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Distillate water quality analysis and economics study of a passive solar still

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Abstract
An experimental investigation on a double slope solar still is carried out to examine the quality of water under outdoor environment. Three synthetic water samples were prepared by adding Na_2CO_3, $NaHCO_3$, $CaCl_2$, and $MgCl_2$. Few physical and chemical parameters were checked before and after the distillation namely: appearance, color, odor, pH, total alkalinity, total hardness and chloride content. It is found that the results agree with the standard values as prescribed by WHO and BIS-1991. Daily yield of the still is 3 L/m^2/day. The payback period of the still is calculated and found to be 67 days which shows the utility of this solar still.

Keywords: Desalination, Economics,Passive solar still, Water purification,Water quality.

INTRODUCTION

Water being one of the essential building blocks of a social mechanism, its need can't be over looked. Due to the fast track development and unsustainable utilization of natural resources, the present sources are either depleting, eroding or getting contaminated and in lieu of that the scarcity of potable water is hiking.

The Ministry of Urban Development,Government of India has proclaimed in the LOK SABHA that 22 out of 32 major cities have to deal with daily water shortage. Few of the enlisted cities are Jameshdpur, Kanpur, Asansol, Dhanbad, Meerut, Faridabad, Vishakhapattnam, Madurai, Kochi, Hydrabad, Delhi, and Mumbai etc where the gap between demand and supply varies from 70-30%. [1]

According to UNICEF and Food and Agriculture Organization (FAO)'s (*Water in India: Situation and Prospects*)despite a sizeable water resource base, unequal distribution, unregulated groundwater extraction, water pollution and deteriorating quality because of poor sanitation and bad waste management, India struggles to meet its water sector requirements. [1] [2]

As per an estimation of Ministry of Drinking Water and Sanitation,Government of India, there has been an increase of 569 cases of deaths due to diseases caused because of drinking contaminated water in 2012. [3]

OBJECTIVE

In the light of aforementioned data the authors have decided to seek an economical way out to purify water. It is seen that the solar water desalination being economical, green in nature, zero maintenance requirements and with no consumption of electricity is gaining popularity for small scale water demands. But a limited data is available which invokes the quality of such water. So authors have initiated to check the quality of water pre and post distillation process.

SAMPLE PREPARATION AND EXPREIMENTAL SET-UP

ThreeSynthetic samples were prepared in the laboratory of chemistry, school of basic science, Sam Higginbottom Institute of Agriculture Technology & Sciences Deemed University by varying the concentration of Na_2CO_3, $NaHCO_3$, $CaCl_2$, and $MgCl_2$. These samples were fed into the double slope solar still.

The experiments were conducted on different days in the chemistry laboratory of school of basic science at the campus of Sam Higginbottom Institute of Agriculture and Sciences Deemed University, Allahabad, India and in the chemistry laboratory of Rajshree Institute of Management and Technology, Bareilly, India. Following physical and chemical parameters were recorded:

- Appearance
- Color
- Odor
- pH
- Total alkalinity
- Total hardness
- Chloride content

Appearance, color and odor are recorded pre and post distillation by physical examination of the samples[4]. pH is recorded on a electronic digital meter having a least count of 0.01. The instrument was standardized with the buffer of 7 and 9 pH before the test.

Total hardness was recordedby following ASTM D1126-12 procedure. Total Alkalinity was analyzed following the standard procedure as prescribed by ASTM D3875-08 and the chloride detection was done by following ASTM D511-09 method[5].

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RESULTS AND DISCUSSION

Table 1 shows the variation observed pre and post distillation process. It is found that values agree with WHO and BIS-1991 standards very well.

Table 1. Parameters of water pre and post distillation process.

Parameters	Sample 1	Sample 2	Sample 3	Distilled water from sample 1	Distilled water from sample 2	Distilled water from sample 3	WHO Standard	BIS-1991 Standard
Appearance	Hazy	Hazy	Hazy	Clear	Clear	Clear	Clear	Clear
Color	White	White	White	Colorless	Colorless	Colorless	Colorless	Colorless
Odor	Agreeable	Agreeable	Agreeable	Agreeable	Agreeable	Agreeable	Agreeable	Agreeable
pH(µ mhos/cm)	8	7.41	7.75	7.2	6.95	7.1	6.5-8.5	6.5-8.5
Total Alkalinity (mg/L)	642	950	1250	76	85	93	-	600
Total Hardness (mg/L)	433	582	720	51	73	82	500	600
Chloride (mg/L)	388	670	825	32	71	80	250	1000

ECONOMICS FOR SOLAR STILL:

In order to check the economic viability of the double slope solar still many scholars [6] [7] [8] [9] have carried out the economic analysis. Following calculations are done for the economic investigation of present system

Cost Analysis

Let P be the initial investment of any double slope solar still, r is the annual rate of interest on the capital amount and n is the number of useful years up to which the system will perform, therefore

(i) Capital Recovery Factor (CRF):
CRF= $r (1+r)^n / ((1+r)^n -1)$
Where r= interest rate, n = number of useful years
Hence the first annual cost = (CRF). P

(ii) Annual Salvage Value:
The sinking fund factor (SFF) for a systemis given by
SFF = $r/((1+r)^n -1)$
Therefore, if the salvage value of the system is S then,
Annual salvage value = (SFF). S

Further, the system requires some maintenance and it is a varyingquantity, therefore the annual maintenance cost should also be considered.

(iii) Annual Cost/m^2 = [First annual cost + annual maintenance cost – annual salvage value]

(iv) Annual yield = 3x365= 1095 L

(v) Annual cost/L= [Annual first cost/ Annual yield]

Assuming the reuse of various components even after the useful life of the system is over; the salvage value can be estimated to be 35% of the initial cost, useful life 10 years, interest rate 12% and maintenance cost as 15% of annual first cost. Results so obtained are tabulated below.

Payback Period

Daily distilled water production per unit area= 3 L/m^2/day
Cost of distilled water in Indian market = Rs 15/L
Worth of distilled water produced everyday (gain)
= 3 x 15 = Rs. 45/ day
Initial cost of present still = Rs. 3000/ m^2
So pay-back period of still is = 67 days.

Table 2. Economics of the passive solar still

S. No.	Parameter	Value
1	CRF	0.177
2	SFF	0.057
3	P	INR 3000
4	S	INR 1050
5	Annual First Cost	INR 531
6	Annual Salvage Value	INR 59.85
7	Annual Maintenance Cost	INR 79.65
8	Annual Yield	1095 L
9	Annual Cost/ L	INR 0.50

CONCLUSIONS

Authors have found following conclusions after a detailed experimental water quality analysis on a passive solar still pre and post distillation

- In order to avoid the human loss it is crucial to maintain the quality of water.
- The data obtained pre and post distillation has well agreed with the WHO and BIS-1991 standards. Thus the passive still can be adopted as a green alternative to purify water in remote areas where supply of electricity is not continuous.
- The economics study has revealed that the annual cost per liter is estimated to approximately 50 paisa which ensures the acceptability of passive solar still in rural and economically backward areas.
- Last but not the least the payback period of passive solar still is calculated and found to be 67 days which is quite considerable and voices to the utility of such passive solar still.

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