

# An Experimental Study on Solar Thermal Sewage Treatment System Using Parabolic Trough Collector: a Review

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**Abstract:** Water is a vital need for biological entities. It is the most required source for biological body hence its availability and preserve must be considered. Various evolving states and under developing countries need a cheap and low running cost system for fresh pure drinkable water. One major issue in these countries is lack of energy source to decontaminate water or the available energy is very costly and available in limited quantity. Rural places in evolving states have a huge problem of drinkable water because they have no other cheap solution and dirty water contains various biological waste, heavy metals and various sorts of bacteria and virus which cause several categories of disease and health related problems. Most of the filtration system which are running are very costly and energy consuming so these water treatment plant cannot be installed in remote rural areas whereas in urban areas there is considerable sum of dirt water and a huge load on ground water this means a limited quantity of fresh water for use. In the present literature review number of numerical and experimental works on the solar thermal sewage system and the components of the system such as parabolic trough collector system and solar stills have been studies. Various literatures on the effectiveness of solar water heater of sewage water filtration systems analysis and effect of climate change and solar radiation during different time, solar thermal system and various filtration of water, important factors which affects the overall efficiency of system in order to provide an economical and feasible solution. From the above literature study it has been observed that in the field of Solar Thermal Sewage Treatment lot of work have been seen in worldwide and still going on so there is a scope to work on this field.

**Keywords:** Sewage Water, Solar Water Heater, Parabolic Trough Collector, Line concentrator etc.

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## Introduction:

Solar radiation poses a huge amount of energy which can be extracted in human usable form. The radiation by sun consists of various wavelength spectrums which has various range of energy carrying capacity which can be further converted into utilizable form such as electrical energy by means of different technology available commercially. Also solar energy is a renewable source of energy and available in quantity which is, more than enough for human civilization of present trend. Depending on its potential use there are various government organizations which take care for the relevant data. For sun oriented authorities which provides sunlight based radiation information as Global Horizontal Irradiance (GHI) is helpful while for sun powered gatherers which are moving in nature Direct Normal Irradiance (DNI) information is required. Sun powered heating power plants are basically Concentrating Solar Power (CSP) units. For planning sunlight based heating power plants, DNI information is essential. Solar thermal energy is foremost source of all forms of energy. Solar energy is available in abundant quantity all over across the world.

Solar energy can be utilized in the following forms:

- ❖ Direct use of thermal energy as heating, cooking, solar drying etc.
- ❖ Conversion of thermal energy into electrical energy with the help of conversion technologies such as photovoltaic cell, silicon chips, increasing enthalpy of vapor and engendering electricity etc.

**Sewage Water Treatment System:** Drinkable pure water availability on earth is in limited quantity and comes in human usable form with some or bulk amount of impurity. These impurities must be eliminated before drinking in order to be safe from hazardous effect of the impurity present in water. In sewage water treatment system impurity is removed from the municipal waste water. The increasing demand of water for drinking and other purpose can be met by sewage water treatment system which contains various impurities such as heavy materials as Lead, Arsenic, Iron & fluoride and various types of salts and pathogens. The solar energy is clean and eco-friendly source of energy which is available abundantly on earth for sewage water treatment which is cheap and feasible technology. Solar energy can be efficiently rehabilitated into heat. Now a days the resources available for conversion into direct heat is not feasible due to shortages such as fossils, but

solar energy has potential in this field of direct heating thus makes it apt for treating water in sewage system for removing impurity this way. Our earth face a large crises, to access pure drinkable water because of large population and low catchment area for rainwater to replenish underground water source which are used for extraction of drinkable water. Thus increase in depth of bore well hints to upsurges in the fluoride in water, which cause major orthopedics disorders. Pollution is addition of some harmful substance to some sort of major need and makes it harmful for use. One of major concern of world is Water pollution due to huge population, various organic and inorganic impurities which get added to drinkable water. Overflow from agricultural land contains various chemicals such as Nitrogen, Potassium, and various other heavy metals, which get dumped into water bodies such as rivers, lakes, underground water sources. Excess amount of Nitrogen and potassium causes algal bloom and cause increase in biological oxygen demand of water bodies and thus in return cause loss of biodiversity due to death of marine animals. Other side the harmful chemicals return to lifecycle on animals and cause various disease and biological defects. In developing as well as in under develop countries 70–80% of health issues is due to lack of pure water for drinking and use.



**Figure 01:** Typical water treatment plant

### Challenges in installing sewage water treatment system

Following challenges encountered in the conventional systems:

1. The major problem in sewage water treatment system is that there is very little domestic level treatment system.
2. There is very high cost for treatment i.e. high capital cost so not possible to install in rural villages.
3. Solar distillation sewage water treatment systems have low efficiency due to fully dependency on solar energy thus low quantity of treated water.

### Literature Survey:

**Ying Zhanga et al. [1]** Dirty water contains various types of pathogens virus which cause various types of water born disease and make raw water undrinkable so when dirty water is passed through solar pasteurizer system the pasteurizer's performance to disinfect raw water at 75 °C showed 100% of E. coli and 99.99% of total coliforms pathogens and 7.32% of turbidity exclusion and make water useful for drinking.

**SumanMor et al. [2]** This study was to find good adsorbent chemicals for exclusion of phosphate from waste water and results shows that the nano-alumina and activated charcoal are good adsorbents for exclusion of phosphate. Upto (100%) exclusion of phosphate was obtained by using nano-alumina in small quantity and time whereas activated charcoal removes phosphate up to (90.2%) with use of large quantity and time. Another major criterion for exclusion of phosphate (PO<sub>4</sub><sup>3-</sup>) from waste water both adsorbents was relevant at lower pH level of waste water.

**Marsidi et al. [3]** The study was to scrutinize the environmental influences of solar water heater (SWH) systems for domestic hot water requirement. The result of the study was that minimum 81% of hot water requirement can be fulfilled by solar water heating system. The energy output from solar water heater was higher than the input (elevation.7–28 times), with the payback periods of one to three years. A similar analysis was done on solar water heater in other two colder regions the outcome was four to five times higher than from boiler.

**Gustavo Carielo et al. [4]** This study was to determine time required for disinfection of pathogens by heating water in solar flat plate water heater with samples treated from 56 °C to 65 °C with average number of counts values from 4.5 x 10<sup>5</sup> to 5 x 10<sup>5</sup> CFU/mL. Heating water at higher temperatures from 72 °C to 91 °C disinfection increased up to 99%. Test shows non-appearance of total Coliforms and Escherichia coli, Pseudomonasaeruginosa and reduction of 98.7% heterotrophic bacteria after treatment of water sample.

**Xiao-Tong Lv et al. [5]** This research shows the reduction of toxicity of chlorinated water when exposed to sunlight for 12 hour it was found that 75% reduction in toxicity due to ultraviolet rays in sunlight. Chlorine in water cause various types on harmful by products which can be abridged by treating water with sunlight.

**Alissa J. O'Donnell et al. [6]** The objective of this study is to find effect of coagulation agent and filtration system with lime-soda ash softening treatment to find a new method to remove strontium from water. Only 12% and 5.9% strontium reduction was found when water was treated in conventional method with aluminum and iron coagulants, whereas while treating water with lime-soda softening method reduction of strontium concentration was as high as 78%. Test showed that exclusion of strontium with lime-soda ash softening method is affected by pH value of water. X-ray diffraction of precipitated solids after treatment shows that strontium was mixed in calcium carbonate crystal and it remove strontium from water during lime-soda softening method.

**Hsiao-Chien Chena et al. [7]** The study was to find solar radiations required for disinfection of microorganism from water, so for test initially concentration of microorganisms in test sample were approximately 104 CFU/ 100 mL with water transmittance 95%. While experiment water temperature reaches 42–45 °C after three hours of solar exposure in bags while, in the PET bottles, the maximum temperatures registered were 39–40 °C. The aim of study was to find the solar radiation required for protective treatment from pathogens according to WHO standard. The solar UV dose for complete treatment was found to be 40 W·h·m<sup>-2</sup> for UVA-B radiation intensity and 110 W·h·m<sup>-2</sup> for UVA radiation.

**Raghvendra Singh et al. [8]** In this research work an integrated natural circulation desalination system, in this research work brackish water continuously flow through solar still installed over solar flat plate collector. Water is heated by solar thermal energy and waste is removed. It is a low cost portable water desalination system and easy to install.

**Al-Ansari et al. [9]** This paper serves to simulate and report the heat flux localization of the conventional air-filled receiver and would conceptually and figuratively contrast the predominant feature of one-sided insulated receiver i.e. elimination of solar heat flux localization with the added reward of reduction in buoyancy-induced convection currents. With increase in temperature, viz. at elevated temperatures thermal efficacy of altered receiver is reckoned to deteriorate. This deterioration is apparently on the account of increase in thermal conductivity of insulating material apropos increase in systems temperature, thus failing to perform adequately with an increase in temperature. . The results have been compared with that of existing data and found a good agreement in the field of accuracy.

**Padilla et al. [10]** given the outcome of study of the heat transfer from a half annulus filled with air and half annulus is insulated in parabolic trough collector system. He also given an equation to calculate the heat transfer from a half insulated and half filled cavity type parabolic trough collector system.

**Siegel et al. [11]** this paper deals with the various mechanism taking places in the heat transfer processes during the radiation heat transfer from the surfaces of the concentrator and the surfaces of the receiver and absorber. Two kinds of heat transfer from absorber tube takes place namely buoyancy induced convective heat transfer given and radiation heat transfer from absorber to glass enclosure which is reckoned by calculating view factors. He also demonstrated the flow feature of heat during radiation heat transfer. He also validated the data with the experimental data and theoretical equations at that time.

**Dudley et al. [12]** In his experiment, tests were performed for various specifications, parameters of receiver and thermo-physical conditions such as vacuumed and aired annuli, varying sunshine, varying temperature range of receiver and heat transfer fluid and with varying heat transfer fluid itself such as water and Syltherm 800. However, for the sake of congeniality and suitability to the present model assessment and validation, a specific and relevant test results were referred and outlined. Test facility specification of Sandia National Laboratory's LS-2 solar parabolic collector is given in the predictions of results. They illustratively demonstrated the comparison between experimental model and simulated model for both insulated as well as non-insulated numerical model and both were paralleled and assessed with the previously documented case.

**Cheng et al. [13]** examined the grid system for accuracy in CFD analysis of parabolic trough collector system. Their work is carried forwarded time to time as a standard for grid generation in CFD analysis of relevant system.

**E. Bellos et al. [14]** studied the variety of fluids to be used in heat transfer tube to enhance the heat transfer coefficient. They examined the behavior of three fluids named thermal fluid, fluid with nanoparticle and pressurized water and observed that the fluid with nanoparticle enhanced the heat transfer coefficient for commercial parabolic collector in terms of efficiency. They

also suggested the geometrical parameter of the nano particle to be used for enhancement of heat transfer coefficient of the heat transfer fluid.

**Suman Mor et al. [15]** Batch-mode adsorption experiments were carried out to investigate the use of two commercially available adsorbents for the removal of phosphate from synthetic wastewater/solution. They explain about the application of nano-alumina & activated charcoal to remove phosphate from wastewater and state that the nano-alumina was found more effective to reduce the eutrophication of water bodies. Results show their amorphous and crystalline nature while FTIR of the adsorbents shows the interaction of adsorbent and adsorbate of solution. Morphology of both adsorbent shows the porous nature of adsorbents which indicates their efficiency in wastewater treatment. Study clearly indicates that the removal potential of nano-alumina is more as compared to the activated charcoal.

**Bakos C et al [16]** They explain that PTCs are the preferred type of collector used for steam generation, due to their ability to work at high temperatures with high efficiencies. The results produced from a simulation program, showing the variation of collector's efficiency as a function of heat transfer fluid flux, pipe diameter, solar radiation intensity and active area of the PTC, are presented.

**Ozgen F et al. [17]** This study experimentally investigates a device for inserting an absorbing plate made of aluminium cans into the double-pass channel in a flat-plate solar air heater (SAH). This method substantially improves the collector efficiency by increasing the fluid velocity and enhancing the heat-transfer coefficient between the absorber plate and air. These types of collectors had been designed as a proposal to use aluminium materials to build absorber plates of SAHs at a suitable cost.

**E. Torres-Reyes et al. [18]** Thermodynamic optimization based on the first and the second law is developed to determine the optimal performance parameters and to design a solar to thermal energy conversion system. An exergy analysis is presented to determine the optimum outlet temperature of the working fluid and the optimum path flow length of solar collectors with various configurations. The collectors used to heat the air flow during solar-to-thermal energy conversion, are internally arranged in different ways with respect to the absorber plates and heat transfer elements.

**Sahar Dalahmeh et al. [19]** This study investigated the potential of biochar filters as a replacement or complement for sand filters for removal of pharmaceutically active compounds (PhACs) from wastewater in onsite sewage facilities (OSSF). Specifically, the study investigated the effects of biodegradation, adsorption and a combination of these processes on removal of four model PhACs from wastewater in biochar filters operated under hydraulic loading conditions mimicking those found in onsite infiltration beds. Concentrations and removal of the four PhACs (i.e. carbamazepine, metoprolol, ranitidine and caffeine) were investigated over 22 weeks in four treatments: biochar (BC) with active or inactive biofilm (BC-active-biofilm, BC-inactive-biofilm), biochar without biofilm (BC-no-biofilm) and sand with active biofilm (Sand-active-biofilm).

**A. Scrivani et al. [20]** The present paper examines the concept of utilizing trough type solar concentration plants for water production, remediation and waste treatment. Solar trough plants are a mature technology which deserves to be diffused throughout the European Union and in the partner countries of the Mediterranean Area. The present study is intended to find applications of the solar through concentration technology beyond heat and refrigeration. At the present stage, a number of possibilities have been identified; the main ones which will be considered here are related to clean water production by processes such as solar distillation, atmospheric condensation, and waste processing.

**SU Fengyi et al. [21]** Purification capacity of a faucet mounted type water filter for home use was evaluated. Biofilms were formed inside the filter, affecting the bacterial quality of the effluent water. Ten different bacterial species were identified in drinking water, four of which were probably contributed to the biofilm formation since they were also present in the biofilm. Fluorescence in situ hybridization (FISH) was used to confirm the API identification results, and direct viable count (DVC) method was employed to improve the sensitivity of FISH for the isolated *Acinetobacter* spp.

**Espen Mariussen et al. [22]** To reduce the potential impact of heavy metal on the environment a field study was performed with different sorbents in order to reduce the metal concentration in polluted water from a shooting range. Two sorbents were tested in situ for their ability to reduce the concentration of Cu, Sb and Pb: Brimac charcoal and Kemira iron hydroxide. The mean sorption of Cu, Sb and Pb was 85%, 65%, and 88% respectively when using the charcoal and 60%, 85% and 92% respectively with the iron hydroxide.

**Solarde Almeria et al. [23]** This work reviews the use of sunlight to produce the HO radicals by TiO<sub>2</sub> photocatalysis. The reacting systems necessary for performing solar photocatalysis described and the factors which govern the kinetics of photocatalysis such as initial concentration of reactant, mass of catalyst, pH, temperature, radiant flux and concentration of oxygen are highlighted. Several approaches in order to improve the photocatalysis efficiency of TiO<sub>2</sub> also described. Solar reactors engineering issues for photocatalytic water treatment as well as the use of the solar photocatalytic processes to inactivate microorganisms present in water, placing special emphasis to the mechanisms acting during the process, mainly hydroxyl radical and singlet oxygen generation, and on experimental systems made to optimize this disinfection technique.

**Giampaolo Manfrida et al. [24]** A solar system for disinfection of water to be applied in developing countries and long-term emergencies is presented. The system uses commercial solar thermal collectors arranged in a self-compensating natural circulation system, using no electricity and sized for adequate residence time for disinfection by pasteurization. The discussion includes an exergy analysis of the system and the definition and assessment of performance indicators. The proposed system is simulated in different locations, demonstrating the capability of producing typically from 40 to 80 kg/day per m<sup>2</sup> of collector surface depending on the location.

**Sergio Gutiérrez-Alfaro et al. [25]** Solar disinfection of urban wastewater can be a suitable technology for improving the

microbiological quality of reclaimed water as a complement to other extensive and environmentally friendly technologies such as microalgae bio-treatment. The objective of this work is to evaluate the feasibility of incorporating the SODIS technology at the end of a pilot scale urban wastewater treatment plant (WWTP) where the processes are based on microalgae biotechnology and comprising three Up-flow Anaerobic Sludge Blanket (UASB, 20 m<sup>3</sup> each one) reactor, six High Rate Algal Ponds (HRAP, 32 m<sup>2</sup> each one), and a Dissolved Air Flotation (DAF, 1 m<sup>3</sup>) unit. *E. coli* concentration was monitored at the effluent of the different units (UASB, HRAP, DAF) of the pilot WWTP. The efficiency of the SODIS process was studied for the inactivation of three of the commonly employed indicator microorganisms (*Escherichia coli*, *Enterococcus* spp. and *Clostridium perfringens*) using a compound parabolic collector (CPC) for five months under various conditions of irradiance and temperature.

### Conclusion:

The present review includes various factors related with solar thermal sewage system, like various types of pathogens virus which cause various types of water born disease, chemicals for exclusion of phosphate from waste water, environmental influences of solar water heater (SWH) systems, reduction of toxicity of chlorinated water when exposed to sunlight, effect of coagulation agent and filtration system with lime-soda ash softening treatment, heat flux localization of the conventional air-filled receiver and calculation of the heat transfer from a half insulated and half filled cavity type parabolic trough collector system. There are number of numerical and experimental works on the solar thermal sewage system and the components of the system such as parabolic trough collector system and solar stills have been studies. Various literatures on the effectiveness of solar water heater of sewage water filtration systems analysis and effect of climate change and solar radiation during different time, solar thermal system and various filtration of water, important factors which affects the overall efficiency of system in order to provide an economical and feasible solution. From the above literature study it has been observed that in the field of Solar Thermal Sewage Treatment lot of work have been seen in worldwide and still going on so there is a scope to work on this field.

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