

Identification of Optimum Operational Parameter Levels for Plain Basin, Corrugated Basin and Compartmental Basin Solar Stills

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Identification of Optimum Operational Parameter Levels for Plain Basin, Corrugated Basin and Compartmental Basin Solar Stills

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Abstract

This study aimed at optimizing or maximizing the distillate production in plain basin, corrugated basin and compartmental basin solar stills by integrating them with optimum level of the four operational parameters - **Mass of Heat Storage Material, Basin Water Depth, Basin Cover Thickness** and **External Mirror Position**. The efficiency of the parameters is not uniform and it differs from still to still due to variation in the structure of the basin. Further, the most efficient level in a parameter differs from still to still. A particular basin water depth which is highly productive in plain basin still may not suit well for corrugated or compartmental basin still. To find out the optimum parameter levels, the 4 operational parameters and the four levels of each parameter were combined as per L_{16} orthogonal array and the distillate production under different combination of operational parameter levels were analyzed using S/N ratio analysis, mean response method, analysis of variance and regression analysis. The analysis revealed that the optimum mass of heat storage material was 16 kg in plain basin, 12 kg in corrugated basin and 10 kg in compartmental basin still. The efficiency of corrugated basin and compartmental basin solar stills was maximum at a lower basin water depth of 15 mm and 10 mm respectively. But plain basin still efficiency was maximum at a higher basin water depth of 20 mm. The optimum basin cover thickness was 4 mm in all the solar stills, in spite of a difference in the structure of the basin. In the same way, the distillate production was maximum when the external mirrors were positioned on the two sloping sides of the solar still (east and west direction). The expected production from the solar stills integrated with the optimum parameter levels was estimated using regression analysis and mean response method. The average distillate production which was 3304, 3493 and 3629 ml/m².day in the modified (not with optimum parameter levels) plain basin, corrugated basin and compartmental basin solar stills respectively, improved to 6414, 7153 and 7629 ml/m².day respectively when they were modified with optimum parameter levels and the increase in production was 94 %, 105 % and 110 % respectively.

Keywords: Optimization, S/N Ratio, Mean Response, Regression Analysis, Taguchi Technique

1. Introduction

Clean potable water is the basic necessity for the survival and continuation of human race in this globe along with food and air. Providing safe drinking water to the people is emerging as a big challenge in underdeveloped and developing countries. Direct consumption of water available in lakes, ponds, rivers, sea and underground sources is not advisable because it may contain dissolved salts, heavy metals and harmful organism. But, pure and protected portable water can be produced from brackish and saline water through distillation and desalination. The existing desalination processes such as multi-stage flash evaporation, electro dialysis and reverse osmosis are energy intensive and costly. They depend on conventional energy sources (Hydrocarbon fuels) which produce negative impact on environment. The best alternative is solar distillation. It requires no extra energy other than solar radiation. It is cost free, pollution free and available in the site. It is suitable for remote arid and semi-arid zones where drinking water shortage is a major problem and solar radiation is high. The simplest form of solar distillation plant is a solar still. Solar stills are easy to fabricate and operate and their maintenance cost is also low. But the main drawback of solar distillation is that its initial investment cost is high and the productivity per unit area is low. To enhance the productivity of the solar still, various research works are being carried out till now. They improved the production capacity of the still by adopting different technologies under proper operational conditions.

The productivity of a solar still is directly related to the area of the absorber plate of the still. The corrugated basin and fin increase the heat transfer rate from the basin to water. Further, the compartments in the basin reduce the volume of water held within each compartment and help the water to reach high temperature level. **Mehrzad Feilizadesh et al. (2017)** investigated the effect of height, length and width of a solar still on its distillate production. Increasing the height of the still decreases the efficiency and extending the length increases the efficiency. For maximum annual efficiency, the width over length ratio is about 0.4. **Omara et al. (2016)** improved the productivity of the conventional solar still

by 55.36 % by placing corrugated plate in the basin of the still. **Alaian et al. (2016)** fabricated a pin-finned wick solar still and the productivity increased by more than 23 %. **El-Naggar et al. (2015)** constructed a single basin solar still with finned basin liner and the increase in heat transfer coefficient was 3.6 times higher, compared to the still without fins. **Kabeel (2009)** designed a solar still with concave base. The concave still design reduced the shading effect. **Zine Saadi et al. (2018)** found that the performance of stepped solar still was higher than the conventional solar still by 47.18 %, 62.73 %, 94.21 % and 104.73 % during spring, autumn, winter and summer respectively. **Velmurugan et al. (2009)**, **Abdullah (2013)** and **Alaudeen et al. (2013)** preferred stepped basin solar still over conventional still for better performance.

Heat storage materials receive and accumulate the thermal energy in sunshine hours and release it during off- sunshine hours. **Abdullah (2013)** used aluminum filling as thermal storage material and the productivity increased by 53 %. **Srithar et al. (2016)** used charcoal and river sand in the solar still and the production improved by 34.28 % and 25.71 % respectively. **Gaurav Raj et al. (2020)** used low cost materials like stone chips, sand stones and calcium oxide and the productivity increased by 19.18 %, 18.41 % and 26.98 % respectively. **Rajaseenivasan et al. (2016)** applied river sand, metal scrap and charcoal as heat storage material and achieved 26.74, 29.3 and 33.7 % respectively higher production. **Rajaseenivasan et al. (2014)** experimentally proved that black granite gravel significantly increased the night time production rate. **Panchal (2015)** used black granite gravel in a double basin solar still and the productivity increased by 9 %. **Kabeel et al. (2018)** found that the fresh water production is determined by mass of sensible energy material and depth of water maintained inside the basin. **Kalidasa Murugavel et al. (2010)** found $\frac{3}{4}$ inch sized quartzite rock as the most effective basin material.

The productivity of the solar still is significantly influenced by the basin water depth. The inverse relationship between water depth and productivity is well established in research works. **Mohammad Al- haraksheh et al. (2018)** decreased the basin water level from 10 cm to 5 cm and doubled the distillate production. **Morad et al. (2015)** found that increasing the brine depth from 1 to 3 cm decreased the system productivity from 1.15 to 1.07 L/m² h for passive solar still and from 1.59 to 1.42 L/m² h for active solar still. **Rajaseenivasan et al. (2016)** augmented the daily output of distillate from 3.12 to 3.25

Kg/day by reducing the water depth from 8 cm to 2 cm. **Rajaseenivasan and Srithar (2016)** concluded that stills at lower depth of water gives higher efficiency in all configurations. **Chang- Dae Park et al. (2016)** evaluated the effect of basin water depth on productivity and found that there was maximum production when the sea water level in the basin was 10mm. **Nafey et al. (2000)** and **Kabeel et al. (2012)** analysed the effect of basin water depth on distillate production and confirmed that there is inverse and proportional relationship between water depth and production. **Sampathkumar et al. (2013)** obtained maximum daily production of 7.03 and 3.225 Kg for active and passive solar stills respectively; when the basin water depth was 0.04 m. **Panchal et al. (2020)** concluded that the distillate output of tubular solar still is inversely proportional to the water depth.

The basin cover plate receives the solar radiation and transmits it to the still. It also receives heat from the basin and transfer it to the atmosphere. During this process, it allows the vapour to condense and pass it to the collecting tray. Hence the cover plate should be efficient to allow the energy flow in both the direction for the efficient operation of the still. **(Kalidasa Murugavel, 2008)**. **Morad et al. (2015)** found that increasing the basin glass cover thickness from 3 to 5 mm decreased system productivity from 1.63 to 1.36 L/m².h for active solar still. **Phadatare and Verma (2007)** achieved enhancement of distillate output when 4 mm thick plexiglass was used at 2 cm depth brine. **Abdulrahman Ghoneyem and Arif Heri (1997)** concluded that a solar still with 3 mm thick glass cover plate produced 16.5 % more distillate than 6 mm thick glass cover. **Kalidasa Murugavel (2008)** conducted experimental study on window glass of different thickness and found that the transmittance was indirectly proportional to the thickness of the glass.

Reflectors increase the solar radiation receiving rate of the basin by reflecting additional solar radiation into the still. Internal and external mirrors increase the basin water temperature and enhance the productivity. **Tanaka (2009)** fabricated a basin type solar still with internal and external reflectors and the productivity increased by about 70 % to 100 %. **Tanaka and Nakataka (2006)** modified the basin type solar still with internal and external reflectors and the increase in distillate production was around 48 %. **Tanaka (2013)** increased the distillate production in tilted wick solar still with the help of flat plate bottom reflector. **Joe et al. (2017a)** focused additional solar radiation into the still with the

help of external reflectors and the distillate production increased from 4333 ml/m².day to 5650 ml/m².day. **Joe et al. (2017b)** used external mirror in double slope solar still and the average daily efficiency achieved was 48.57 %. **Deshmukh Renuka and Kolhe (2016)** used reflectors to increase the temperature of evacuated tube. **Omara et al. (2014)** attached internal and external reflectors in the stepped solar still and the productivity increased by about 125 %.

Taguchi method is a statistical technique to identify the best parameter level among the different parameter levels available. This helps us to fabricate a Robust design solar still. **Singh and Francis (2013)** investigated the effect of water temperature and inclination angle in the performance of solar still with the help of Taguchi method and found water temperature as the most significant contributing factor. **Verma et al. (2013)** attempted to optimize the performance of a solar still using Taguchi method. They found water temperature as the most significant parameter and inclination angle of the glass cover as the least significant parameter. **Gupta and Singh (2015)** applied Taguchi method and concluded that water temperature and salt concentration were significant parameters and inclination angle and water depth were insignificant parameters in enhancing the performance of the solar still. **Joe and Ramachandran (2017)** fabricated a Robust design solar still by integrating all the best parameter levels identified by the Taguchi method and the distillate output collected was 95.54 % higher than the conventional still.

From the above literature study, we come to know that some modifications in the design of the still basin were introduced to improve the productivity. In addition to this, incorporation of some operational parameters in the stills also significantly increased the production. Without resorting to any heat source other than solar energy, the productivity was increased by incorporating some internal and external modifications. Spreading heat storage material and wick materials in the basin, maintaining optimum basin water depth, using appropriate basin cover material, thickness and inclination angle and fixing internal mirrors were some of the internal modifications introduced in the still. External modifications in the form of external mirrors to focus additional solar radiation was also made. In this study, an attempt was taken to maximize the productivity of the plain, corrugated and compartmental basin solar stills by incorporating them with heat storage

material, regulating the basin water depth, varying the basin cover thickness and attaching and positioning the external mirrors. But the crux of the problem is this.

An operational parameter which is very productive in a particular basin type may not be as much effective in another basin type. There is difference in the contribution of heat storage material to distillate production in plain basin, corrugated basin and compartmental basin stills. Further, the efficiency of a parameter level is different at different stills, when the structure of the basin changes. A particular basin water depth which is very productive for plain basin may not suit well for corrugated and compartmental basin stills. So identification and integration of suitable parameters and parameter levels efficient for a still type is necessary. For this, we have to take into consideration not only the efficiency of parameters and parameter levels but also the basin type of the still. A solar still which is designed by incorporating the parameters and parameter levels which are efficient or optimum for the basin type is called as Robust design solar still and this will ensure maximum production. Identification of ideal parameter level suitable from solar still is done with the help of Taguchi method and regression technique.

2. Objective and Methodology Adopted

In this work, the productivity of the plain basin, corrugated basin and compartmental basin solar stills was to be improved by incorporating the stills with optimum (most efficient) levels of the four operational parameters. It was already proved that there is no single parameter level that can be used indiscriminately in different types of solar stills. So the focus of the present study was to select the best operational parameter level that yield maximum production in each solar still. The four parameters and the four parameter levels of each parameter which were considered for this study are summarized below

Table.1 Parameters and Parameter levels

Level	Parameter			
	Mass of Heat Storage Material (kg) A	Basin Water Depth (mm) B	Basin Cover Thickness (mm) C	Position of External Mirrors D
1	10	10	3	I-High end side

2	12	15	4	II-Low end side
3	14	20	5	III-Both high and low end sides
4	16	25	6	IV-Two sloping sides

The objective of the study was to identify the significant parameters and the parameter levels that optimize or maximize the production in the plain basin, corrugated basin and compartmental basin solar stills with the help of Taguchi method and regression technique.

To identify the best parameter levels that maximize production, the experiments are to be conducted by the combining the 4 parameters and the 4 levels of each parameter in all possible ways. This requires 256 experiments to be conducted. To minimize the number of experiments, we resort to Taguchi method. This necessitates only 16 experiments to be conducted. The four parameters and their 4 levels were combined as per L₁₆ orthogonal array (Refer [Appendix I](#) for the orthogonal array used) and the experiments were conducted. To minimize the variation, each trial was repeated twice. The distillate collected from each trial was recorded and the collected data were analysed.

The following techniques were used to analyze the data

- a) **S/N Ratio analysis** - S/N ratio for each parameter level was calculated and the parameter level bearing the highest S/N ratio was identified as optimum parameter level
- b) **Analysis of Variance** - The analysis of variance was used to spot out the significant parameters among the different parameters taken for the study. The contribution of each parameter in determining the yield was also calculated.
- c) **Mean Response method** - The average mean response value for each parameter level was calculated. Using these values, the average mean response graph was drawn. From the graph, we identified the optimum parameter levels. The optimum response was also predicted.
- d) **Regression Analysis** - The Regression equations for the 3 solar stills were fitted. This helped to study the nature and degree of relationship between the dependent variable (Production) and independent variables (Parameters) and

enabled to predict the output expected when the optimum parameter levels were incorporated in the solar still.

3. Experimental Setup

For conducting the experiments, 3 solar stills were fabricated. They were

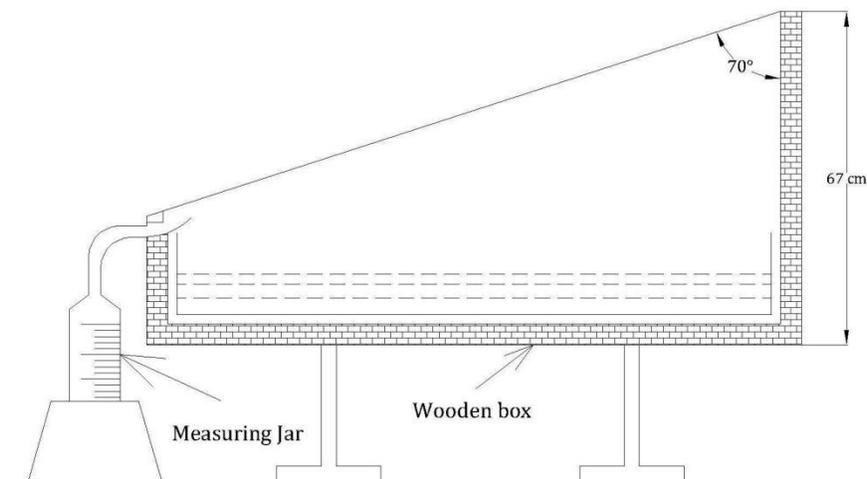
Still I – Plain basin solar still

Still II- Corrugated basin solar still

Still III- Compartmental basin solar still

The solar stills were fabricated using 2 mm thick iron sheet. The length and width of the basins were 100 cm and 100 cm respectively. The height of the basin at the low end side was 31 cm and the height was 67 cm in the high end side. The stills were placed inside the wooden boxes and a gap of 1 cm was maintained between the still wall and the wooden box. The gap was filled by heat resistant materials to prevent loss of heat energy from the basin to the ambient. The stills were covered by glass covers and an inclination angle of 20° was maintained. The schematic diagram of solar still is given in [Figure 1](#).

Fig.1 Schematic Diagram of Solar Still



In the plain basin, the entire 100 x 100 cm bottom basin plate was kept as plain surface and it was free from any basin liner modification. The entire basin area can hold the brine to be desalinated. The actual experimental setup of plain basin solar still is given in [Figure 2](#).

Fig.2 Plain Basin Solar Still – Experimental Setup



In the corrugated basin, the bottom basin plate had corrugated arrangements. It had 4 pyramid like structures extending from one side of the basin wall to the other side of the wall. The length, width and height of each pyramid was 100 cm, 10 cm and 8 cm respectively. Between one pyramid and another there was plain surface of 12 cm x 100 cm. Water to be desalinated was kept in the plain surface only that was in the 60 % of the basin area. The corrugated basin arrangement is shown in [figure 3](#).

Fig.3 Corrugated Basin Solar Still – Experimental Setup



In the compartmental basin still, the bottom basin plate had 27 compartments. The length, width and height of 15 compartments were 20 x 12 x 8 cm respectively and the remaining 12 compartments were 20 x 10 x 8 cm respectively. Water to be desalinated was kept within the 27 compartments only (60 % of the basin area). The arrangement of compartments in compartmental basin is shown in [figure 4](#).

Fig.4 Compartment Basin Solar Still – Experimental Setup



Since the experiments were to be conducted by varying the 4 operational parameters, the following additional arrangements were made

- a) **Heat storage material** – Four separate quantity of 10 Kg, 12 Kg, 14 Kg and 16 Kg of 5 mm thick black granite gravel were kept ready for the study
- b) **Basin water depth**- The flow of water into the still was controlled by a control valve and this enabled the maintenance of required basin water level. To maintain the basin water depth at a constant level, throughout the experiment, topup of basin water was done at the end of every one hour. The quantity of water added was equal to the quantity of distillate collected during the 1 hour period.
- c) **Basin cover thickness**- To conduct the experiments by varying the basin cover thickness, 3 mm, 4 mm, 5 mm and 6 mm thick glass basin covers were fabricated.
- d) **External mirrors**- For each solar still, 2 external mirrors were fabricated. The length and width of each mirror was 40 cm and 100 cm respectively and it was fitted in a metal frame. The angle of the mirror was periodically adjusted to focus maximum radiation into the still. The 2 mirrors were placed at 4 different position as per the requirement of the experiment.

Position I – at the high end side of the basin (north side)

Position II – at the low end side of the basin (south side)

Position III- at the low end and high end side of the basin
(north & south side)

Position IV- at the two sloping sides of the still (east and west side)

4. Result and Discussions

The experiments were conducted during the months of April and May 2019 in Tuticorin, Tamilnadu. The experiments were started at 7 a.m. in the morning and continued upto 6 p.m. The distillate collected at the end of every one hour was measured and recorded. The measuring jar of 1000 ml capacity was used.

4.1 S/N Ratio Analysis

The signal to noise ratio (S/N ratio) is a statistic that combines mean and variance. The objective in Taguchi method is to minimize the sensitivity of a quality characteristics to noise factors. This is achieved by selecting the factor levels corresponding to the maximum S/N ratios. In **Table 2**, S/N ratios for different parameter levels are given.

Table 2 S/N Ratios- Plain, Corrugated and Compartmental basin (larger the better)

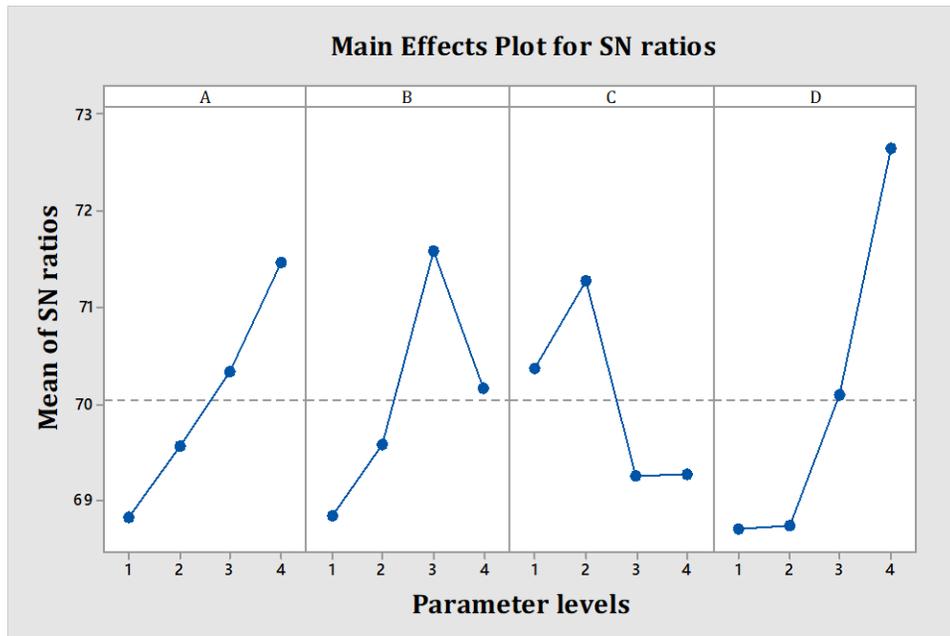
Level	Plain basin				Corrugated basin				Compartmental basin			
	A	B	C	D	A	B	C	D	A	B	C	D
1	68.83	68.85	70.38	68.71	70.99	71.08	70.27	68.91	72.97	73.21	70.7	68.86
2	69.56	69.59	71.29	68.74	72.05	72.45	71.44	68.75	70.04	71.51	72.17	68.96
3	70.34	71.58	69.26	70.11	69.49	69.31	69.87	70.04	69.83	69.12	69.58	70.32
4	71.46	70.17	69.27	72.65	68.91	68.6	69.86	73.73	69.45	68.44	69.83	74.15
Delta	2.63	2.73	2.02	3.94	3.14	3.85	1.58	4.98	3.52	4.76	2.59	5.29
Rank	3	2	4	1	3	2	4	1	3	2	4	1

A, B, C & D – Parameters

1, 2, 3 & 4 – Parameter levels

The S/N ratios for the plain basin, corrugated basin and compartmental basin stills are shown in **fig. 5, 6 and 7**.

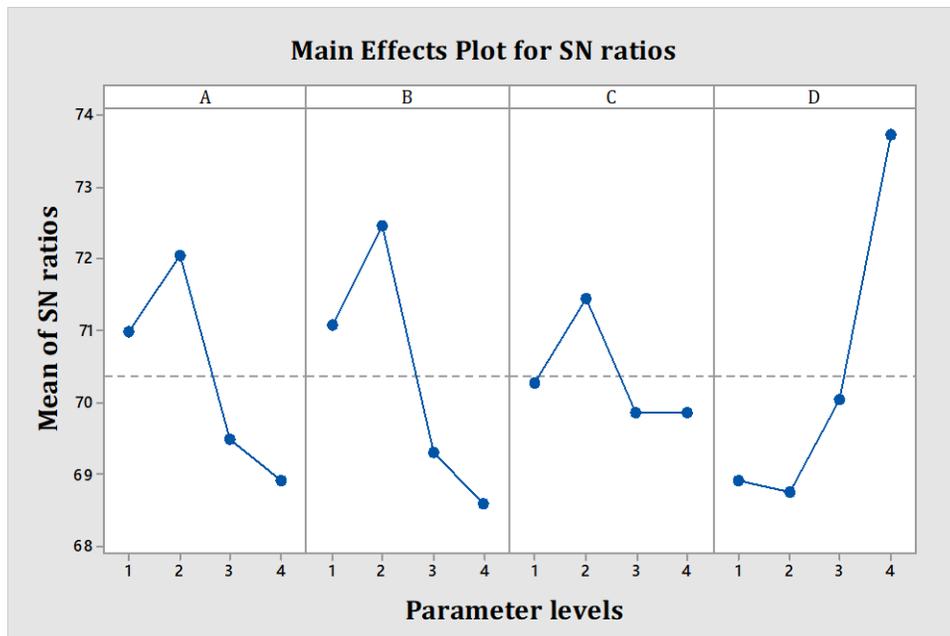
Fig.5 Parameter levels and S/N Ratios – Plain Basin



A, B, C & D – Parameters

1, 2, 3 & 4 – Parameter levels

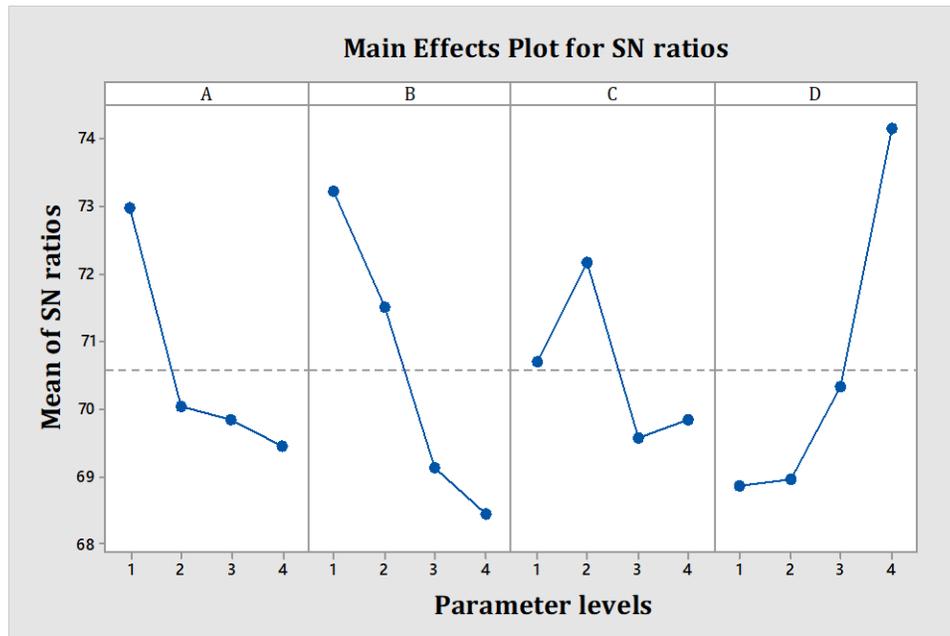
Fig.6 Parameter levels and S/N Ratios – Corrugated Basin



A, B, C & D – Parameters

1, 2, 3 & 4 – Parameter levels

Fig.7 Parameter levels and S/N Ratios – Compartmental Basin



A, B, C & D – Parameters

1, 2, 3 & 4 – Parameter levels

4.1.1 Optimum Parameter Levels

In plain basin solar still, the parameter levels with highest S/N ratios are A₄, B₃, C₂ and D₄. So the parameter levels recommended for maximum production are- 16 Kg of heat storage material, 20 mm basin water depth, 4 mm thick basin cover and position IV for placing external mirrors. In corrugated basin solar still, the parameter levels A₂, B₂, C₂ and D₄ have the highest S/N ratio values. So to maximize production, the corrugated basin still has to be incorporated with 12 Kg of heat storage material, 15 mm basin water depth, 4 mm thick basin cover and the external mirrors are to be placed in position IV. In compartmental basin solar still, the parameter levels A₁, B₁, C₂ and D₄ have highest S/N ratio values. So, integrating the compartmental basin solar still with 10 Kg of heat storage material, 10 mm basin water depth, 4 mm thick basin cover and placing the external mirrors in position IV ensure maximum production.

The optimum parameter levels differ from still to still. In parameter A (mass of heat storage material), the optimum mass for plain basin, corrugated basin and compartmental basin solar stills is 16 Kg, 12 Kg and 10 Kg respectively. In the plain basin still, the material is spread in the entire basin surface (1 m² area). So more basin material is required. In the

corrugated basin still, the heat storage material is spread in the narrow gap of 12 cm x 100 cm between the two pyramid like structures. In the compartmental basin still, the material is to be spread within the narrow compartments only. In other words, the material spreading area is only 60 % of the basin surface area, in corrugated and compartmental basin solar stills. So the requirement of heat storage material is less. In parameter B (basin water depth), the optimum water depth is more in plain basin still, than in corrugated basin and compartmental basin stills. In plain basin, the surface area of the basin is wide. So maintaining uniform water depth was difficult. An attempt to reduce the water depth below a particular level resulted in the appearance of dry spots here and there because the surface area was slightly uneven. So maximum production was achieved only when the basin water depth was 20 mm. In corrugated basin solar still, the water to be desalinated is stored within a narrow strip of basin area (12 cm x 100 cm) . So there was not much difficulty in maintaining a lower water depth. The optimum basin water depth in corrugated basin still is lower than the optimum water depth of plain basin. In compartmental basin solar still, the water is stored within each compartment only. Since the water is stored within a small and enclosed area, it was feasible to keep the basin water at a very low level. The optimum basin water depth in compartmental basin still is the minimum (10 mm). In parameter C (basin cover thickness), the optimum thickness of the glass basin cover is 4 mm in all the 3 solar stills. The 4 mm thick glass cover proved to be the most efficient in many earlier studies also. In parameter D (position of external mirrors), the position IV (placing the mirrors on the two sloping sides of the still) is the best level in all the 3 solar stills because only in this position, the solar stills received the maximum solar radiation throughout the day.

4.1.2 Ranking of Parameters

S/N ration analysis helps us to identify the best parameter levels suitable for the 3 solar stills. Integration of these levels in the respective solar still maximizes the production. Sometime, we may like to restrict ourself with those modification which are major contributors to production. One or two parameters may be the major contributors and the rest may be marginal performers. The delta value of a parameter shows the difference between the lowest and the highest S/N ration values in a parameter. Higher delta value is an indication that the incorporation of the best parameter level in that parameter brings

maximum increase in production compared to other parameters with low delta value. The parameters are ranked on the basis of delta value. It guides us to choose the most contributing parameter in the midst of different parameters taken for the study. The inclusion of the parameter bearing the rank 1 must be given the top most priority and the inclusion of other parameters, may be as per the ranking order. In the case of low ranking parameters, we have to consider the cost involved and the returns expected. The uneconomic modification (parameters) may be dropped.

From the analysis of delta value we infer that placing external mirrors in position IV must be given the top most priority in all the 3 solar stills. The second priority must be for maintaining optimum water depth in the basin. If the third modification is to be incorporated, spreading heat storage material in the basin must be considered. Since the delta value for basin cover thickness (Parameter C) is the least, we have to analyse the cost and benefit of this modification in the parameter and decide accordingly.

4.1.3 Analysis of S/N Ratio using ANOVA

In this method, the S/N ratio is treated as response and the data is analysed using ANOVA method. This analysis helps as to identify the significant parameters and contribution of each parameter to total production.

We take

H_0 = The operational parameters have no significant influence on production

$\alpha = 0.05$

The summary of ANOVA analysis for S/N Ratios is given in **Table 3** (Refer [Appendix II](#))

Table 3 Analysis of Variance for S/N Ratios

Parameters	DF	Plain basin			Corrugated basin			Compartmental basin		
		F-Value	P-Value	Contribution	F-Value	P-Value	Contribution	F-Value	P-Value	Contribution
A	3	6.5	0.079	18	11.5*	0.037	18	75.16*	0.003	17
B	3	6.85	0.074	19	17.15*	0.022	27	138.64*	0.001	32
C	3	4.88	0.113	13	3.16	0.185	5	39.25*	0.007	9
D	3	17.51*	0.021	48	30.51*	0.01	48	176.27*	0.001	41

*Significant at 5 % level

The calculated F values are compared with the table F values. At 5 % level of significance, parameter D alone is significant in plain basin still. But the parameters A, B and C significantly contribute to production. The contribution of parameters A,B and C are 18 %, 19 % and 13 % respectively. The 3 parameters taken together contribute 50 % of the production. (The parameters A and B are significant at 8 % level and parameter C at 12 % level). In corrugated basin solar still, the parameters A, B and D are significant at 5 % level and parameter C alone is not significant. In compartmental basin solar still, all the four parameters A, B, C and D are significant at 5 % level.

The significance of a parameter in a solar still can be determined by the contribution of that parameter to distillate production. Parameter D (position of external mirror) was the major contributor in all the 3 solar stills. It was 48 % in plain basin and corrugated basin solar stills and 41 % in compartmental basin solar still. The second significant contributor was parameter B (basin water depth). Its contribution was the highest in compartmental basin still (32 %) followed by the corrugated basin solar still (27 %) and plain basin solar still (19 %). The contribution of heat storage materials (parameter A) was around 18 % in all solar stills. The contribution of parameter C (basin cover thickness) was the least in all the 3 solar stills. The contribution was only 5 % in the corrugated basin solar still.

4.2 Analysis of Variance

The experimental findings are also analysed using the ANOVA technique

4.2.1 Significant Parameters

Analysis of variance helps to find out whether the parameters taken for the study, significantly influence the production or not. The summary of the findings of the analysis of variance is given in [Table 4](#). (Refer Appendix III)

Table 4 Analysis of Variance

Parameters	DF	Plain basin			Corrugated basin			Compartment basin		
		F-Value	P-Value	Contri bution	F-Value	P-Value	Contri bution	F-Value	P-Value	Contri bution
A	3	1239.57*	0.000	19%	5202.38*	0.000	19%	2679.81*	0.000	16%
B	3	1258.19*	0.000	19%	7380.87*	0.000	26%	5107*	0.000	31%
C	3	1048.26*	0.000	16%	1658.37*	0.000	6%	1431.38*	0.000	9%
D	3	2978.71*	0.000	46%	13671.55*	0.000	49%	7111.13*	0.000	44%
R-sq (adj)		99.92 %			99.98 %			99.97 %		
*Significant at 5% level										

The R-sq (adj) values for ANOVA analysis of plain basin, corrugated basin and compartmental basin solar stills show that the fitted model is a good fit of the data.

The following hypothesis is drawn.

Ho= The parameters have no significant influence on production

$\alpha = 0.05$

The calculated F values are greater than the table F values. So the null hypothesis is rejected. It is concluded that the parameters A, B, C and D significantly influence the distillate production in plain basin, corrugated basin and compartmental basin solar stills.

4.2.2 Contribution of Parameters

Analysis of variance also gives the percentage contribution of each parameter to total production in a solar still. The major contribution comes from parameter D (position of external mirror) in all the 3 solar stills and it ranges between 44 % and 49 %. It is 46 % in plain basin still, 49 % in corrugated basin still and 44 % in compartmental basin still. The second major contributor is basin water depth (Parameter B). It's contribution is the highest in compartmental basin solar still (31 %) followed by 26 % in corrugated basin still and 19 % in plain basin solar still. The contribution of parameter A (mass of heat storage material) is almost equal in all the 3 solar stills. It is 19 % in plain basin and corrugated basin stills and 16 % in compartmental basin still. The contribution of parameter C (basin cover thickness) is noteworthy only in plain basin still (16 %). In the other two stills, it is less than 10 %. The contribution is 6 % in corrugated basin still and 9 % in compartmental basin still.

To conclude, top most priority must be given for the identification and integration of the best external mirror positions in solar stills because this modification alone brings substantial increase in production. In addition to this, maintaining optimum basin water depth is important in corrugated basin still and compartmental basin still. The third priority may be for spreading optimum mass of heat storage material in the basin of corrugated and compartmental basin stills. Since the contributions of mass of heat storage material and basin water depth are equal, we cannot make a choice between the two. Modifications in the basin cover thickness need not be given much importance in corrugated and compartmental basin stills because its contribution to production is not significant. Only in plain basin still, optimum basin cover thickness brings substantial improvement in production.

4.3 Mean Response Method

From the experimental results, the response value corresponding to each parameter level is calculated. The average response value for level 1 of parameter A is calculated by adding all the experimental values obtained in different experimental trials which involves level 1 and dividing the sum by the number of observations. In the present study, the average response for level 1 of parameter A (A_1) in plain basin solar still is calculated as follows

$$\begin{aligned} &\text{Mean response of level } A_1 \text{ in plain basin still} \\ &= \frac{(1940+2030+2530+2780+3200+3010+3640+3490)}{8} \\ &= 2828 \text{ ml/m}^2\cdot\text{d} \end{aligned}$$

The mean response value of a parameter level shows the average contribution of that level to distillate production. The parameter level that has the highest mean response value is considered as the best parameter level. The mean response values are summarized in **Table 5**.

Table 5 Mean Response Values

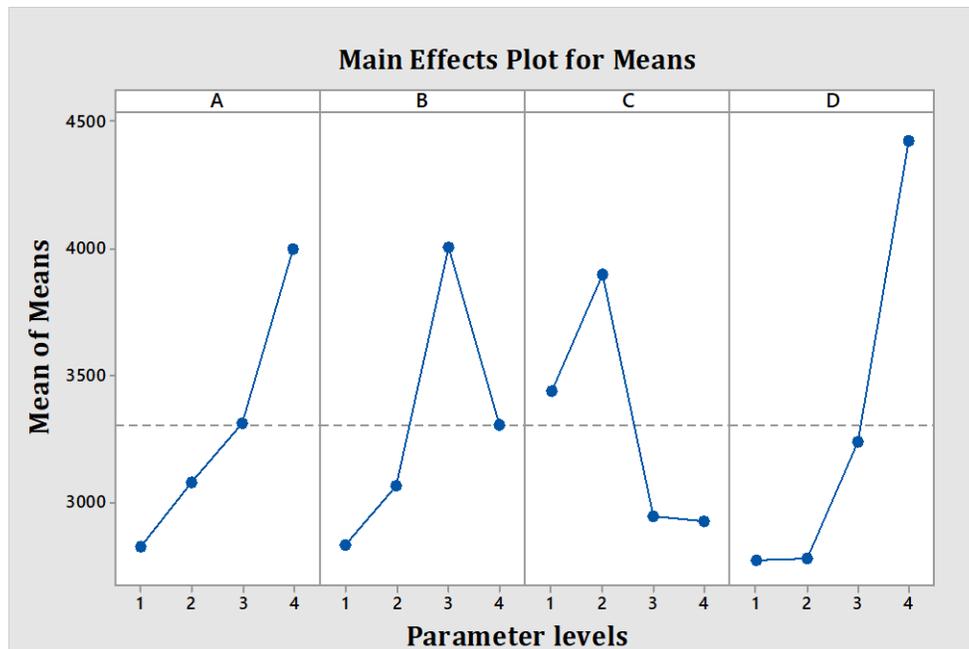
Level	Plain basin				Corrugated basin				Compartmental basin			
	A	B	C	D	A	B	C	D	A	B	C	D
1	2828	2838	3436	2774	3603	3741	3678	2823	4508	4678	3761	2971
2	3079	3068	3900	2779	4325	4430	3900	2850	3600	3975	4215	3006
3	3314	4006	2949	3239	3141	3015	3199	3323	3318	3025	3283	3423
4	3995	3304	2930	4424	2903	2785	3195	4976	3091	2839	3258	5116
Delta	1168	1169	970	1650	1423	1645	705	2154	1416	1839	958	2145
Rank	3	2	4	1	3	2	4	1	3	2	4	1

A,B,C & D – Different parameters

1,2,3 & 4 – Different parameter levels

The above mean response values are represented in the form of a graph. The response graph shows the average response values for different levels of a parameter. The Figure 8, 9 and 10 shows the mean response values of parameter levels in plain basin, corrugated basin and compartmental solar stills.

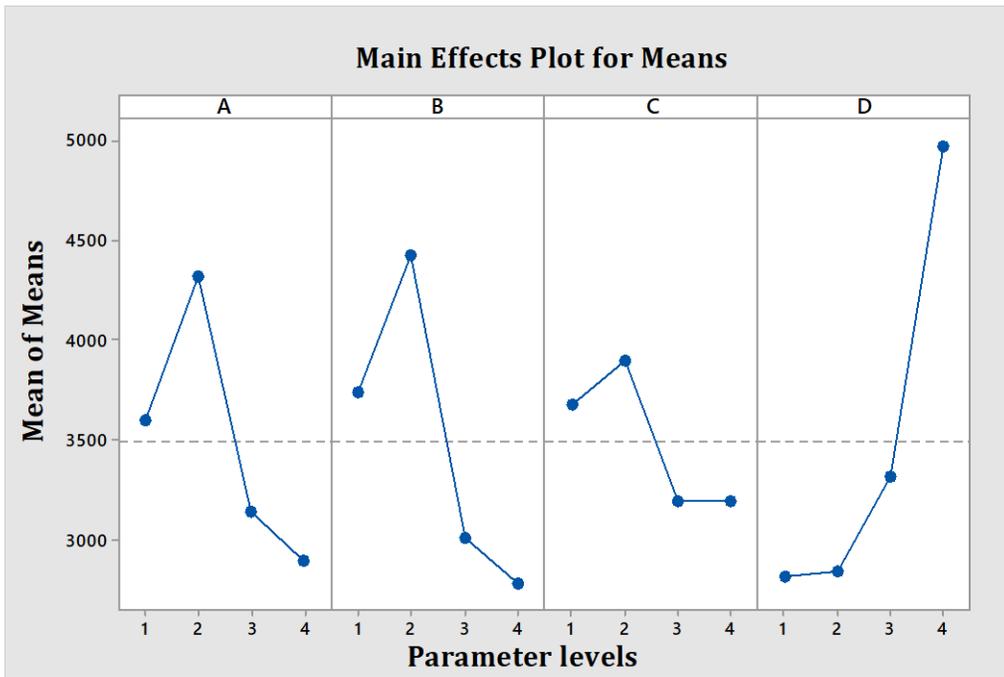
Fig.8 Mean Response Values – Plain Basin



A,B,C & D – Different parameters

1,2,3 & 4 – Different parameter levels

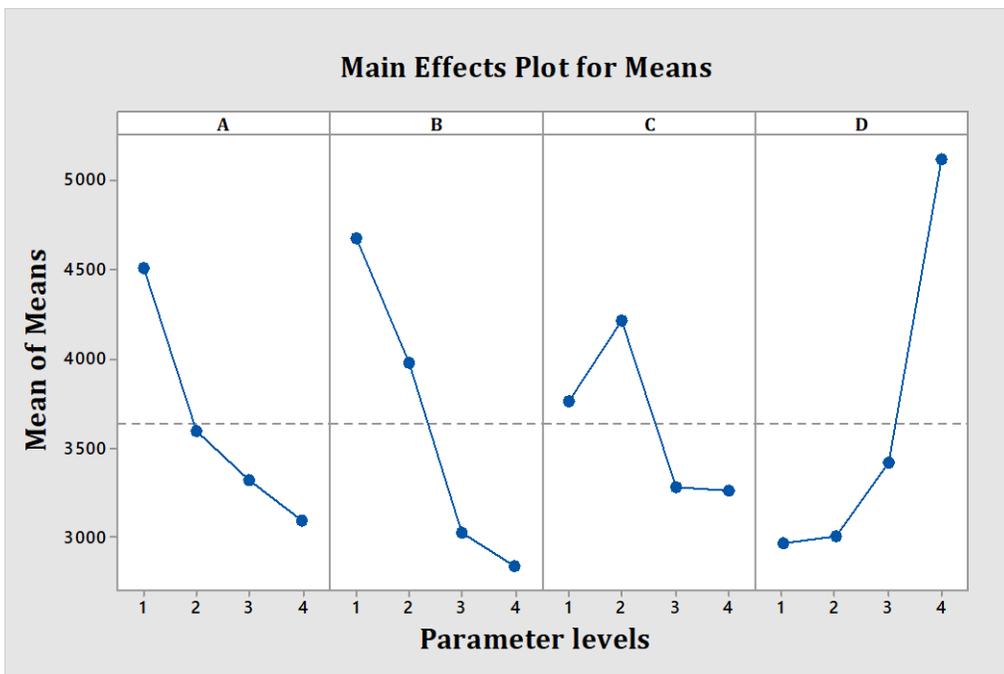
Fig.9 Mean Response Values – Corrugated Basin



A,B,C & D – Different parameters

1,2,3 & 4 – Different parameter levels

Fig.10 Mean Response Values - Compartmental basin



A,B,C & D – Different Parameters

1,2,3 & 4 – Different Parameter levels

From the mean response table and graph we infer that the parameter levels A₄, B₃, C₂ and D₄ in plain basin still, A₂, B₂, C₂ and D₄ in corrugated basin still and A₁, B₁, C₂ and D₄ in compartmental basin solar still have the highest mean response value. Since our objective is maximization of response, the incorporation of the above selected parameter levels in the respective solar still maximize or optimize the distillate production. The above analysis reveals that the mass of heat storage material recommended for plain basin, corrugated basin and compartmental basin solar stills are 16 Kg, 12 Kg and 10 Kg respectively and the optimum basin water depth is 20 mm, 15 mm and 10 mm respectively. For all the 3 solar stills, the optimum basin cover thickness is 4 mm. In the same way, position IV is the best position for all the three solar stills. The findings of the mean response method coincide with the findings of S/N ratio analysis.

The delta value shows the difference in the mean response value of the best contributing parameter level and the least (smallest) contributing parameter level in a parameter. Based on the delta value, the parameters are ranked. The parameter that has the highest value is given the rank 1 and the least delta value, the rank 4. The ranking order gives the contribution order of parameters. The delta value reveals that the parameter D (position of external mirrors) is the best contributing parameter in all the 3 solar stills. In corrugated basin and compartmental basin, the second and third contributing parameters are parameter B (basin water depth) and parameter A (mass of heat storage material) respectively. In plain basin still also, the parameter B and A are the second and third contributors but their contributions are almost equal. The parameter C (basin cover thickness) is the least contributing parameter in all the 3 stills.

The distillate production in the solar stills are maximum when the solar stills are integrated with the identified best parameter levels. The response graph method helps us to estimate the distillate production of the modified or robust design solar stills. The predicted optimum response (μ predicted) is given by

$$\mu = \bar{Y} + (\bar{A}_i - \bar{Y}) + (\bar{B}_i - \bar{Y}) + (\bar{C}_i - \bar{Y}) + (\bar{D}_i - \bar{Y})$$

\bar{Y} = overall mean response

$\bar{A}_i, \bar{B}_i, \bar{C}_i$ & \bar{D}_i - Mean response of the best parameter level in parameters A, B, C and D
 i – best level

The overall mean response \bar{Y} is calculated by adding all the experimental values and dividing the sum by the number of observations. In this study, 16 trials were conducted and each trial was repeated twice. So the overall mean response refers to the mean value of the 32 experimental values.

$$\text{Overall mean response } (\bar{Y}) = \frac{\text{Grand total of observations}}{\text{Total number of observations}}$$

Plain basin solar still = 3304 ml/m².day

Corrugated basin solar still = 3493 ml/m².day

Compartmental basin solar still = 3629 ml/m².day

The **predicted optimum response for plain basin solar still** is

$$\mu \text{ Pred (Plain basin)} = \bar{Y} + (\bar{A}_4 - \bar{Y}) + (\bar{B}_3 - \bar{Y}) + (\bar{C}_2 - \bar{Y}) + (\bar{D}_4 - \bar{Y})$$

$$= 3303.75 + (3995 - 3303.75) + (4006 - 3303.75) + (3900 - 3303.75) + (4424 - 3303.75)$$

$$= 6414 \text{ ml/m}^2\text{day}$$

In **Corrugated basin solar still**, the estimated optimum production will be

$$\mu \text{ Pred (Corrugated basin)} = \bar{Y} + (\bar{A}_2 - \bar{Y}) + (\bar{B}_2 - \bar{Y}) + (\bar{C}_2 - \bar{Y}) + (\bar{D}_4 - \bar{Y})$$

$$= 3492.81 + (4325 - 3492.81) + (4430 - 3492.81) + (3900 - 3492.81) + (4976 - 3492.81)$$

$$= 7153 \text{ ml/m}^2\text{day}$$

The estimated production from the compartmental basin solar still designed as per Taguchi method will be

$$\mu \text{ Pred (Compartmental basin)} = \bar{Y} + (\bar{A}_1 - \bar{Y}) + (\bar{B}_1 - \bar{Y}) + (\bar{C}_2 - \bar{Y}) + (\bar{D}_4 - \bar{Y})$$

$$= 3629.06 + (4508 + 3629.06) + (4678 + 3629.06) + (4215 + 3629.06) + (5116 + 3629.06)$$

$$= 7629.8 \text{ ml/m}^2\text{day}$$

4.4 Regression Analysis

When the experiments are conducted involving only quantitative factors, the nature of relationship between output (response) and input variables (Parameters) can be studied with the help of regression technique. This technique can be used to predict the output corresponding to an input or parameter level and thereby helps us to maximize the production process. In the present study, it is assumed that the response (y) is linearly related to more than one independent variables. So multiple regression model can be used to study this problem. Suppose, A, B, C and D are the four independent variables (Parameters), the regression model describing the relationship between output (response) and independent variables can be written as

$$Y = \beta_0 + \beta_1 A + \beta_2 B + \beta_3 C + \beta_4 D$$

Y = response (production)

β_0 = Constant

β_1 - Reg. coefficient of parameter A

β_2 - Reg. coefficient of parameter B

β_3 - Reg. coefficient of parameter C

β_4 - Reg. Coefficient of parameter D

A, B, C and D are parameters (independent variables).

Using the experimental data, the linear regression models for the 3 solar stills are fitted.

They are given below

Plain basin solar still

$$Y = 1050 + 374 A + 234 B - 247 C + 541 D$$

Corrugated basin solar still

$$Y = 4188 - 328 A - 428 B - 215 C + 693 D$$

Compartmental basin solar still

$$Y = 5277 - 453 A - 647 B - 244 C + 685 D$$

We have to test whether there is any linear relationship between the response (y) and parameters A, B, C and D. The ANOVA technique and F-test are used for this purpose.

The following hypothesis are drawn

$$H_0 = \beta_1 = \beta_2 = \beta_3 = \beta_4 = 0$$

$$H_1 = \beta \neq 0 \text{ for atleast one variable}$$

The ANOVA computation for the regression equation are given in Table 6

Table 6 ANOVA for Multiple Regression

Still type	Source	DF	Adjusted M.S	F value	P Value
Plain basin solar still	Regression	4	2740091	6.09*	0.008
	Error	11	449647		
Corrugated basin solar still	Regression	4	4091377	5.06*	0.015
	Error	11	808008		
Compartmental basin solar still	Regression	4	5762808	12.20*	0.000
	Error	11	472285		
* Significant at 5 % level					

The calculated F values are greater than the table F values for the 3 solar stills. So the null hypothesis is rejected. Rejection of H_0 implies that there is linear relationship between (y) response and atleast one independent variable.

After establishing that there is linear relationship between the dependent and independent variables, our next task is to identify the parameters that have significant linear relationship with distillate production. The regression coefficient of each parameter is tested with the help of t-test. When the calculated t-value is higher than the table t value ($\alpha=0.05$), the parameter is said to have significant linear relationship with the dependent variable. The regression coefficients and their significant levels are summarized in [Table 7 \(Refer Appendix IV\)](#)

Table 7 Regression Coefficients and Significant Levels

Parameters	Plain Basin			Corrugated basin			Compartmental basin		
	Reg. Coeff.	t-value	P-Value	Reg. Coeff.	t-value	P-Value	Reg. Coeff.	t-value	P-Value
A	374	2.49*	0.030	-328	-1.63	0.131	-453	-2.95*	0.013
B	234	1.56	0.147	-428	-2.13	0.056	-647	-4.21*	0.001
C	-247	-1.65	0.128	-215	-1.07	0.308	-244	-1.59*	0.14
D	541	3.61*	0.004	693	3.45*	0.005	685	4.46	0.001
* Significant at 5 % level									

The parameters A and D in plain basin still , parameter D in corrugated basin still and parameter A, B and D in compartmental basin still have significant linear relationship with the dependent variable.

A closer study of the regression coefficients help us to draw valuable inferences about the performance of the parameters at different levels and guide us to choose the most efficient parameter level. For the sake of mathematically studying the relationship between the dependent variable (distillate production) and the independent variables (the parameters) , the four parameter levels are arranged in the ascending order, starting from the lower level to higher level and they are given the numerical values 1, 2, 3 and 4. The regression coefficient explains the nature and degree of relationship between the dependent and independent variable. The sign (positive or negative) of the regression coefficient and the significance level enable us to locate the optimum parameter level. The positive sign of the regression coefficient indicates that the selection of higher parameter level maximizes the production. The negative sign indicates that the choice must be a lower parameter level. Further, to pin-point the optimum parameter level, we have to take into consideration the significance level also. When the regression coefficient of a parameter is significant, the optimum parameter level is 4 when the regression coefficient has positive sign and 1 when it has negative sign. In case, the regression coefficient is not significant, the optimum parameter level may be 2 or 3. When the regression coefficient is not significant, but reasonably high, the optimum parameter level is 2 when the regression coefficient is negative and 3 when the coefficient is positive.

In plain basin solar still, the parameters A, B and D have positive regression coefficients. It is an indication that for maximizing production higher parameter levels (Level 3 or 4) are recommended. The regression coefficient is significant in parameter A and D and not significant in parameter B. So the optimum parameter level is 4 in parameter A and D and 3 in parameter B. In corrugated basin solar still, the parameter D alone has significant positive regression coefficient value. So the optimum parameter level for parameter D is 4. The regression coefficient values for parameter A and B are negative. So a lower parameter level of either 1 or 2 is recommended. Since the coefficient is not significant, the optimum level is 2 in both the parameters. In compartmental basin solar still, the parameters A and B have significant negative regression coefficient values. So the

optimum parameter level is 1 in both the cases. The parameter D has significant positive regression coefficient value. This suggests that the optimum level for parameter D is 4. The regression coefficient for parameter C is negative and not significant in all the 3 solar stills. So the optimum level for parameter C is 2.

To sum up, the optimum parameter levels for maximizing the production in plain basin solar stills are A₄, B₃, C₂ and D₄. In corrugated basin solar still, the identified optimum parameter levels are A₂, B₂, C₂ and D₄. For maximizing production in the compartmental basin solar still, the parameter levels A₁, B₁, C₂ and D₄ are to be incorporated.

The distillate production will be maximum or optimum, when the identified parameter levels are incorporated in the respective solar still. Using the regression technique, we can estimate the optimum output of the modified solar stills. For this, we need the regression coefficient of different parameter levels taken for the study. The regression equation involving all the parameters and parameter levels gives the regression coefficient for each parameter level. The comprehensive regression equations are given below

Plain basin solar still

$$Y= 3303.75 - 476.3 A_1 - 225.0 A_2 + 10.0 A_3 + 691.3 A_4 - 466.3 B_1 - 236.2 B_2 + 702.5 B_3 + 0.0 B_4 + 132.5 C_1 + 596.3 C_2 - 355.0 C_3 - 373.8 C_4 - 530.0 D_1 - 525.0 D_2 - 65.0 D_3 + 1120.0 D_4$$

Corrugated basin solar still

$$Y=3492.81 + 109.69 A_1 + 832.19 A_2 - 351.56 A_3 - 590.31 A_4 + 248.44 B_1 + 937.19 B_2 - 477.81 B_3 - 707.81 B_4 + 184.69 C_1 + 407.19 C_2 - 294.06 C_3 - 297.81 C_4 - 670.31 D_1 - 642.81 D_2 - 170.31 D_3 + 1483.44 D_4$$

Compartmental basin solar still

$$Y= 3629.06 + 878.4 A_1 - 29.1 A_2 - 311.6 A_3 - 537.8 A_4 + 1048.4 B_1 + 345.9 B_2 - 604.1 B_3 - 790.3 B_4 + 132.2 C_1 + 585.9 C_2 - 346.6 C_3 - 371.6 C_4 - 657.8 D_1 - 622.8 D_2 - 206.6 D_3 + 1487.2 D_4$$

Here,

Y= Output

A₁, A₂, A₃, A₄ - levels of parameter A

B₁, B₂, B₃, B₄ - levels of parameter B

C₁, C₂, C₃, C₄ - levels of parameter C

D₁, D₂, D₃, D₄ - levels of parameter D

The above regression equations give the regression coefficient for each parameter level. The regression coefficients are tested using t-test to find out the significance level. The complete list of regression coefficients, their calculated t-values and significance level are given in [Appendix V](#).

The regression coefficient gives the contribution of each parameter level to production. Higher the regression coefficient, higher the contribution level. From the list, the most contributing parameter level in each parameter is identified and they are given in [Table 8](#) along with the significance level. The parameter levels identified as most contributing are A₄, B₃, C₂ and D₄ in plain basin solar still, A₂, B₂, C₂ and D₄ in corrugated basin solar still and A₁, B₁, C₂ and D₄ in compartmental basin solar still. The identified parameter levels coincide with the parameter levels identified in the earlier analysis.

The distillate production estimated for the **Plain basin solar still** modified with parameter levels A₄, B₃, C₂ and D₄ are

$$\begin{aligned}\mu &= \beta_0 + \beta_1 A_4 + \beta_2 B_3 + \beta_3 C_2 + \beta_4 D_4 \\ &= 3303.75 + 691.3 + 702.5 + 596.3 + 1120.0 \\ &= 6414 \text{ ml/m}^2.\text{day}\end{aligned}$$

In **Corrugated basin solar stills**, the estimated production with modification of parameter levels A₂, B₂, C₂ and D₄ is

$$\begin{aligned}\mu &= \beta_0 + \beta_1 A_2 + \beta_2 B_2 + \beta_3 C_2 + \beta_4 D_4 \\ &= 3492.81 + 832.19 + 937.19 + 407.19 + 1483.44 \\ &= 7153 \text{ ml/m}^2.\text{day}\end{aligned}$$

When **Compartmental basin solar still** is integrated with parameter levels A₁, B₁, C₂ and D₄, the estimated production is

$$\begin{aligned}\mu &= \beta_0 + \beta_1 A_1 + \beta_2 B_1 + \beta_3 C_2 + \beta_4 D_4 \\ &= 3629.06 + 878.4 + 1048.4 + 585.9 + 1487.2 \\ &= 7629 \text{ ml/m}^2.\text{day}\end{aligned}$$

Table 8 Optimum Parameter levels- t value – Significance level

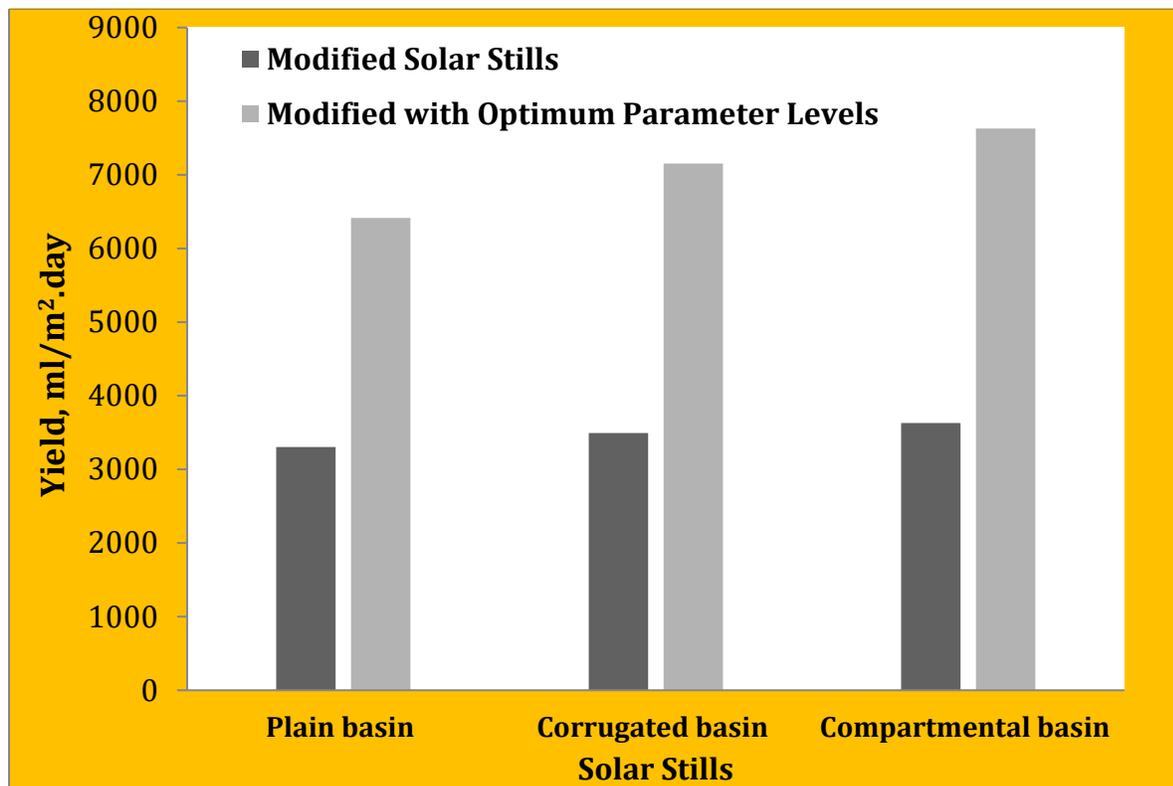
Still type	Parameter and optimum parameter level	Reg. Coefficient	t-value	P-value
Plain basin still	A- A4	691.3	56.00	0.000
	B- B3	702.5	56.92	0.000
	C- C2	596.3	48.31	0.000
	D- D4	1120.0	90.74	0.000
Corrugated basin still	A- A2	832.19	110.67	0.000
	B- B2	937.19	124.63	0.000
	C- C2	407.19	54.15	0.000
	D- D4	1483.44	197.28	0.000
Compartmental basin still	A- A1	878.4	84.49	0.000
	B- B1	1048.4	100.84	0.000
	C- C2	585.9	56.35	0.000
	D- D4	1487.2	143.03	0.000

4.5 Modified Solar Stills vs Solar Stills Modified with Optimum Parameter Levels - A Comparison of Production

The plain basin, corrugated basin and compartmental basin solar stills were modified in 16 different ways (16 different combination of parameters levels) and the average distillate production collected from the modified solar still were recorded by conducting the experiments. Then it was assumed that the above 3 solar stills were incorporated with the optimum parameters levels identified and the production expected from these solar stills were predicted (estimated). A comparison between the average production obtained from modified solar stills and production estimated from solar stills modified with optimum parameters level is given in **figure 11**.

The average production obtained from modified plain basin, corrugated basin and compartmental basin solar still was 3304, 3493 and 3629 ml/m².day respectively. The estimated production when the above 3 solar stills were integrated with optimum parameter level was 6414, 7153 and 7629 ml/m².day respectively and the increase in production predicted was 94 %, 105 % and 110 % respectively.

Fig. 11 Comparison of Performance



5. Conclusion

This study aimed at optimizing or maximizing the distillate production in plain, corrugated and compartmental basin solar stills by integrating them with optimum level of the four operational parameters - **Mass of heat storage material**, **Basin water depth**, **Thickness of basin cover** and **External mirror position**. The distillate collected from 16 different combination of 4 parameters and 4 levels of each parameters were analyzed using S/N ratio, ANOVA, Mean Response Method and Regression technique. The main findings are summarized below.

1. All the operational parameters are not equally efficient. The most contributing parameters was external mirror. Basin water depth and mass of heat storage material were the second and third contributing parameters in corrugated and compartmental basin stills and equal contributors in plain basin still. The contribution of basin cover thickness was very low except in plain basin still.
2. The efficient operational parameters levels differ from still to still. The optimum parameters level in mass of heat storage material was 16 kg in plain basin 12 kg in corrugated basin and 10 kg in compartmental basin solar still.

3. The optimum basin water depth differs from still to still. The efficiency of compartmental and corrugated basin solar stills was maximum at a lower basin water depth of 10 mm and 15 mm respectively. But the optimum depth in plain basin still was 20 mm, a slightly higher level.
4. In spite of difference in the still basin type, the optimum basin cover thickness remains the same. The efficiency of the solar stills were optimum only when 4 mm thick basin cover was used.
5. Only when the external mirrors were placed on the two sloping sides of the solar still (the eastern and western direction), there was maximum focusing of solar radiation into the still and this is the optimum position for all the solar stills.
6. The average distillate production collected from plain, corrugated and compartmental basin solar stills with different combination of modification was 3304, 3493 and 3629 ml/m².day. When the above stills were integrated with optimum parameter levels, the distillate production expected was predicted as 6414, 7153 and 7629 ml/m².day respectively and the increase in production was 94 %, 105 % and 110 % respectively.

I. Ethics approval and consent to participate

Status : Not applicable

II. Consent for publication

Status : Not applicable

III. Availability of data and materials

Status : Not applicable

IV. Competing interests

Status : "The authors declare that they have no competing interests" in this section.

V. Funding

Status : No funding agencies are not involved

VI. Authors' contributions

Status : All authors contributed to the study conception and design.

Material preparation, data collection and analysis were performed by [Sundararaj Joe Patrick Gnanaraj] and [Solaisamy Ramachandran]. The first draft of the

manuscript was written by [Joe Patrick Gnanaraj] and all authors commented on previous versions of the manuscript. All authors read and approved the final manuscript.

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Appendix I

L₁₆ Orthogonal Array

Trail	A	B	C	D
1	1	1	1	1
2	1	2	2	2
3	1	3	3	3
4	1	4	4	4
5	2	1	2	3
6	2	2	1	4
7	2	3	4	1
8	2	4	3	2
9	3	1	3	4
10	3	2	4	3
11	3	3	1	2
12	3	4	2	1
13	4	1	4	2
14	4	2	3	1
15	4	3	2	4
16	4	4	1	3

Appendix II

(a) Analysis of Variance for S/N Ratios - Plain Basin

Source	DF	Adj SS	Adj MS	F-Value	P-Value
A	3	15.248	5.0828	6.5	0.079
B	3	16.07	5.3566	6.85	0.074
C	3	11.455	3.8182	4.88	0.113
D	3	41.09	13.6965	17.51	0.021
Error	3	2.346	0.7821		
Total	15	86.209			

(b) Analysis of Variance for S/N Ratios - Corrugated Basin

Source	DF	Adj SS	Adj MS	F-Value	P-Value
A	3	24.383	8.1275	11.5	0.037
B	3	36.352	12.1172	17.15	0.022
C	3	6.69	2.23	3.16	0.185
D	3	64.691	21.5635	30.51	0.01
Error	3	2.12	0.7067		
Total	15	134.235			

(c) Analysis of Variance for S/N Ratios - Compartmental Basin

Source	DF	Adj SS	Adj MS	F-Value	P-Value
A	3	31.374	10.4579	75.16	0.003
B	3	57.872	19.2906	138.64	0.001
C	3	16.384	5.4613	39.25	0.007
D	3	73.583	24.5276	176.27	0.001
Error	3	0.417	0.1391		
Total	15	179.63			

Appendix - III

(a) Analysis of Variance - Plain Basin

Source	DF	Adj SS	Adj MS	F-Value	P-Value
A	3	3021462	1007154	1239.57	0
B	3	3066838	1022279	1258.19	0
C	3	2555138	851713	1048.26	0
D	3	7260600	2420200	2978.71	0
Error	3	2438	813		
Total	15	15906475			

(b) Analysis of Variance -Corrugated Basin

Source	DF	Adj SS	Adj MS	F-Value	P-Value
A	3	4706530	1568843	5202.38	0
B	3	6677380	2225793	7380.87	0
C	3	1500305	500102	1658.37	0
D	3	12368480	4122827	13671.6	0
Error	3	905	302		
Total	15	25253598			

(c) Analysis of Variance - Compartmental Basin

Source	DF	Adj SS	Adj MS	F-Value	P-Value
A	3	4635242	1545081	2679.81	0
B	3	8833517	2944506	5107	0
C	3	2475842	825281	1431.38	0
D	3	12300030	4100010	7111.13	0
Error	3	1730	577		
Total	15	28246361			

Appendix - IV

(a) Plain Basin - Regression Coefficients for Parameters

Term	Coef	SE Coef	T-Value	P-Value
Constant	1050	768	1.37	0.199
A	374	150	2.49	0.03
B	234	150	1.56	0.147
C	-247	150	-1.65	0.128
D	541	150	3.61	0.004

(b) Corrugated basin - Regression Coefficients for Parameters

Term	Coef	SE Coef	T-Value	P-Value
Constant	4188	1030	4.07	0.002
A	-328	201	-1.63	0.131
B	-428	201	-2.13	0.056
C	-215	201	-1.07	0.308
D	693	201	3.45	0.005

(c) Compartmental basin - Regression Coefficients for Parameters

Term	Coef	SE Coef	T-Value	P-Value
Constant	5277	787	6.7	0
A	-453	154	-2.95	0.013
B	-647	154	-4.21	0.001
C	-244	154	-1.59	0.14
D	685	154	4.46	0.001

Appendix - V

(a) Plain Basin - Regression Coefficients for Parameter levels

Term	Coef	SE Coef	T-Value	P-Value
Constant	3303.75	7.13	463.61	0
A				
1	-476.3	12.3	-38.59	0
2	-225	12.3	-18.23	0
3	10	12.3	0.81	0.477
4	691.3	12.3	56	0
B				
1	-466.3	12.3	-37.78	0
2	-236.2	12.3	-19.14	0

3	702.5	12.3	56.92	0
4	0	12.3	0	1
C				
1	132.5	12.3	10.74	0.002
2	596.3	12.3	48.31	0
3	-355	12.3	-28.76	0
4	-373.8	12.3	-30.28	0
D				
1	-530	12.3	-42.94	0
2	-525	12.3	-42.54	0
3	-65	12.3	-5.27	0.013
4	1120	12.3	90.74	0

(b) Corrugated basin - Regression Coefficients for Parameter levels

Term	Coef	SE Coef	T-Value	P-Value
Constant	3492.81	4.34	804.54	0
A				
1	109.69	7.52	14.59	0.001
2	832.19	7.52	110.67	0
3	-351.56	7.52	-46.75	0
4	-590.31	7.52	-78.5	0
B				
1	248.44	7.52	33.04	0
2	937.19	7.52	124.63	0
3	-477.81	7.52	-63.54	0
4	-707.81	7.52	-94.13	0
C				
1	184.69	7.52	24.56	0
2	407.19	7.52	54.15	0
3	-294.06	7.52	-39.11	0
4	-297.81	7.52	-39.61	0
D				
1	-670.31	7.52	-89.14	0
2	-642.81	7.52	-85.49	0
3	-170.31	7.52	-22.65	0
4	1483.44	7.52	197.28	0

(c) Compartmental basin - Regression Coefficients for Parameter levels

Term	Coef	SE Coef	T-Value	P-Value
Constant	3629.06	6	604.55	0
A				
1	878.4	10.4	84.49	0

2	-29.1	10.4	-2.8	0.068
3	-311.6	10.4	-29.97	0
4	-537.8	10.4	-51.73	0
B				
1	1048.4	10.4	100.84	0
2	345.9	10.4	33.27	0
3	-604.1	10.4	-58.1	0
4	-790.3	10.4	-76.01	0
C				
1	132.2	10.4	12.71	0.001
2	585.9	10.4	56.35	0
3	-346.6	10.4	-33.33	0
4	-371.6	10.4	-35.74	0
D				
1	-657.8	10.4	-63.27	0
2	-622.8	10.4	-59.9	0
3	-206.6	10.4	-19.87	0
4	1487.2	10.4	143.03	0

Figures

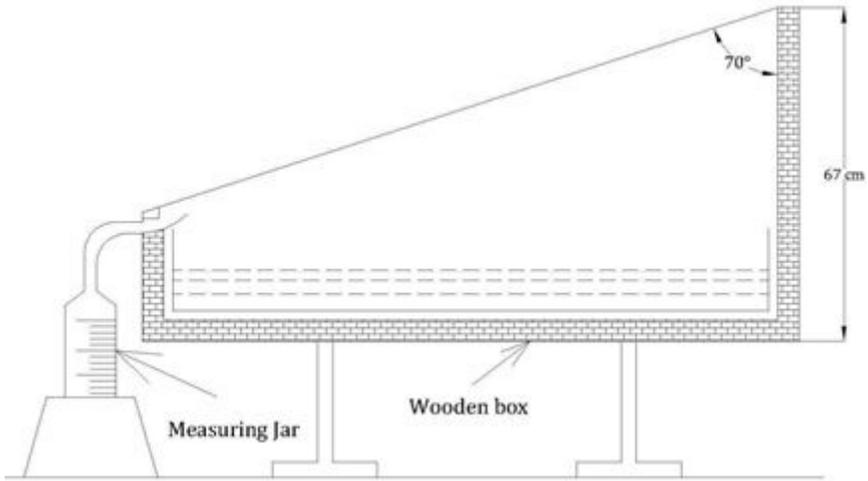


Figure 1

Schematic Diagram of Solar Still



Figure 2

Plain Basin Solar Still – Experimental Setup



Figure 3

Corrugated Basin Solar Still – Experimental Setup



Figure 4

Compartment Basin Solar Still – Experimental Setup

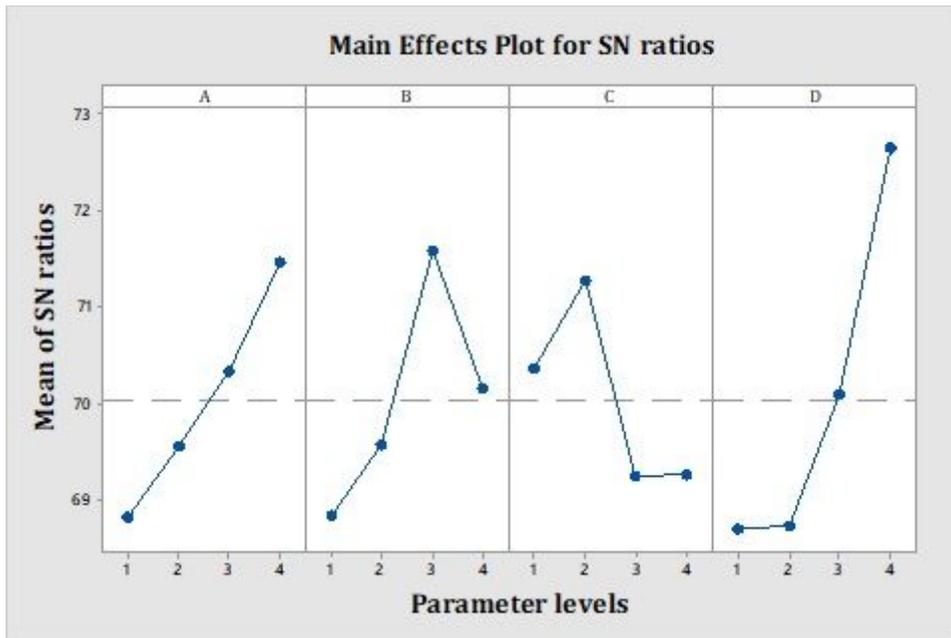


Figure 5

Parameter levels and S/N Ratios – Plain Basin. A, B, C & D – Parameters 1, 2, 3 & 4 – Parameter levels

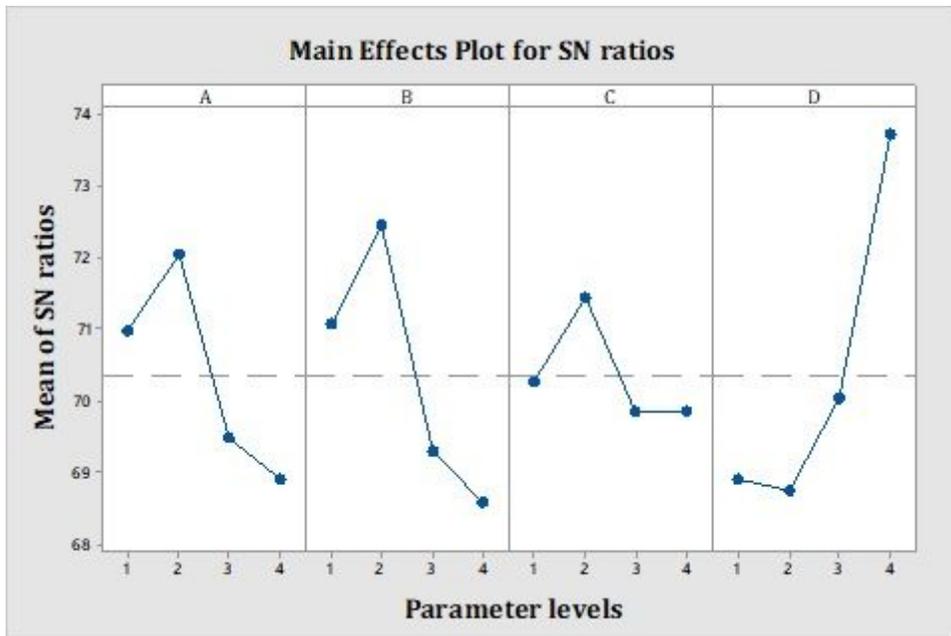


Figure 6

Parameter levels and S/N Ratios – Corrugated Basin. A, B, C & D – Parameters 1, 2, 3 & 4 – Parameter levels

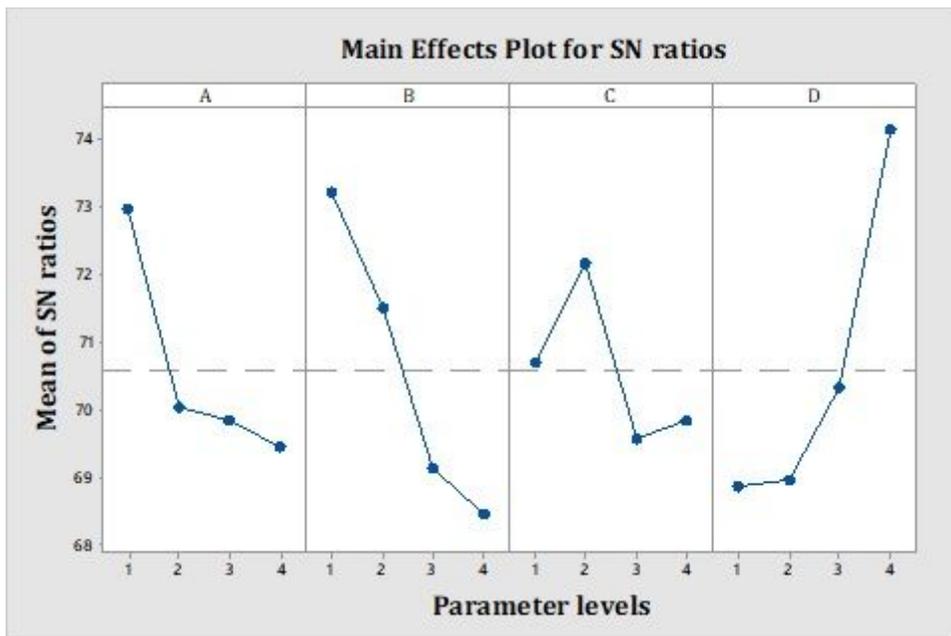


Figure 7

Parameter levels and S/N Ratios – Compartmental Basin. A, B, C & D – Parameters 1, 2, 3 & 4 – Parameter levels

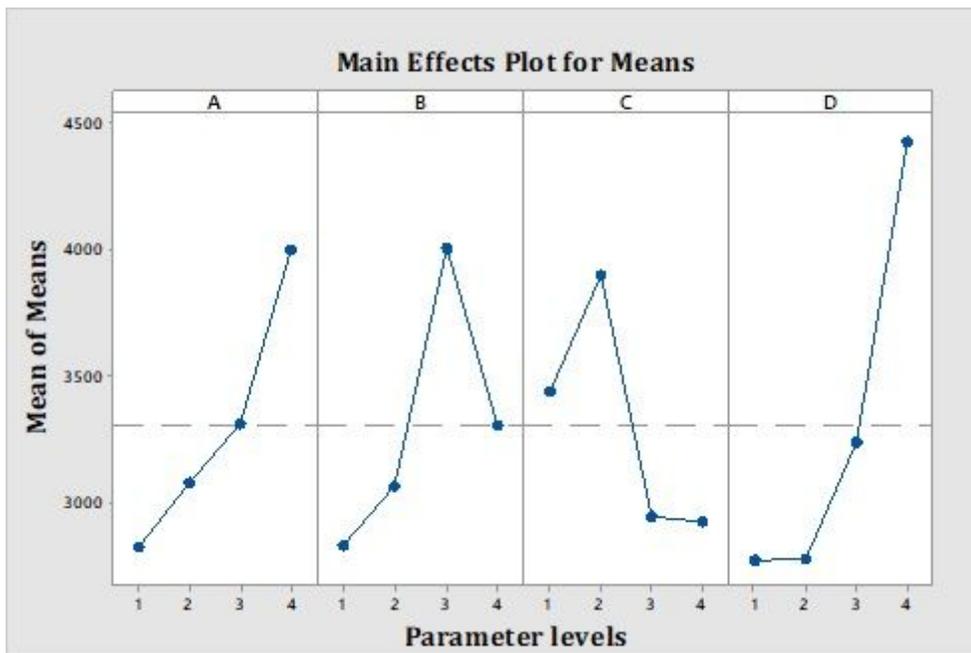


Figure 8

Mean Response Values – Plain Basin. A,B,C & D – Different parameters 1,2,3 & 4 – Different parameter levels

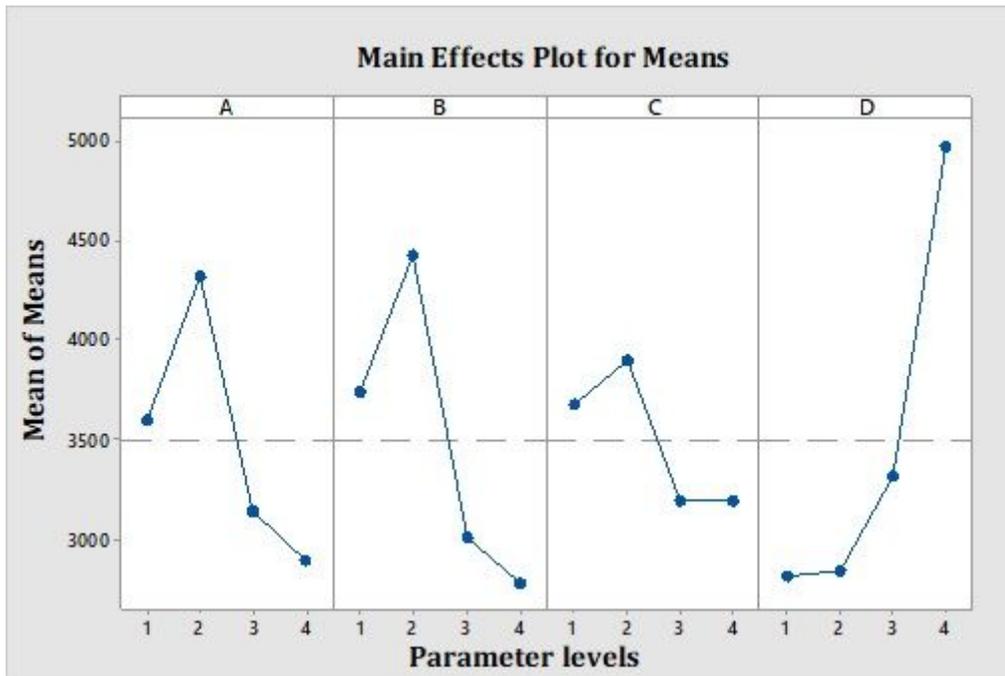


Figure 9

Mean Response Values – Corrugated Basin. A,B,C & D – Different parameters 1,2,3 & 4 – Different parameter levels

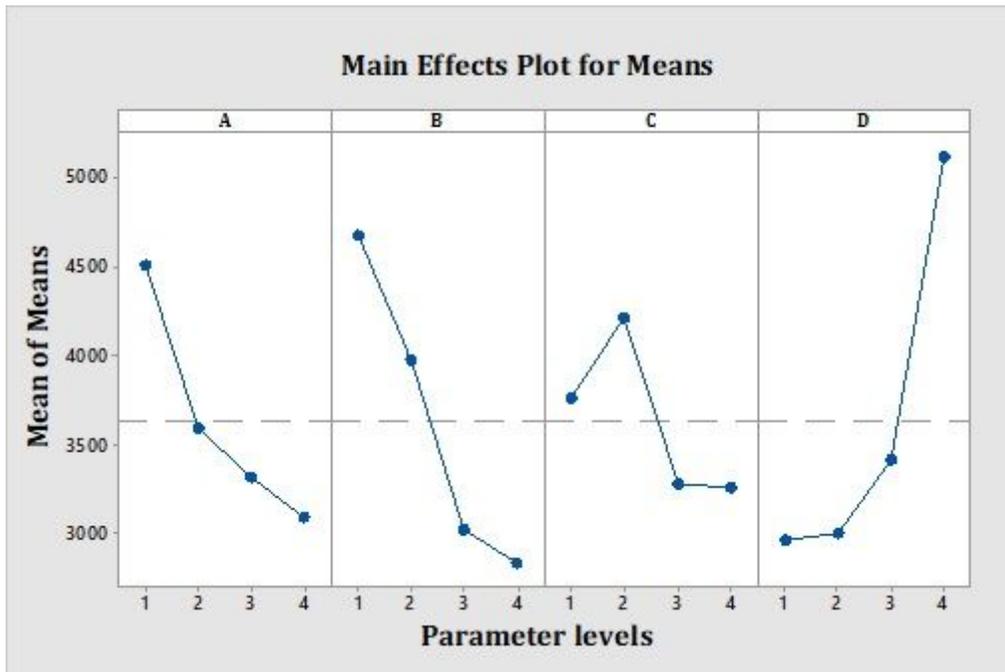


Figure 10

Mean Response Values - Compartmental basin. A,B,C & D – Different Parameters 1,2,3 & 4 – Different Parameter levels

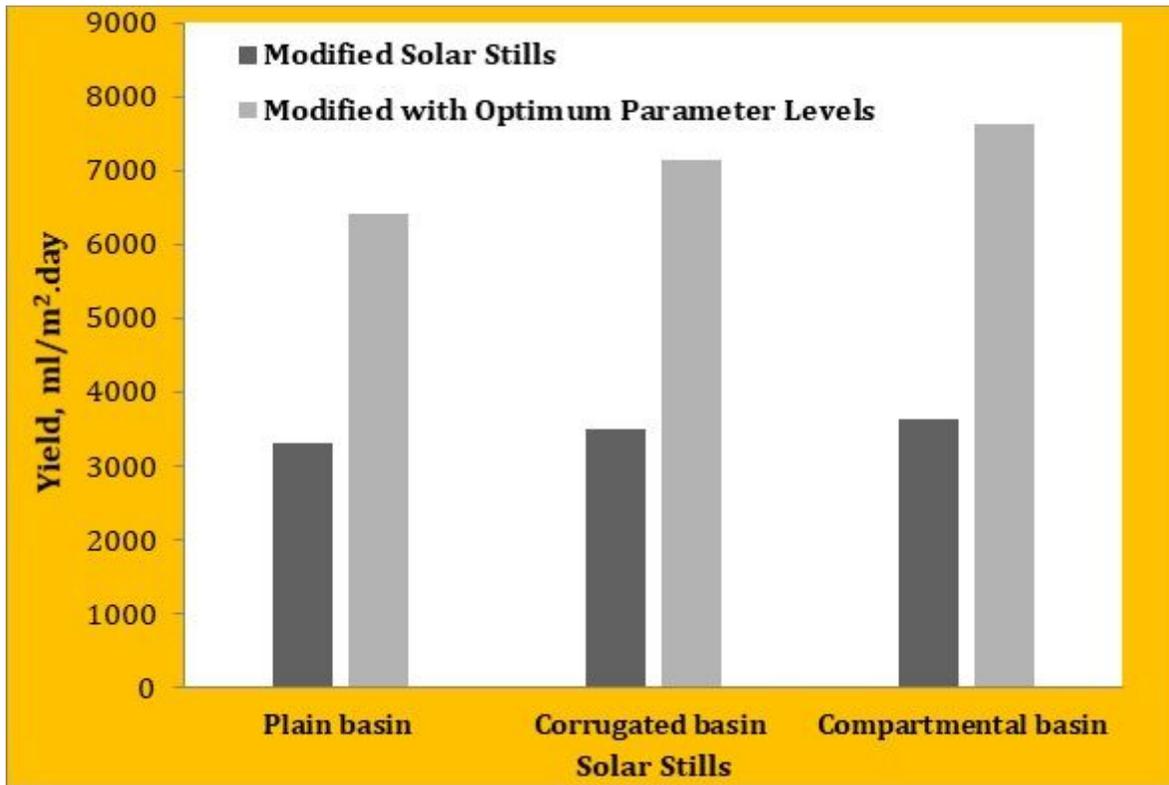


Figure 11

Comparison of Performance