ENERGY AND EXERGY ANALYSIS OF ACTIVE SOLAR STILLS USING COMPOUND PARABOLIC CONCENTRATOR

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Abstract - *The numeral (N) of alike slightly photovoltaic thermal (PVT) compound parabolic concentrator (CPC) water collectors(aggregator) integrated with solar stills which is also called PVT-CPC active solar filtration(distillation) system(apparatus) analysis over gorge(basin) type which having sole and dual incline. In New Delhi weather condition the analysis is carried out for the solar filtration system for the given gorge size. In the experiment we are evaluate various efficiency, productivity of the system, work duration cost estimation, exergoeconomic and enviroeconomic parameter. Energy payback duration is considered for sole and dual incline PVT-CPC active solar filtration apparatus for estimation of work duration cost (LCCA), thermal model developed for the analysis of LCCA. For this analysis we has to determine the annual yield, factor of energy generation, at the 5 % of interest rate the cost of water production, energy payback time (EPBT), perfect numeral of collector, discharge of mass from the system and the gorge size and its water deepness. The system developed is self sustainable and during sunshine hours of the day on commercial level it can fulfill the portable water requirement and also DC electrical power.*

Key Words: **Eenegy[1], Exergy[2], LCCA[3], EPBT[4], Power[5]**

1. INTRODUCTION

For remote area to provide and overcome with the crisis of potable water supply the solar distillation system is the best option because it is economical, does not produces any inverse effect on the environment easy to maintain and also during day time when sunshine it provide DC power supply, its technology is simple and also easy to design and fabricate. It is function in feedback loop that is the only difference with natural hydrological otherwise it can say as the xerox copy of the natural hydrological cycle. This technique is used to provide the potable water to the remote area by cleaning the saline or brackish water, for this purpose it can use solar still which is a solar equipment.

Rai and Tiwari [1] first time they made research on the forced mode active solar distillation study theoretically and compare his result with the conventional solar still system and found that there is higher yield daily. Zaki et al. [2] first time they made research on the natural circulation mode active solar distillation study and compare his result with the conventional solar still and they found that natural circulation mode having boost up in yield. Lawrence and Tiwari [3] get the big break through in the solar distillation system by the help of the theoretical result they success to developed an empirical relation for internal heat transfer coefficient. Hamadou and Abdellatif [4] studied the solar still as the cost is one of the big factor in any research both the research able to develop an optimum design in the area of solar filtration apparatus. Tripathi and Tiwari [5], performed there research on solar distillation in the some different mode they varies the basin water depth and find the result on its effect over the internal heat and the mass transfer and provided the result that there is effect on the heat transfer convective is varies by varying the water depth, in addition to this they provided a great break through result that during off sunshine the heat transfer convective is greater than the sunshine heat transfer because of the high heat content of water mass on the given water deepness. Kumar and Sinha [6] has performed his research with the help of cylindrical parabolic collector which is integrated with the double slope solar distillation system and he got his result and compare his result with the flat plate collector.

From the above result some researcher conclude that. The system become self sustainable due to this the arrangement got the biggest advantage that is by the help of PV module the electricity produces is having higher value and also the temperature is lower.

Kern and Russell [7] during his research work he got the biggest break through and first time they develop PVT. Gordes et al. [8] during his research study they build a system in which they used PVT-CPC collectors integration and after the research he give the conclusion that there is increase in efficiency and reduction in the quantity of PV cells. Saeedi et al. [9] have done his research study and able to obtain the perfect numeral of aggregator(collector) and the mass discharge. Tripati et al. [10] during his study over the series connection of N-alike slightly shelter PVT-CPC water aggregator and provided the relation equation between them, and this is the first time the solar stills linked with N alike slightly shelter PVT-CPC water aggregator having gorge type research work is done. For the given deepness of water and perfect numeral of plate and mass discharge the calculation is done for the different parameters, they are namely exergoeconomic parameters, enviroeconomic parameter, energy matrices, productivity and various efficiencies have been evaluated Desh Bandhu Singh [11].

2. LITERATURE REVIEW

Della porta [12] in the 16th century used the inverted earthen pots to perform his research over the solar distillation system hence we can say that by seeing this it is not the new process. The first document on the solar distillation research was found in Arab alchemists (Mouchot, 1969). In (1991) the first time the collector plate is used in the solar still apparatus by Tiwari and Dhiman and on his experiment. In Saeedi et al.[9] used simulation technique.

As per there use and purpose the solar still is divided into two type active and passive still. For active solar filtration, to climb up the temperature of gorge water we need to add some heat energy from the outside medium. Due to the climb up of temperature the conversion rate of water into vapors is also climb and we obtained more amount of pure water. In the active solar still there are two type one is high temperature filtration still and second is nocturnal filtration still. If in the active solar still if the heat exchanger is used to provide the thermal energy to the gorge water directly or with some other means this type is known as active high temperature solar still filtration. To increase the gain which is obtain by the system they integrate the solar filtration apparatus with collector due to this there is decrease in thermal loss. But after the research the researcher told that there is the limitation on the area if the area increased more then for the same water deepness there is heat storage capacity is large and due to this there is reduction in the gross thermal efficiency and the daily yield. The solar still with heat exchanger and tracking concentrator the researcher got the result and compare this result with the conventional solar still system and give conclusion that there is climb in productivity.

3. EXPERIMENTAL SETUP

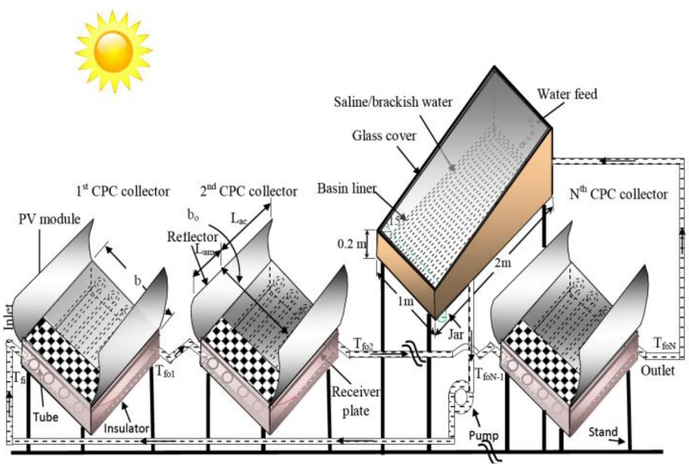

Fig1: Schematic diagram of sole incline PVT-CPC active solar filtration apparatus

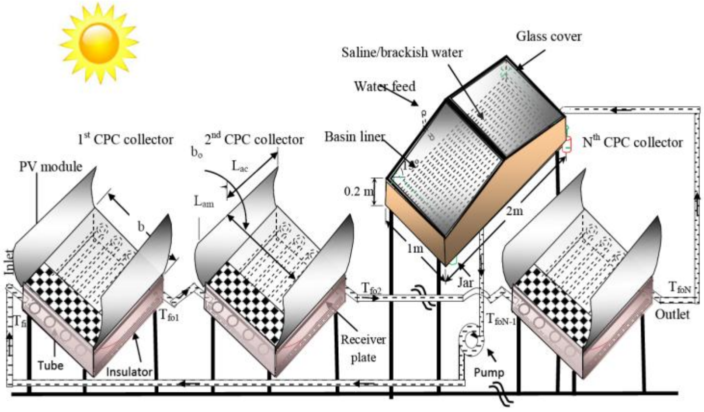

Fig- 2: Schematic diagram of dual incline PVT-CPC active solar filtration apparatus

Fig1& 2 shows the sole and dual incline energy and exergy analysis of active solar stills using compound parabolic concentrator diagram respectively. In the system N alike CPC water collectors which is slightly shelter upto 25% are used. PVT used of size 0.25 m × 1 m and placed below side of collector. Collector are arranged in series connection. The CPC collector having parabolic shape are coated by aluminum. 30°inclination is made by the PVT-CPC water collectors with horizontal surface to receive the solar radiation maximum. Gorge size of 2 m × 1 m is integrated with the sole and dual incline active solar still which is created by a composite material of glass reinforced plastic. 15°inclination is made by a clear glass cover with the horizontal surface which is known as the condensing surface. The side and inner bottom of the wall is made black because the black surface having maximum absorbing property.

3.1 THEORETICAL ANALYSIS

The theoretical analysis is based on energy balance equations between sole and dual incline PVT-CPC solar filtration and the water gorge.

Equation which is related to Sole incline solar still is

Water mass in the gorge is

$$\dot{Q}_{uN} + \acute{\alpha}_w I_s(t) A_b + h_{bw}(T_b - T_w)A_b = h_{1w}(t_w - t_{gi})A_b + M_w c_w(dt_w/dt) \quad (1)$$

Equation which is related to Dual incline solar still is

Water mass in the gorge is

$$(M_wC_w)(dT_w/dt)=(I_{SE}(t)+I_{SW}(t\acute{\alpha}_w \quad (A_b/2)+h_{bw}(T_b-T_w)A_b-h_{1w}(T_w-T_{giE})(A_b/2)-h_{1w}(T_wT_{giE})(A_b/2)+\dot{Q}_{uN} \quad (2)$$

The total thermal energy (E_{out}) of PVT-CPC solar filtration is given as

E_{out}= {(M_{ew}×L)/3600} + {(P_m-P_u)/0.38} (3)

For sole incline and dual incline PVT-CPC active solar filtration apparatus the exclusive annually exergy gain($G_{ex,annual}$) is determine by

$G_{ex,annual}$ = Ex_{out} + (P_m – P_u) (4)

Energy payback time (EPBT)

It is defined as the ration of Energy exhausted due to the consolidate part to the annual energy output.

On premise of energy EPBT = Consolidate part energy(E_{in})/ Annual energy output(E_{out}) (5)

On premise of exergy EPBT = Consolidate part energy(E_{in})/ Annual exergy output($G_{ex,annual}$) (6)

Energy production factor (EPF)

It is used to represent the system execution, it is defined as the ratio of the obtained to supply energy.

EPF on energy premise = E_{out}/E_{in} (7)

EPF on exergy premise= $G_{ex,annual}$/E_{in} (8)

Life cycle conversion efficiency (LCCE)

Form PVT-CPC active solar distillation system net output for its complete life time estimation the total solar radiation come over it is expressed in term of LCCE.

LCCE on energy premise={(E_{out}×n)– E_{in}}/(E_{sol} × n) (9)

LCCE on exergy premise= {($G_{ex,annual}$ × n)– E_{in}}/{(annual solar exergy) × n} (10)

Exergoeconomic analysis

For PVT-CPC active solar filtration apparatus on the premise of exergy gain, the exergoeconomic parameter ($R_{g,ex}$), is given as

$R_{g,ex}$ = $G_{ex,annual}$/UAC (11)

Similarly, for sole and dual incline PVT-CPC active solar filtration apparatus, on the premise of output gross energy for exergoeconomic and it is given as

$R_{g,en}$ =E_{out}/UAC (12)

Enviroeconomic analysis

The CO_2 emission reduction is the parameter to determine the enviroeconomic analysis, in this analysis we can calculate the environmental cost.

C_{CO2} = C_{CO2} × X_{CO2} (13)

Productivity(η_p) analysis

Productivity is used to correlate between the input and output. Our aim is to increase productivity it means to increase the output by the given input by considering different factors.

(η_p)= [{M_w×$(SP)_w$}+{E_e×$(SP)_e$}/{UAC}]×100 (14)

Overall exergy efficiency

For sole and dual incline PVT-CPC active solar filtration apparatus, the addition of electrical exergy and thermal exergy provides us the value of overall exergy, and it's exergy daily efficiency is given as

$\eta_{daily,overallexergy,s}$=$[\sum_{t=1}^{24}\{\dot{E}x_{out,s}(t)+(\dot{E}x_e(t)\dot{p}_u(t)\}]/[0.933\times \sum_{t=1}^{24}\{(A_b\times I_s(t)+(A_{am}+A_{ac})\times N\times I_b(t)\}]\times 100$ (15)

$\eta_{daily,overallexergy,d}$=$[\sum_{t=1}^{24}\{\dot{E}x_{out,d}(t)+(\dot{E}x_e(t)\dot{p}_u(t)]/[0.933\times\sum_{t=1}^{24}[\{(A_b/2)\times(I_{SE}(t)+I_{SE}(t))\}+(A_{am}+A_{ac})\times N\times I_b(t)]]\times 100$ (16)

Overall thermal efficiency

For sole and dual incline PVT-CPC active solar filtration apparatus, the thermal daily efficiency gross can be determine and it is expressed as

$\eta_{daily, overall thermal, s}$ = $[\{\sum_{t=1}^{24}(\dot{m}_{ew}\times L)\} / \{\{\sum_{t=1}^{24}\{(\dot{Q}_{uN}(t) + A_b\times I_s(t))\}\times 3600\} + [\{\sum_{t=1}^{24}(\dot{E}_{xe}(t) - \dot{p}_u(t))\} / \{\sum_{t=1}^{24}(0.38 \times A_{am}\times N\times I_b(t)\}]\times 100$ (17)

$\eta_{daily, overall thermal, d}$ = $[\{\sum_{t=1}^{24}\{(\dot{m}_{ew} + \dot{m}_{ew})\times L\}\} / \{\sum_{t=1}^{24}\{\dot{Q}_{un}(t) + (A_b/2)\ (I_{SE}(t) + I_{SW}(t)\}\times 3600\}] + [\{\sum_{t=1}^{24}(\dot{E}_{xe}(t) - \dot{p}_u(t))\} / \{\sum_{t=1}^{24}(0.38\times A_{am}\times N\times I_b(t)\}]\times 100$ (18)

4. RESULTS AND DISCUSSION

In the month of June and January for the collector of sole and dual incline PVT-CPC active solar filtration apparatus, Fig. (3), as per the expectation the yield value is reduced as the rate of mass flow is increase. It is due to water in the tube gets fewer period to engross heat because the rate by which water tube engross the heat transfer is increase and the N^{th} collector outlet temperature becomes lower as the increase in the dischargeof mass. Hence, we can conclude that the perfect discharge of mass is 0.04 kg/s, because upto this climb in temperature of working fluid is occur after this there is decrease in maximum temperature.

For sole and dual incline PVT-CPC active solar filtration apparatus the PVT electrical exergy monthly variation is shown in the Fig. (4). As per expectation for sole and dual incline PVT-CPC active solar filtration apparatus both systems having approximately the same value of electrical exergy, because in both cases the direction of orientation of PVT-CPC water collector are same.

Fig. (5), shows for sole and dual incline PVT-CPC active solar filtration systems average exergy daily efficiency disparity with the basin depth of water. From figure it is observed that upto 0.7 m deepness of water for sole and dual incline PVT-CPC active solar filtration apparatus the daily exergy efficiency increase but after 0.7 m of gorge water deepness this become constant approximately, therefore from graph we say that on the aspects of mean exergy efficiency the maximum at 0.7 m deepness of water. But at this depth the system become to bulky. From Fig. (6) for sole and dual incline PVT-CPC active solar filtration apparatus, it is used to represent the average daily variation of exergy efficiency in both the case. From figure it is observed that the value of photovoltaic module is approximately same for all depth of water in both the cases.

In Fig. (7) for sole and dual incline PVT-CPC active solar filtration apparatus, it is used for both the case to represent the mean of exergy daily efficiency overall disparity with the basin depth of water. From figure it is found that in both the case upto 0.7 m gorge water deepness the exergy efficiency increases and after 0.7 m its value become constant almost. Hence we can say for sole and dual incline PVT-CPC active solar filtration apparatus both the optimum deepness of water is 0.7 m, but at this depth the system become bulky. From Fig. (8), For sole and dual incline PVT-CPC active solar filtration apparatus represent the average daily disparity of gross thermal efficiency with basin water depth. From fig. we can find that upto 0.31 m of gorge deepness of water the dual incline performance is best than the sole incline PVT-CPC active solar filtration apparatus, where as when the gorge deepness of water is more than 0.31 m than sole incline start to perform better than the dual incline PVT-CPC active solar filtration system, it occur due to same variation in the thermal efficiency.

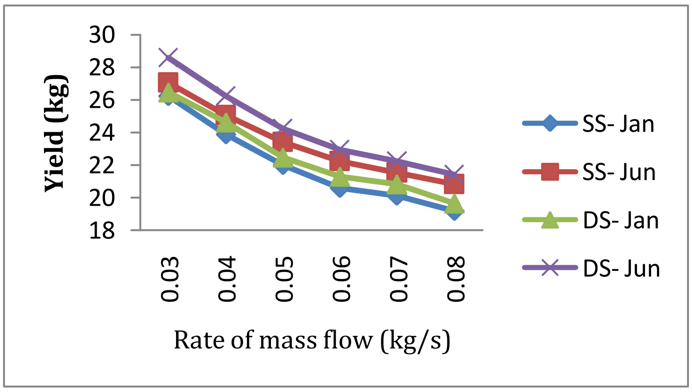

Fig. 3: For sole and dual incline slope PVT-CPC active solar filtration system hourly yield disparity for representative day in the month of June and January

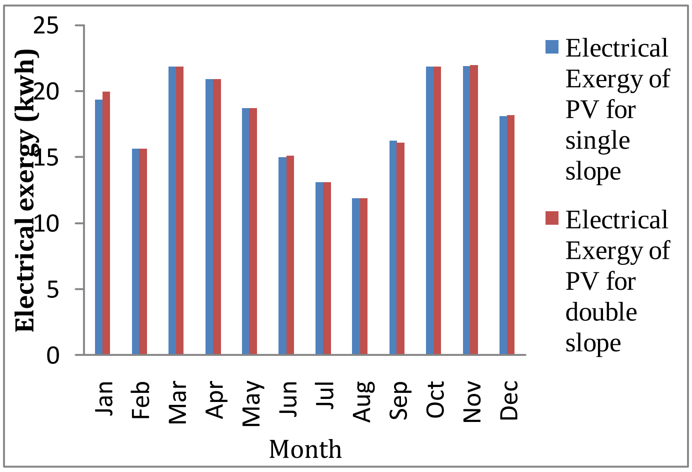

Fig.4: For sole and dual incline PVT-CPC active solar filtration systems electrical exergy of PVT monthly disparity

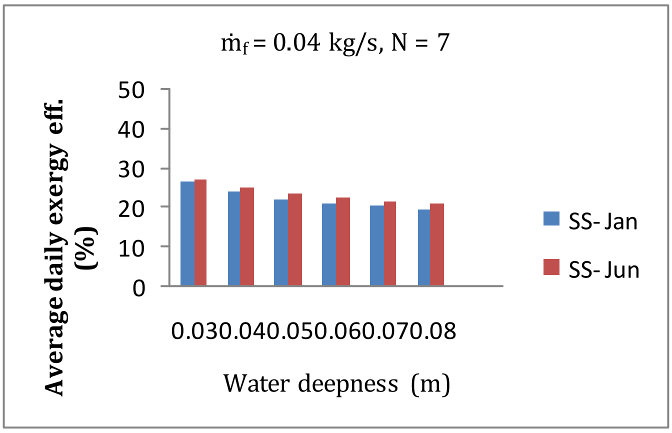

Fig. 5: For sole and dual incline PVT-CPC active solar filtration apparatus average daily disparity of gross exergy efficiency with the deepness of water

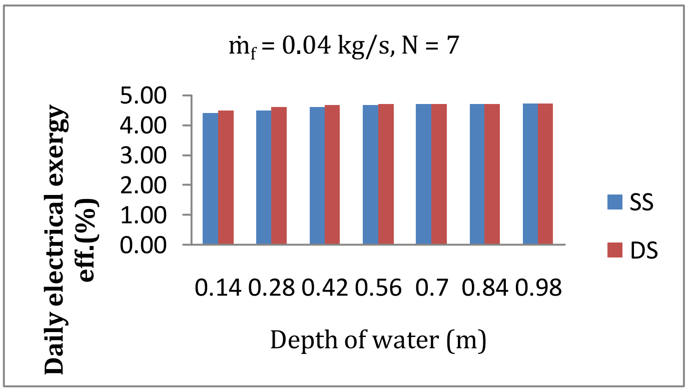

Fig. 6: For sole and dual incline PVT-CPC active solar filtration systems average disparity of day to day electrical exergy with deepness of water

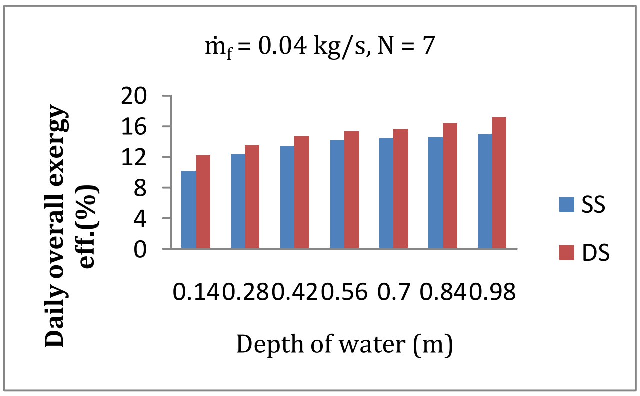

Fig . 7: For sole and dual incline PVT-CPC active solar filtration systems average daily disparity of overall exergy efficiency with the deepness of water

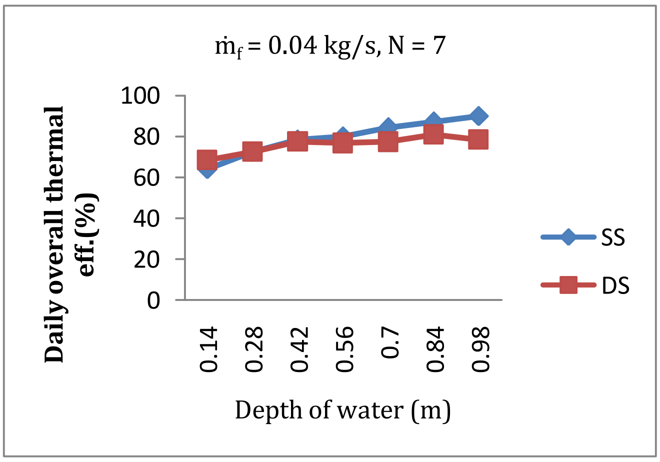

Fig. 8: For sole and dual incline PVT-CPC active solar filtration systems daily disparity of overall thermal efficiency with deepness of water

5. CONCLUSIONS

For the analysis of sole and dual incline PVT-CPC active solar filtration systems theoretically we can find that the change in life cycle cost analysis in energy matrices and its effect on payback period by incorporating energy. We analyzed Sole and dual incline PVT-CPC active solar filtration apparatus gorge type systems on the aspects of daily yield 0.04 kg/s, 7 and 0.74 are the perfect rate of mass discharge, optimum numeral of collectors and optimum depth of the systems respectively. But as the depth of basin water is 0.74 m the system will become bulky due to this we have further analyzed the system for its durability, feasibility and strength. As per analysis we find that for the deepness of gorge water less than 0.19 m the dual incline gives best performance than the sole incline PVT-CPC active solar filtration apparatus for the given rate of mass discharge and numeral of plate and vice versa for deepness more than 0.19 m.

For 0.14 m deepness of gorge water, the dual incline active solar filtration system is best than the sole incline active system because the value of exergy, energy and energy matrices is better for the given number of collector plate and rate of mass flow. On the aspects of EPBT there is loss or lower the value of exergy and energy for dual incline than sole incline PVT-CPC active solar filtration system by 17.98% and 7.5% respectively. Based on EPF the exergy and energy has been get higher value for dual incline than the sole filtration system by 12.72% and 5.12% respectively. Similarly based on LCCE we find that the higher value of exergy and energy by 22.223% and 5.557% respectively for dual incline than sole incline PVT-CPC active solar filtration apparatus. We have computed the value of water price production in ⍰/kg and gain of electricity cost in ⍰/kwh.

For the perfect rate of mass discharge and the numeral of collector plate at a depth of 0.14 m the value of overall exergy and thermal energy annually it is determined that the dual incline has higher value than the sole incline PVT-CPC active solar filtration apparatus by 12.79 % and 4.2% respectively. Similarly at 0.14 m gorge water deepness and lifetime of 50 year and rate of interest is 5%, based on the parameter of exergoeconomic parameter and enviroeconomic parameter the exergy obtained by dual incline is higher than the sole incline PVT-CPC active solar filtration apparatus by 16.09% and 21.48% respectively. Similarly at 0.14 m gorge water deepness 50 year life time cycle and rate of interest is 5%, the energy based on annual productivity obtained by dual incline is more than the sole incline PVT-CPC active solar filtration apparatus by 8.41%.

On considering the average daily productivity, overall exergyexergy, daily mean thermal energy and thermal efficiencies overall, the perfect usefulness of depth of water for gorge type sole and dual incline PVT-CPC active solar filtration apparatus is found to be 0.7 m. For the deepness of water lower than 0.31 m on considering daily mean thermal energy, daily mean productivity and thermal efficiency overall the dual incline perform better operation that sole incline PVT-CPC active solar filtration apparatus and if the gorge water deepness is found to high than 0.31 m than the performance of sole incline is best. From the above analysis we can find that as the depth of water increase, the overall energy, overall thermal energy, the productivity and the thermal efficiency overall of both sole and dual incline PVT-CPC active solar filtration systems will decrease.

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