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Design and Construction of a Solar-Powered Seawater Desalination System for Remote Areas in India

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Abstract: Solar energy, a renewable energy source with zero emissions, has attracted attention all over the world as a supplier of sustainable energy. The present study, is to develop a sustainable and cost-effective solution for producing fresh water using renewable energy resource and desalination method, addressing minimal electricity generation and water shortage in coastal and arid regions, respectively. Solar stills are simple to build, can be executed by indigenous folks using locally provided accoutrements, uncomplicated in procedure by untrained manpower, no stringent conservation conditions and almost no operating cost, However, they have the drawbacks of being expensive initially, requiring a lot of land for installation, and being reliant on the amount of solar radiation available. The work serves as the initial reference for identifying electricity generation and the quality of fresh water production, which contributes to overall environmental sustainability.
Keywords: Desalination, Electricity generation, renewable energy resource.

I. INTRODUCTION

One of the most important resources in the world is water. 30% of earth island and 70% is water. Water is strictly needed for human existence as well as animal health. Purification of water is done by removing unnecessary chemicals, suspended particles, biological contaminants and gases. According to our survey of doctors the average amount of water that a male or female should drink each day to maintain a healthy lifestyle is roughly 3.7 litres / 2.7 litres. In India water-born illness like cholera, diarrhoea typhoid caused roughly 2439 deaths and nearly 1.5 million cases of the disease. A resource of water has to be both affordable and reliable. In most areas of the country the water is brackish, salty or contaminated. Salinity is one of the major issues in the Mumbai area and along the, sea lines of Thane.

Water purification is possible using the RO process, and sunlight is a traditional energy source that can be utilized to energize our system. RO filtration is the most dependable method to purify dirty water. The semi permeable membrane of the RO systems removes excess minerals and other soluble particles from the water such as bacteria fungi algae and viruses. The gadget effectively eliminates particles measuring as small as 0.0001 microns while rotating the motor in India, clean drinking water remains a high challenge in rural as well as urban regions. Various traditional methods for treating drinking water chlorine pills, pots for chlorination of wells, slow and fast sand filters, and fluoride remover are some of the technique employed, but they are more complex to employ and have in a tank and provide power to a RO system for purification. If there is an environmental problem or blackout like a flood or any disaster the battery in the solar purifiers stores power, allowing the process to run on solar energy.

It is an easy-to-assemble portable purifier which can be applied in off-grid areas without electricity. Pollution-free operation is achieved by this purifier.

II. LITERATURE REVIEW

1) Gowtham M., et al. (2012): In this research work, the efficiency of solar concentrated distiller with latent heat storage capacity is compared with solar concentrated distiller with trays on the basin..
2) Ozuomba J.O. et al. (2012): In the present paper a roof-type solar water distillation (RSWD) kit was designed and tested under real environmental conditions of Ursula, an old town in the Eastern region of Nigeria. The components of the system are four, which are the rectangular wooden basin. the a absorber surface, the glass roof and the condensate channel. The RSWD generated 2.3m3 of distilled water in six days. Although the condensate was not sizable enough relative to human requirement as is characteristic in mots solar stills, its efficiency can be improved.

3) Prof. Alpesh Mehta et al. (2011): In this paper we observed that the increase in temperature and hence the evaporation is maximum in the period of 11:15 am to 1:30 pm. The maximum temperature achieved is 53 0C which is at 1:30 pm. then the temperature decreases. This experiment was done to obtain pure water from the available brackish water. Our supplied brackish water was 14litres and we obtained 1.5litres at the end of the experiment. The experiment was performed during winter season. The TDS reading of purified water obtained is 81 PPM. So the water obtained is potable. Theoretically, the experiment should fetch out 2.33litres. So the system efficiency is 6%.
4) Numerical simulation, Zhang 2019: Developed a mathematical model to optimize the design parameters of a solar powered multi-effect distillation desalination system.
5) M. Z. H. Khan, M. R. Al-Mamun, S. C. Majumder, and M. Kamruzzaman (2015): They investigated iron removal from water using the ash generated from banana waste. Controlled burning produced ashes of different materials i.e., dry banana leaf, pseudo stem, rind, bamboo, rice husk. Removal mechanism involves oxidation of iron under pH or alkaline environment generated by potassium in banana due to subsequent generation of potassium hydroxide. The research involved the analysis of chemical content of banana ash and its effectiveness in iron removal form prefabricated water.
6) Designed and fabricated a Solar power Desalination, Smith et al 2018: Designed and fabricated a solar-powered reverse osmosis desalination system. The system produced 5 liters of water per hour with a mean energy efficiency of 75%.
7) Aayush Kaushal et al. (2010): Based on this there are several techniques for brackish water desalination into drinking water. Thus, various solar stills are described to yield clean water. The optimal choice of cooling film parameters improved the still efficiency by 20%. In multi-effect diffusion model the efficiency drops around 15% with the rise of diffusion gaps between partitions from 5 mm to 10 mm. Thus for particular requirement there is a need choose solar still very continuously depending on the local condition and operating conditions.

III.METHODOLOGY

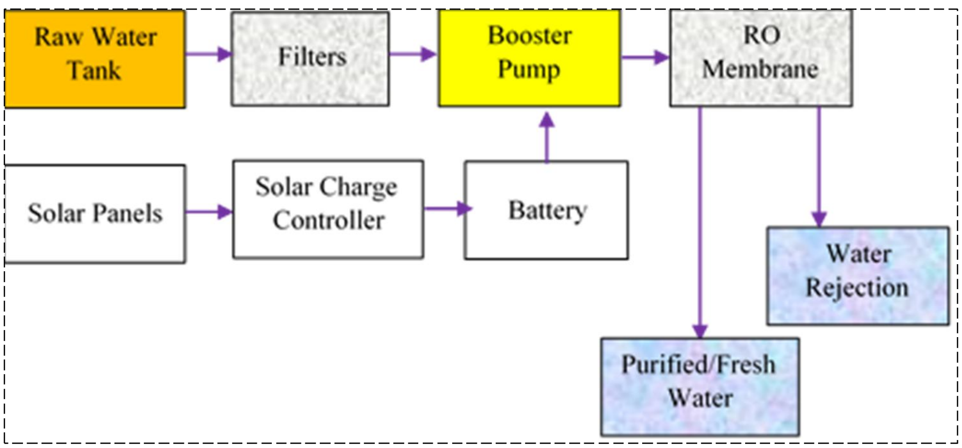

Fig. 1 Solar Powered Water Purification System-Block Diagram

The figure 1 illustrates a solar powered desalination system using reverse osmosis technology. The system integrates water treatment components with renewable energy construction to build a sustainable water generation. The photovoltaic cell in a solar panel is converts solar radiation into electrical energy. The energy generated by the panel is stored in batteries, and a solar charger controller controls the voltage and amperage the panel delivers to keep the batteries' load from being overcharged. The water scaffold is then turned, the motor rotor rotates, the filters are activated, and the eccentric swing wheel is pulled to produce eccentric movements by the power source. Three cameras arranged in an assembly next to the eccentric tread wheel that reverses, powering the diaphragm. The RO booster pump's diaphragm can replicate continuously thanks to the engine's constant spinning, which serves to pump and increase the amount of water that enters. When water is forced across a semi-permeable membrane, the RO membrane may remove the bulk of pollutants from the water, leaving just impurities behind. There are three layers in the membrane. The first layer, which is 0.2 microns in size and composed of polyamide sheet, does not enter any form of particle, and the polysulfide layer can eliminate any nutrients, chemicals, viruses, and bacteria that are present in the water. The cleansed water then passes through the polyester base. Both the clean and the dirty water get divided after purification process.

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IV. CAD MODEL

Figure 2 Illustrates the assembly of the CAD Model, Highlighting the coordination between product design and manufacturing. One of the most popular methods for creating 3D Models is through the employment of commercial packages like solid works. The main research is to explore the assembly model CAD quality and research how they need to be coordinated for maximizing the efficiency and capability of assembly processes.

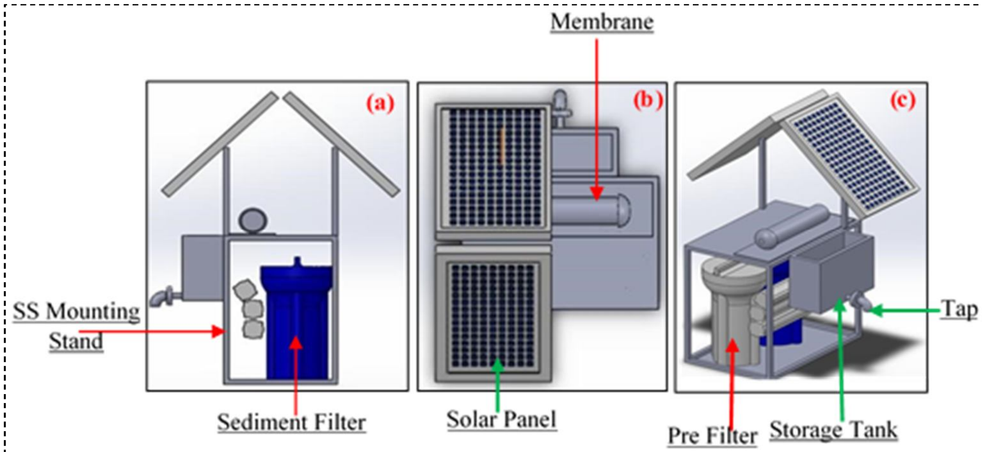

Figure 1: CAD Model illustrates the basic components assembly system[12]

V. COMPONENTS

The Figure 3 shows the essential components are required for conducting experimental work and further details are described as follows

Figure 2: Components of SPDS System (a) Solar Panel
(b) Controller (c) Booster Pump (d) Membrane (e) Battery

A. Solar Panel

The solar energy in this model is harvested using a solar panel. Photovoltaic cells are employed to produce solar panels. Depending on light intensity, how much power it is entirely dependent on light intensity. We are utilising a 20-watt small solar panel to charge a 12-volt battery that is exposed to sunlight. This portable solar panel has a wide range of applications due to its lightweight design. The panel is specifically made to charge tiny batteries with a maximum capacity of 10,000 mAh or 10 Ah. The dimensions of little solar panels vary from 0.6 x 2.55 inches to 14 × 18 inches, or 1.7 square feet, which is similar to a standard medium-sized home mirror.

B. Controller for Solar Chargers:

By doing this, the deep cycle battery is protected from in order to prevent the battery from running out of power, the solar panel is replenished during the day and receives energy back at night. Although load control and lighting are two extra features that some charge controllers offer, power management is the primary objective.

C. Booster Pump

Water pressure can be raised by using booster pumps. The osmotic pressure is typically higher. For purification to take place, water has to change from a high concentration to low focus. The high-concentration lateral pressure should, therefore be higher than the osmotic pressure to accomplish the reverse osmosis process.

D. Reverse Osmosis Membrane

Energy storage has been identified as a critical part of greatly increasing the penetration of renewable energy generation like other contaminants and dissolved salts (ions). Through the use of a thin, semi-permeable membrane, RO devices filter out contaminants and suspended and dissolved impurities from water.

E. Storage Battery

It is a crucial component of the setup. Seasonal changes in atmospheric conditions lead to changes in the intensity of solar radiation. It guards the contaminants pump from high voltage by supplying a stable 12-volt supply.

VI. FABRICATED MULTI SYSTEM

The figure 4 shows the fabricated assembly with solar-powered water purification system involves design engineering, manufacturing the stainless steel mounting frame, assembling the solar panel on top, installing the pre-filter and RO membrane components, connecting the storage tank, completing plumbing work, wiring the electrical connections from the solar panel to the RO system, and finally testing the entire unit to ensure proper water purification. This compact system is designed for deployment in remote areas of India to provide clean drinking water using solar energy.

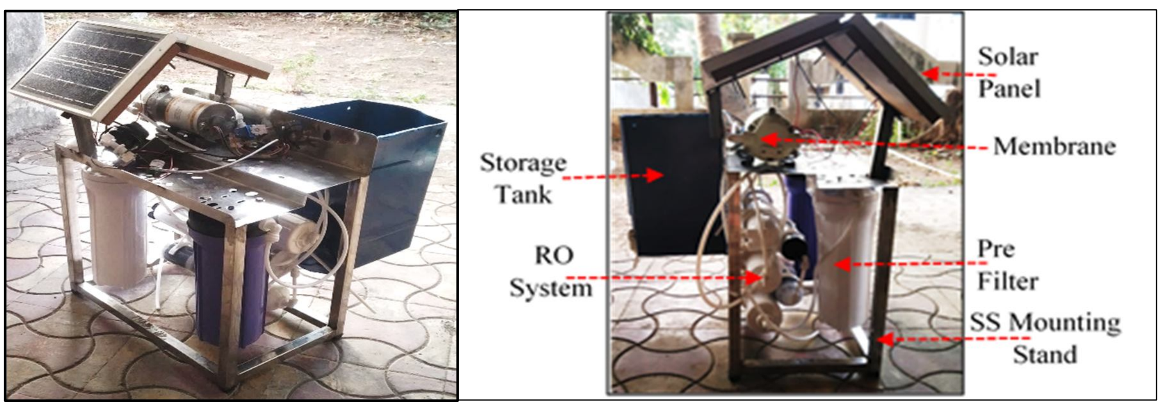

Figure 3: Fabricated Assembly

VII. RESULTS AND DISCUSSION

The following are the primary panel designs that have an impact on collector panel performance.

1) Power for Application: The manifold panel is directly impacted by the power needed for a certain application. improved power received and improved efficiency are directly correlated with larger panel areas. Expense. This panel contains an 18W maximum power supply.
2) Angle of Latitude: The angle at which the solar panel should be kept in order to absorb the most sun energy is known as the latitude angle. Any location's angle of latitude is the angle between the earth's equatorial plane and the line from a specific place on its surface to the equatorial centre.

The following method is used to determine the latitude angle:

a) Check off all three points. e.g., the location of the Earth's centre, the Equatorial plane line, and the designated panel design location on a global map.
b) Join the location point with the earth point.
c) Determine the angle formed by the earth's centre point and the equatorial plane line. as displayed for Wardha district on the map, because it equals 200, the collector should be installed at 200 directed towards south.

The table-1 shows visualize the dramatic decrease in TDS concentration throughout the day. This could indicate the effectiveness of a water treatment system, possibly a desalination or purification process that's removing dissolved solids from the water. The steepest decline occurs between 1:00 PM and 2:00 PM, where TDS levels drop by 2000 ppm. After 3:00 PM, the rate of decline slows, suggesting the treatment process may be approaching its maximum efficiency point.

Sr.no	Date	Time	TDS [ppm]
1	02/03/2025	10:00 AM	5600
2	02/03/2025	11:00 AM	4500
3	02/03/2025	12:00 AM	3555
4	02/03/2025	01:00 PM	3000
5	02/03/2025	02:00 PM	1000
6	02/03/2025	03:00 PM	1000
7	02/03/2025	04:00 PM	850
8	02/03/2025	05:00 PM	545
9	02/03/2025	05:30 PM	545

Table-1: TDS Output: Solar Powered [12]

The table shows-2 TDS & Solar Output, the with measurements taken over 10 consecutive days (April 1-10, 2025) at the same time each day (5:00 PM). The table tracks two parameters across these days:

1. Output Voltage (V): The readings range from 8.8V to 9.5V, showing slight variations in output voltage over the period.
2. Total Dissolved Solids (TDS): Measured in parts per million (ppm), the TDS values range from 502 to 530 ppm.

This data appears to be monitoring the performance of a water treatment or purification system, possibly a solar-powered desalination unit (based on context from previous messages). The output voltage likely represents the electrical output from a solar panel or power source, while the TDS readings indicate the level of dissolved minerals, salts, and metals in the processed water.

The relatively stable TDS values (all around 500-530 ppm) suggest consistent water quality output from the system across different days. Similarly, the fairly consistent voltage readings indicate stable power generation conditions. This data would be valuable for evaluating the reliability and consistency of the purification system's performance over time.

Sr.no	**Date**	**Time**	**Output (V)**	**TDS [ppm]**
1	01/04/2025	05:00 PM	9.2V	530
2	02/04/2025	05:00 PM	9.3V	527
3	03/04/2025	05:00 PM	9.3V	518
4	04/04/2025	05:00 PM	9.5V	510
5	05/04/2025	05:00 PM	8.8V	509
6	06/04/2025	05:00 PM	8.9V	504
7	07/04/2025	05:00 PM	9.1V	511
8	08/04/2025	05:00 PM	9.2V	508
9	09/04/2025	05:00 PM	9.0V	502
10	10/04/2025	05:00 PM	9.5V	504

Table-2: TDS Output with Solar output

3) Comparative Analysis of Solar Panel & Battery

The Table-3 shows the data tracking the performance of a solar power system throughout a single day (February 3, 2025) from 10:00 AM to 5:30 PM. The table contains 9 entries with three key parameters: time of observation, Solar Panel Output (measured in volts), and Battery Voltage (also in volts).

The Solar Panel Output shows a steady decline throughout the day, starting at 7.5V in the morning (10:00 AM) and gradually decreasing to 6.4V by late afternoon (5:30 PM). This pattern likely reflects changing solar intensity as the sun's position shifts throughout the day.

Similarly, the Battery Voltage also shows a gradual decrease from 8.7V at 10:00 AM to 7.9V by 5:30 PM. This decline suggests that the battery is discharging more than it's being charged as the day progresses, possibly because the decreasing solar panel output is insufficient to maintain the battery's charge level.

Sr.no	Date	Time	Solar Panel Output[V]	Battery Voltage[V]
1	02/03/2025	10:00 AM	7.5	8.7
2	02/03/2025	11:00 AM	7.3	8.6
3	02/03/2025	12:00 AM	7.1	8.5
4	02/03/2025	01:00 PM	6.9	8.4
5	02/03/2025	02:00 PM	6.8	8.3
6	02/03/2025	03:00 PM	6.7	8.2
7	02/03/2025	04:00 PM	6.6	8.1
8	02/03/2025	05:00 PM	6.5	8
9	02/03/2025	05:30 PM	6.4	7.9

Table-3: Comparative Analysis of Solar Panel & Battery

VIII. CONCLUSION

In situations where electricity supplies and water purification infrastructure are unavailable, this solar-powered system provides an accessible, low-cost solution for water disinfection. The integrated structure uses a motor powered by solar energy to facilitate filtration, effectively removing viruses, minerals, bacteria, and other contaminants to produce potable water. The data reveals a gradual decline in both solar panel output and battery voltage throughout the day, indicating that energy harvesting efficiency decreases as daylight wanes, which is crucial information for optimizing the system's operational hours and storage capacity for reliable water purification in remote areas.

IX. ACKNOWLEDGEMENT

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Annexure-I

(I) Average power intensity

The unit of electricity collected per day is the average power intensity for any given locality. The map's reference indicates India's global radiation.

The average global radiation for Vidarbha is 6.1 KWh/sq.m. day and 1 KWh/sq.m. equals 3.6 MJ/sq.m. day.

Total radiation average worldwide = 6.1 * 3.6 = 21.96 MJ/sq.,
=(21.96 x 10^6) / (24 x 60)
= 15250 J/sq.m.mm; 5250/60
= 254 J/sq.m.

Thus, average worldwide radiation is equal to 254 W/sq.m.

i. Angle of Incidence: This is dependent on the time of day and how the sun's rays angle to the horizontal surface being measured with respect to For twelve hours, the sun covers an angular distance of 1800. It moves at 180/12, or 150 mph, at an angle.
ii. The angle at which the sun appears at angle of Latitude (Q) & incidence = 90^0 is the ideal angle of incidence. Given that latitude angle = Q = 20^0
iii. The ideal incident angle is = 90^0-20^0=70^0
iv. Area of Collector: A collector's area mostly affects the power that collectors produce. The following protocol is adhered to during its design. in = ibn x A x COSǾ
Where, in = the development of power
    v. A is the collector's area.
    vi. Ibn = Sunlight intensity on average
    Since 700 In is the ideal angle of incidence, we have Ibn x A x COS
    6 = 254 x A x cos 70.

Consequently, A = 0.069066 m

Imagine a rectangular panel with the following side ratio: 1:3

I^2 = 0.069066 and 0.325m = 32.5cm, B = 3 x I = 47 cm

Area of panel: 32.5 x 47 = 1527.75 cm2

Discharge of water: (Q) = Area x Velocity

Now area = 0.01 x 0.01 = 0.0001 mm2 Now find velocity of water through pipe,

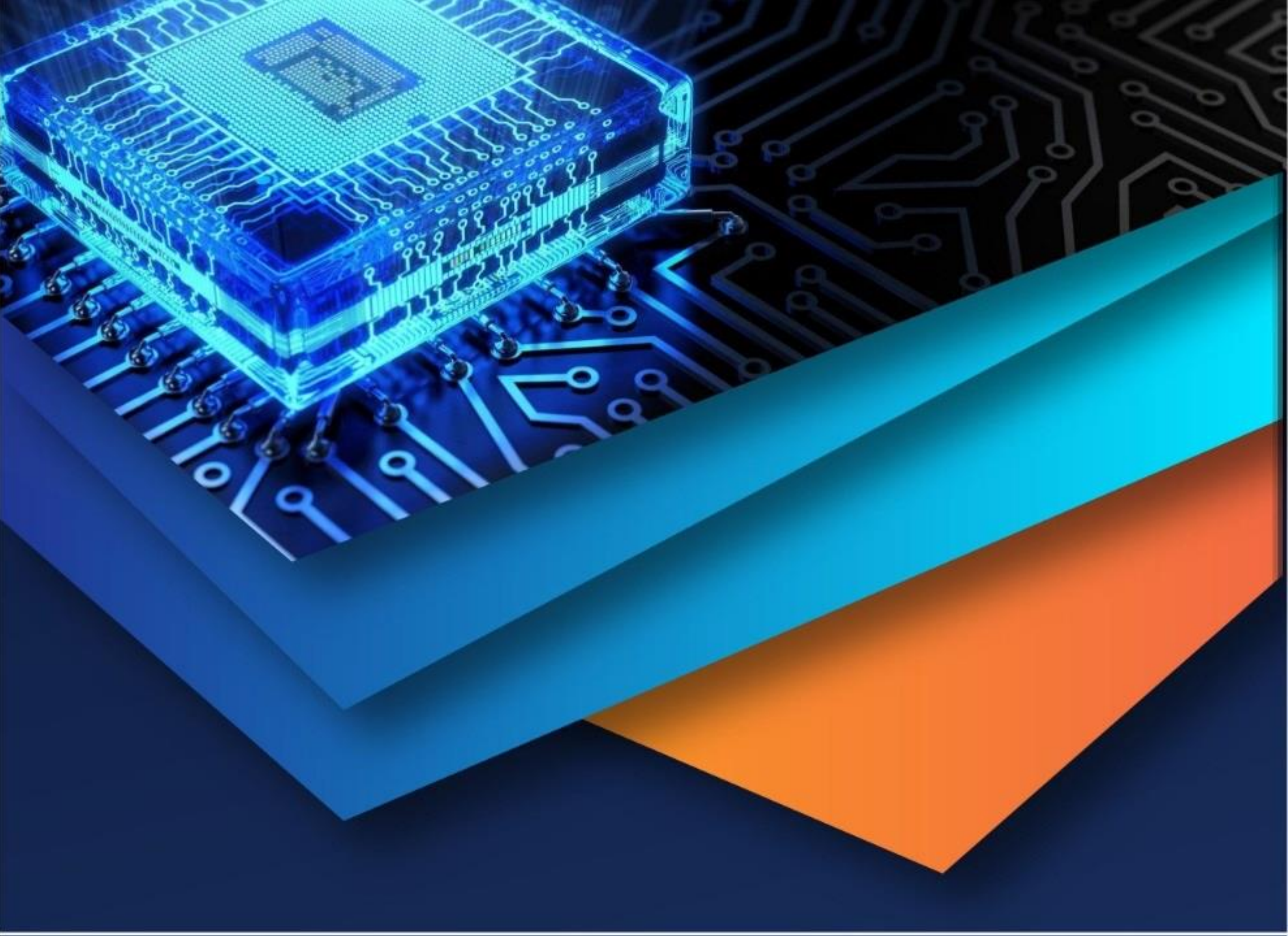
Hf= (4 x f x L x V2)/Area of c/s x 2g

Hf= pressure head difference = 4 m

F = coefficient of friction = 0.009, L = total length of pipe = 10.0584 m

V = (4 X 0.009 X 10.058 X V2) / 0.0001 x 2 x 9.8 = 1.4721 m/s

Q= 0.0001 x 1.4721 =0.000014721 m^3/s = 0.01472 litre/s



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