Scope
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Investigation of a Concentrator-Style Solar Still using Various Materials Analysis using Python Program

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Abstract
This research explores the development and evaluation of a single-basin solar still integrated with a concentrator for water desalination. Various experimental parameters were investigated, including water depths, sensible heat storage materials, latent heat materials, and porous substances under controlled heat inputs. The study incorporated a heat exchanger within the concentrator to enhance the temperature of the standard solar still. The collector tray, with an area of 0.9 m² and made from 4 mm thick galvanized iron (G.I.) sheet, was painted black and connected to a heat exchanger pipe. The glass cover was positioned at a 30-degree angle. Water depths of 2 cm, 3 cm, and 4 cm were tested to assess their impact on still efficiency, alongside the use of sensible heat storage materials, latent heat materials, and porous materials. The highest evaporation rate of 2220 ml/m² was recorded at a 2 cm water depth. The use of sensible heat storage materials in the concentrator led to the shortest payback period.

Keywords: concentrator, solar still, water depth, sensible heat storage, latent heat, porous materials, payback period

Introduction

It sounds like you're summarizing various studies on enhancing the productivity of solar stills through different methods and innovations. Here's a concise synthesis of the key findings from the studies you mentioned:

1. **Rai et al. (1990)**: Examined flat plate collectors in solar stills and found that productivity decreases with increased salt concentration.
2. **Badran & Tahaneih (2005)**: Demonstrated that coupling a flat plate solar collector with a still can boost productivity by 36%.
3. **Bassam & Hamzeh (2003)**: Investigated the use of different sponge cubes in the basin of the still, leading to a productivity improvement of 18% to 27.3%.
4. **Voropolulos et al. (2004)**: Found that coupling a hybrid still with heaters doubled its productivity.

5. **Benon Bena & Fuller (2002)**: Combined a natural convection solar dryer with a biomass backup heater, achieving a fourfold increase in performance compared to the solar dryer alone.
6. **Nakatake (2009)**: Increased the productivity of solar stills by using an external reflector.
7. **Muafag Suleiman &Tarawneh (2007)**: Used sprinklers for glass cooling to lower the glass cover temperature, improving productivity by 14% compared to conventional stills.
8. **Senthilrajan & Ramji (2016)**: Studied various still types and enhanced productivity by integrating biomass boilers, electric heaters, and evaporative materials.

These studies collectively highlight the potential for significant improvements in solar still productivity through various modifications and enhancements.

2. Test Configurations

The experimental setup (see Figure 1) includes a flat plate collector and a concentrator. The flat plate collector is housed in a wooden box with an area of 0.9 m^2 and varying heights of 0.54 m and 0.61 m, constructed from 4 mm thick G.I. sheet. A 3 mm thick glass panel covers the box, allowing solar radiation to enter. Insulation made of Thermocol is placed between the bottom surface and the side walls. A 25 mm diameter G.I. heat exchanger pipe is fixed at the basin's bottom, connecting the concentrator and recirculation pipe. A measuring box is positioned outside the still to collect water from the gutter. An elevated input tank supplies saline water to the collector via a valve. Thermocouples are used to monitor temperatures of the saline water storage tank, basin, and glass surface. Solar radiation is measured with a Kipp-Zonen Pyranometer, and wind speed is measured with a digital vane-type anemometer. Distilled water is collected and measured in a beaker. Initial experiments were conducted with water depths of 2 cm and 3 cm. The setup was tested at the University College of Engineering, Ramnad, India, from May to June 2016.

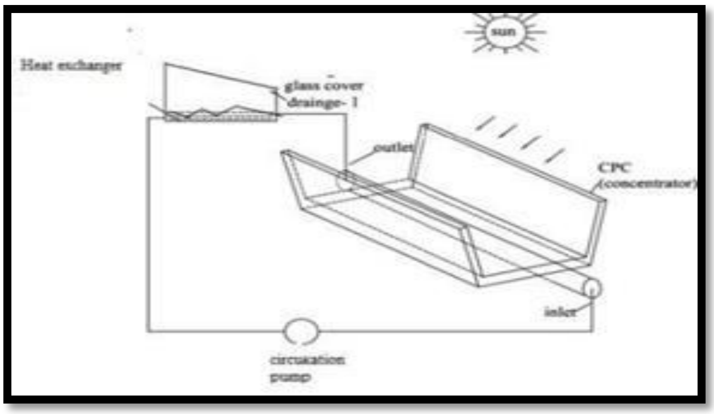

Fig.1 Experimental setup

3. Results and Discussion

3.1 Impact of Sensible Heat Materials on Still Productivity

Sensible heat storage materials improve still performance by retaining excess heat. Stone fragments (25 mm in diameter), sand, and brick pieces were used at different points along the still's base. Results showed that stone fragments enhanced productivity by 52% at 2 cm and 47% at 3 cm. Sand and brick also improved productivity by 42% and 34%, respectively (see Figure 2).

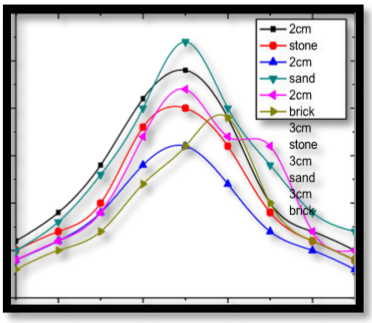

Figure 2: Effect of sensible heat materials on different water depths in reflector attached still

3.2 Impact of Latent Heat Materials on Still Productivity

Latent heat materials increase water temperature by capturing and releasing heat during phase changes. Wax pieces (30 mm in diameter) were placed in containers at various locations in the still. Using wax increased productivity by 47% at 2 cm depth, while other latent heat materials such as oil showed a 37% increase. The functioning of these materials is illustrated in Figure 3.

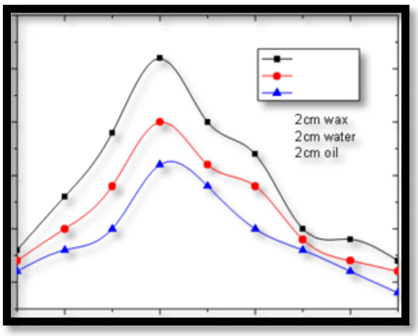

Figure 3: Effect of latent heat materials on different water depths in reflector attached still

3.3 Impact of Porous Materials on Still Productivity

Porous materials facilitate faster evaporation by wicking water to the glass cover for condensation. Experiments used sponges and cotton, cut into 100 mm x 70 mm pieces. Wicking increased evaporation rates, resulting in a 34% improvement with sponges, 28% with porous cloth, and 21% with cotton at 2 cm depth (see Figure 4).

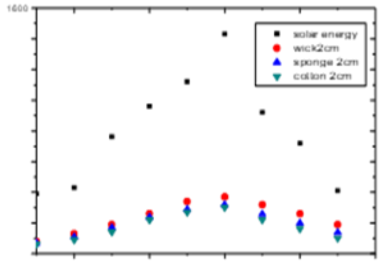

Figure.4 Effect of porous materials in reflector attached still

4. Python programme for analysis

```
# Constants
sigma = 5.67e-8  # Stefan-Boltzmann constant (W/m^2K^4)
epsilon_w = 0.9  # Emissivity of water
epsilon_g = 0.9  # Emissivity of glass
hfg = 2.26e6     # Latent heat of vaporization (J/kg)
hc_bw = 135      # Convective heat transfer coefficient between basin and water (W/m^2K)
Ub = 14          # Heat loss coefficient (W/m^2K)
h_c_wg_base = 0.884
h_c_wg_coeff = 268.9e3
epsilon_eq = (1/epsilon_w + 1/epsilon_g - 1)**-1
h_e_wg_const = 16.273e-3
V = 2.0          # Wind speed (m/s) for example
h_c_g_sky_base = 2.8
h_c_g_sky_coeff = 3.0

# Given values (example values, replace with actual values)
Ab = 1.0       # Area of the basin (m^2)
Aw = 1.0       # Area of water (m^2)
Ag = 1.0       # Area of glass (m^2)
Ta = 25.0      # Ambient temperature (°C)
Tsky = Ta - 6  # Effective sky temperature (°C)
Tg_initial = 35 # Initial glass temperature (°C)
Tw_initial = 50 # Initial water temperature (°C)
Tb_initial = 40 # Initial basin temperature (°C)
dt = 1         # Time step (hours)

# Define temperature arrays
Tb = Tb_initial
Tw = Tw_initial
Tg = Tg_initial
```

```
# Function to calculate heat transfer coefficients
def calc_hc_wg(Tw, Tg):
   P = 101.325  # Atmospheric pressure in kPa
   return h_c_wg_base * ((P - 0) * (Tw + 273.15) ** (1/3)) / ((Tw - Tg) + 0.5 * (Tw - Tg))
def calc_hr_wg(Tw, Tg):
   return epsilon_eq * sigma * (((Tw + 273) ** 2 + (Tg + 273) ** 2) / (Tw + Tg + 546))
def calc_h_e_wg(Tw, Tg, pw, pg):
hc_wg = calc_hc_wg(Tw, Tg)
   return h_e_wg_const * hc_wg * (pw - pg) / (Tw - Tg)
def calc_hc_g_sky(V):
   return h_c_g_sky_base + h_c_g_sky_coeff * V
def calc_hr_g_sky(Tg, Tsky):
   return epsilon_g * sigma * (((Tg + 273) ** 4 - (Tsky + 273) ** 4) / (Tg - Tsky))
# Loop for time steps
def update_temperatures():
   global Tb, Tw, Tg
   # Calculate heat transfer rates
hc_wg = calc_hc_wg(Tw, Tg)
hr_wg = calc_hr_wg(Tw, Tg)
h_e_wg = calc_h_e_wg(Tw, Tg, 1.0, 1.0)  # Example values for pw and pg
   # Energy balances
Qc_b_w = hc_bw * Ab * (Tb - Tw)
Qloss = Ub * Ab * (Tb - Ta)
Qc_w_g = hc_wg * Aw * (Tw - Tg)
Qr_w_g = hr_wg * Aw * (Tw - Tg)
Qe_w_g = h_e_wg * Aw * (Tw - Tg)
Qr_g_sky = calc_hr_g_sky(Tg, Tsky) * Ag * (Tg - Tsky)
Qc_g_sky = calc_hc_g_sky(V) * Ag * (Tg - Tsky)
   # Update temperatures based on energy balances
dTb = (Qc_b_w - Qloss) / (Ab * 1.0)  # Assume a specific heat capacity of 1 J/kgK for
simplicity
dTw = (Qc_b_w - Qc_w_g - Qr_w_g - Qe_w_g) / (Aw * 1.0)  # Assume specific heat
capacity of water = 1 J/kgK
dTg = (Qc_w_g + Qr_w_g + Qe_w_g - Qr_g_sky - Qc_g_sky) / (Ag * 1.0)  # Assume
specific heat capacity of glass = 1 J/kgK
   Tb += dTb * dt
   Tw += dTw * dt
Tg += dTg * dt
# Update temperatures for each time step
for _ in range(24):  # Simulating for one day
```

```
update_temperatures()
    print(f"Hour {_ + 1}: Tb = {Tb:.2f} °C, Tw = {Tw:.2f} °C, Tg = {Tg:.2f} °C")
# Efficiency calculation (assuming average solar radiation and latent heat)
Ig = 800  # Example average solar radiation (W/m^2)
m = 0.05  # Example mass of condensate (kg)
efficiency = (m * hfg) / (Ab * Ig)
print(f"Daily Efficiency: {efficiency:.2f}")
```

5. Conclusion

This study evaluated the performance of a single-basin solar still with a concentrator and heat exchanger using various materials. Key findings include:

- The concentrator-style still achieved higher productivity, though dependent on solar radiation, which varies throughout the day.
- A shallower water depth (2 cm) led to higher productivity compared to deeper depths.
- Sensible heat storage materials significantly enhanced productivity.
- The use of latent heat materials increased production by 52%, while porous materials improved evaporation rates by up to 31%.
- Python program model is created to check with experimental data.

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