SOME ASPECTS REGARDING THE PRODUCTIVITY OF A SIMPLE EFFECT SOLAR EXPERIMENTAL STILL

NEKI ASPEKTI VEZANI UZ PRODUKTIVNOST JEDNOSTAVNOG POSTROJENJA SOLARNOG DESTILATORA

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Abstract: *This paper’s goal is to offer practical solutions for improving the water input, in terms of both quality and cost, for some communities or establishments with drinkable water problems, by using solar energy. Thereby, the present paper reports the performance of a solar distiller designed to be used in a rustic establishment, studied during a number of years.*

Key words: *solar energy, distillation, sunstroke, solar still productivity*

Sažetak: *Cilj ovog članka je predstaviti praktična rješenja korištenja solarne energije u svrhu unapređenja korištenja vode u odnosu na cijenu i kvalitetu u zajednicama i domaćinstvima koja imaju probleme s pitkom vodom. Rad govori o učinkovitosti solarnog destilatora namijenjenog korisnicima u ruralnih krajeva.*

Ključne riječi: *solarna energija,destilacija, produktivnost postrojenja solarnog destilatora*

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1. Introduction

Concerning the quality of water courses in Romania [1], currently we can state that:
- only 55,8% out of the fluent waters were part of the waters used for supplying with drinkable water the populous centers, zoo technical farms and trout farms;
- 27.6% were adequate in pisciculture for supplying with technological water and for pleasure resort;
- 6.1% of the surface water were represented by the waters used for irrigating the agricultural crops, yielding of electrical energy in hydro-electric power station, industry and laundries;
- 10.6% was part of degraded waters in which piscicultural fauna cannot flourish.

Not only the surface water but also the ground water can present a high level of pollution and therefore can no longer be sources of input water for a lot of communities in our country.

The most intensive and aggregate depreciation of underground water quality was found in rustic establishments where, due to a lack of minimum endowment, liquid waste reach the underground, so that in time, most of the underground waters were contaminated with nitrogenous compounds and also with hardware and zoo technical products. It is important to note that the pollution of underground waters, which supplies the fountains of rustic establishments, is almost irreversible and remediation is extremely toilsome and often impossible. In isolated establishments, with tourism profile or potential, thus with a variable number of inhabitants according to the season, the supplementary need of drinkable water demands its providence from sources often improper to use. Distillation, a method used for obtaining drinkable water, is not very popular due to the high consumption of electrical energy, registered by the actual procedures, which determines a prohibitive expense of the water produced using “classic” distillation. If we replace electrical energy with the solar one in order to obtain thermal energy, a requisite for the process of distillation, then this new method will be more attractive. Our purpose was to use solar energy in order to find practical solutions to improve the water input for some communities possessing a matter of drinkable water. The finality of previous studies was drafting an installation called “solar distillation still“, corresponding to the specific needs of drinkable water for an establishment with 3 - 4 members [1]. The present work reports the dealing of solar distillation still between 1995 and 2009. The complexity of the problems due to the assurance of drinkable water, involved a number of researches with a marked interdisciplinary character, demanding for knowledge of hydrology, ecology, chemistry, physics, technology, economy, hygiene of feeding. Taking into consideration the problems we proposed to solve, we consider that our research demonstrates that solar energy can replace or supplement successfully the other energies procured from different sources.

2. Theoretical considerations

Among the unconventional sources of energy are comprised solar energy, wind energy, geothermal energy and wave’s energy. An absolute interest is presented by the wind energy and above all solar energy, in order to procure drinkable water. The Sun energy can be used like thermal energy or can be turned into electrical energy, depending on the method selected to generate drinkable water. Based on the climate conditions and the relief of the selected area for application, we decided that the most suitable method for generating drinkable water is solar distillation with natural outcome. The optimal installation that fits with our method is the basin solar distiller. For the mentioned method, the arguments are in the same time technical and economical, due to the fact that technical ones imply economical connotations.

1. The flexibility of the procedure is very important, knowing that the purpose of our study is to improve the drinkable water input for some communities. Thus, the modulated basin distiller fits perfectly.
2. Adequate materials for designing the distiller are conventional and easy to find.
3. The design of the installation is easy and can be feasible anywhere.
4. The selected method can be easily combined with other methods.
5. The maintenance and the movement of the installation do not need qualified staff.
6. Solar distillation corresponds to the most exigent ecological requirements.
7. Solar distillation is the cheapest method and can assure drinkable water from waters which poses different agents of impurity.

Figure 1 presents in a conceptual way a water distilling still. The operating principle is simple enough: solar incidence emanation goes through the glassy cover and is absorbed like heat by the backwashed surface of the basin distiller, stuffed with raw water, which follows to be distilled. According to this occurrence, the water is heated, as a consequence of glass-house effect and boiled. The vapors condense on the icy plate glass of the cover. Pure water seeps toward the lateral down-tank ducts and so the salts and germs are retained in the concentrated water from the basin. The supply with raw, saline water can be intermittent (refilling up daily or weekly) or perpetual. In the second case the efficiency is lower but the distiller presents the advantage of movement at beneficial parameters, avoiding in the same time the deposits. The materials of the installation must be resistant to solar emanation (UV, IR), saline water, vapors, wind, rain, hail and storms. The most advanced models use standard materials: glass, concrete, asphalt and certain plastic materials, durable to corrosion. The latent heat of vaporization for water is 2260 kJ/kg; thus we need 2260 kJ for supplying the distilling installation to obtain 1 L of pure water of density 1kg/L. This does not affect the efficiency of the method as long as the absorbed energy is entirely delivered throughout the condensation phenomenon; the so called "single" effect distillation [2]. The vaporization temperature is moderate, from 50° C to 85° C.

3. Experimental

The paper has as objective to provide an integrated assessment of the suitability of domestic solar still as a viable safe water technology. A single basin double slope solar still was proposed to study the effect of augmentation on the still performance under local conditions. Also an attempt has been made to critically assess the operational feasibility and costs incurred for using this technology.

The single effect or successive solar distillation can offer between a few liters and thousands of m^3/day. This leads to the removal of residues, different smelling - salts (sodium, calcite, iron, manganese salts etc), heavy metals (lead, cadmium, mercury), bacteria (E.Coli, Cholera, Botulinus), parasites (Giardia, Cryptosporidium).

Figure 2 presents a cross section of a solar distillation still, conceived for supplying with drinkable water a rustic establishment with 4 members, during the summer time [3].

The glassy plates that represent the cover were glued with filming silicone and blacked on a metallic frame, fitted upon the basin distiller, which can be manufactured from any resistant material to saline water from its inside and also to mechanical actions and to the weather. The black color of the basin is important in order for a good absorption of the sun emanations and for increasing the temperature inside the distiller. The cover joint and tight seal were realized with black silicone, resistant to high temperatures. Likewise, the basin was lined-out with a film to stop out any warmth leaks.

In order to assure a good efficiency, the still installation must keep a high temperature of the input water for a long time. The smaller the heat loss throughout the walls and the base of the distiller, the higher the temperature is inside it. In the mean time, saline water must be in a shallow layer and the temperature of the input water must be different enough from the one of the condensation surface. That is why the distiller cover must absorb a small fragment of the incidence radiation and dissipated heat by the condensed water backed away from the condensation surface, for example with a cold spay or air.

The flow of a solar distiller can be reproduced with the rapport (1) [4].

Table 1 presents the hourly variation of the solar radiation intensity, registered in a single day of June, July and August, in Timisoara, between 1995-2009.

Taking into consideration that the medium daily intensity of solar radiation in a summer day reaches the value of 28.6 MJ/m^2, and that global efficiency of the solar distiller, corresponding to literature, is 20 - 30%, we can appreciate that the efficiency coefficient is 3.1 - 3.7 L/day. We admit that the minimum consumption of drinkable water is 5 L/subject/day. In consequence we can appreciate that a distiller with an absorption plan area of 2 m^2 could comply with daily needs of drinkable water for a single subject [2].

We registered daily flows of drinkable water produced by the distiller in order to appreciate its efficiency, remarked between 1995-2009, in June, July and August. The results are presented in the graph of figure 3. It is also important to mention that daily out-comings in terms of sunstroke are bigger in the morning, when the water temperature is still high, although the intensity of solar radiation is weak and outside the temperature is still low.

Analyzing the operational efficiency of an experimental solar still involves identifying the effort determined by the solar still construction and operation and also the effects obtained as a result of solar still operation and calculation of performance indicators.

The effort involved by the solar still construction concerns the investment costs of obtaining a solar still and includes the following expenditure categories:

- costs for preparing the land for solar still building and fitting ;
- costs of concrete constructions, masonry, pipes, aluminum frames, special operations;
- costs for insulation materials, glass;
- equipment costs, the cost of distillation tank;
- labor costs for the solar still construction.

Depending on the solar still's location, the size of investment spending may record relatively large variations. Solar still operation involves the following costs:

- the water cost - depends on drilling costs (where water is taken from wells);
- the energy cost for pumping raw water in the solar still basin;
- the cost of chemicals added for controlling microorganisms development in the basin;
- investment amortization - depends on the functioning period of time of the solar still;
- the cost of water storage and distribution determined by the energy cost for pumping the produced water to the storage tanks or to the distribution systems;
- the cost of maintenance and repair of solar still - conventionally defined as an annual rate of 1-2% of investment costs;
- the cost of activities related to the solar still operation and supervision.

The effects obtained from the solar still operation are focused on:

- the production of drinking water for personal consumption;
- cost savings from obtaining one cubic meter of drinking water (the cost of a cubic meter of water produced using solar still is significantly lower than using other technical options for obtaining drinking water);
- improving the quality of drinking water used by the public;
- increasing the amount of water accessible to the public in the area;
- environmental awareness;
- social effects (water quality improvement decrease health care costs [5].

Quantifying the productivity of solar still requires calculating the following indicators that reflect the causal relations between effects and resources seen in the dynamic:

Updated economies of financial resources express, at the moment of updating, the size of financial savings resulting from the difference between the cost of 1 m^3 of drinking water produced in the solar still and the cost of 1 m^3 produced by other technical solutions. Given that the financial savings are achieved throughout the entire period of operation of a solar still (which can reach up to 20 years) and investment expenditure is consumed in a shorter time (up to 1 month) and further, economies of financial resources are done in a certain period of time and investment expenditure is consumed in another time, should apply the updating technique, after the relationship (2).

The experimental solar still productivity reflects the production of drinking water obtained at 1 Euro investment capital (3). If we analyze the productivity of several installations of drinking water production, the installation with the highest value of productivity will be preferred.

The specific investment expresses the specific effort or the investment consumption for obtaining one cubic meter of drinking water produced using experimental solar still (4).

When assessing the productivity of many installations for obtaining drinking water, it is recommended to choose a "threshold" level of the indicator that can be the domain average value of the specific investment or the investor expected average value of the specific investment (*Is*), comparing with the result. The installation with the lowest value of specific investment will be preferred.

Experimental solar still economies express the economies of financial resources obtained at 1 Euro invested. These savings are achieved due to the fact that the cost of one cubic meter of drinking water obtained by using the experimental solar still is less than the cost of one cubic meter of drinking water produced by other technical solutions. in accordance with relationship (5) [6]. If we analyze several types of solar stills, that which is generating the greatest savings value at 1 Euro invested will be preferred.

4. Table

Hourly intensity of solar radiation (MJ/m²)									
Hour / *Month*	5	6	7	8	9	10	11	12	13
June	10.8	18.0	28.8	43.2	50.4	55.8	57.6	61.2	63.0
July	7.2	18.0	29.5	50.4	61.2	72.4	79.2	75.6	80.3
Aug.	10.8	21.6	19.8	46.8	57.6	72.0	75.6	81.0	79.2
Hour / *Month*	14	15	16	17	18	19	20	21	
June	57.6	46.8	39.6	28.8	21.6	14.4	5.4	1.8	
July	74.5	61.2	46.8	32.4	21.6	10.8	5.4	1.8	
Aug.	73.8	64.8	50.4	36.0	19.8	10.8	3.6	1.8	
	Daily intensity of solar radiation (MJ/m²)					*Medium daily intensity of solar radiation (MJ/m²)*			
June	605.5					25,2			
July	728.7					30,4			
Aug.	726.4					30,3			

Table 1: The mean and global hourly daily intensity of solar radiation in a single summer day of June, July and August

5. Pictures

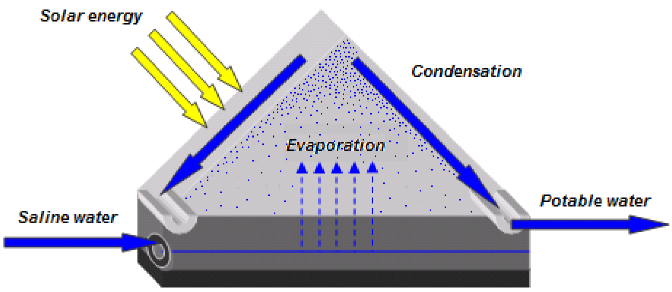

Figure 1: Principle of water solar distillation

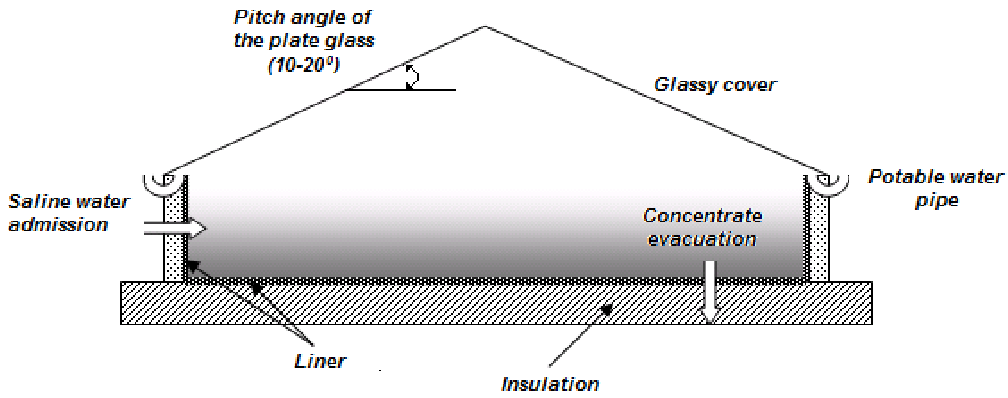

Figure 2: Cross section of a solar distillation still

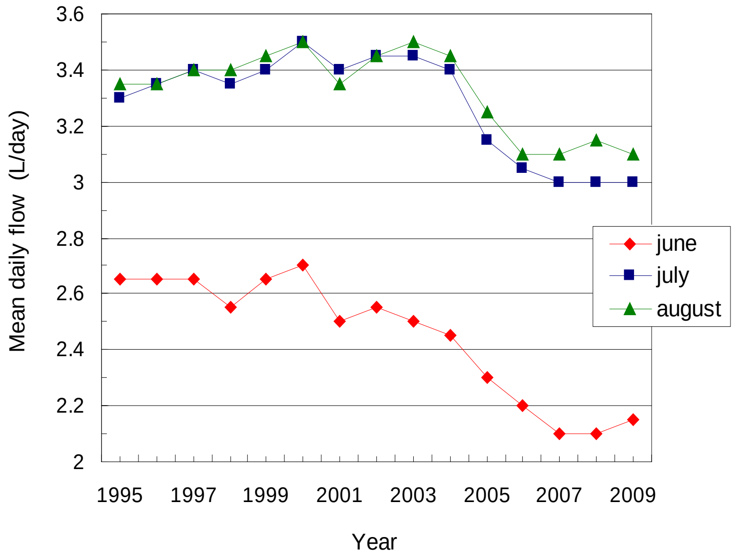

Figure 3: Variation of the mean daily flow of drinkable water produced in the summer time between 1995 ÷ 2009

6. Equations

$$Q = \frac{E \times G \times A}{2,3}$$

(1)

where: Q = daily flow of distilled water (L/day)

E = global efficiency of the installation (%)

G = the daily medium intensity of solar radiation (MJ/m^2)

A = plan aria of the basin (m^2)

$$Efr = \sum_{t=1}^{d} Q_t(K_a - K_{ss})\frac{1}{(1+e)^t}$$

(2)

where: Efr = updated economies of financial resources;

Q_t = the drinking water production of solar still in year "t" (m^3);
K_a = the cost of obtaining one cubic meter of drinking water using other technical options;
K_{ss} = the cost of obtaining one cubic meter of drinking water using the solar still
$t = 1 \div d$ = the length of the solar still operation period (years);
e = the cost of capital used to finance investment spending / opportunity cost.

$$P = \frac{\sum_{t=1}^{d} Q_t}{I} \qquad (3)$$

where: P = the experimental solar still productivity;
I = investment costs of obtaining the experimental solar still.

$$Is = \frac{I}{\sum_{t=1}^{d} Q_t} \qquad (4)$$

where: Is = the specific investment of an experimental solar still;

$$E = \frac{\sum_{t=1}^{d} Q_t (K_a - K_{ss}) \frac{1}{(1+e)^t}}{I} \qquad (5)$$

where: E = the experimental solar still economies;

7. Conclusion

Distillation is one of many processes that can be used for water purification and can use any heating source. Solar energy is a low tech option. In this process, water is evaporated, using the energy of the sun then the vapor condenses as pure water. This process removes salts and other impurities.

The main features are the same for all solar stills. The solar radiation is transmitted through the glass or plastic cover and captured by a black surface at the bottom of the still. A shallow layer of water absorbs the heat which then produces vapor within the chamber of the still. The vapor condenses on the glass cover, which is at a lower temperature because it is in contact with the ambient air, and runs down into a gutter from where it is fed to a storage tank.

The monitoring of the solar distilling installation through a period long enough showed that it keeps its input functional parameters and the restitution intercessions are minimal. The small cost both of the distilling still and the water produced, performance conservation and the ecological character of the method, determine this installation to be a very important and efficient alternative as regards to the generation of drinkable water for ecological communities with a small and medium consumption.

8. References

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Photo 014. Wood cutting / Cijepanje drva