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EXPERIMENTAL INVESTIGATION OF SINGLE SLOPE BASIN SOLAR STILL FOR DESALINATION WITH MAGNIFYING LENSES

Ayesha Rasheed[1], Ans Ahmed Memon[*2], Irshad Ali Gopang[3], Mohammad Waqas Chandio[4]

[1]*Institute of Environmental Engineering, Mehran University of Engineering and Technology, Jamshoro 76080, Sindh Pakistan*
[*2,4]*Department of Mechanical Engineering, Mehran University of Engineering and Technology, Jamshoro 76080, Sindh Pakistan*
[3]*Institute of Petroleum & Natural Gas, Mehran University of Engineering and Technology, Jamshoro 76080, Sindh Pakistan*

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Corresponding Author: *
Ans Ahmed Memon
ans.memon@faculty.muet.edu.pk

Abstract
One of the major problems with human beings is to fulfill growing demands for freshwater resources, fossil fuel depletion, and climate change. People living in remote areas worldwide, especially underdeveloped countries, need more access to safe drinking water, energy, and environmental security. All highlighted needs desalination of saline water powered by renewable energy. Water desalination with solar energy is the best option for countries with abundant solar energy potential. This study focuses on novel design, development, and water quality analysis of modifying single slope basin still for desalination of hard water experimentally. The solar still in this research work was designed using AutoCAD software, fabricated with glass material, modified with polyethylene sheet, nanoparticles, and magnifying lenses, and finally tested in the climate of Jamshoro city in the Sindh province of Pakistan. The experimental results revealed that incorporating magnifying lenses into essential solar still led to the highest yield of distilled water at 320 mL/h.

1. INTRODUCTION
Fresh water is necessary for a healthy life and is utilized in residential, industrial, and agricultural applications. Fresh water consumption is rising rapidly because of rapid industrialization and population growth. The naturally available water is either impure or saline, which is unsuitable for drinking and requires treatment. The earth consists of 70% of water, of which 97% is saline [1]. The remaining 3% of this freshwater comprises 1.65 % glacial masses, including icebergs, 1.8 % groundwater, and 0.0012 % as mists and fumes. The remaining 1.5 % of the freshwater is suitable for drinking [2, 3]. Adults typically consume 2-4 liters of drinking water daily, whereas newborns consume 0.75 liters [4]. Similarly, the amount of water used at home for cooking and washing varies significantly between nations, usually ranging from 50 to 500 L/day[5]. Further, figure. 1 demonstrates the global use of freshwater in various sectors. Large-scale water purification and desalination technologies consume vast amounts of input energy, usually from fossil fuels, resulting in environmental damage [6]. Alternative energy sources that include solar energy are suitable. However, in

isolated locations with sparse populations and plenty of solar energy, solar energy is more cost-effective than fossil fuels. Solar distillation effectively purifies water to meet potable water needs in low-population areas with abundant sunshine [7, 8]. Hyder Azeez and Neamah Diabil [9, 10] investigated the solar still performance experimentally utilizing aluminum foils and stainless steel balls to increase still productivity; their results revealed that the thermal efficiency of the still reaches 27.81%.

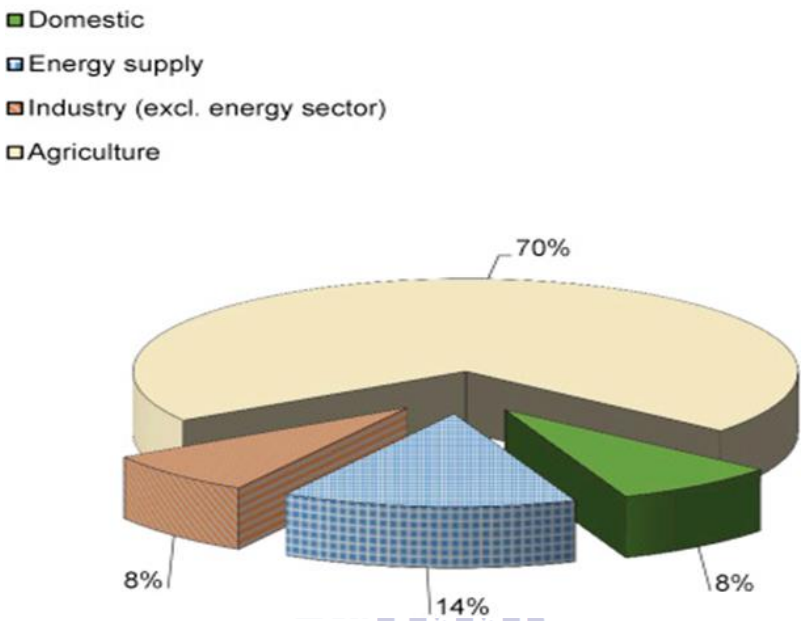


Figure 1 Global usage of freshwater in various sectors based on UN-Water data[5]

Due to the insufficiency of fresh water, seawater purification plays a significant role in drinking and other uses. Sea water has elevated salinity levels quantified as total dissolved solids (TDS) in the 35,000-45,000 ppm [7, 11]. Hence, to utilize this seawater desalination, it is necessary to do it cheaply. Solar still is easy to assemble, convenient, and eco-friendly, and it may be readily utilized by anyone in situations of scarcity of purified water. However, the yield of distillate and efficiency needs to be improved. This helped researchers optimize its performance in terms of design, operational parameters, and climatic conditions. Solar still is one of the economical ways of desalinating seawater.

It is evident from the literature review that most researchers have tried to enhance the productivity of solar panels using numerous modifications in design material, reducing heat loss and increasing evaporation rate using nanofluids. However, this study focuses on novel modification of enhancing distillate yield using magnifying lenses.

2. Methods and Materials:

2.1 Solar Still Description

Initially, the single slope basin solar design was still developed through AutoCAD software by selecting suitable dimensions, as shown in Figure 2. During the development phase, preference was given to glass material for the incline top due to its transparency, which will allow sunlight to enter through it and trap the heat inside the basin. The basin area of the still is 0.431 m × 0.304 m (0.131 m^2), which is covered with a glass of 4 mm thick. The basin of the still is further painted with a super black color to enhance its absorptivity. Finally, the solar still is oriented to face sunlight to utilize the maximum amount of solar radiation and positioned at the inclination of 10° horizontally, as shown in Figure 2.

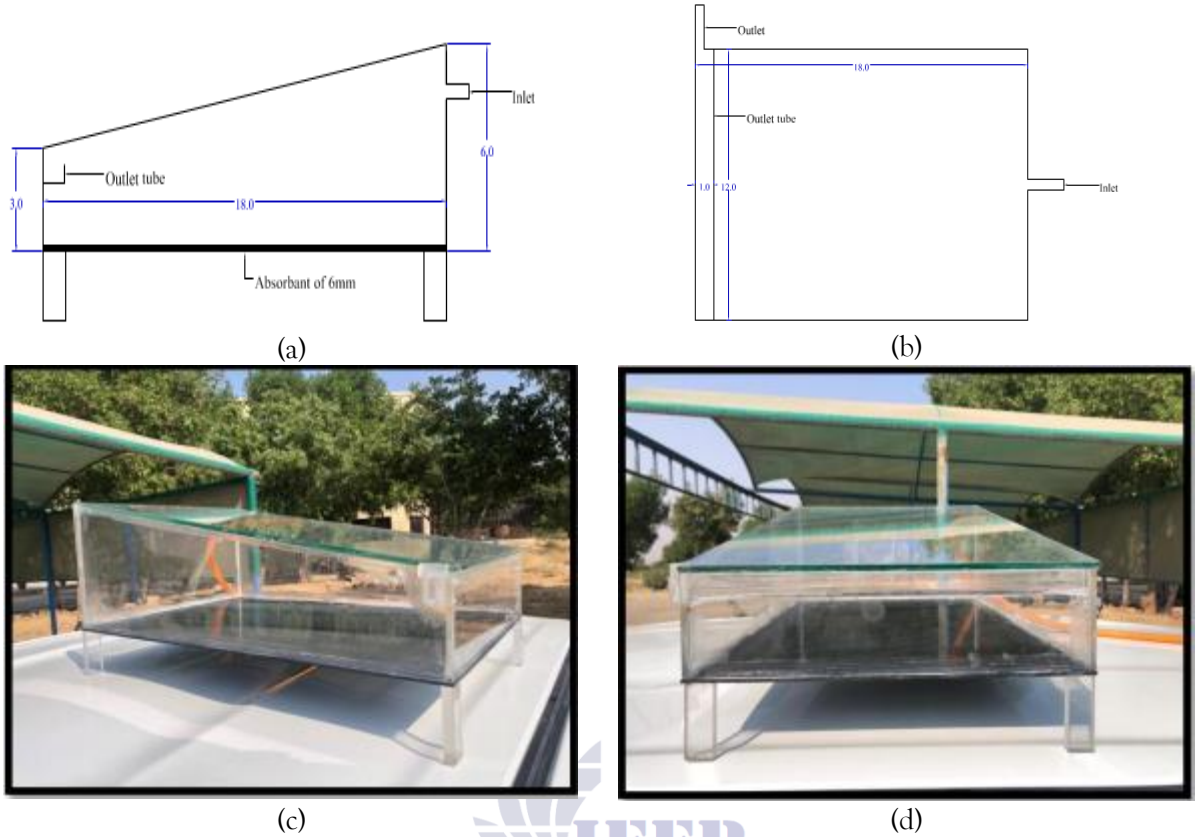


Figure. 2 Design Layout of Solar Still (a) Side View (b) Front View (c) Actual Model Side view (d) Actual Model Front View

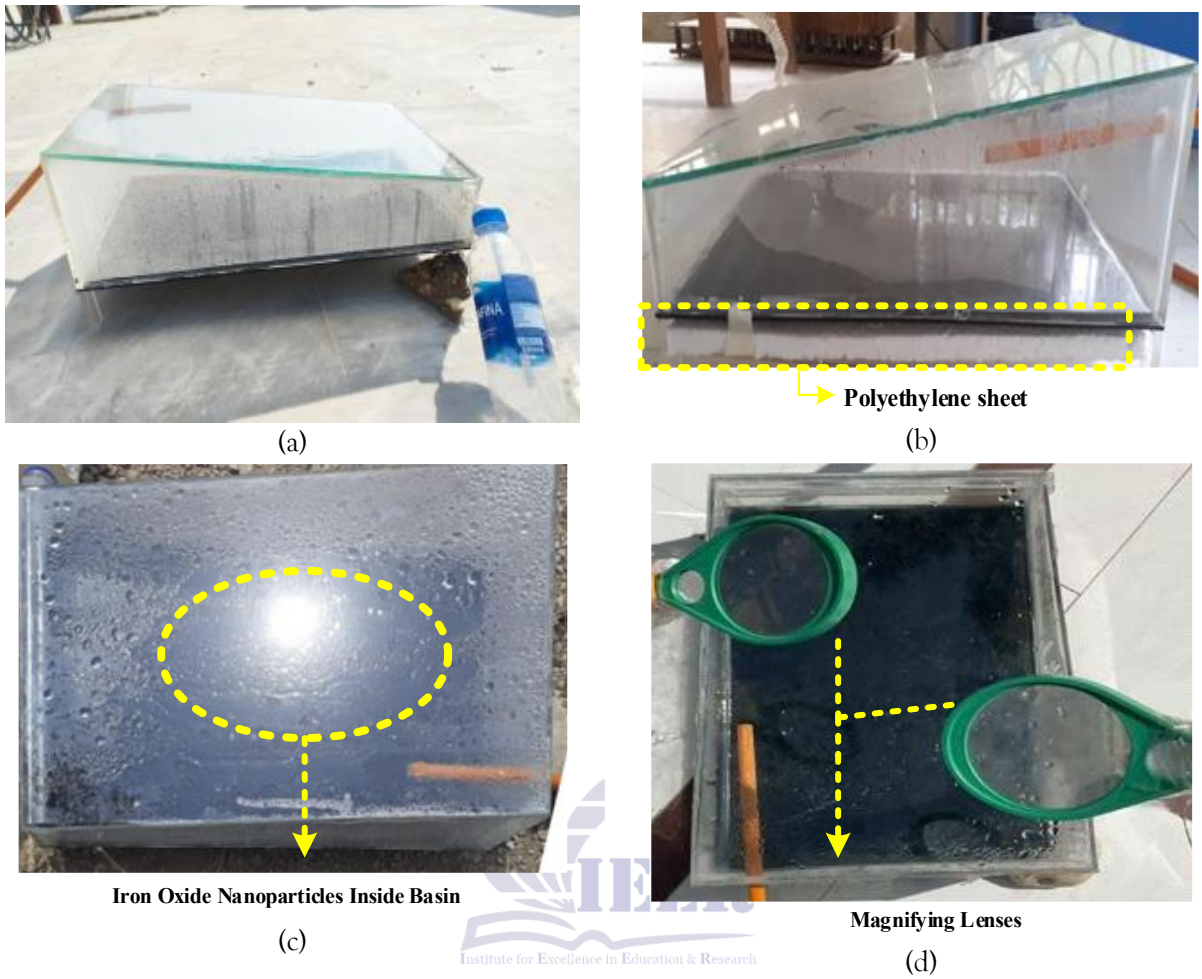
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2.2 Experimental Procedure

To analyze its performance, the experimental study was conducted for single slope basin solar still in the environment of Jamshoro, Sindh, Pakistan (25.41914° N, 68.279417°E).

The study was conducted in May 2023 during the day, from 10:00 am to 5:00 pm, in the Jamshoro region of Pakistan. Initially, one liter of Saline groundwater was supplied to the still with the help of an opening on the side. Ultimately, the system is positioned to face sunlight to trap the maximum amount of heat from incoming solar radiation to evaporate the water. The temperature of the main components was measured with the help of a K-type thermocouple. The weather data of selected locations were collected from the Alternative Energy Development Board (AEDB) weather station located at Mehran University of Engineering & Technology Jamshoro. A graduated cylinder of 1000 mL was used to measure the quantity of evaporated distilled water. Before desalination, characteristics of Saline water such as pH, turbidity, TDS, and EC were evaluated.

To enhance solar still distillate, different trials were performed on solar still with several modifications, as shown in Figure 3 by changing surface materials like polyethylene sheet, nanoparticles, and magnifying lenses with solar still.



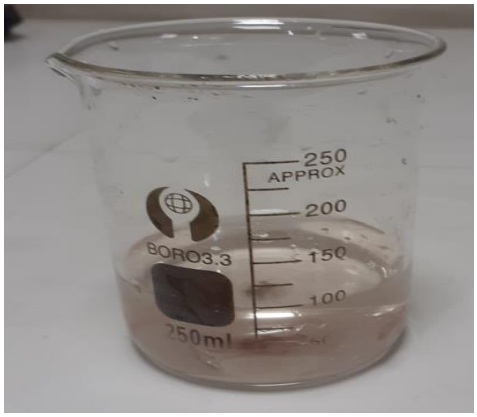
(a) (b) (c) (d)

Figure 3 Snapshots (a) Simple Solar Still (b) Modified Solar Still with Polyethylene (c) Solar Still with Iron oxide Nanoparticles (d) Solar Still with magnifying lenses

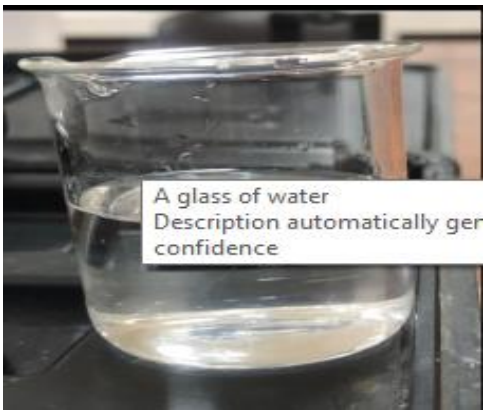
Table. 1 Chemical characteristics of Saline water sample

Parameters	values
pH (-)	7.18
Turbidity (NTU)	4.97
TDS (mg/L)	1030
EC (mS/cm)	860

Table 1 summarizes the results from the chemical analysis of saline water before desalination. Saline water is supplied to solar still for desalination under different modifications to analyze its chemical characteristics.



(a)



(b)



(c)



(d)

Figure 4 Snapshots (a) Saline water Input (b) Purified water sample (c) Turbidity Test before desalination (d) Electrical Conductivity Test

Figure 4 demonstrates photoshoots of saline water before and after desalination, along with various tests. The turbidity test was conducted using a turbidity meter and similar electrical conductivity.

4. RESULTS AND DISCUSSION

The solar irradiance concerning time was recorded during May 2023, as shown in Figure 5. It indicates that solar irradiance intensity increases during selected time intervals and reaches its highest value of 943 W/m^2 at 02:00 pm on 2nd May 2023.

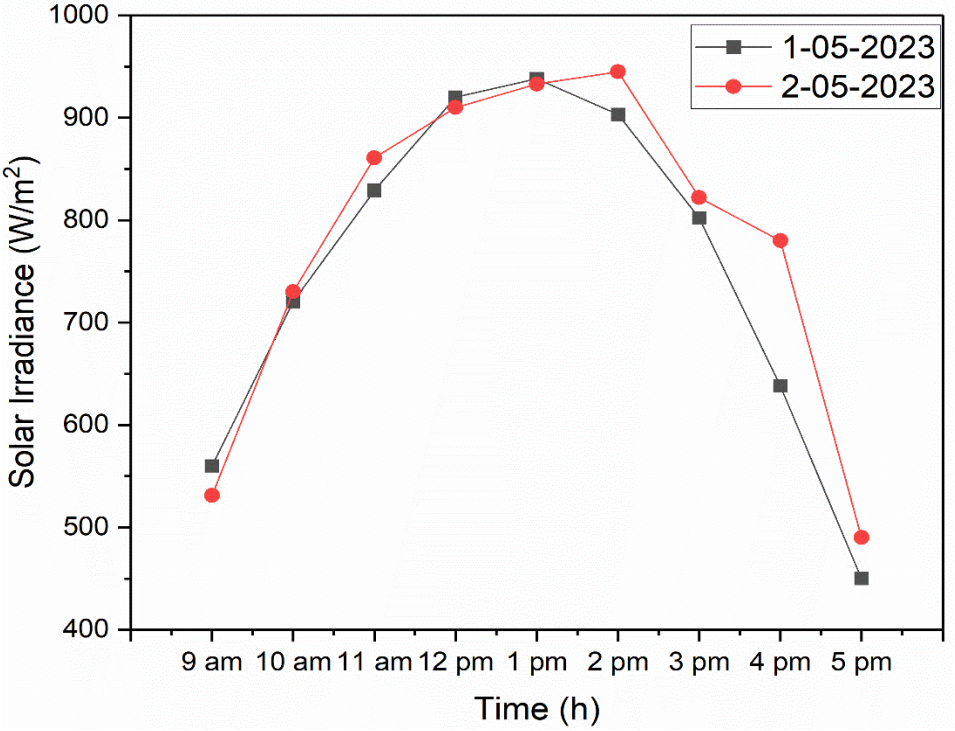


Figure. 5. Global solar irradiance variation throughout testing days as a function of time

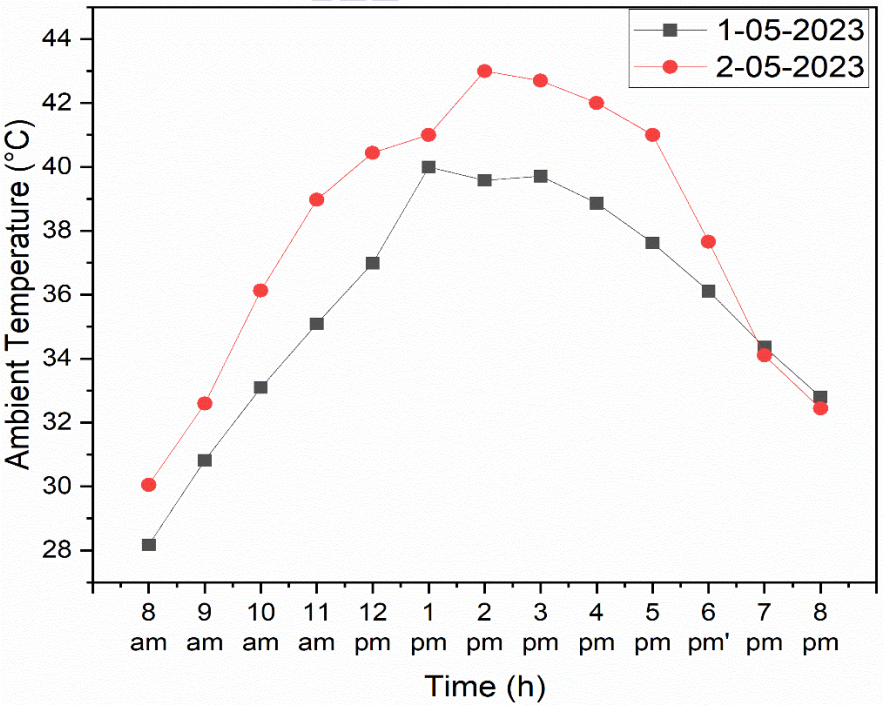


Figure. 6. Changes in Ambient temperature throughout testing days

Additionally, figure. 6 shows how the ambient temperature changed concerning time during the test days in that same month. It indicates that ambient temperature increases during the daytime of the experiment and

reaches its maximum value of 43 °C around 2:00 pm on 2nd May 2023. This temperature variation dependent on solar irradiation.

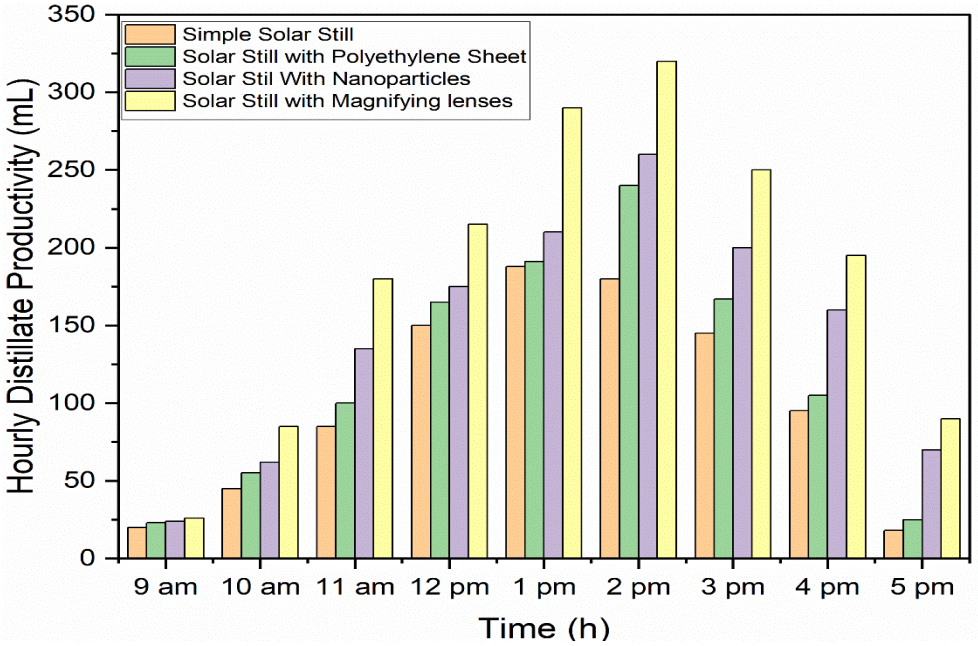


Figure. 7. Evolution of the productivity of hourly distillation under various modifications

Figure. 7 demonstrates the hourly productivity of distillate under different modifications to simple solar still. The hourly output of solar still reaches its maximum value of 188, 240, 260, and 320 mL for simple solar still, with polyethylene, with nanoparticles, and using magnifying lenses, respectively. The maximum collected distillate was at 2:00 pm. The findings demonstrated that incorporating magnifying lenses into essential solar still led to the highest yield of distilled water, 320 mL.

Magnifying lenses enhance solar distillation productivity by focusing and intensifying sunlight onto the surface of the still. This increased concentration of solar energy raises the temperature within the still, which accelerates the evaporation rate. As a result, more water vapor is produced and condensed, leading to higher distillate collection rates than standard solar still without magnifying lenses.

Table. 2 Physical parameters of distilled water samples

Chemical Parameter	Solar Still Without Modification	Polyethylene Sheet	With Nanoparticle (Iron oxide)	Magnifying Lenses	WHO Drinking Water Quality Guidelines[12]
pH	6.81	6.82	6.34	6.7	6.5–8.5
Turbidity (NTU)	3.7	3.9	5.77	2.7	< 4
TDS (mg/l)	30	20	40	0	1000
EC (mS/cm)	80	50	145	0.02	2800

Table 2 highlights the chemical characteristics of distillate collected from various modifications of solar stills. Based on the above results, it can be concluded that the abovementioned modifications to the solar still effectively bring the saline water within the safe ranges as outlined by the World Health Organization (WHO)[13]. By incorporating magnifying lenses into the system, the turbidity of saline water notably diminishes to

a reading of 2.7, and Total Dissolved Solids (TDS) content in the saline water reaches zero reading.

5. CONCLUSIONS AND FUTURE WORK

A single basin solar still was fabricated and tested in the climate of Jamshoro city of Pakistan to evaluate the distilled water yield. Several experiments were conducted with and without adjustments or modifications to assess the productivity output. The experiment results reflect that the solar output still reaches its maximum value of 320 mL at 2:00 pm with the addition of magnifying lenses. The turbidity of saline water reaches 2.7, and the Total Dissolved Solids (TDS) content in the saline water reaches zero reading.

Finally, the following challenges are identified as future work:

- Most researchers focus on distillate enhancement using different media, but using magnifying lenses could lead to overheating of solar stills and damage their design.
- The optimal position and angle of the magnifying glass would need to be adjusted to track the sun's movement.
- Most studies were conducted on conventional heat transfer fluids, but binary nanofluids can be integrated to enhance distillate productivity.

Nomenclature

AEDB	Alternative Energy Development Board
EC	Electrical Conductivity
TDS	Total Dissolved Solids
NTU	Nephelometric Turbidity unit
L/day	Liter per day
mL	milli liter
UN	United Nation
pH	Power of Hydrogen
ppm	Parts per million

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