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Estimation of Blockage in Thermo siphon Flat Plate Solar Water Heater: Feasibility in Chhattisgarh

Prafull Hishikar+ Lakhvindar Singh Ajji, and Anil Kr Tiwari
1 Department of Mechanical Engineering, National Institute of Technology Raipur
2 Department of Mechanical Engineering, National Institute of Technology Raipur
3 Department of Mechanical Engineering, National Institute of Technology Raipur

Abstract. Flat plate Solar Water Heaters (FSWH) is widely used mainly because of its robust design, simple working principle and low maintenance and functioning on renewable energy. Flat plate Solar Water Heater is popular due to their resilient design and low maintenance cost. But its performance deteriorates over the years due to system and location related issues like scaling. Especially problem due to scaling is significant as it is based on quality of water supplied to Solar Water Heaters. Since in Flat Plate Collector the flow of water is maintained by thermo siphon, the problem of scale increases the pressure drop and the result is reduced water flow rate. In present work it has been found that the water of Korba takes shortest time for blockage with comparison to other four cities of state Chhattisgarh. The water of Korba contains pH, CH and EC 14.6%, 85%, and 8.8% respectively more than water of Durg that takes longest time (60% more) for blockage i.e 5 years 4 months. However TH value of water of Korba is 21.6% less as compare to water of Durg. As per the above analysis blockage period time is maximum (5 year 4 months) for Durg city and minimum (3 years 4months) for Korba, If water is used in Thermo siphon flat plat solar water heater. Thus Durg is the better place for the functioning and maintenance of Thermo siphon flat plat solar water heater than Korba. The co-relation discussed below incorporating various water quality parameters could be used to predict the probable time of blockage in the tubes of Flat Plate Collector and proper maintenance can be scheduled at proper time. Even the feasibility of installing FSWH can be checked for any place if water properties are known.

Keywords: Scaling , Blockage period , water quality.

1. Introduction

Flat plate Solar Water Heaters (FSWH) is widely used mainly because of its robust design, simple working principle and low maintenance. Due to the stringent compliances of BIS [1], in India the performance deterioration factors such as absorber plate degradation, masking of the glass cover, leakage from deteriorated gaskets etc are eliminated. Scaling in flow system are to be avoided or minimized by taking due care. Performance degradation due to scaling is perhaps less noticeable, since the system continues to operate and the degradation is a slow process. The objective of the present study is to use a co-relation between water quality and Flat Plate Collector (FPC) blockage period. It helps in analyzing the performance degradation rate and even feasibility of installing the FSWH. Once the approximate blockage period is determined based on water quality, routine maintenance can be scheduled. The co-relation used can be applied for any location. In many places where water quality is better, the flow passage showed modest loose deposition of sedimentation which could be removed easily by passing pressurized soap water.

2. Water Sample Analysis

Water flows worldwide and takes many forms as it goes through its hydrological cycle. It picks up oxygen, nitrogen and carbon dioxide along with dust, fumes, smoke and other matter as it falls as rain. Surface water accumulates silt, organic matter, sewage and industrial wastes. Ground water dissolves and carries with it mineral matter as salts of calcium and magnesium.

+ Corresponding author. Tel.: + 919827400455;
E-mail address: *prafullhishikar@gmail.com*

Chemical quality of water is based on pH value, dissolved and undissolved particles. Corrosion decreases with pH value. Undissolved particles like sand may lead to erosion of tubes if excess in level. Scale growth rate is very sensitive to the level of dissolved salts and is mainly due to salts of calcium and magnesium and to a lesser extent to silicates. Hardness generally enters groundwater as the water percolates through minerals containing calcium or magnesium. The most common sources of hardness are limestone (which introduces calcium into the water) and dolomite (which introduces magnesium). Since hardness enters water in this manner, groundwater generally has a higher hardness level than surface water. The hardness of water varies considerably from place to place. The hardness of water reflects the nature of the geological formations with which it has been in contact. The water is commonly classified in terms of degree of hardness as given in the Table 1.

Table 1; Water hardness level [2]

Hardness(mg/l of CaCO3)	**Description of water**
0-75	Soft
75-150	Moderately hard
150-300	Hard
300 up	Very hard

The water samples were taken from places where major blockage in FPC was found. The value of total hardness, calcium hardness, pH, total dissolved solids and conductivity are incorporated in the analysis.

2.1 Various Properties of Water at Different Locations in Chhattisgarh

Table 2 shows the properties of water at different locations of Chhattisgarh which shows the range of pH,TH,CH & EC value.The pH was alkaline values ranges from 7.19 to 8.55. The maximum pH value (8.55) was estimated for Korba and minimum (7.19) for Raipur. The factors like air temperature bring about changes the pH of water. Most of bio-chemical and chemical reactions are influenced by the pH. The reduced rate of photosynthetic activities reduces the assimilation of carbon dioxide and bicarbonates which are ultimately responsible for increase in pH. The value of hardness fluctuates from 98 mg/l to 176mg/l, The maximum value of hardness (176 mg/l) was estimated for Bhilai and minimum value (98 mg/l) for Korba. High value of total hardness can be attributed to decrease in water volume and increase of rate of evaporation of water. The values of chlorides range from 43.5 mg/l to 124 mg/l. The maximum value (124 mg/l) was found for Korba and minimum value (43.5 mg/l) for Mungeli. conducting property of electrical values having almost same for Raipur, Durg and Korba &minimum for Bhilai & Mungeli.

Table 2: Physico-chemical properties of water at different locations in Chhattisgarh [3]

Sr no.	**City**	**pH**	**TH (mg/l)**	**CH (mg/l)**	**EC (µs/cm)**
1	Raipur	7.19	141	112	989
2	Bhilai	7.91	176	54	445
3	Durg	7.46	125	67	910
4	Mungeli	8.1	106	43.5	345
5	Korba	8.55	98	124	990

3. Scale formation in FPC

Scaling is connected with the thermic decomposition of hydro carbonates, hydrolysis of carbonates and also decreased solubility in hot water of calcium sulphate, magnesium hydroxide and silicates of calcium and magnesium. Moreover additional quantities of silicates of magnesium and calcium can Be formed at high temperature [4]. In FSWH, scale build up can take place in different components at different rate (shown in Fig. 1). It is observed that, scaling in risers is more detrimental when compared to that in other components. In order to observe the scale growth trend within the FPC, scale mapping is done. For extensive study, all risers, header and footer were cut. The complete footer and risers for the length of 1000 mm from footer are free from scaling in axial and radial direction. This is because of low water temperature in the region. Thereafter the axial and radial scale growth is severe till the header end due to water temperature rise. It is observed that in most of the risers the scale growth is concentric and due to scale formation in radial direction and pipe is getting blocked as the time passes. It indicates uniform temperature radially within the riser (Shown in Fig. 1).

The less soluble salts such as calcium carbonate precipitate and settle in the flow tubes and inflow water becomes more concentrated. At a given water temperature and pressure, the limiting concentration of both calcium and magnesium salts are quickly reached with the formation of insoluble precipitates. The resulting sludge is harmless, as long as the salts settle as solid particles that flow easily with water. But, if the precipitates adhere to metal surfaces, the resulting scale seriously interferes with normal operation of the water heater. The scale forming salts are those that become less soluble as water temperature increases. A thin film of water next to the collector tube remains always hotter than the main body of water. Therefore, less soluble salts will be deposited directly on the heating surfaces. Based on the composition, scale can be classified as:

- Sulphate scale, containing up to 95 % of $CaSO_4$, is having relatively high heat conductivity.
- Carbonate scale, containing up to 90 - 95 % of $CaCO_3$, is having lower heat conductivity than sulphate scale.
- Silicate scale, containing up to 45 - 48 % of SiO_2, having low heat conductivity

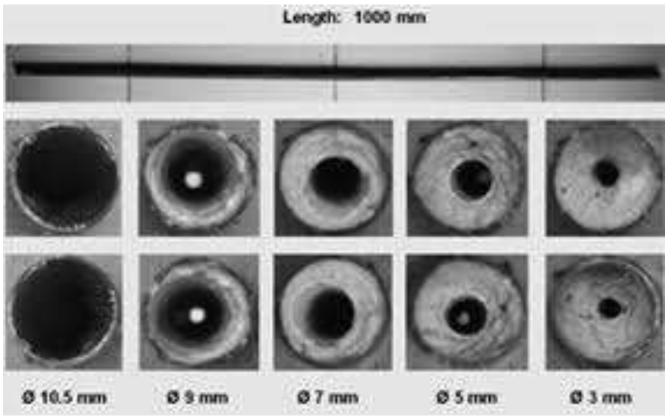

Fig. 1: Scale growth in flat plate collector in sectional Riser

In FPC, scale tends to grow the fastest in the collector risers. It chokes the flow by reducing the flow area and this increases the pressure drop and the result is reduced water flow rate. The other effect of scale formation is reduced transfer of heat from fins to the circulating fluid. The Scale on a heat transfer surface can act as a layer of insulation and thereby increasing the heat transfer resistance. Significant scaling in FPC will result in increased absorber plate temperatures and hence poor system performance.

4. Correlation to find scaling time [5]

The correlation to find scaling time that is based on the properties of water is shown below using which the scaling tendency can be found: To predict the approximate period for the major blockage in FPC, the various water quality parameters are co-related with the time of operation and brought out in the form of an equation (Eq. 1), shows the safe deviation of predicted values with the observed results. This Correlation calculates the blockage time in years which depends on pH, TH, CH and EC values of water. The data is correlated as:

$$T = \{23.6-(2.25*pH)-(0.00796*TH)+(0.00518*CH)-(0.00094*EC)\} \quad (1)$$

T = Time duration in year
pH = pH value
TH = Total hardness
CH = Chloride
EC = Conductivity

5. Observations and Calculation of Blockage Time according to Water Sample

With the help of above equation and properties of water of different places of state Chhattisgarh of India the possible blockage time has been calculated and graphically represented in Figure 6, which shows that earliest blockage is possible (in 3 year 4 months) in the riser of FSWH of Korba, whereas Durg is the place where the blockage will take place by taking 60% more time i.e in 5.4 years.

As far as pH value concern (shown in Fig.2), pH value of water at Korba is 8.55 which is higher than all five cities of Chhattisgarh, pH value of Korba is 14.5%, 18.9%, 8.09% and 5.55% percentage higher than Durg, Raipur, Bhilai and Mungeli respectively. Similarly Fig.3 shows that value of total hardness which is minimum in Korba 98 mg/l and maximum in Bhilai. Fig.5 indicates that value of chloride in water is also higher in Korba is 124 mg/l which is 85.07% higher than chloride value of water of Durg which takes longest time for the blockage of the riser. Thus higher is the chloride shorter is the time for the blockage of tubes. Conductivity of the water is almost same and higher for the Korba, Durg and Raipur with comparison to the Mungeli (shown in Fig 4).

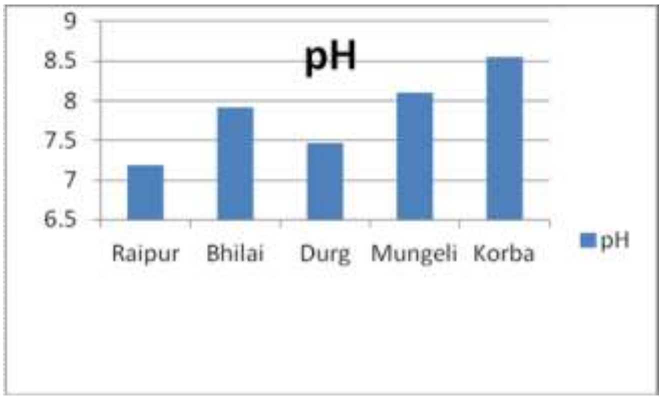

Fig. 2: pH value of water for different location of Chhattisgarh

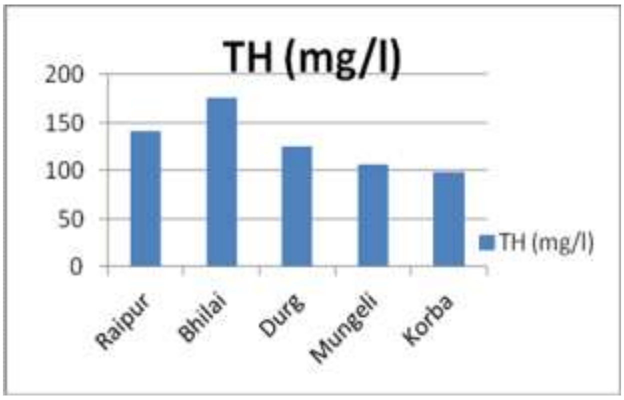

Fig. 3: Total hardness range of water for different location of Chhattisgarh

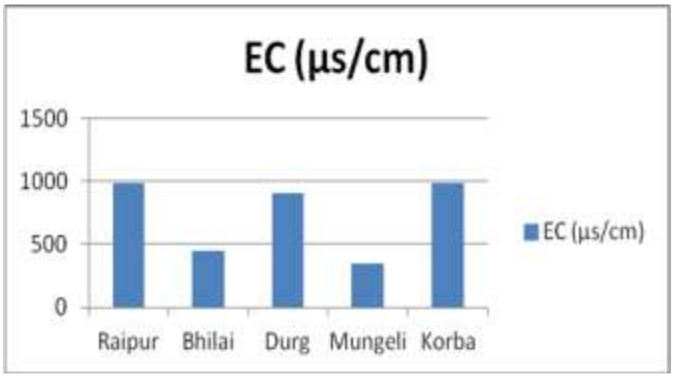

Fig. 4: conductivity of water for different location of Chhattisgarh

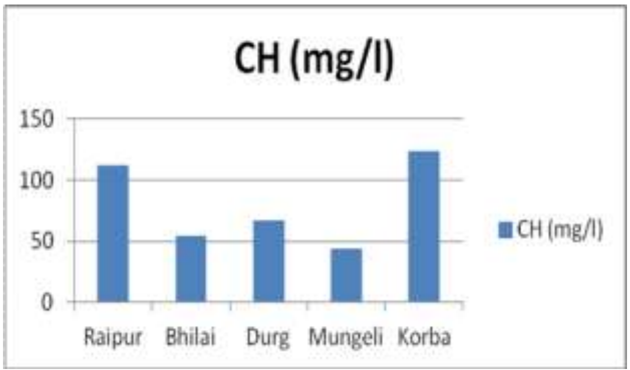

Fig. 5: Range of Chloride in water for different location in Chhattisgarh

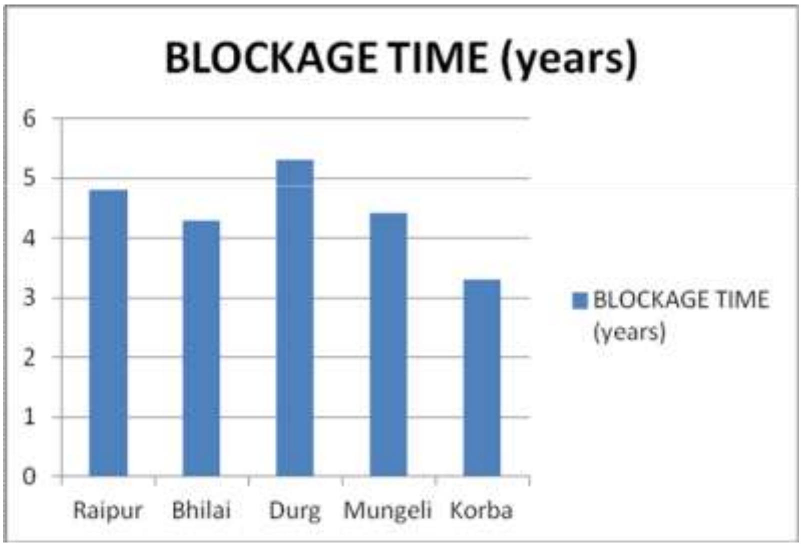

Fig. 6: Comparison of predicated blockage time period in Chhattisgarh

6. Result and Conclusion-

Present work deals with the assessment of physico-chemical parameters of water samples of Different Sites (n=5) of Chhattisgarh a state of India. The constituents those have monitored includes pH, EC, total hardness, chloride to calculate the blockage period of the tubes of FSWH. The conclusions are helpful for the quality use of Flat plate Solar Water Heaters (FSWH) using the relationship between the water quality and the blockage period of Flat Plate Collector so that the performance degradation can be analyzed with respect to time and water quality. Scale growth range of minor deposition to major blockage of the risers and header is noticed with pH, CH, TH & EC value of water. This research shows that pH, Ch, and EC value of water is higher in Korba due to which predicted blockage period is shortest (3 year 4 months) with comparison to Durg, Raipur, Bhilai and Mungeli. The water of Korba which takes shortest time for blockage with comparison to other four cities of state Chhattisgarh. The water of Korba contains pH, CH and EC 14.6%, 85%, and 8.8% respectively more than water of Durg that takes longest time (60% more) for blockage i.e 5 years 4 months. However TH value of water of Korba is 21.6% less as compare to water of Durg. As per the above analysis blockage period time is maximum (5 year 4 months) for Durg city and minimum (3 years 4months) for Korba, If water is used in Thermo siphon flat plat solar water heater. Thus Durg is the better place for the functioning and maintenance of Thermo siphon flat plat solar water heater than Korba. The co-relation discussed above incorporating various water quality parameters could be used to predict the probable time of blockage in the tubes of Flat Plate Collector and proper maintenance can be scheduled at proper time. Even the feasibility of installing FSWH can be checked for any place if water properties are known.

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