Research Journal of Recent Sciences ISSN 2277-2502
Vol. 3(**ISC-2013**), 366-369 (**2014**) *Res. J. Recent. Sci.*

Studies on the use of Solar Energy for the Treatment of Iron Industry Effluent

A. Pandia Rajan[1], M.Velusamy[1], K. Kousalya[1], K. Kandasamy[1], M.S. Dheenadhayalan[1] and Ignatius Navis Karthika[2]
[1]Department of Chemistry, GTN Arts College, Dindigul, INDIA
[2]P.S.N.A College of Engineering and Technology, Dindigul, INDIA

Available online at: www.isca.in, www.isca.me
Received 26th November 2013, revised 6th February 2014, accepted 14th April 2014

Abstract

In general iron industries are present in large number when compared to other industries in Tamil Nadu. Efforts are taken to prevent the iron industry effluent pollution in India, but it is not successful due to so many factors. Hence an attempt has been taken to solve the impact of Iron industry pollution by using non conventional energy sources like solar energy. Black body Kadappa stone tank are utilized for evaporation of the iron industry effluent to zero level discharge of the effluent. Hence it is very useful for the successful effort to ensure zero level discharge. The utilization of overall depth of the primary black kadappa tank is around 9cm to 10cm just like evaporation of sea water on land for the preparation of the salt. By using solar evaporation, the chemicals and salts can be evaporated and recycled.

Keywords: Effluent treatment, effluent, iron stuff, solar evaporation, zero liquid discharge.

Introduction

Evaporation: Interestingly evaporation is often not defined in pure chemical and physics texts[1], this is because the evaporation is a non-technical interpretation of more fundamental physical processes. Evaporation or condensation occur when a liquid is not in equilibrium with its vapour or gas phase. Therefore, evaporation can be defined as the physical process in which a liquid is changed into a gas by molecular transfer. Condensation is the reverse process. Evaporation is often misleadingly defined as 'the transfer of water from the liquid state", though this definition is adequate for most purposes[2].

Iron Industries are 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 completed, India, being the tropical country, solar radiation is available in plenty during most of the year, enables the industries to use the solar evaporation tanks as a simple and economical treatment system. Since the available solar radiation energy is not used properly in the ponds, an attempt has been taken to use the solar evaporation tanks to recover the salts from the effluent led to a wrong impression that solar evaporation tanks are ineffective treatment systems.

Solar pond technology has made tremendous progress in the last fifteen years. An excellent monograph is now available on the science and technology of salinity gradient solar ponds[3]. The wastewater or effluent is used as a heat source or sink for a heat pump that can provide heating or cooling energy[4].

In Iron Industries, evaporators can be installed to achieve zero liquid discharge of the 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 waste 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 tanks, or through the use of commercially available evaporation equipment[5].

Solar evaporation tanks may be extensively used in the Iron Industry and foundry 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 tanks 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 tanks so as to suggest a method for an effective operation of the tanks[6].

The development of solar evaporation technology gained attraction in the effluent purification both economic and environmental benefits. The present paper covers the idea of solar evaporation system by constructing solar tanks to avoid groundwater contamination and safe recovery of salt removal[7].

In solar evaporation a vessel or pond area containing brine is allowed to evaporate under the prevailing environmental conditions. This technique works best at low latitudes where sunlight duration and intensity are highest and areas with low relative humidity and rainfall. Solar evaporation also becomes the default method when fuel resources are scarce and boiling of brine is unfeasible. Historically this technique was common in coastal areas and continues to be a viable commercial process worldwide[8,9]. Solar evaporation could have been practiced at many inland salines where brine concentrations tend to be high, thus reducing total evaporation time[10].

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,

$$Q = A \sigma T4 \quad (1)$$

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.

$$Q = \varepsilon A \sigma T4 \quad (2)$$

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.

Material and Methods

Black Kadappa stone – natural material quite impervious, long-lasting, hard, and 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 and it is 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.

The three tanks are kept in open exposed sunlight from the greater absorption of solar energy in the stepwise position. Dust and debris much heavier than water will sink to the bottom. They have reported that the dust accumulating at the bottom of the pond does not adversely affect the absorption of solar radiation at the bottom of the pond. The dust floating in the gradient zone can be settled by adding alum[11].

The solar evaporation tank contains untreated/partially treated Iron Industry 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 flocculation 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.

Studies were conducted in the solar evaporation tanks. i. The daily average rate of evaporation of the effluent stored in the tank. ii. The initial liquid depth of the effluent that is to be stored in the tank for the efficient operation of the tank. iii. A simple method to increase the rate of evaporation of the effluent stored in the tank. iv. A regression equation to estimate the rate evaporation of the effluent stored in the tank using the generally available meteorological data and the TDS of the effluent.

Results 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, so the concentration of effluent in the tanks increases and clearly indicates the evaporation.

Table-1
Solar Evaporation of 15 L Effluent

S.No.	Day	Temp.(^{0}C)	Depth,(cm)	TDS, ppm)
		Tank-I and Tank-II		
1	Day 1 (Start)	31	4.2	4103
2	Day 1 (End)	35	3.5	5423
3	Day 2 (Start)	29	3.4	5620
4	Day 2 (End)	36	2.9	6910
5	Day 3 (Start)	32	2.7	7860
6	Day 3 (End)	36	2.1	12022
7	Day 4 (Start)	30	1.9	12456
8	Day 4 (End)	37	1.5	18653
9	Day 5 (Start)	32	1.4	21850
10	Day 5 (End)	38	0.8	23062
11	Day 6 (Start)	29	0.7	25639
12	Day 6 (End)	Completely Evaporated		

Table-2
Solar Evaporation of 10 L Effluent

S.No.	Day	Temp.(^{0}C)	Depth,(cm)	TDS,(ppm)
		Tank-I and Tank-II		
1	Day 1 (Start)	31	2.9	4533
2	Day 1 (End)	35	2.6	5443
3	Day 2 (Start)	29	2.4	5620
4	Day 2 (End)	36	1.9	6510
5	Day 3 (Start)	32	1.7	7560
6	Day 3 (End)	36	1.1	10022
7	Day 4 (Start)	30	0.9	11456
8	Day 4 (End)	37	0.5	13653
9	Day 5 (Start)	29	0.3	15639
10	Day 5 (End)	Completely Evaporated		

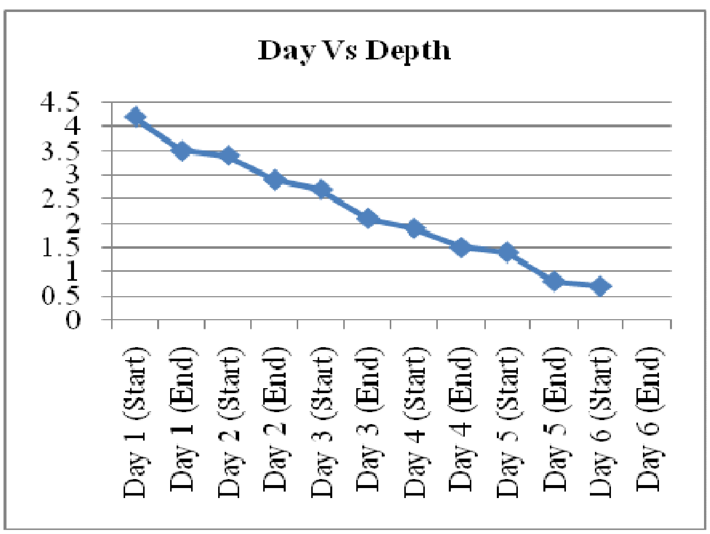

Figure-1
Depth of the tank at various days (15L)

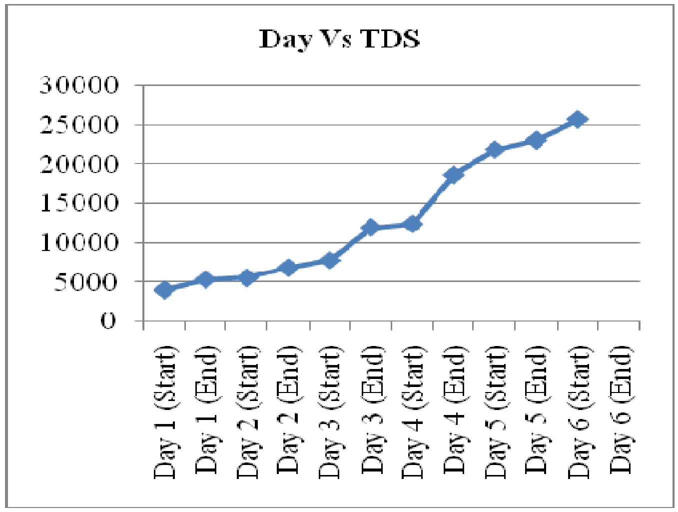

Figure-2
TDS of the tank at various days (15L)

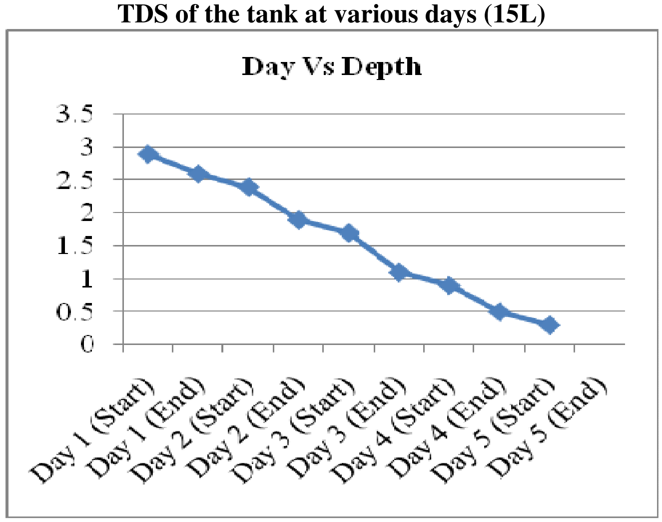

Figure-3
Depth of the tank at various days (10L)

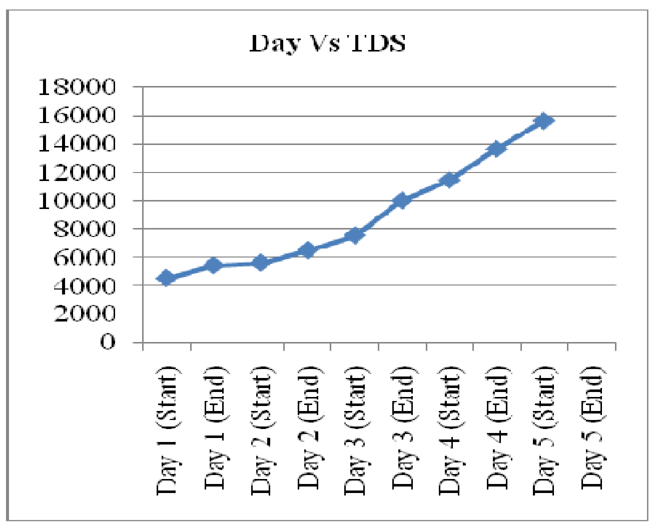

Figure-4
TDS of the tank at various days (10L)

The Figure-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.

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.

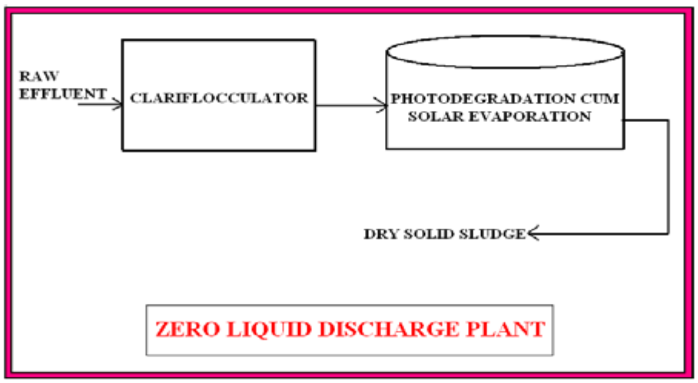

Figure-5
Proposed Zero Liquid Discharge Plant

The Studies have indicated that the effectiveness of the tank depends mainly on the intensity of the solar radiation of the day and the initial liquid depth of the effluent stored in the tank. The usage of the overall tank 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 tank an effective treatment system for the recovery of the dissolved salts. Usage of natural black kadappa stone alternate to cement concrete tanks increases the rate of 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 Iron Industry 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 eco friendly, 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.

Acknowledgement

The authors are thankful to their concerned Management and Principal of their college for financial support to promote such innovative solution for the environmental effluent problem.

References

1. Linsley R.K. and J. B. Franzini, et al. Water-Resources Engineering, McGraw-Hill Book Co. **(1992)**
2. Weast R.C. and M.J. Astle, et al. CRC Handbook of Chemistry and Physics. Florida, CRC Press Inc. **(1986)**
3. Hull J.R., Nielsen C.E. and Golding P., Salinity gradient solar ponds (Boca Raton, FL: CRC Press) **(1989)**
4. Heat Recovery from Wastewater, Ottowa, Ontario, Canada Canadian Water and Wastewater Association (CWWA), December **(2009)**
5. Nielsen C., A. Akbarzadeh, J. Andrews, H.R.L. Becerra and P. Golding, The History of Solar pond Science and Technology, in: Proceedings of the 2005 Solar World Conference Orlando, FL , **(2005)**
6. Salzman S.A., G. Allinson, F. Staqnitti, M. Coates and R.J. Hill, *Water Res.,* **35(9),** 2121-2128 **(2001)**
7. Jarboui R., F. Sellami, C. Azri, N. Gharsallah and E. Ammar, *J Hazard Mater.,* **176(1-3),** 992 **(2010)**
8. LeConte J., How to Make Salt from Sea-Water?, Governor and Council of South Carolina, olumbia (**1862**)
9. Kostick D.S., Salt. In: Metals and Minerals. U.S. Geological Survey Minerals Yearbook, 1. U.S. Government Printing Office, pp. 1e17 (Chapter 64) **(2002)**
10. Demir I., Seyler B., Chemical composition and geologic history of saline waters in Aux Vases and Cypress Formations, Illinois Basin, *Aquatic Geochemistry,* **5,** 281e311 (**1999**)
11. Srinivasan J. and Guha A., The effect of bottom reflecting on the performance of a solar pond. Sol., *Energy,* **39,** 361-367 **(1987)**