Effect of colour and Al_2O_3 nano particles on the efficiency of the solar still

[1]Prem Shankar, [1]Raghvendra Sharma, [1]Dr.BhupendraGupta,
[2]Dr. Hemant Parmar
[1]*Department of Mechanical Engineering, Jabalpur Engineering College, Jabalpur, India*
[2] *Ujjain Engineering College, Ujjain, India*

Abstract

Solar energy is an unconventional source of energy which may be utilisedfor water purification. Portable water accessibility by the whole mankind is still difficult. In this paper a new kind of still, painted in white from inside is analysed. Nano particles(Al_2O_3) were also added to the basin water to increases heat transfer and the productivity. The distillation performance experimentation has been conducted at the Jabalpur Engineering College, Jabalpur India (23° 10' N, 79° 59' E). The performance of proposed still has been compared with conventional still of same dimensions. The conventional still with blackened inside surfaces yields 2605 ml/m^{2}and the proposed still produces 3258 ml/m^2 in a day. Hourly efficiency of both still has been also compared in this paper.

Keywords: Water desalination; Solar still; white painted side walls; nanoparticles Al_2O_3; efficiency.

1. Introduction

More than 97% of the earth's water is salty and around 2.6% water is fresh water. Uneven distribution of fresh water is such that less than 1% fresh water is within human reach [1]. A single basin vacuum solar still made up of copper sheet has been fabricated by Gnanadason et al. [2]. The distilled water production rate in single basin copper solar still has been compared with and without nanofluids. They concluded that addition of nanofluids in the basin water increases yield up to 7.5 l/day.Suneesh et al. [3] have fabricated a "V" type solar still with a Cotton Gauze Top Cover Cooling (CGTCC) and experiment with and without air flow over the glass cover. In this new design solar still, due to CGTCC, distribution is even and distillate output increased to 4300 ml/(m^2-day). With CGTCC and air flow, it further increased to 4600 ml/(m^2-day).Panitapu et al. [4] have improved the productivity and efficiency of solar still by using Titanium Oxide as a nano-material and have reported the variations in temperatures of basin water, glass outer surface, glass inner surface due to presence of titanium oxide in basin water.

Tenthani et al. [5] have experimented on two conventional stills with internal surfaces of their walls were painted in different colours while having the identical construction. One was painted in black and other in white. It was found that the average daily distillate outputs were 2.55 kg/m^2 and 2.38 kg/m^2 for the white painted still and conventional black painted still.Kumar et al. [6] have carried out performance analysis of solar still and result obtained is verified by developing MATLAB model. They have taken different depth of basin water as 5cm, 10 cm and 15 cm for inclination of glass cover at angle of 23^0 and 30^0 respectively. They concluded that yield was greater for low water depth at angle of inclination of 30^0.Sharma et al. [7] have evaluated performance of a solar still using water film cooling over the glass cover and mixing CuO with basin water in their experimental work. They have concluded that conventional solar still yield 1906 ml/ (m^2-day) while solar still fitted with sprinkler to reduce glass temperature, yields 2765 ml/ (m^2-day). Finally, production of experimental solar still with sprinkler & nanoparticles increased to 3485 ml/ (m^2-day).

Kabeel et al. [8] have studied the effect of integrating solar still with external condenser and adding $Al_2O_3$to basin water. They have observed that external condenser alone increases the distillate water yield by 53.2% while adding Al_2O_3 additionally increases the productivity by 116%. Al_2O_3 alone increases productivity by 76% when condenser fan is switched off.Sharma et al. [9] have reviewed different methods for increasing productivity of solar still by enhanced condensation. Sakthivel and Shanmugasundaram [10]have added black granite gravel of size 6 mm as storage medium in the single basin solar still and analysed the effect. They concluded through their experimentation that still yield was increased by 17-20% comparatively.Some other methods like using wick was also proposed by researchers [11] but again these were not popular due to low productivity.

Dutt at el. [12]have investigated the effect of adding dyes in basin water and concluded that addition of dyes increases the daily yield and efficiency of the system about 10%. Kumar et al. [13]have experimented on double basin solar still and concluded that due to better utilization of latent heat of vaporization it gives better performance than the single basin still. Tiwari and Suneja [14]have fabricated and experimented with an inverted absorber solar still. Theyconcluded that inverted absorber solar still gives about double output of the conventional still.Sindal et al. [15] have used CuO nanoparticles as photocatalyst and concluded that productivity as well as quality of the raw water increases to remarkable extent.

A large number of modification has been proposed but either they have low productivity or more expensive. In this context, sidewalls of a still have been painted in white and then nanoparticles were added to basin water. The productivity and efficiency of the proposed still has been compared with conventional still in this paper.

2. Materials and Methods

2.1 Experimental Setup

Two single slope solar still with basin area 1 m^2 (1m ×1m) has been fabricated. Sidewalls of one of the still have been painted in white and other in black. Base of both stills were painted in black. Completely blackened still from inside (Figure 1) is conventional still while other with white sidewalls (Figure 2) is modified still. The height of front and back walls of both stills are 21 cm and 63 cm respectively. Basins were made up of 1 mm thick grey cast iron sheet and insulated with 10 mm thick thermo-col sheet. Both stills were supported by 10 mm thick plywood from outside. The basin was covered at top by 4 mm thick glass. The glass was tilted about 23^0which is the latitude of Jabalpur city. Both stills were placed facing towards south in such a manner that solar light incidents continuously during sunshine. Temperatures at various points were recorded with the help of K-type thermocouple (least count of 1^0C), attached to a digital display (Figure 3). A solar power meter (range 0-2000 W/m^2) was used to measure instantaneous solar radiation at glass surface.

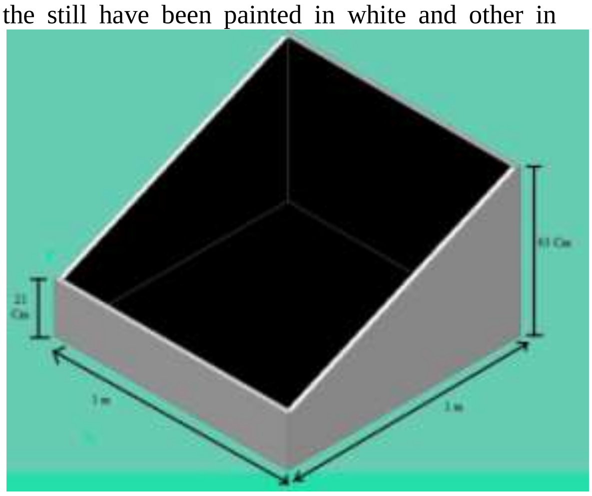

Figure1: Perspective view of conventional solar still

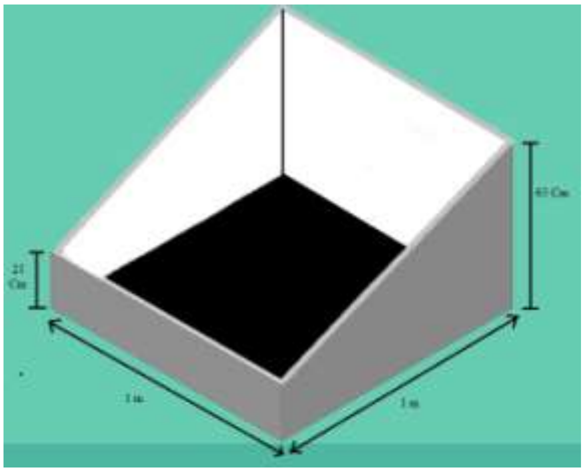

Figure 2: Perspective view of modified solar still

Figure3: Experimental setup of White painted (modified) and Black painted single slope solar stills

2.2 Observations

Experiments have been performed at Jabalpur Engineering College, Jabalpur (23^0 10' N, 79^0 59' E), India in month of April 2015. Various parameters as water temperature, vapour temperature, glass inside and outside surface temperatures were measured on hourly basis during sunshine. The distillate (yield) was measured hourly during sunshine and collectively at next day morning for whole night. Both stills were filled up with water up-to the depth of 5 cm before sunshine. Nanoparticles were added to the modified white painted solar still and stirred properly for proper mixing. It increases the heat transfer characteristics of the fluid and consequently evaporation rate increased. Water gets evaporated and vapours get condensed on the inside glass surface. This experiment explores the effects of adding nanoparticles on different parameters in white painted solar still.

2.3 Numerical computation:

Hourly efficiency as well as overall efficiency describes the performance of solar still. Hourly efficiency describes the performance of solar still for each hour while overall efficiency shows the effectiveness of solar still for a day. Efficiencies are measured by applying the relations given below.

$$\eta_{hourly} = \frac{m*L}{I*A*3600} \quad (1)$$

$$\eta_{overall} = \frac{\sum m*L}{\sum I*A*3600} \quad (2)$$

Where,

$L = [2.4935*10^6*(1-9.4779*10^{-4}*T_v+1.3132*10^{-7}*T_v^2-4.7974*10^{-9}*T_v^3)]$

for $T_v < 70^0C$ *[16 Tiwari and Tiwari].*

3. Results and Discussion

Water purification using solar energy works on natural principle of raining. Water inside basin get heat and converted into vapour utilizing the thermal energy. Nanoparticles present within the water enhance the rate of heat transfer as well as serves as heat storage medium. As a result the rate of evaporation increased in the still and more of the water present inside still get converted into vapour.Vapour is itself a greenhouse gas. It absorbs more and more solar energy with increasing evaporation. White painted sidewalls reflect solar light to the water. It will further increase the rate of evaporation.

Intensity of solar radiation varies from sunrise to sunset. Ambient temperature is a strong function of solar radiation. Both of them first increases and then decrease simultaneously. Solar intensity was maximum (878 W/m^2) at 12:00 hrs. Ambient temperature was highestduring afternoon. Hourly variations in solar intensity and ambient temperature are depicted in figure 5.

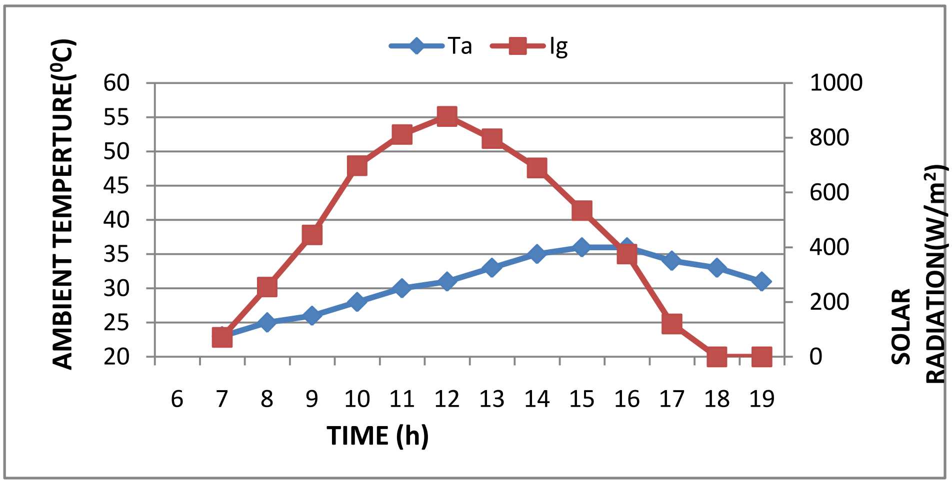

Figure 4: Hourly variation of ambient temperature with solar radiation

Various temperatures as basin water temperature, vapour temperature, glass inside surface and outside surface temperatures are strong function of solar intensity. As shown in Fig.5, for conventional solar still, temperatures at various points are varying with solar intensity. Water temperature rises with addition of solar energy in the still basin. Till after noon vapour traps solar energy as it is a greenhouse gas. In the evening there is lack of solar intensity and then energy stored within water itself transforms water into vapour. In conventional solar still solar energy is stored by bottom and sidewalls of basin and then it is supplied to basin water. Basin water get evaporated using this energy and it losses some of it energy to sidewalls during its upward movement.

In white painted still energy is absorbed by base and vapour generated using this energy is further heated by scattered light.White painted sidewalls scatter the solar light and more and more solar energy is available for vapour directly. In conventional still vapour losses its heat content to sidewalls and ultimately to atmosphere but on the other hand in modified still sidewalls provides energy to vapour. As shown in Fig.6, vapour temperature of modified still is nearer to glass inside surface temperature. It shows the loss reduction in modified still.

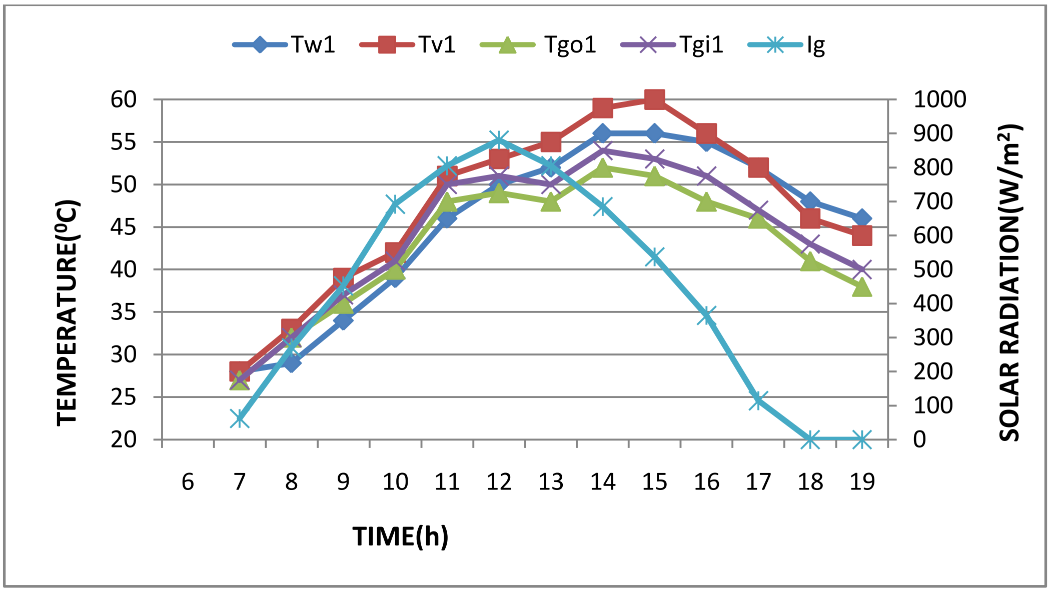

Figure 5: Hourly variation of various temperature with solar radiation for conventional still

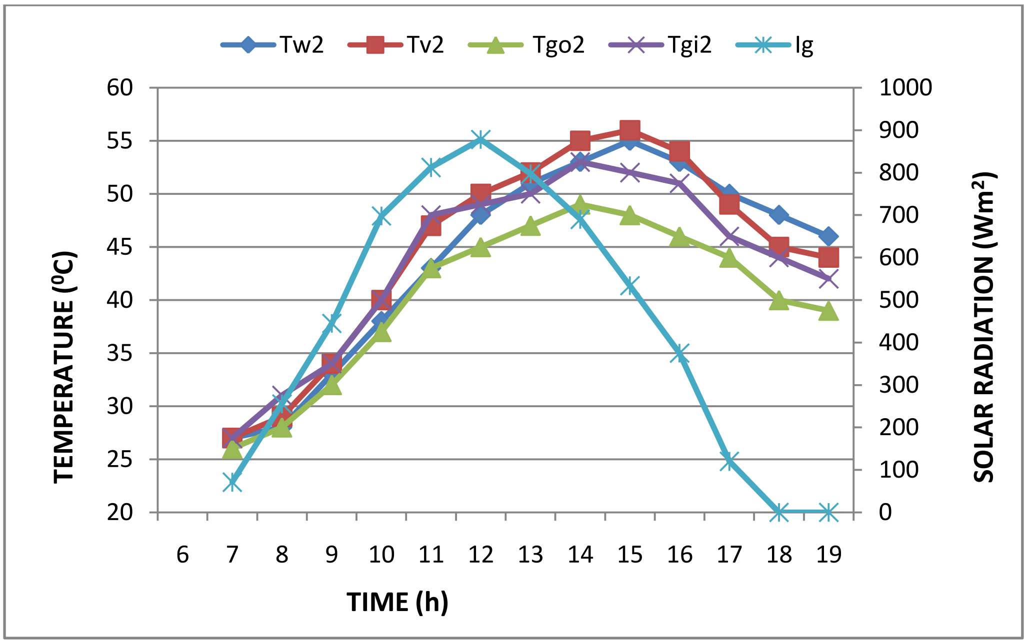

Figure 5: Hourly variation of various temperature with solar radiation for modified still

In this experiment Al_2O_3 nanoparticles were mixed properly with basin water for enhanced evaporation. Nanoparticles enhanced the heat transfer by increasing surface area. They also work as storage medium and provide sufficient energy during night for yielding. White painted sidewalls and mixing of nanoparticles collectively enhances the yielding of modified solar still. Figure 7 shows the hourly variation of yielding from both of still. Modified still provides better yield than that of conventional still. Hourly efficiency of both stills are compared in Figure 8, and it implies that modified still with nanoparticles has better utilization of solar energy.

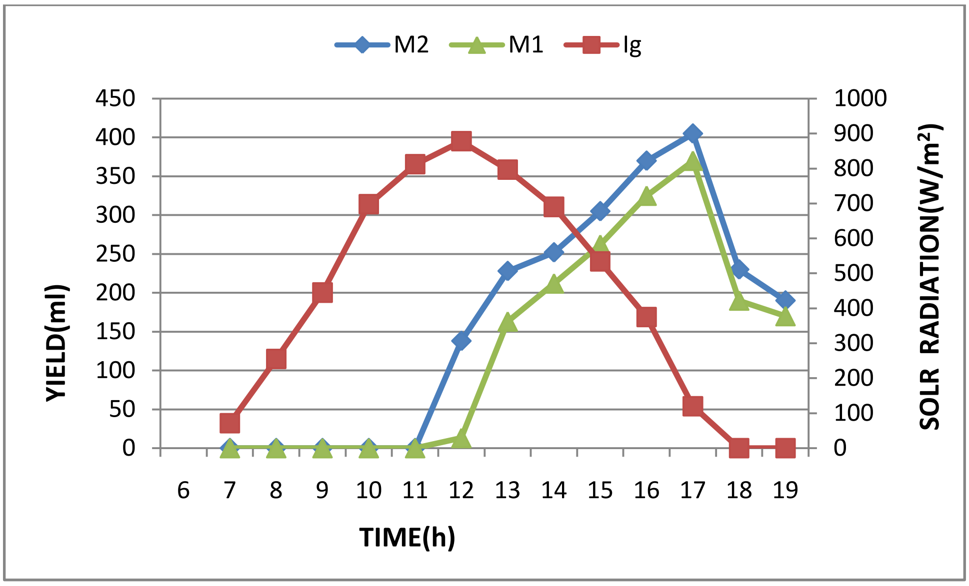

Figure 6:Hourly variation of distillate of both still with solar radiation

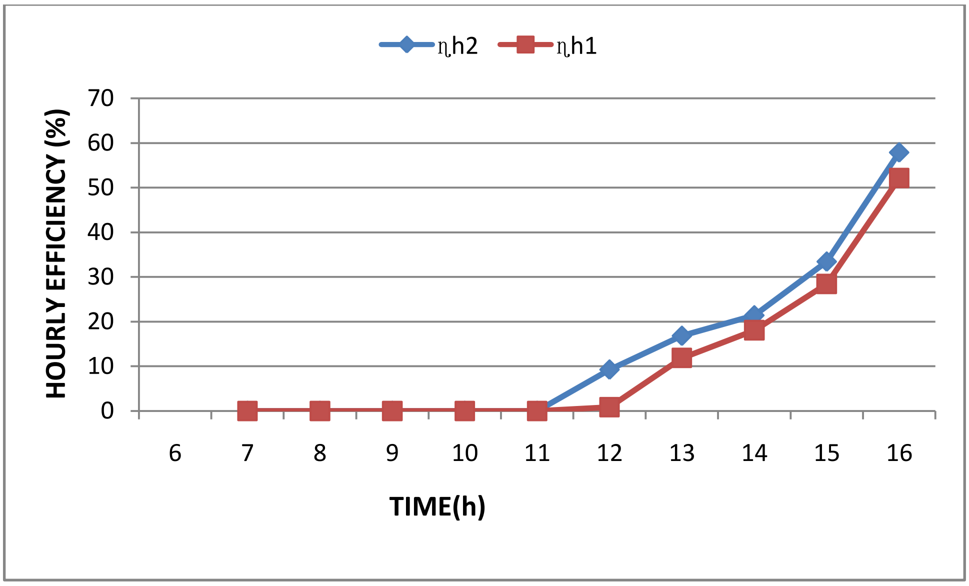

Figure 14: Variation in hourly efficiency for both still

4. Conclusions

Pure drinking water is essential for the whole mankind. The experimentation has been done with two different kinds of solar stills and then analysed critically to following conclusions:-

- White painted solar still with added nanoparticles gives 3258 ml/m^2 of fresh water while conventional still gives 2605 ml/m^2, which is 25% more than conventional still.

- Hourly efficiency of each still is also calculated and it shows that modified still has better efficiency at each hour.
- Difference between glass inner surface temperature and vapour temperature of both still respectively implies that there was reduction in losses to atmosphere in modified still as compare to conventional still.
- Nano particles (Al_2O_3) added in basin water increases the productivity of still by providing stored energy to water for evaporation after sunset.

Nomenclature

T_a = Ambient temperature, ^0C
T_w = Water temperature, ^0C
T_v = Vapour temperature, ^0C
T_{gi} = Inside glass surface temperature, ^0C
T_{go} = Outside glass surface temperature, ^0C
I_g = Solar radiation, W/m^2
M = distillate output, Kg
η_h = Hourly efficiency
η_o = Overall efficiency
A = Area of glass, m^2

References

[1]. G.N. Tiwari, H.N. Singh, Rajesh Tripathi. "Present status of solar distillation". Solar Energy 75 (2003) 367-373.
[2]. M. KoilrajGnanadason, P. Senthil Kumar, G.Jemilda, S.Sherin Jasper. "Effect of Nano fluids in a Modified Vacuum Single Basin Solar Still". International Journal of Scientific & Engineering Research Volume 3, Issue 1, January-2012.
[3]. P.U. Suneesh, R. Jayaprakash, T. Arunkumar, D. Denkenberger. "Effect of air flow on "V" type solar still with cotton gauze cooling". Desalination 337 (2014) 1–5.
[4].BhramaraPanitapu, VijayaKoneru, Sri LalithaSwathiSagi, Ajay Parik. "Solar Distillation Using Nano-Material". International Journal of Scientific Engineering and Technology, Volume No.3, Issue No.5, pp: 583-587.
[5]. C. Tenthani, A. Madhlopa, C. Z. Kimambo. "Improved Solar Still for Water Purification". Journal of Sustainable Energy & Environment 3 (2012) 111-113.
[6]. Dinesh Kumar, Patel Himanshu, Zameer Ahmad. "Performance Analysis of Single Slope Solar Still". International Journal of Emerging Technology and Advanced Engineering Volume 3, Issue 3, March 2013.
[7].Raghvendrasharma, Prem Shankar, BhupendraGupta, Brahman Singh Bhalavi. "Effect of glass temperature and nano particles (CuO) on performance of single basin solar still: An experimental study". International Research Journal Sustainable Science & Engineering. Volume 3, Issue: 9, 2015.
[8].A.E. Kabeel, Z.M. Omara, F.A. Essa. "Enhancement of modified solar still integrated with external condenser using nanofluids: An experimental approach". Energy Conversion and Management 78 (2014) 493–498.
[9].Raghvendrasharma, Prem Shankar, Bhupendra Gupta, Brahman Singh Bhalavi. "Different methods to increase condensation effect of solar still: A detailed review". International Research Journal Sustainable Science & Engineering. Volume 3, Issue: 9, 2015.
[10]. Sakthivel M. Shanmugasundaram S. Effect of energy storage medium (black granite gravel) on the performance of a solar still. International journal of energy research 2008; 32(January 1):68-82.
[11]. Tiwari G.N, Sharma S.B, Sodha M.S. Performance of a double condensing multiple wick solar still. Energy Conversion and Management 1984; 24(2): 155-159.
[12]. Dutt D.K, kumar Ashok, Anand J.D, Tiwari G.N. performance of a double basin solar still in the presence of dye. Applied Energy 1989; 32(3):207-23.
[13]. kumarAshok, Anand J.D, Tiwari G.N. Transient analysis of a double slope double basin solar distiller. Energy Conversion and Management 1991; 31(2):129-39.
[14]. Tiwari G.N., Suneja Sangeeta. Performance evaluation of an inverted absorber solar still. Energy Conversion and Management 1998; 39(3-4):173-80.
[15]. SindalManisha, Singh Narendra, Sharma Ajay. Use of Cupric Oxide as Photo catalyst in Solar Desalination. International Journal of Green and Herbal Chemistry 2013; 2(2):203-07.
[16].Tiwari G.N, Tiwari A.K. Effect of the condensing cover's slope on internal heat and mass transfer in distillation: an indoor simulation. Desalination 180 (2005):73-88.