Solar Greenhouse Aided Drying Of The CETP Primary Sludge

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Abstract: The objective of this thesis is to study reduction in the moisture content achieved on solar aided drying of the dewatered sludge. Dewatering is capable of complete removal of free waters and small removal of interstitial waters contained in the sludge. Bound water content of the sludge includes physically and chemically bounded waters to the lattice structure (of sludge) which cannot be simply drained using gravitational forces and require thermal processes for their reduction. Solar drying is the focus of the present study amongst various available thermal drying technologies. Solar greenhouse dryers open or closed are used for drying purpose and its performance is recorded for different seasons. The present study is focused on volume reduction of CETP primary sludge for winter and summer seasons using SGD constructed of LLDPE sheet. The reduction in the winter season for moisture content and total volume observed was 88.98% and 82.66% respectively. The reduction in moisture content and volume for the summer months observed was 93.45% and 83.67% respectively. Also reduction in drying period was observed for the summer months as compared to winter months.

Keywords: CETP sludge, dewatering, moisture content, volume reduction, SGD-solar greenhouse dryers.

Introduction

Increasing urbanization has led to increase in installations of wastewater treatment plants that have led to increase in the quantity of all kinds of sludges. All types of sludge primary, secondary, mixed, require proper management either for their end use or disposal. When the sludge is categorized as hazardous waste it becomes useless and needs to be securely landfilled. Landfill sites in present times are facing heavy dumping beyond their designed capacity. This scenario in which landfills are getting exhausted makes the study for volume reduction of sludges imperative.

The sludge management system train consists of following

Thickening is the application of simple stirring to remove the free water from the sludge.
Conditioning is the application of the chemicals that enhances dewatering of the sludge.
Dewatering is the application of the mechanical strain to the sludge to drain water from it.
Drying is thermal application of heat either directly or indirectly

Thermal dryers are broadly classifieds as:

1. Convective dryers- in this type of dryers the heat application is direct i.e. the sludge to be dried is in direct contact with the source of heat. These dryers are efficient to reduce the moisture content by 90% but there are various drawbacks like they are energy intensive, due to direct heating there is possibility of complete sludge burnout, also due to direct heating there is problem of excess CO2 generation. Due to this major drawbacks solar dryers are well suited for sludge drying.

2. Conducting dryers- the sludge to be dried is indirectly heated in conducting dryers and the heat is applied to sludge by conduction through contact with the hot surfaces. The major drawback of this kind of dryer is that the sticky sludges are tough to dry using indirect heat application. Also the problems of odour and flies restrict the use of this type of dryers.

3. Solar dryers- solar drying is generally carried out in an open or closed greenhouse that works on the principles of greenhouse effect and evaporation enthalpy. Sticky sludges can be best handled by solar drying. There are manifold benefits achieved by solar drying like:

- Low energy consumption as solar energy is available free of cost.
- Low carbon footprint as CO_2 generation is eliminated.
- Minimal skill required.
- Sticky sludges can be handled easily.
- There is no fear of complete burnout of sludge.

The only drawback is that solar drying is highly governed by variable weather parameters.

Solar irradiation, relative humidity, temperature and wind velocity majorly governs the drying process of the sludge.

Solar greenhouses work on the principle of Evaporation Enthalpy. The ambient air enters the greenhouse and gets heated up due to the greenhouse effect taking place inside. The air inside the greenhouse is warmer as compared to the outside air. The warmer air has lower relative humidity as compared to the cool air and hence takes up moisture from the sludge until the inside warmer air gets saturated (with water vapour), thus drying the sludge. The saturated air mass leaves the system via ventilation system**.**

Important functional elements of a solar greenhouse are:

1. Travelling and turning bridge arrangement is very crucial that the dewatered sludge is applied evenly across the bed to ensure even drying rate across the entire bed. Turning is achieved by „S" shaped scoops that tosses up the sludge and exposes lower wet surface to warm inside air of the greenhouse.

2. Fans are provided inside the greenhouse at definite intervals to ensure proper air velocity throughout the dryer.
3. Sludge feeding and removal mechanism are applied in two fashions, pass through and return type systems. In pass through system sludge is fed at one end and removed at the opposite end. The benefit of the return kind of system is that the provision for loading and unloading of the sludge is to be provided at only one end.
4. Auxiliary heating is provided during the periods when the drying rate starts declining. This facilitates the storage area and enhances the drying efficacy and lowers the drying time of the sludge.

Design considerations that must be accounted are following:

- Maximum mass of sludge per year
- Type of sludge
- Average dry solids ratio of the dewatered sludge
- Required dry solids ratio of the dried product
- Climatic conditions
- Auxiliary heat supply
- Storage capacity of dewatered sludge
- Sludge feeding and removal regime
- Type of greenhouse

Optimum performance of a solar greenhouse is ensured by proper mixing, prevention of under and over drying of the sludge, back mixing and required ventilation.

Materials and methods

The framework of mild steel was fabricated to support the LLDPE sheet. Also the sludge tray of mild steel was prepared to feed dewatered primary sludge into the model for drying. Both, the framework and tray were painted in black. The dimension of the model and sludge tray is given below:

Model= 80cm×30cm×40cm

Inclination angle= 48.5°

Sludge tray dimension= 20cm×20cm×10cm

The primary dewatered sludge with initial moisture content of 88.99 %and 90.66% moisture content for the month of January and February respectively were fed inside the model.

The mixing was provided once every 6 hours and sampling was done after thorough mixing to ensure representative sample. The ventilation was provided after apt calculation. The model was placed under the sun in such a way that one face of the free standing shade faced solar radiations at an angle of 90°. The experiments were conducted for winter season from 22 Jan to 6 Feb and for summer season from 14 Feb to 28 Feb. the drying period for the sludge to reach moisture content of 10% were considered. The inside temperatures of the model were regularly monitored and noted using a clinical thermometer.

Figure 1: a) framework b) final setup

Moisture content reduction

The reduction in moisture content for the summer and winter months were considered to establish the effective drying conditions. The LLDPE sheet creates greenhouse effect inside the model due to which the air inside the model warms up and its relative humidity reduces as compared to relatively cool ambient air. This warmed air with lower relative humidity takes up the moisture from the sludge until it reaches its saturation vapour pressure. Ventilation is provided to ensure the replacement of saturated warm air with ambient air so that the drying process continues.

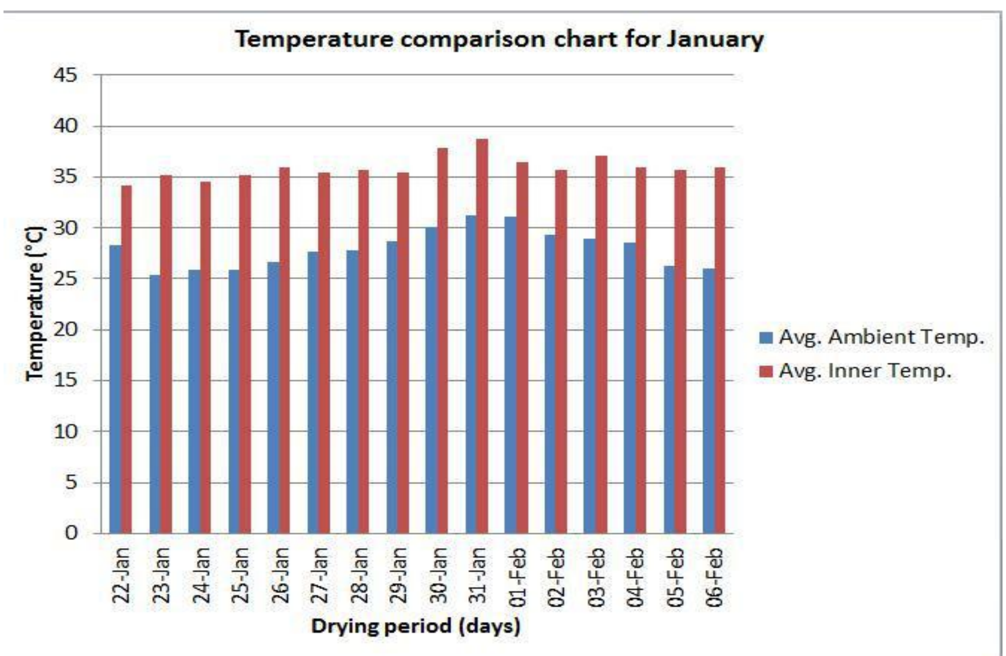

Figure 2: Chart

Table 1: Hourly reduction in moisture content (January)

Trial month (January)	Hours	Primary sludge moisture content (%)
	0	88.99
22	6	87.45
23	12	86.83
24	18	85.75
25	24	84.72
26	30	83.66
27	36	82.61
28	42	82.59
29	48	79.74
30	54	76.66
31	60	72.72
1	66	62.94
2	72	56.42
3	78	47.40
4	84	9.8

. The % reduction in moisture content obtained for the months of winter and summer at intervals of 6 hours are plotted as below:

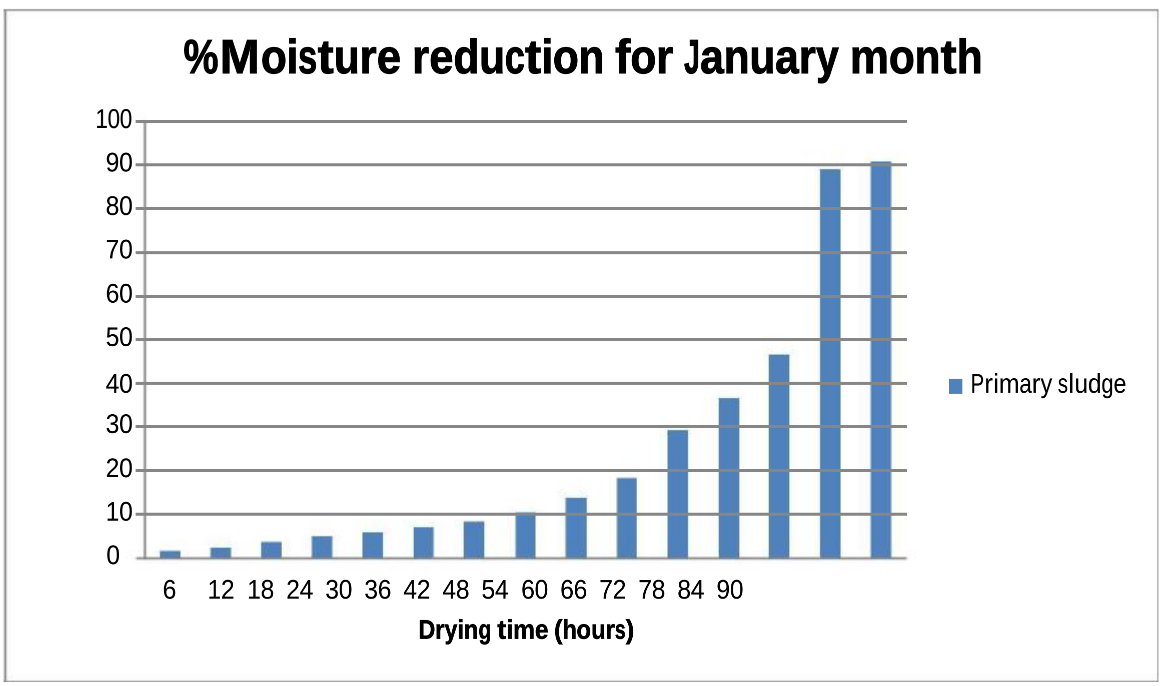

Figure 3: Chart 2

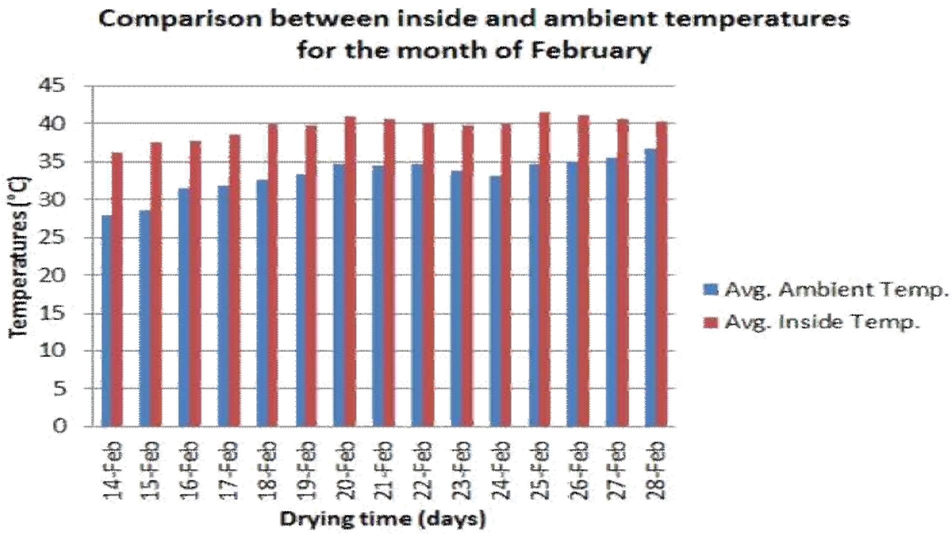

Figure 4: Chart 3

Table 2: Hourly reduction in moisture content (February)

Trial month (February)	Hours	Primary sludge moisture content (%)
14	0	90.66
15	6	89.58
16	12	88.41
17	18	86.32
18	24	85.06
19	30	83.45
20	36	80.57
21	42	76.03
22	58	69.39
23	54	61.89
24	60	51.94
25	66	40.07
26	72	26.20
27	78	12.26
28	84	5.93

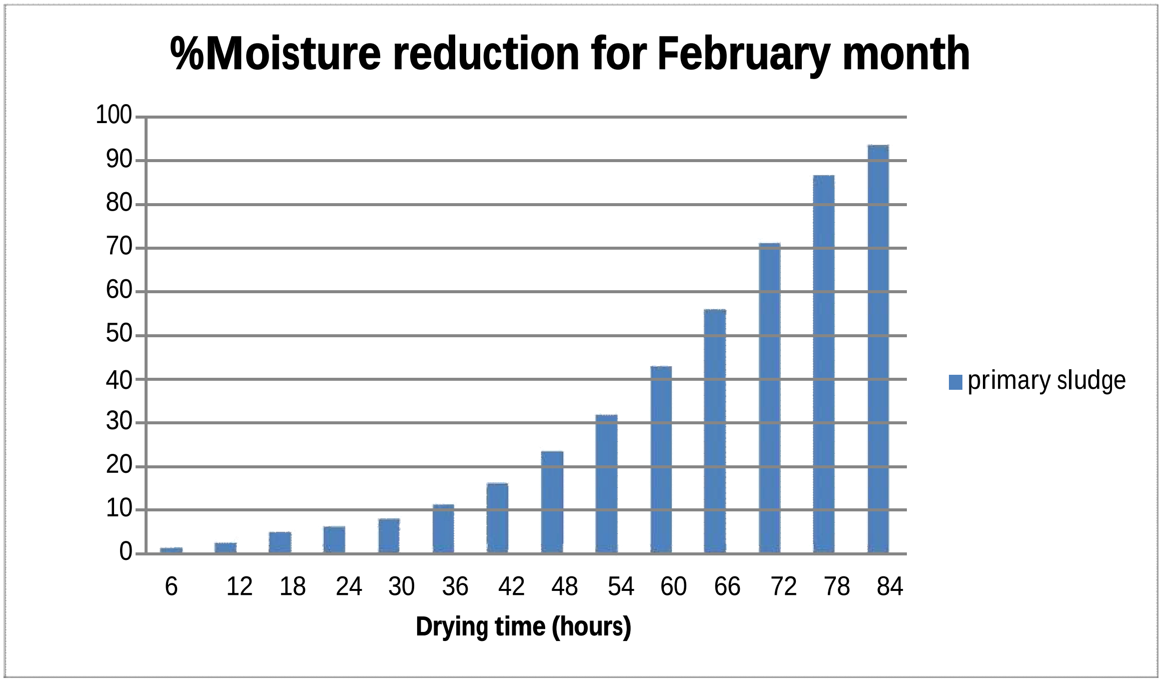

Figure 5: Chart 4

As the representation in the graphs the primary sludge took 84 hours in the month of January to reach the moisture content of 10% while it took 80 hours in the month of February when the average ambient temperatures were higher due to which the average inside temperatures of the model were higher.

Volume reduction

Due to remarkable reduction in the moisture content of sludge reduction in total volume was observed during both the trials.

The initial volume occupied by sludge was calculated and the final volume after drying at 10% moisture content was measured and the volume reduction was computed.

Table 3: Volume reduction computation

Trial period	Volume (cm^3)	% reduction
January	Vi= 2000	82.66
	Vf= 346.65	
February	Vi=2000	83.67
	Vf= 326.56	

Vi= initial volume

Vf= final volume (after drying)

Conclusion

The study conducted concludes that solar drying of the sludge is efficient in removal of moisture and enhances volume reduction. Solar drying is also efficient in removal of bound water content that is not removed using mechanical dewatering systems. The solar drying is highly dependent on weather parameters like solar radiations, wind velocity and relative humidity. Also the reduction in moisture content and volume is more during warmer period due to increase temperatures and decreased relative humidity. The volume was reduced by 1.01% in the study done for the month of February as compared to month of January. The Moisture content reduction during the month of February was 4.47% more as compared to January trial. The drying time was reduced by 6 hours during February due to higher temperatures.

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