Greenhouse Solar Dryers: A Cost-Effective Solution to Ensure Safe Application of Faecal Sludge in Agriculture

Safe application of faecal sludge in agriculture will not only address food security issues but reduces climate change effects. However, there are concerns of pathogens present in sludge specially Helminths eggs. Here, greenhouse solar dryers come as a cost-effective solution for faster drying and pathogen inactivation.

Girija R[1 2]; Hiranya T[1]; Krishna K[1]; Ganapathy PG[1]

[1]Consortium for DEWATS Dissemination India, Bengaluru
[2]Indian Institute of Science, Bengaluru

Background:

Non-judicious and long-term application of chemical fertilizers not only deteriorate soil quality but also contributes to climate change effects due to the emission of greenhouse gases during the production and application of these fertilizers. On the other hand, there is an urgent need to look for alternative nutrient sources for food production to feed the growing population.

It is widely known that human excreta is rich in nutrients, specifically Nitrogen and Phosphorous. With the recent thrust on faecal sludge treatment and safely managed sanitation, there is an opportunity to use human excreta as a nutrient source. However, there are concerns of health risks due to the presence of pathogens in faeces. The main cause of concern is the soil-transmitted helminth infections as these are highly resistant to treatment and viable for several years.

In this context, this study was conducted in 4 locations (FSTPs – Faecal sludge treatment plants) of India – Angul, Dhenkanal, Karunguzhi and Devanahalli with the main objective to evaluate the efficiency of polycarbonate-based greenhouse solar dryers in reducing the Helminths eggs in the final treated sludges. Greenhouse solar dryers (GHSD) use passive drying to help increase the temperature and decrease humidity to ensure pathogen kill as well as faster drying.

Scenarios studied under the project:

Following were the assumptions made for the study,

- Increased temperature and decreased relative humidity inside the GHSD chamber will help in reducing the sludge drying time.
- Longer exposure of sludge to higher temperature (>50°C) will inactivate Helminths eggs.

GHSD is the polycarbonate sheet installed over the drying beds. This has a parabolic shape to resist wind and to induce greenhouse effect inside the drier. This greenhouse effect inside the drying chamber helps removing the moisture laden air and the moisture content from the drying product (Figure 2).

Solar pasteurisation unit (SPU) follows the same working principle and the structure of the GHSD. However, the height of the roof is less compared to the GHSD. The dried sludge from the GHSD is placed in the SPU. Due to reduced height of the chamber and low moisture content of the sludge, SPU can reach to a higher temperature of more than 60 degrees Celsius which will help eliminating the pathogens (Figure 3).

Galvanised (GI) sheet is one of the most used roofing materials over the sludge drying beds. These are galvanized metals made of thin sheets, coated with zinc. The main purpose of these sheets is to protect the drying beds from getting wet during rainy season.

Below mentioned scenarios were studied under the project,

1) Greenhouse solar dryer (GHSD): Angul and Devanahalli FSTP
2) Galvanised (GI) sheet + Solar Pasteurisation Unit (SPU): Dhenkanal FSTP
3) GI sheet and GHSD: Karunguzhi FSTP

The process flow of the FSTPs is as given in the below figure,

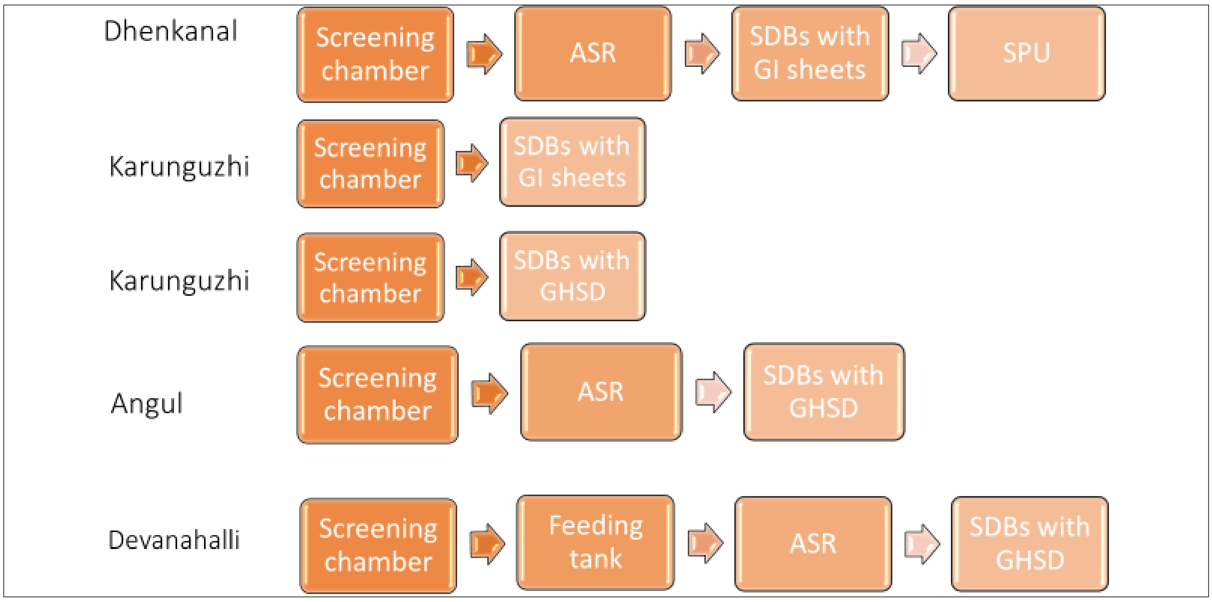

Figure 1: Process flow of FSTPs

*SDB: Sludge Drying Bed, ASR: Anaerobic Stabilisation Reactor

Study set-up:

Sensors were installed to get the real-time data on chamber, sludge, and ambient temperature. The sludge drying time and moisture content were recorded for the experimental Sludge drying beds (SDBs). The output samples from the SDBs were sent to the lab for analysis.

In total, 25 output samples from all the 4 locations were tested for the presence of Helminths eggs. In addition, Helminths viability test was conducted for 18 samples to further investigate the presence of viable and non-viable eggs. The method followed for Helminth analysis was Improved AmBic Method (Pebsworth, Archer, et al.;2012).

Figure 2: Sludge drying beds with Greenhouse Solar Dryers (GHSD), Angul FSTP

Figure 3: Solar Pasteurisation Unit (SPU), Dhenkanal

Variation in temperature of chamber and sludge due to GHSD, SPU and GI sheets:

The variation in temperature of the chamber (Temperature inside GHSD) and sludge due to GHSD and the GI sheet is given in the below graphs,

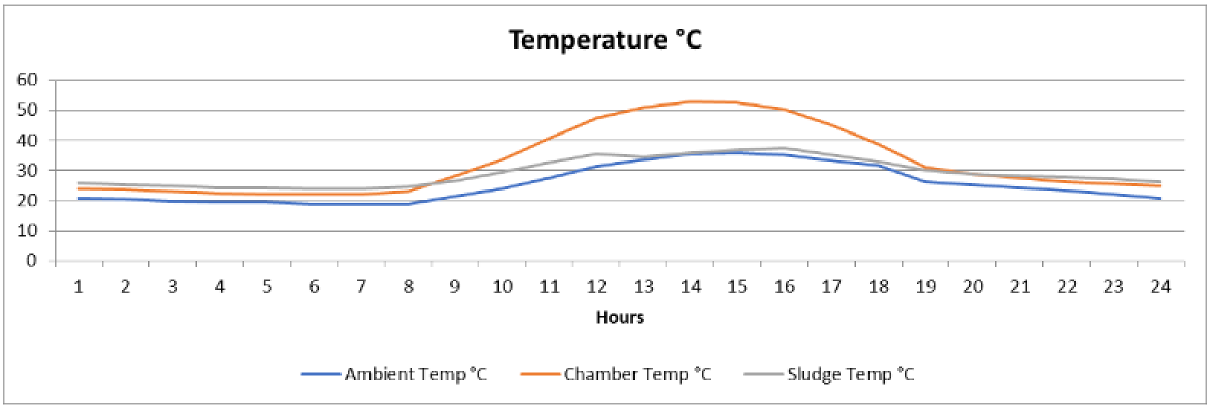

Figure 4: Scenario 1, Greenhouse solar drier (GHSD), Angul FSTP

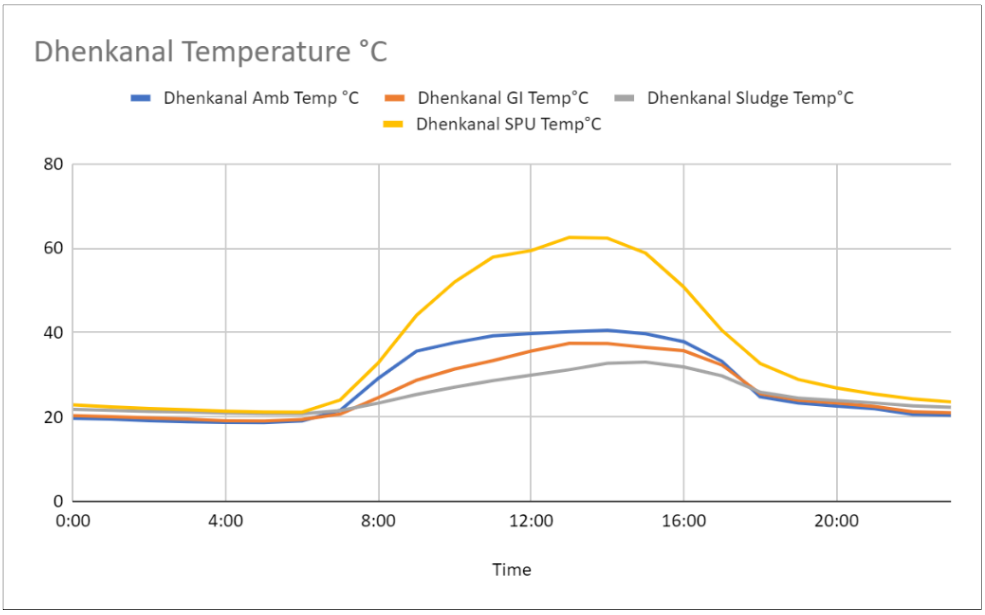

Figure 5: Scenario 2, Galvanised (GI) sheet + Solar Pasteurisation Unit (SPU), Dhenkanal

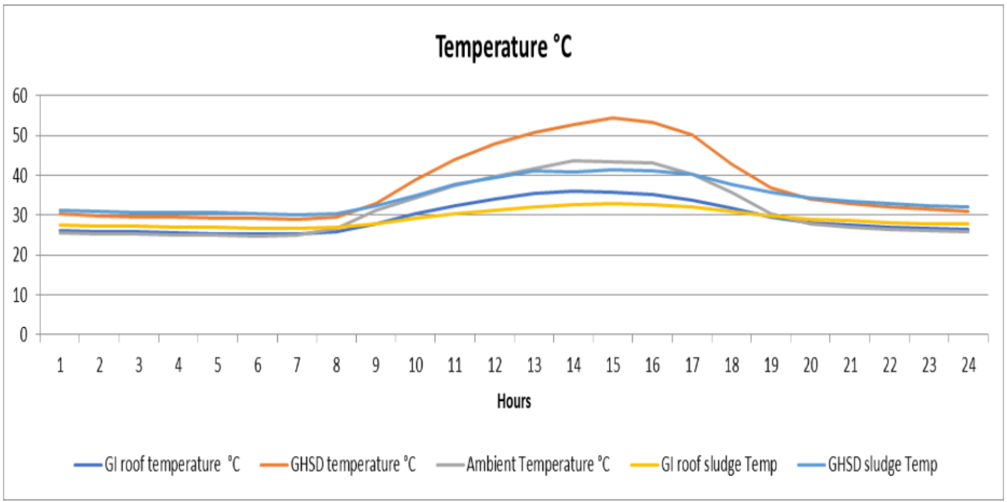

Figure 6: Scenario 3, Galvanised (GI) sheet and Green House Solar Drier, (GHSD) Karunguzhi

Above graphs shows that the GHSD chamber temperature is higher than the ambient temperature both during the peak hours and throughout the day. Chamber temperature during the peak hours is 12 - 16°C higher than the ambient and around 7°C higher throughout the day. Sludge temperature under GHSD is higher (5-8°C) compared to the ambient.

In case of GI sheet, the temperature under the GI sheet (around 4°C during peak hours) is lower than the ambient conditions and hence, the sludge temperature is also lower. Under SPU, chamber temperature is 21°C higher than the ambient conditions. SPU temperature has reached a maximum of 69°C during summer.

This study evaluates the efficiency of greenhouse solar dryers in reducing Helminths eggs in the treated faecal sludge. The findings of the study have shown that the sludge temperature is increased due to the greenhouse solar dryers and hence helps in reducing Helminths eggs.

Helminths eggs inactivation due to green-house effect inside the chamber

Helminths eggs in the final treated sludge:

Site wise Helminths analysis in Eggs per Gram (EPG) is as given in the below table,

Site with sample details	Helminths (EPG)	CLASS (A/B) standards-USEPA
Angul – GHSD		
Sample 1	BDL	Class A
Sample 2	BDL	Class A
Devanahalli – GHSD		
Sample 1	0.5 non-viable eggs	Class A
Sample 2	BDL	Class A
Sample 3	0.5 non-viable eggs	Class A

Sample 4	BDL	Class A
Dhenkanal – GI + SPU		
Sample 1	2 non-viable EPG	Class A
Sample 2	BDL	Class A
Karunguzhi		
SDBs under GI sheet		
Sample 1	BDL	Class A
Sample 2	0.31 non-viable eggs	Class A
Sample 3	0.42 viable, 0.42 non-viable eggs	Class B
Sample 4	BDL	Class A
Sample 5	BDL	Class A
SDBs under GHSD		
Sample 1	BDL	Class A
Sample 2	BDL	Class A
Sample 3	0.47 viable eggs	Class B
Sample 4	BDL	Class A
Sample 5	BDL	Class A

Table 1: Helminths Eggs Test results

*BDL: Below detectable level

Above table shows that, out of the 13 samples from the SDBs under GHSD, 12 have met Class A Biosolid standards. 4 of the 5 samples from GI Roofs also had no viable helminth eggs, but that was after a drying time of more than 10 days which is longer than the time taken by GHSD drying beds (average 5 days).

Almost 92% of the samples tested for Helminths (Table 1) under GHSD beds have met the USEPA class A standards for Helminths. This is due to increased sludge temperature due to desiccation of shell and hence, eggs become fragile (Maya, C et al., 2012).

Another interesting observation from the study was there was reduction in Helminths eggs with increase in drying time and decreased moisture content of the sludge. Similar results were observed in the study conducted by Maya, C et al., 2019 where in the increased drying condition of the sludge led to increased Helminths inactivation. The study shows that the prolonged drying period of the sludge will help in reducing the Helminths eggs count.

Key learnings and opportunities:

Reduction of Helminths eggs is a function of temperature, time, and moisture content of the sludge. GHSD will help in increasing the sludge temperature and hence, eliminates the Helminths eggs in the treated faecal sludge.

GHSD for sludge drying is a cost-effective option compared to GI sheet as it will reduce the Helminths eggs as well as drying time thereby reducing the land requirement for the treatment plant. Though GI sheet will also lead to Helminths inactivation, the time required for drying and hence, the pathogen inactivation is comparatively longer than GHSD.

Retrofitting existing drying bed based FSTPs with GHSD roofs will increase their capacity to treat faecal sludge (approx. ~40%) depending on the climatic conditions. For newer FSTPs, GHSD based designs not only help achieve helminth eggs inactivation but also area reduction and capex reduction for nature-based systems. Combination of GHSD and SPU could potentially help to reduce the Helminths eggs as well as drying time reducing the land requirement. However, there are operational challenges involved – the treated dried sludge from the SDBs needs to be pulverised and shifted to SPU for further processing. Automation of these steps will help in ease of operation.

The study was conducted for a limited period (Over a period of 5 months spread over January-May 2022) where in the ambient conditions of the location plays a major role in chamber temperature and relative humidity. For instance, in case of Angul, the average ambient temperature during peak hours varied from 26-41 degree Celsius across different cycles/period of the study, accordingly the chamber temperature varied. Though the findings show promising results, the study recommends further investigation by carrying out the same study year-round in different seasons and context. This would help drawing the definitive conclusions.

Acknowledgements:

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