the water using energy efficient method of solar distillation."

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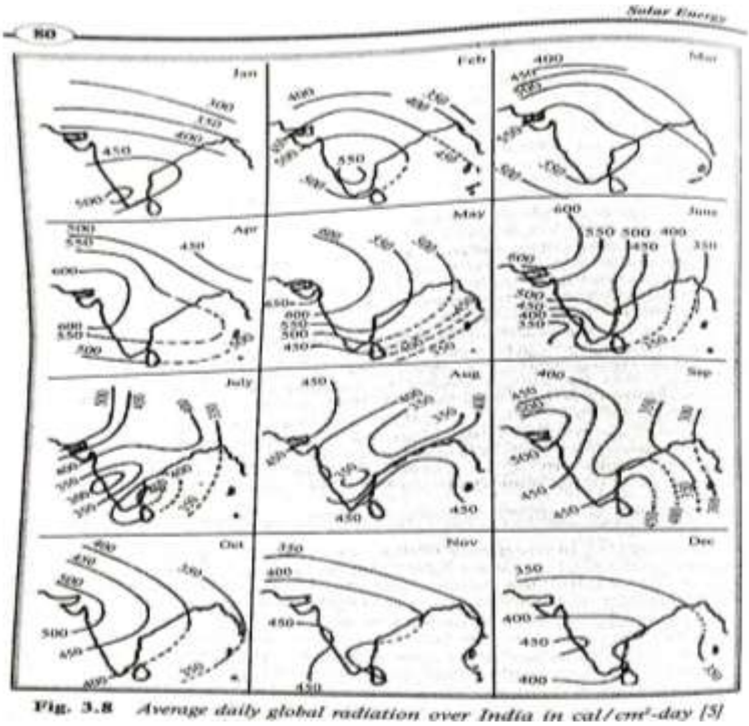

Figure 1: Solar radiation throughout the year across India

4. Solution offered to the problem:

This project offers the solution to the above stated problem, by developing a system which can perform distillation using solar energy. This system is to be designed in such a way that it can collect maximum solar radiation in order to heat the water. The heating ensures that the rate of vapor formation is increased.

Evaporation can be defined as phase transition from the liquid phase to vapor. Distillation is the process of converting a liquid mixture into vapor, and then condensing the vapor back into a liquid, allowing for the separation of substances with different boiling points.

Both of the above processes are to be carried out using the heat energy obtained from solar radiation.

The design includes an evacuated solar water tube as the means of providing heat energy to the wastewater. It consists of a concentric tubed structure. It consists of multiple parallel transparent glass tubes connected to a heater pipe. Each tube has a vacuum between the annular space, preventing heat conduction and convection inside the tube. This design enhances energy absorption and reduces heat loss. The inner tube is black in colour. This is done to improve the absorptivity of the pipe. This ensures that most of the incident solar radiation is utilized in heating the working fluid.

This heat causes vapourization of the wastewater. This occurs in a common header which is used for connecting multiple evacuated tubes in a parallel manner. Thus, the vapours rise and are transferred to the condenser through the header. In the condenser, the vapours exchange heat with the surroundings and condense. Thus, distilled water can be obtained.

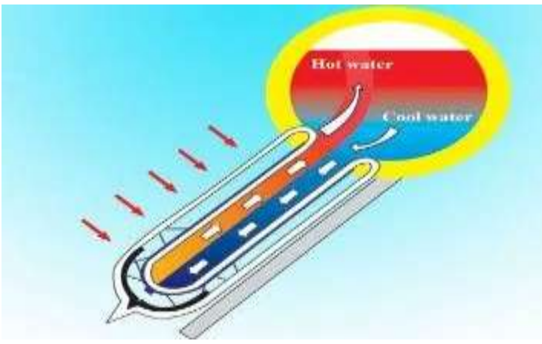

Figure 2: Working of evacuated solar tube

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This distilled water is then collected in a storage tank which can then be used for various purposes.

5. Benefits:

The project is aimed towards environmental sustainability. By reducing the water wastage, significant benefits are provided to the society in terms of water conservation. Similarly, the costs on water consumption can be significantly reduced by using this procedure over longer periods of time.

Also, the recycled water can be used for a variety of different purposes. The water that is obtained from distillation is free from contaminants and can be used for many household activities.

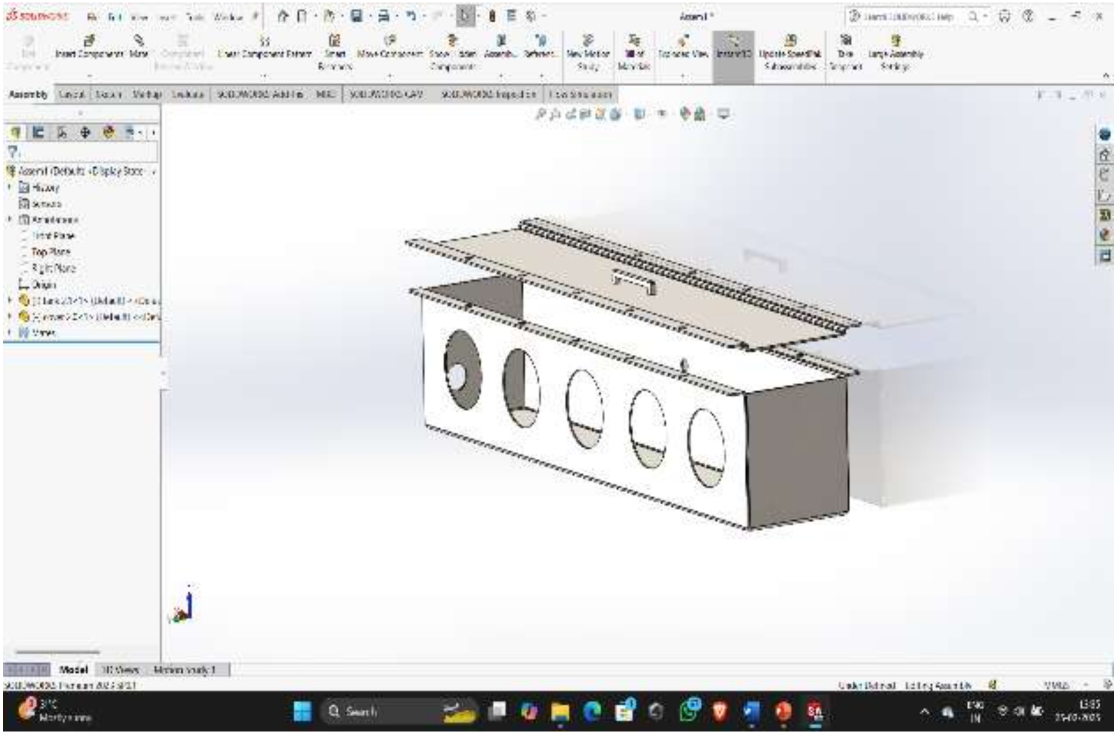

Figure 3: Sheet metal manufacturer-Shree mech

6. Assumptions:

1. Availability of Solar energy- It is assumed that the process is being carried out on a sunny day with enough exposure to the sun.
2. Open workspace- In continuation to the previous point, it is assumed that the setup is placed in an open space without any obstructions to sunlight. The exposure to the sunlight is the key element in the project.
3. The water vapour exchanges heat by conduction to the condenser pipes and condenser pipes exchange heat to the atmosphere by convection.

II. METHODOLOGY

1. Problem and Objectives

- Objective: To develop a system that treats and recycles wastewater from washing machines for potential reuse, either in non-potable applications (e.g., toilet flushing, gardening) or back into the washing process.
- Scope: Specify the washing machine types, target reuse applications, and quality standards required for the treated water.
- Importance: Highlight environmental benefits, such as reduced water consumption and decreased discharge of contaminants into municipal wastewater systems.

2. Literature Review

- Investigate existing wastewater recycling systems, especially those for household or laundry settings.
- Examine studies on contaminants in washing machine wastewater (e.g., detergents, microfibers, pathogens, organic matter).

- Review treatment technologies that could be suitable, such as filtration, chemical treatment, biological treatment, or advanced oxidation, distillation.

3. Survey

- Carried out a survey to get insights about layouts, number of loads, type of washing machines across different households.

Methodologies Proposed.

Water Filtration with help of different chemical processes

Water filters are devices designed to remove impurities and contaminants from water, making it safe and clean for consumption. Following are some key points about water filters:

How They Work:

Water filters use a combination of physical and chemical processes to trap and remove harmful substances. Some common methods include:

- Activated Carbon Filtration: Uses a porous material to adsorb contaminants like chlorine, volatile organic compounds (VOCs), and some heavy metals.
- Reverse Osmosis: Forces water through a semipermeable membrane, removing bacteria, viruses, and dissolved solids.
- Ceramic Filtration: Uses fine pores to trap impurities and bacteria.

Types of Water Filters:

- Point-of-Use Filters: Installed at a single tap, like a faucet-mounted filter or a water pitcher with a built-in filter.
- Whole-House Filters: Installed at the main water line, treating all the water entering the home.
- Portable Filters: Small, lightweight filters used by hikers or in emergency situations.

Benefits:

- Health: Removes harmful contaminants, ensuring safer drinking water.
- Taste: Improves the taste and odder of water by removing chlorine and other chemicals.
- Convenience: Provides clean water directly from the tap or in portable formats for on-the-go use.

III. MODELING AND ANALYSIS

After analyzing all these methods, we decided to use solar distillation

While traditional water filtration methods such as activated carbon filtration, reverse osmosis, and ceramic filtration effectively remove impurities and improve water quality, they often rely on electricity from non-renewable sources, contributing to operational costs and environmental impact. In contrast, water filtration using renewable resources, particularly solar-powered systems, not only provides the same level of purification but also utilizes sustainable energy. This approach reduces carbon emissions, lowers operational costs, and ensures access to clean water in remote or off-grid areas. Ultimately, renewable resource-based water filtration is a more eco-friendly and cost-effective solution, promoting long-term sustainability and resilience in water treatment practices.

Even though we decided to proceed with solar based distillation process, there are different methods of evaporating water. We proceeded to choose evacuated tubes for the evaporation based on the following study.

Devices for thermal collection and storage

In any collection device, the principle usually followed is to expose a dark surface to solar radiation so that the radiation is absorbed. A part of the absorbed radiation is transferred to a flid like air or water.

1) Liquid flat plate collectors- In this type of collector, no optical concentration is done. This is the most important type of solar collector, because it is simple in design, has no moving parts and requires little maintenance. It can be used for applications in which temperatures ranging from 40-80 deg Celsius are required.

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The basic parts that make up a conventional liquid flat plate collector are a) The absorber plate, b) The tubes fixed to the absorber plate, c) The transparent covers, d) The insulated container.

The main advantage of this type of collector is that it can utilize both the beam and diffuse components of solar radiation. However, because of absence of optical concentration, the area from which heat is lost is very large. As a result, the collection efficiency is very low.

2)Evacuated Tube Collectors (ETC)- One way to improve the performance of liquid flat plate collector is to reduce or suppress the heat lost. This is done by providing vacuum above the absorber unit. As a result, it is essential to use a glass tube as cover, because only a tubular surface is able to withstand the stress introduced by the pressure difference. This type of collector has various designs-

A) This design consists of concentric tube structure. The inner tube Contains the fluid which is housed within the outer tube. Its outer surface acts as the absorbing surface. There is vacuum between these two tubes to ensure minimal heat loss to the surroundings.

B) This design consists of a heat pipe housed in the evacuated glass tube. The length of the heat pipe within the evacuated glass tube constitutes the evaporator section in which heat is absorbed and the fluid inside the heat pipe evaporates.

This vapourised fluid rises up to the condenser section; which is in form of a bulb, and condenses. This heat of condensation is conducted to the fluid flowing in the collector header pipe.

Generally, with ETC, a back reflector is used. Thus, the radiation falling on the absorber surface in each module consists of beam and diffuse radiation falling directly as well as radiation that is reflected back from the reflector

In ETC, because of suppression of convection and provision of selective surface, the overall loss coefficient of ETC is low. Consequently, its efficiency is significantly higher than that of a conventional collector.

A performance plot obtained on a commercially available ETC using heat pipe modules and curved surface back reflectors yields the following equation for a straight line fitted to the data.

(ni)ETC= 0.527-1.736(Tfi-Ta)/Lt

(ni)FP= 0.572-4.796(Tfi-Ta)/Lt

where, Tfi=Fluid inlet temperature of the collector, Ta=ambient air temperature, Lt=solar radiation incident on collector.

A comparison of this equation with an equation derived similarly for flat plate collector shows that the efficiency of the ETC is nearly twice for a Thermal resistivity value of 0.08 K

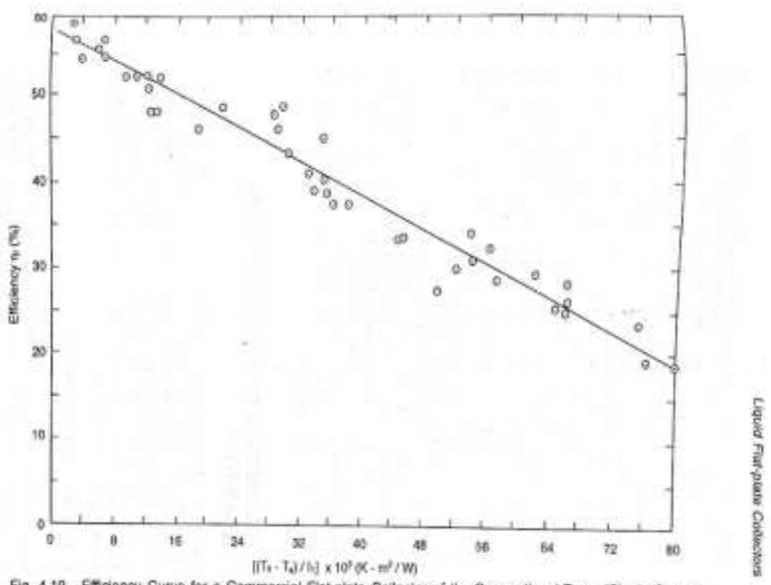

Fig. 4.19 Efficiency Curve for a Commercial Flat-plate Collector of the Conventional Type. (Single Cover, Selective Copper Absorber Plate. $A_C = 2.11 \times 1.02 = 2.15$ m²; $A_a = 1.96 \times 0.93 = 1.823$ m², $\dot{m} = 0.0363$ kg/s. η_i is Based on Collector Gross Area)

Figure 4:

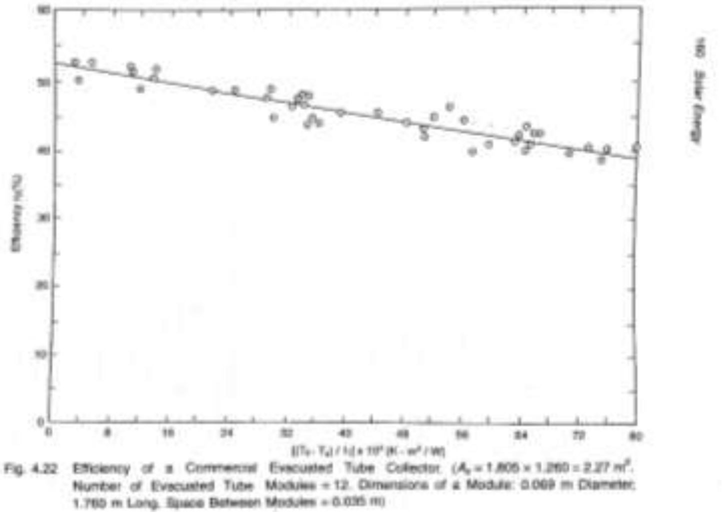

Figure 5: Efficiency vs thermal resistivity

IV. EXPERIMENT SETUP

- The setup consists of an evacuated tube, DS18B20 water proof temperature sensor, ESP 32.
- This experiment provided us the plot of the changes in water temperature over a period of 7 hrs. (10am – 5pm)

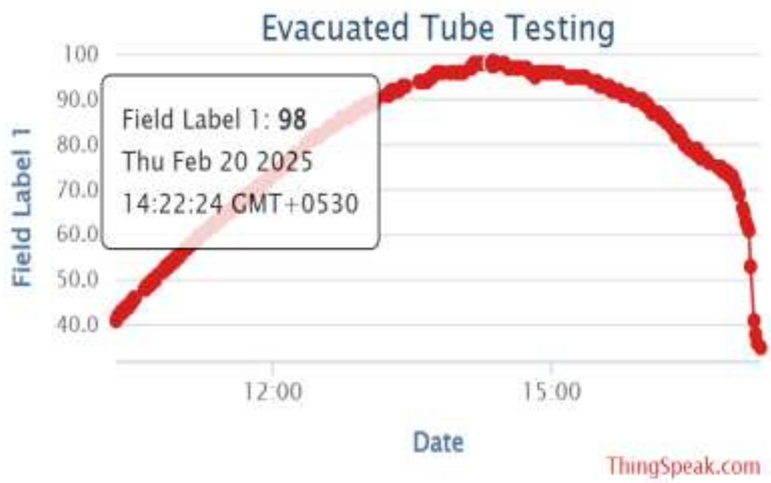

Figure 6: Temperature variation of water in evacuated tube from 10am to 5pm

V. DATA ANALYSIS AND INTERPRETATION

- From this data we found the vaporization rate, time of peak temperature.
- The water inside the evacuated tube achieved 98° Celsius for almost 20 minutes.
- The temperature of water was above 90° Celsius for almost 3 hours.
- Throughout the experiment 500 mL water had evaporated. The tube was able to hold a total of 3 L water.

VI. EVALUATION AND OPTIMIZATION

- From the above data we deduced that a significant increase in evaporation rate is required.
- This can be achieved through two methods by increasing number of tubes or using a solar concentrator.

VII. MODELLING AND DESIGN

- We created a 3D model using solidworks software to help us visualize how the system will be created.
- We created a header using Sheet metal feature in solidworks to obtain the flat pattern required for laser cutting and subsequently bend the cut sheet.

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- Also, the static structural analysis of the frame supporting the entire assembly was performed using Ansys software to verify if the frame can withstand the forces exerted by the assembly.

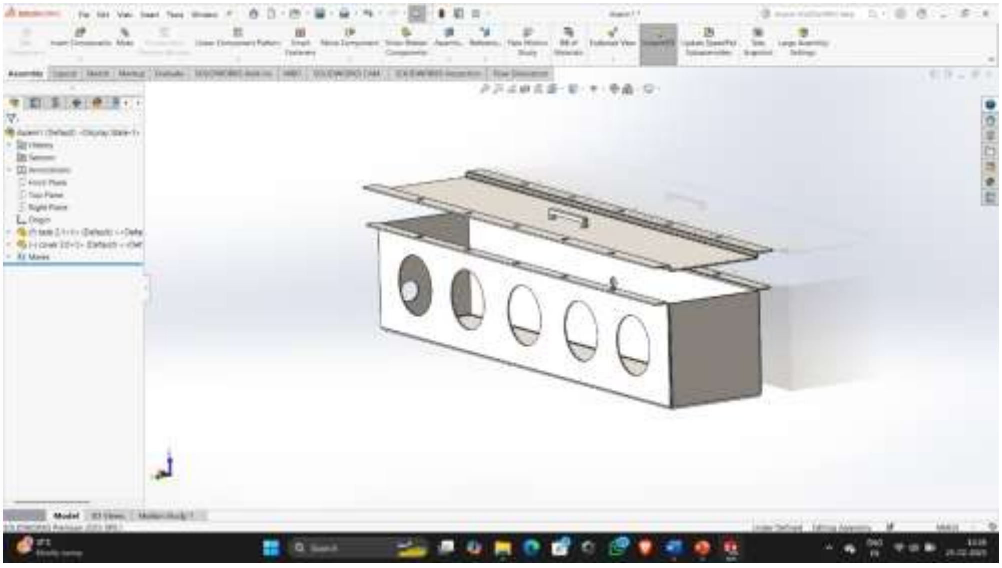

Figure 7:

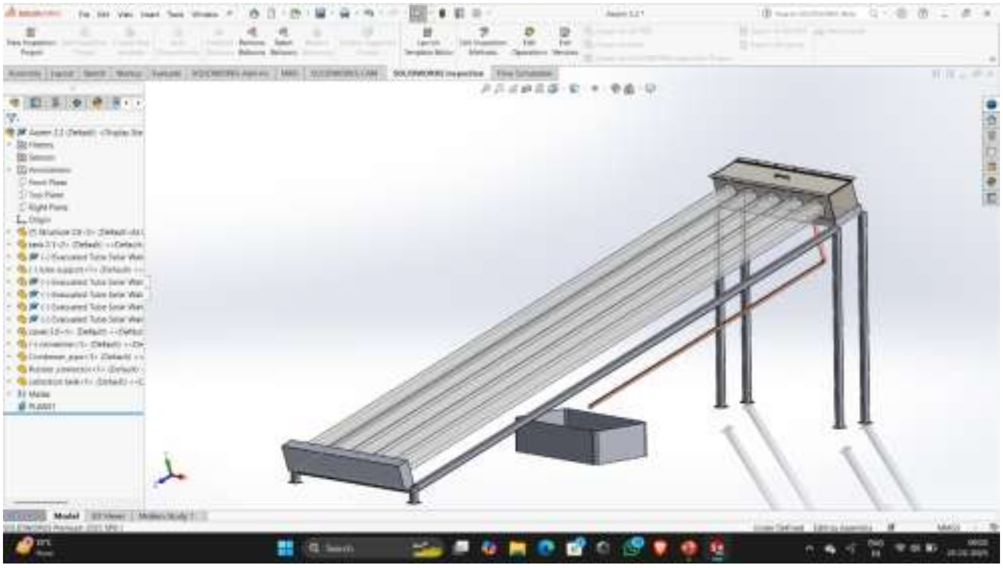

Figure 8: Views of the concept CAD model

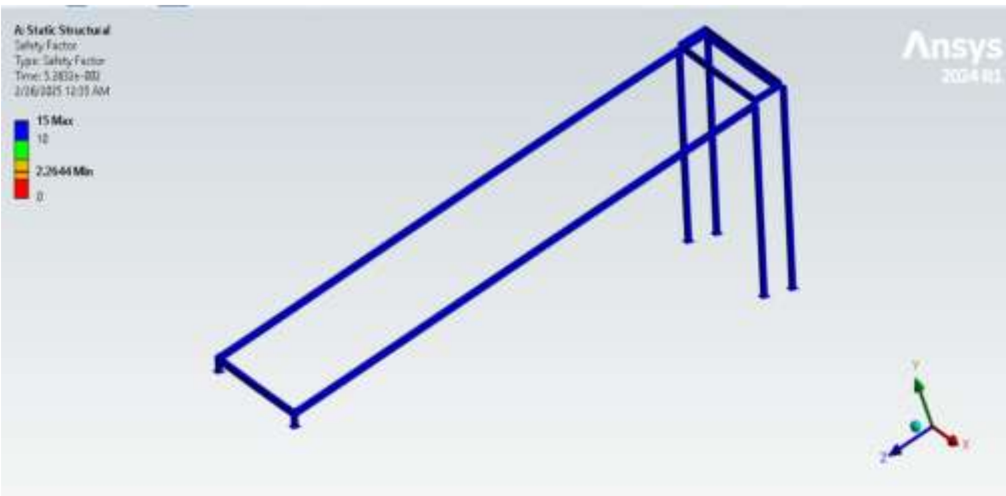

Figure 9:

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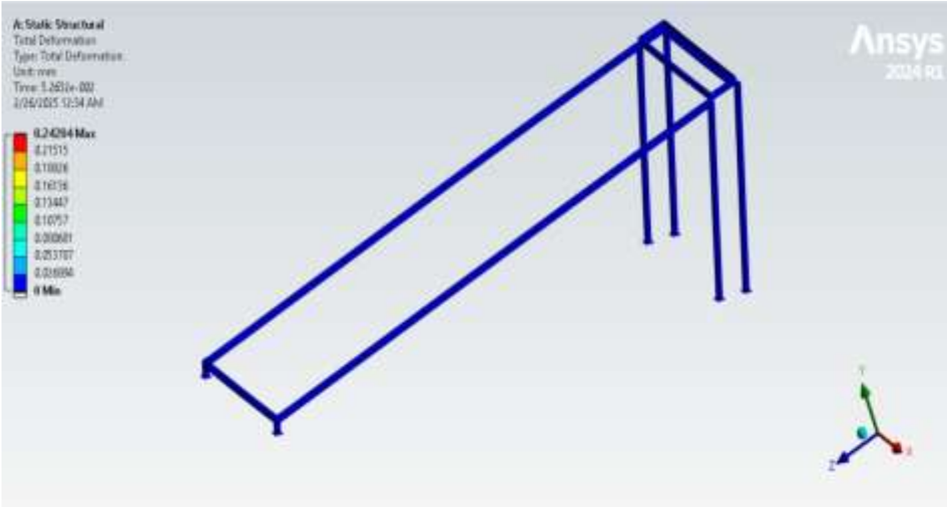

Figure 10: CAE analysis of the frame

VIII. RESULTS AND DISCUSSION

By implementing this project we can recycle water with renewable resources like Solar Energy, as fresh water is limited and renewable resources are abundant in nature, we interlink both for better utilization of resources and limited sources.

Evaluation of the efficiency of water treatment by a solar heating and distillation system

This study evaluates a solar heating and distillation system for treating wastewater containing carmine red dye at 25 ppm. The system combines a parabolic solar heater for preheating water and a distillation unit that separates clean water from pollutants. It introduces a galvanized ZnO plate into the distillation unit enhanced photodegradation, achieving 93% dye degradation within 120 minutes. The process showed 87% efficiency in distilled water production, meeting Mexican water quality standards. Parameters like pH, conductivity, COD, turbidity, and total solids indicated compliance with regulatory limits. The study highlights solar distillation as a sustainable and low-cost method for wastewater treatment, offering high-quality distilled water.

IX. CONCLUSION

Through the project, we were able to get insights about lot of important aspects. Firstly, we understood the need of properly defining a problem statement. Without clearly defining it, proceeding further is quite difficult. After stating the problem, research has to be done regarding the methodology which will be followed throughout the process. After completing these steps, only then it is possible to effectively proceed to the step of finding various methods and alternatives for satisfying the problem statement.

Secondly, we understood the key aspects of the problem itself. The concerns about freshwater depletion and environmental sustainability might not be easily observable. However, a brief survey and research helped us understand the gravity of these issues.

Also finding a solution to that problem is not just about solving the problem directly, but also about how efficient the solution is. Using energy intensive filtration techniques wont sustainable to the environment.

Thirdly, we understood how Solar based water heating systems work and their advantages and disadvantages. The design and modelling of the project assembly using modern software tools, such as Solidworks gave us the opportunity to learn these advanced design softwares. We were able to not only model the 3D geometry of the project, but also were able to do the 2D drawing sheets using Solidworks software. We also got the opportunity to learn working of electronic sensors for the purpose of validation and data acquisition.

Lastly, we understood the need of time management. Without proper allocation of time to different tasks, it is very difficult to carry out the project requirements.

Thus, we got to know all the different aspects which have to be taken into consideration while carrying out a full-fledged project.

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X. REFERENCES

[1] Solar Energy: principles of thermal collection and storage -S.P. Sukhatme & J.K. Nayak

[2] Fundamentals of Heat exchanger design -Ramesh Shah and Dusan Sekulic

[3] A textbook of Heat and mass transfer- R.K. Rajput, S. Chand publications

Research Papers

[4] Sustainable water supply: potential of recycling laundry wastewater for domestic use by Omolara Lade and Zainab Gbagba Department of Civil Engineering, University of Ibadan, Nigeria

[5] Removal of cationic surfactants from aqueous solutions by modified cotton as a novel high capacity and low-cost adsorbent by Majid Baghdadi, Mahmoud Mazarji, Mohammad Sabouhi, Abbass Jafari Kang, Aghdas Jafari, faculty of environment, university of Tehran, Iran

[6] A SOLAR IRRADIANCE CLIMATE DATA RECORD by O. Coddington, J. L. Lean, P. Pilewskie, M. snow, and D. Lindholm

[7] Removal of detergents and fats from waste water using allophane by Hiromasa Nishikiori, Kiyokazu Kobayashi, Satoshi Kubota, Nobuaki, Tsuneo Fujii, Graduate school of science and technology, Shinshu University, Japan

[8] Soapy science: How detergents work, The University of York, U.K.

[9] ADSORPTION OF ANIONIC SURFACTANTS FROM SYNTHETIC PRODUCED WATER ON CRUDESORB AND KAOLIN By Nur Alia Aqilah by Zulkifli, Universiti Teknologi PETRONAS, Malaysia

[10] The Usage of Domestic Water Filtration Systems in Malaysia A dissertation submitted by LAW BEE BEE, University of Southern Queensland Faculty of Engineering and Surveying

[11] Evaluation of the efficiency of water treatment by a solar heating and distillation system, Faculty of Chemistry, Autonomous University of the State of Mexico, Paseo Colón S/N

[12] An up-to-date review on evacuated tube solar collectors, Indian Institute of Technology, Jodhpur, India & College of Engineering, University of Sharjah, United Arab Emirates & National Technical University of Athens, Athens, Greece.

[13] A brief review on analysis and recent development of parabolic trough collector, GMR Institute of technology, Rajam, Andhra Pradesh, Seacom engineering college, Howrah, West Bengal.

[14] FIRP booklet #E300-A: Surfactants- types and uses, Universidad de Los Andes, Venezuela.

Websites

[15] https://en.wikipedia.org/wiki/Solar_irradiance

[16] https://www.newport.com/t/introduction-to-solar-radiation
[17] https://www.britannica.com/science/solar-energy
[18] https://www.sciencedirect.com/topics/chemistry/reverse-osmosis
[19] https://www.ariel.co.uk/en-gb/about-ariel/ingredients/your-detergent-ingredient
[20] Compare Solar Thermal | Compare Evacuated Tube Collectors Vs. Flat Panel Collectors Comparison
[21] How do Vacuum Tubes Collectors Work?
[22] Evacuated Tube Testing - ThingSpeak IoT