STUDIES ON THE UTILIZATION OF SOLAR ENERGY IN THE EFFLUENT TREATMENT

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Textile industry is the largest number compared to other industries in Tamil Nadu. In spite of the continuous efforts to prevent water pollution from these industries, solving of the high total dissolved solids (5000-10000 mg L^{-1}) in the effluent is not yet successfully done. India, being the tropical country, solar radiation is available in plenty during most of the year, enables the industries to use the solar evaporation ponds as a simple and economical treatment system. An experimental textile effluent evaporation tank made by natural black colored stone is developed. It showed excellent results of evaporation utilizing solar energy. The usage of overall pond depth of 17.5 cm and an initial liquid depth ranging from 5 cm to 15 cm depending upon the season with a salt removal period ranging from 5 to 6 days will make the solar evaporation pond an effective system for the recovery of the dissolved salts. Data have been collected, allowing us to know the mean evaporation to be expected in the region of Tamil Nadu, India. A solar wastewater treatment system is proposed for textile industry from this, which leads to possible recycling of chemicals and water by using solar evaporation. Calculation shows that the proposed system is quite competitive with conventional coagulation in the range of small textile effluent treatment installations.

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Introduction

Textile industry is the largest number compared to other industries in Tamil Nadu. In spite of the continuous efforts to prevent water pollution from these industries, solving of the high total dissolved solids (TDS) in the effluent is not yet successfully done. India, being the tropical country, solar radiation is available in plenty during most of the year, enables the industries to use the solar evaporation ponds as a simple and economical treatment system. Since the available solar radiation energy is not used properly in the ponds, the attempt to use the solar evaporation ponds to recover the salts from the effluent led to a wrong impression that solar evaporation ponds are ineffective treatment systems.

In textile industries, evaporators can be installed to achieve zero liquid discharge of effluent. Evaporation is being considered as an alternative process in an increasing number of wastewater treatment applications. It can be effective for concentrating or removing salts, heavy metals and a variety of hazardous materials from solution. Also, it may be used to recover useful by-products from a solution, or to concentrate liquid wastes prior to additional treatment and final disposal. Most applications of the technology also produce a high quality, reusable distillate-a very important feature where water conservation is a priority.

During evaporation, a solution is concentrated when a portion of the solvent, usually water, is vaporized, leaving behind saline liquor that contains virtually all of the dissolved solids, or solute, from the original feed. The process may be carried out naturally in solar evaporation ponds, or through the use of commercially available evaporation equipment. [1]

Solar Evaporation Ponds may be extensively used in the textile dyeing and bleaching industries to treat the effluent which contains high total dissolved solids in the range of 5000 to 10000 mg L^{-1}. Presence of TDS in the treated effluent discharge by the industries poses a great danger to the agricultural lands. Optimum usage of the existing solar evaporation ponds is the need of the hour. Hence, there is a necessity for a study to find the variation in the rate of evaporation from the effluent stored in the ponds so as to suggest a method for an effective operation of the ponds.[2]

The development of solar evaporation technology gained attraction in the effluent purification both economic and environmental benefits. This chapter covers the idea of solar evaporation system by constructing solar ponds to avoid groundwater contamination and safe recovery of salt removal. [3]

Principle of solar evaporation tank

Radiation is a process by which heat flows from a body at a higher temperature to a body at a lower temperature when the bodies are separated in space or even a vacuum exists between them. The energy transmitted so called radiant heat. Radiation is the mode of the heat transfer by which the sun transfers energy to the earth. The quantity of energy leaving a surface as radiant heat depends on the absolute temperature and the nature of the surface. A perfect radiator, so called black body emits radiant energy from its surface at a rate ‘Q’ is given by,

$$Q = A\,\sigma\,T^4 \qquad (1)$$

Where, A is the area of the body, T is absolute temperature in K and σ is a constant known as Stefan’s Boltzmann constant.

Real bodies do not meet the specifications of an ideal radiation and emit radiation at a lower rate than black bodies. The ratio of the radiation emission of a real body to the radiation emission of a black body at the same temperature is called the emittance. Thus a real body emits radiation at a rate.

$$Q = \varepsilon A \sigma T^4 \quad (2)$$

where, ε is the average emittance of the surface. According to physical phenomena, the surface which absorbs all incident energy is called black surface. It is defined as one which absorbs the entire energy incident upon it and reflects none; such a body is used extensively in radiation heat transfer work.

Materials and Methods

Black Kadappa stone – natural material quite impervious, long-lasting, hard, more resistant than most other sedimentary rocks and can withstand to any exposure. Its hardness is 3 to 4 on Mohr's scale, density is between 2.5 and 2. 7 g $cm^{-3,}$ compressive strength is between 60 and 170 N mm^{-2}, water absorption is less than 1% and porosity is quite low.

Industrial mixed effluents collected from outlet of the local industry. It is measured for TDS about 4700 ppm.

The solar evaporation tank is constructed with three segments. They are having the depth of 17.5 cm and area of 1849 cm^{-2} in stepwise position. The outlet pipe from tank-I is located near the upper part of the tank-II. Likewise the outlet pipe from tank-II is located near the upper part of the tank-III. These three tanks are placed on cemented roof in North-South direction as shown in the figure. The three tanks are kept in open exposed sunlight from the greater absorption of solar energy in the stepwise position.

The solar evaporation tank contains untreated/partially treated dyeing effluent. By natural buoyancy forces causes the heated layers of water to rise as it becomes less dense, once it reaches the surface the water loses it heat to the air through convection. The cold part which is heavier moves down to replace the warmer part creating a natural convective circulation that mixes the water and dissipates the heat. Initially, 15 L of effluent is placed in the tank-I, measured depth is about 9.2 cm. 10 ppm alum and 0.5 ppm polyelectrolyte is added into the tank so as to facilitate clariflocculation and then the supernatant liquid is allowed to flow into the tank-II and tank-III. Now the depth of the each tank is 4.2 cm. TDS of both tanks is measured with the help of TDS meter is about 4264 ppm. Now both the tanks are exposed to solar radiation on first day. The temperature of the effluent at 10 am is measured with the help of thermometer and then is measured for one hour time interval for the effluent level depth. TDS and temperature effluent in the tanks II and III was noted. This process was continued upto 4 pm and the same is continued for 6 days for complete evaporation.

The same procedure is followed with 10 L of effluent in tank-I. The tank-I depth is 6.2 cm. The tank-II and III depth is about 2.7 cm each. The process had 5 days for complete evaporation.

Studies have been conducted in the solar evaporation ponds to find the following:

1) The daily average rate of evaporation of the effluent stored in the pond

2) The initial liquid depth of the effluent that is to be stored in the pond for the efficient operation of the pond;

3) A simple method to increase the rate of evaporation of the effluent stored in the pond;

4) A regression equation to estimate the rate evaporation of the effluent stored in the pond using the generally available meteorological data and the TDS of the effluent.

5) The variations in the rate of evaporation of the effluent with that of water, salt water, and effluent added with black dye that were stored in the different ponds under similar conditions are also studied.

Result and Discussion

The experimental observation is presented in the Table 1 and 2. Solar evaporation certainly causes the decrease in depth of effluent level in tanks II and III to a greater extent corresponding to the value of temperature and so the concentration of effluent in the tanks increases, clearly indicates the evaporation.

Table 1 -Solar Evaporation of 15 L Effluent

Sl. No.	**Day No.**	**Temp.(°C)**	**Depth, cm**	**TDS, ppm)**
	Tank-II and III			
1	**Day 1 (Start)**	**30**	**4.1**	**4264**
2	Day 1 (End)	35	3.5	5418
3	Day 2 (Start)	28	3.4	5450
4	Day 2 (End)	36	2.8	6910
5	Day 3 (Start)	32	2.7	7012
6	Day 3 (End)	36	2.1	12022
7	Day 4 (Start)	30	2	12124
8	Day 4 (End)	37	1.5	17520
9	Day 5 (Start)	32	1.4	17610
10	Day 5 (End)	38	0.8	23820
11	Day 6 (Start)	29	0.7	24010
12	**Day 6 (End)**	**Completely Evaporated**		

Table 2 Solar Evaporation of 10 L Effluent

Sl. No.	**Day No.**	**Temp., °C**	**Depth,cm**	**TDS,ppm**
	Tank-II and III			
1	Day 1 (Start)	30	2.7	4214
2	Day 1 (End)	33	2.6	4340
3	Day 2 (Start)	28	2	5520
4	Day 2 (End)	36	1.5	6840
5	Day 3 (Start)	32	1.4	6880
6	Day 3 (End)	36	1	11840
7	Day 4 (Start)	30	0.9	11900
8	Day 4 (End)	37	0.4	16862
9	Day 5 (Start)	32	0.3	16940
10	**Day 5 (End)**	**Completely Evaporated**		

The Fig.1 to 4 explains the day vs depth of the tank and day vs TDS in the tank effluent. The five parameters such as temperature, velocity of the wind, the atmospheric pressure, extent of free surface of effluent and the quantity of vapor already present in the environment plays important role in the evaporation.

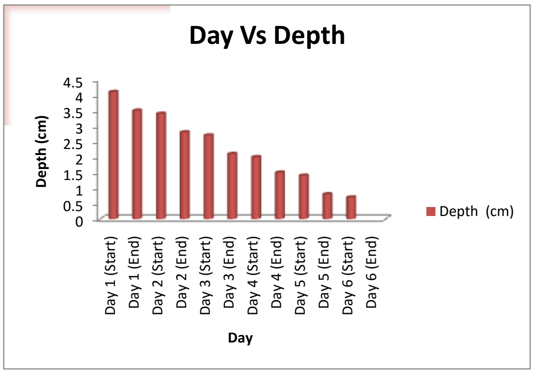

Fig. 1. Depth of the tank at various days (for 15 L)

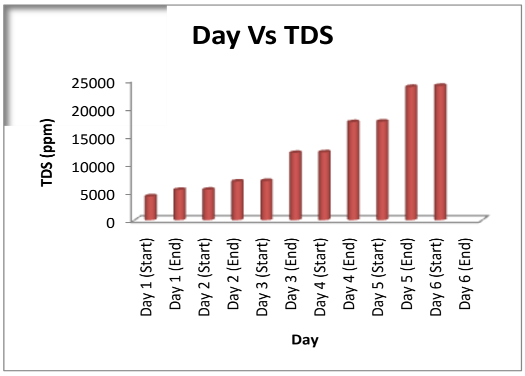

Fig. 2. TDS of the tank at various days (for 15 L)

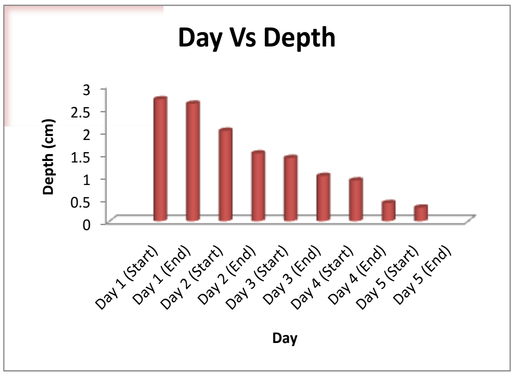

Fig. 3. Depth of the tank at various days (for 10 L)

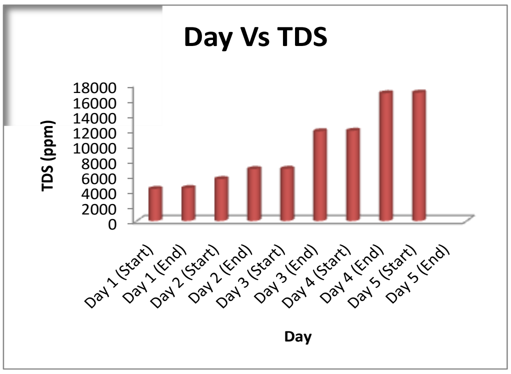

Fig. 4. TDS of the tank at various days (for 10 L)

As higher the temperature of the liquid the greater is the kinetic energy of the molecules and hence faster is the formation of vapor. The rate of evaporation increases with the velocity of the wind blowing over the surface of the exposed effluent, since the molecules of effluent escaping from its surface are carried away immediately as they are out of the effluent. The rate of evaporation is inversely proportional to the atmospheric pressure. It has been found experimentally that low atmospheric pressure increases the rate of evaporation and it is maximum in vacuum. The larger area of the free surface of the effluent exposed to the atmosphere increases the rate of evaporation. Moreover the rate of evaporation of any effluent decreases with the increase of the quantity of vapor of that liquid in the air.

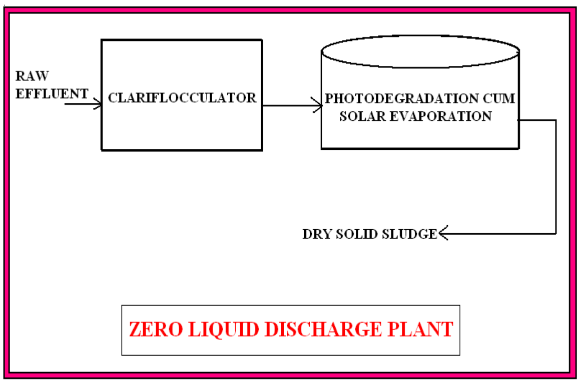

Fig. 5. Proposed Zero Liquid Discharge Plant

The studies have indicated that the effectiveness of the pond depends mainly on the intensity of the solar radiation of the day and the initial liquid depth of the effluent stored in the pond. The usage of the overall pond depth of 15 cm and an initial liquid depth ranging from 4 cm to 13 cm depending upon the season with a salt removal period ranging from 7 to 10 days will make the solar evaporation pond an effective treatment system for the recovery of the dissolved salts. Usage of natural black kadappa stone alternate to cement concrete ponds increases the rate evaporation of the effluent by around 100% which can be easily adopted by industries to increase the rate of evaporation. The proposed zero liquid discharge plant is shown in the Figure 5.

Conclusion

The rise in temperature of dyeing effluent from 50ºC to 70ºC improves the greater evaporation of effluent having high TDS.

Solar energy can be dependable energy source with specialized nature of its wide and comfort utilization without any new requirement of high technical ideas. In addition there is no underground seepage which causes groundwater contamination.

This black colored kadappa stone evaporation system can be offered as ecofriendly, simple and easy for adoption. It offers better performance during summer with very high evaporation rate. The total number of days taken for the complete evaporation of 15 L of effluent is 6 days and 5 days for 10 L for the designed tank. This is comparatively better performance than cement concrete tank which takes average 10 days for complete evaporation.

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