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Performance evaluation of plain pan with gunny bag arrangement (PPGA) solar evaporation systems for treating textile dye effluent

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Abstract: **The reject from the reverse osmosis plant in the treatment of textile effluents is one of the major environmental concerns due to its high total dissolved solids (TDS). Solar evaporation is one of the cost effective treatment techniques for effluents with high TDS. In the plain pan (PP) solar evaporation system, the rate of evaporation is 4.5 lit/m2 day which further requires significantly large land area. In this study, the plain pan with gunny bag arrangement (PPGA) was fabricated for the evaporation of textile effluent to increase the rate of evaporation. Hence, this comparison study between PP and PPGA was directed towards estimating the enhancement in evaporation rate due to this proposed modification in PP solar evaporation systems. The daily rate of evaporation and TDS along with the meteorological parameters such as temperature, relative humidity and wind speed were measured for a period of 20 days. It was observed that, the rate of evaporation in PPGA was about 5.7 fold greater than the PP System.**

Key words: **Solar evaporation systems; Plain Pan; Gunny Bag arrangement; Textile dye effluent; Cost effective treatment technologies.**

I. INTRODUCTION

There are about 10,000 garment manufacturers and 2100 bleaching and dyeing industries in India and majority are concentrated at Tirupur and Karur of Tamil Nadu, Ludiyana of Punjab and Surat in Gujarat [1, 2]. Textile dyeing is a combined process of bleaching and coloring, which generates voluminous quantities of wastewaters and in turn causes serious environmental degradation. Wastewater from the textile finishing industry commonly contains moderate concentrations (10-200 mg/l) of dyestuffs, contributing significantly to the pollution of aquatic ecosystems. Various physico-chemical and biological techniques have been employed for the treatment of dye containing effluents. They include coagulation/ flocculation, biological degradation using aeration system, activated carbon adsorption, oxidation, ozonation, membrane separation and multiple effect evaporation etc. The mechanical evaporation were reported as expensive and not environment friendly [3, 4]. The technical and economic feasibility of each of these techniques is determined by several factors such as the type of dyes used, wastewater composition, operation costs and generated waste products. Also, the use of one individual technique is not sufficient to achieve complete disposal and therefore textile effluent strategies consisting of a combination of different techniques may be necessary.

In recent years, the use of reverse osmosis (RO) technique in wastewater treatment is a highly efficient process, in terms of high recovery, low operating cost and easy operation and maintenance. RO membranes have a retention rate of 90% or more for most types of ionic compounds and they produce a high quality of permeate. However in RO permeates, the removal of all mineral salts, hydrolyzed reactive dyes and chemical auxiliaries, but the problem involved is that the higher the concentration of salts, the more important the osmotic pressure becomes and consequently, the greater the energy required. Nano filtration membranes retain organic compounds of low molecular weight, divalent ions or large monovalent ions, such as hydrolyzed reactive dyes and dyeing auxiliaries. Multiple effect evaporators were used in large scale industries wherein the initial investment and operational costs are high. Small scale industries generating small quantity of effluent can’t go for such costlier technologies and depend on low cost technology of solar evaporation. In Solar wind evaporation, the initial investment, maintenance cost and operational cost are less [6].

Hence, economical evaporation technologies for the disposal of waste water become need of the industries. Solar evaporation is one of the efficient methods. The construction of solar evaporation system can easily be built, operation cost is very less and no skilled persons are required. The rate of evaporation in conventional solar evaporation pan is relatively very less and hence requires large surface area [7-10]. The availability of land and its capital cost makes plain solar evaporation system as an uneconomical. The efficient use of the given surface area by utilizing the vertical space over the solar evaporation pan also will increase the rate of evaporation. This concept led to development of plain pan with gunny bag arrangement (PPGA) evaporation systems and hence this study was directed further to estimate the enhancement rate of evaporation due to its modifications on the conventional plain solar evaporation systems. In this study, we have reported the natural evaporation along with PPGA evaporation systems for the treatment of textile dye effluents.

II. MATERIALS & METHODOLOGY

2.1. Experimental Set-up

Two types of evaporation system Viz. plain pan (PP) and plain pan with gunny bag arrangement (PPGA) evaporation system was fabricated in lab scale as given below. For PP, a pan of 1m×1m×0.3m was taken and filled with 250 L of the pre-characterized dye effluents. The system was kept open to atmosphere in an open area. The atmospheric air is blown using an electrical blower (air cooler) over the pan. Fig 1 (a) and (b) represents the photographic images of PP and PPGA respectively.

Fig. 1. Experimental set-up of PP and PPGA evaporation systems

For PPGA, a pan of size 1m×1m×0.3m was taken and the gunny bags were placed vertically into the pan by using wooden frames arrangements. The system was kept open to atmosphere in an open area. The wastewater is filled in the overhead tank, and the wastewater is spread frequently along the gunny bags through tubes. Gunny bags were wetted with dyeing effluent and air was blown using a small blower to attain an increased rate of evaporation. Further, the gunny bags were allowed to touch the textile effluent makes the effluent uptake due to its capillary forces could enhance the evaporation rate.

2.2. Performance evaluation methods of PP and PPGA

The initial and final depth of liquid was measured using Vernier Caliper for both PP and PPGA evaporation systems. The rate of evaporation was observed during day time. The experiment was conducted for the period of 27 days with PP and PPGA systems. The raw textile dyeing wastewater was collected from the textile industry and subjected to characterization at regular intervals. The metrological parameters such as temperature, relative humidity and wind speed were taken from the nearest metrological station situated at 300m distance from the experimental site.

III. RESULTS & DISCUSSION

3.1. Characterization of textile dyeing effluent

The textile dyeing effluent was obtained from a textile industry at Tirupur, Tamilnadu, India. Raw effluent samples were collected from equalization tank in the industry and preserved in the refrigerator at 4°C in accordance with the standard methods for the Examination of Water and Wastewater (APHA, 2002). The collected wastewater samples were characterized in terms of the pH value as well as of BOD, COD, TDS, TSS, Chlorides and Sulphate concentrations (APHA, 2002).The characteristics of raw textile dyeing effluent are varied in the range of pH (7-8.5), TDS (3000-4000), TSS (10-15), Chlorides (1000-1500), Sulphates (500-750), BOD (100-200), COD (250-450). All values except pH are in mg/L.

3.2. Metrological parameters at the study location:

The metrological parameters such as temperature, relative humidity and wind speed were observed at the study location to realize the influence of these parameters on the evaporation efficiency. Mechanical evaporation could operate to concentrate by converting the water component into condensable water vapor, leaving behind a wet salt to be landfilled. The most common combination of technologies used for this purpose is a vertical tube falling film brine concentrator followed by a forced-circulation crystallizer. Since this arrangement is found to be more economical, this treatment method is seen as an alternative treatment to RO. Even the mechanical evaporation could substitute the RO process by influencing the parameters such as temperature, humidity and wind speed. This particular aspect delineates the scope and significance of comprehending the metrological parameters at the study location. Fig 2 depicts the metrological parameters at the study location during the study period.

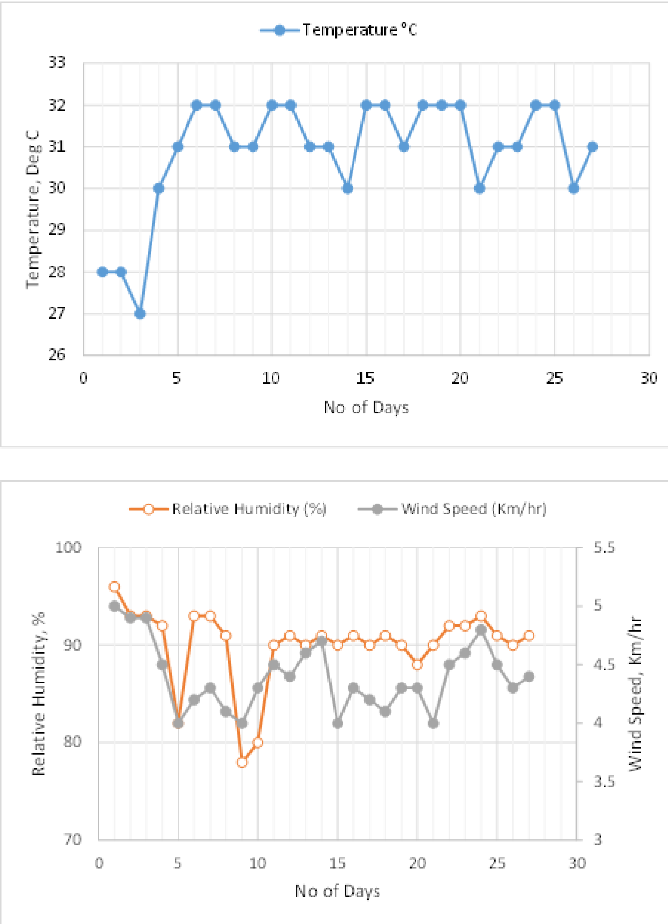

Fig. 2: Metrological parameters at the study location

3.3. Performance evaluation of PP and PPGA evaporation systems:

The initial volume of 250 litres of effluent was taken and fed into the PP and PPGA evaporation systems. The duration of evaporation per day was kept at constant for 8 hrs throughout the study and the rate of evaporation was calculated. The initial height of wastewater in the pan was measured before the start of the experiments. The meteorological parameters such as temperature, relative humidity and wind speed were as given in the Fig. 2. It was observed that the rate of evaporation is higher for PPGA when compared to PP evaporation systems. This might be due to the increase in the surface area by gunny bag arrangement in PPGA evaporation systems. The average rate of evaporation for water from textile effluent in PP and PPGA was observed as 0.5 and 2.9 l/m^2.hr respectively. Also the rate of evaporation of PPGA was found to be 5.7 times more than PP evaporation systems. The average rate of enhancement in evaporation efficiency is around 80 % dictates that the inclusion of gunny bags could provide more surface area for the natural evaporation to be occurred.

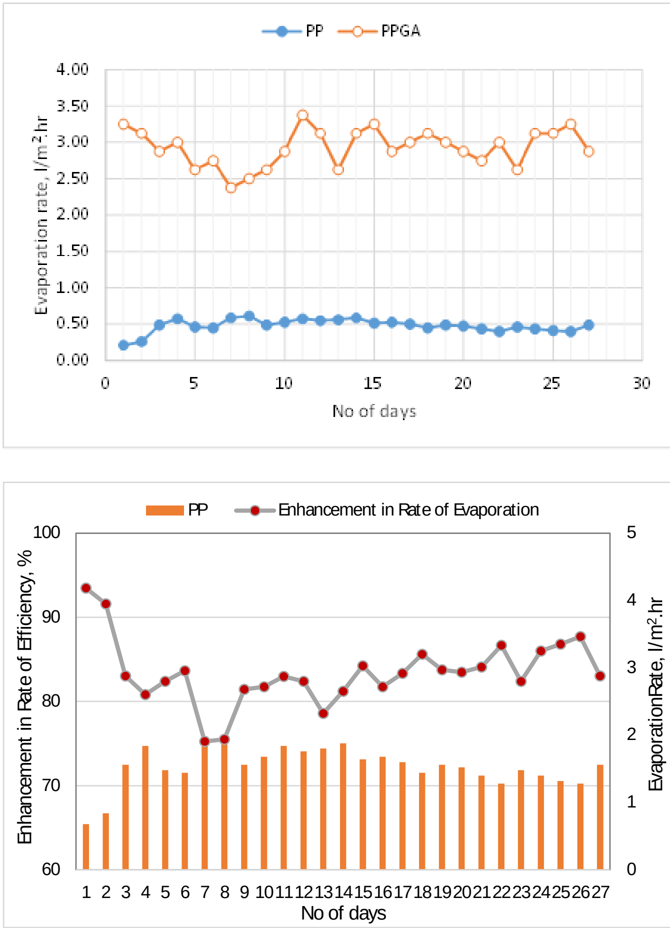

Fig. 3: Metrological parameters at the study location

3.4. Influence of metrological parameters for PP and PPGA systems

The influence of meteorological parameters such as temperature, relative humidity and wind speed on rate of evaporation for both PP and PPGA system was studied.

3.4.1. Effect of temperature on rate of evaporation

The experiment was conducted for the period of 20 days. The temperature of the study period varies from the range of 27°C-32°C. The average rate of evaporation of each temperature was calculated and the plot was drawn between rate of evaporation against temperature for both PP and PPGA system. Fig. 4 shows the effect of temperature on PP and PPGA. It was observed that the rate of evaporation increased with increase in temperature. The increasing trend was observed for both PP and PPGA system. Also it was observed that the rate of evaporation is higher for PPGA when compared to PP at all temperatures. The average rate of evaporation for temperatures was observed as 0.45 and 2.95 lit/m^2.hr for PP and PPGA respectively. Hence the rate of evaporation of PPGA was found to be 6.5 times more than PP for the effect of temperature.

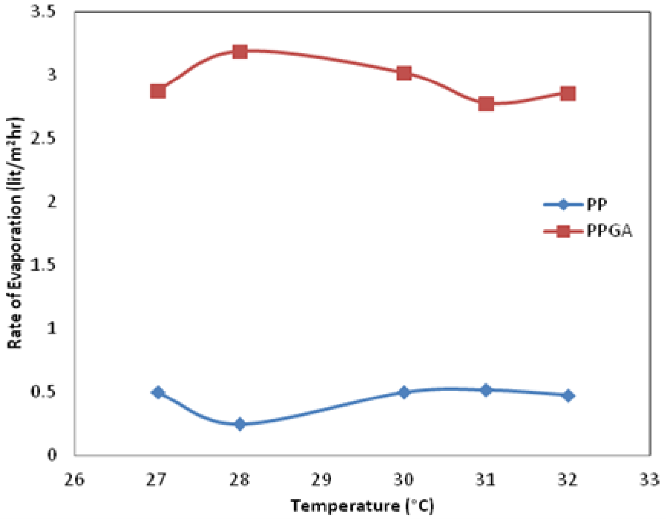

Fig. 4: Effect of temperature on rate of evaporation for PP and PPGA evaporation systems

3.4.2. Effect of Relative humidity on rate of evaporation

The relative humidity of the study period varies from the range of 78% to 96%. The average rate of evaporation of each relative humidity was calculated and the plot was drawn between rate of evaporation against relative humidity for both PP and PPGA system. Fig. 5 shows the effect of relative humidity for both systems and it was observed that the rate of evaporation decreased with increase in relative humidity. The decreasing trend was observed for both PP and PPGA system. Also it was observed that the rate of evaporation is higher for PPGA when compared to PP at all relative humidity. The average rate of evaporation for relative humidity was observed as 0.42 and 2.42 lit/m2hr for PP and PPGA respectively. Hence the rate of evaporation of PPGA was found to be 6.48 times more than PP for the effect of relative humidity

3.4.3. Effect of Wind Speed on rate of evaporation

The experiment was conducted for the period of 27 days and the wind speed during the study period varies from the range of 4-5 kmph. The average rate of evaporation of each wind speed was calculated and the plot was drawn between rate of evaporation against wind speed for both PP and PPGA systems. Fig. 6 shows the effect of wind speed for PP and PPGA evaporation systems and it was observed that the rate of evaporation increased with increase in wind speed. However the decreasing trend was observed at higher wind speeds (for instance: wind speed at 5 kmph) for both PP and PPGA might due to the effect of various other parameters.

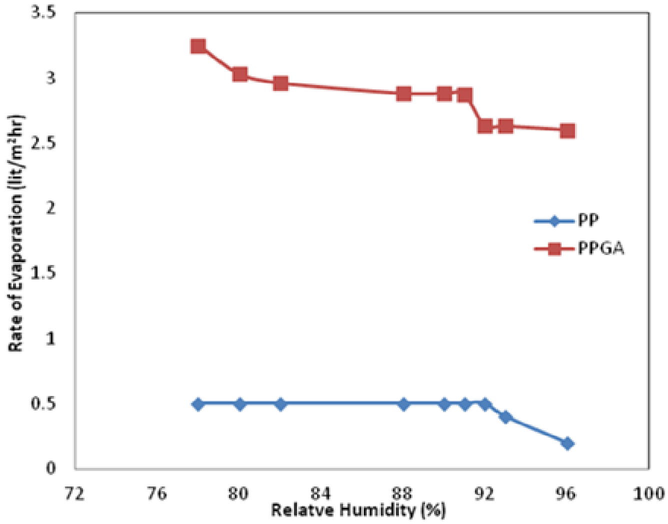

Fig. 5: Effect of relative humidity on rate of evaporation for PP and PPGA evaporation systems

Also it was observed that the rate of evaporation is higher for PPGA when compared to PP at all wind speed. The average rate of evaporation for wind speed was observed as 0.52 and 3.9 lit/m2hr for PP and PPGA respectively. Hence the rate of evaporation of PPGA was found to be 6 times more than PP for the effect of wind speed.

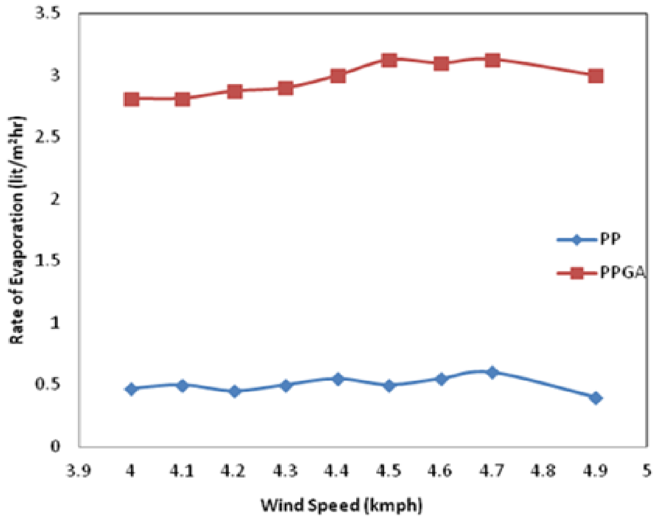

Fig. 6: Effect of wind speed on rate of evaporation for PP and PPGA evaporation systems

IV. CONCLUSION

The natural solar evaporation systems were usually equipped with plain pans and so the exploration of cost effective techniques to increase the evaporation rates led to fabrication of gunny bag arranged solar evaporation systems for the treatment of textile dyeing effluent were attempted. The metrological parameters were observed during the study and the possible influences on the improvement of evaporation rates were outlined. Comparative analysis were made between PP and PPGA systems and observed that the rate of evaporation is higher for PPGA when compared to PP evaporation systems. This may be due to the increase in the surface area by gunny bag arrangement in PPGA. The rate of evaporation was increased with increase in temperature and wind speed and decreased with increase in relative humidity. The rate of evaporation of PPGA was found to be 5.7 to 6 times more than PP. The use of gunny bags as a low cost alternatives could be suggested to enhance the evaporation rates of textile effluent as a measure in concentrating the effluent before its disposal.

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