A Review on Solar Greenhouse Aided Drying of the Sewage Sludge

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***Abstract*: The objective of this review 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 review is focused on volume reduction of sewage sludges using SGD constructed of different materials of construction.**

***Keywords:* Sewage, dewatering, moisture content, volume reduction, SGD-solar greenhouse dryers.**

I. 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 airinside 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 untilthe inside warmer air gets saturated (with water vapour), thus drying the sludge. The saturated air mass leaves thesystem 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.

II. MATERIALS AND METHODS

SrNo.	Type and quantity of sludge	Type of dryer	Material of construction	Methodology and dimensions	Drying period
1	Sewage primary and secondary sludge Quantity :18kg/m^2	Open type solar greenhouses	Roofing of polycarbonate sheet	Pilot scale plant of Length=160cm Width=60cm Height=80cm	Experiment was conducted for 72hours in hot and cold periods
2	Activated sludge of pharmaceutical industry Quantity:200kg	Solar sludge drying sand bed	Roofing of 3mm thick window glass	Comparison was carried out between conventional sludge sand drying bed (CSSDB)and solar sludge sand drying bed(SSSDB)	Drying period of 12 days
3	Sewage sludge	Greenhouse solar dryer with solar panels	-	Comparison of GSD was carried out with thermal dryers using optimization models for cost and area requirements.	-
4	Aerobically digested sewage sludge	Thermo system solar sludge dryer	Roofing of UV stabilized three layered air bubble foil	The drying time of flocculated and non-flocculated sludge was compared and studied	64 days for flocculated sludge 83 days for non-flocculated sludge
5	Sewage sludge Quantity: 16.5m^3	Solar greenhouse sludge drying	Transparent polycarbonate foils	Dimensions of the pilot plant used are: Length=14m Width=4.7m Depth=25cm The drying rates were compared for different months summer winter and monsoon.	9-18 days for months of May-September (summer) Longer drying periods recorded for typical rainy days.
6	Digested dewatered biosolids	Solar dryer coupled with solar panel	Wooden chamber enclosure	Wooden enclosure of 122cm*46cm*61cm Evaporation rates were determined for different conditions.	The experiment was carried out for 102 hours.

III. DRYING BEHAVIOUR OF SLUDGES UNDER DIFFERENT DRYERS

When applying convective drying three phases of sludge drying are distinguished:

A-Adaptation phase

B-Constant drying phase

C-Falling drying rate

Free water contained in the sludge is removed during adaptation phase. This is also referred as constant drying phase. Falling rates are classified as first and second falling periods. Interstitial waters are removed during firstfalling period and hydration waters are removed during second falling period.

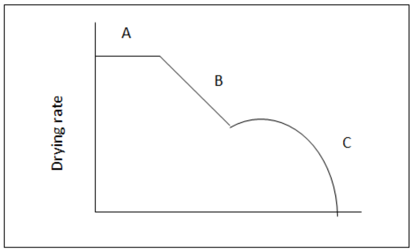

Figure 1: Drying behaviour in a convective drying

While applying conductive drying the sludge undergoes three phases:

A-Pasty phase

B-Lumpy phase

C-Granular phase

A special focus is given to the sticky phase as it can adversely affect the drying performance of the dryer.

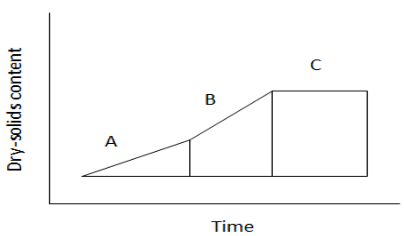

Figure 2: drying phases during a conductive drying

Solar drying wholly depends upon climatic conditions such as solar radiations and air temperature. No regular shape of drying kinetic is observed for the sample dried under solar dryers.

IV. SEASONAL CONSIDERATIONS

Mohamed ousamabelloulid in his paper has experimented solar drying for hot and cold periods. The summer campaign began at August 1 at 2:00a.m. and ended once the sample reached a moisture content of 0.25kg water/kg DS solids and dry solids concentration of 80%.

The winter campaign began at 2:00 a.m. from January 1 until the achievement of 80% DS concentration.

The temperature and relative humidity were measured during both the campaigns. During summer campaign the inside temperature of greenhouse was always 2-7 degrees higher than the ambient temperatures. During the winter campaign the difference was negligible. The measurement of air velocity showed that the air velocity was more defining parameter in drying process compared to temperatures.

V.L. mathiadaukis has reported drying time during different seasons. The experiments were carried out in the batches for 7 months April to October and November to April. The drying period recorded for the months from May-September ranged between 9 and 18 days. Experiments conducted during months of April and October was increased reaching upto 31 days. The observed evaporation rate during the summer months was 8-12 kg water/m^2. During cold autumn and spring periods the drying rate was considerably reduced.

V. MOISTURE AND VOLUME REDUCTION

Mohammed oussamabelloulid have measured volume reduction in terms of sludge volume calculated from diameter and height measurements. The volume of the sample was reduced to half only after 24 hours of sola drying. Shrinkage and crack phenomenon was recorded following the shape change of the sample. Shrinkage developed only after the period of 12 hours in hot and 24 hours in cold climate. The volume reduction of 80% was recorded at the end.

Mehardadi has compared the moisture content reduction and drying time between SSDSB and CSDSB. Sludge moisture content was always less than the one in CSDSB being typically above 30% and 38.2% respectively at the end of 12 days. The drying time for 40% and 60% dry solids cake was compared and it was found about of 37.6% and 34.40% for SSDSB and CSDSB respectively.

M bux.Has showed the reduction comparison between flocculated and non-flocculated sludges. In both the cases the volume reduction recorded was about 12kg/m^2 from 425kg/m^2.

The volume reduction in percentage was of about 97%.

V .L Mathioudakis noted the volume reduction of 90% and the moisture content of the sludge cake was reduced to 10-15%.

Domenec jolis has considered volume reduction in terms of water evaporation. Four cups filled with water out of which two were placed outside the solar dryer and the other two were placed inside the dryer and the evaporation rates were for each cup was determined. It was found that the evaporation rates for cups placed inside the dryer were higher compared to that placed outside the dryer.

VI. PATHOGEN REDUCTION

V.l. Mathidoukis has suggested that for sewage sludge the pathogen reduction is observed of 2-3 degrees because of ultraviolet radiations of the sun and rise in temperatures of the sludge. Though complete sludge sanitization is not achieved with the help of solar dryers even during summer season.

Mohammed oussamabelloulid observed a significant reduction in total and fecal coliforms in hot period. A decrease of order 1 was observed only in 24 hours in hot summerperiod. 50% moisture content is required for microbial activity, solar drying reduces moisture contentbeyond this requirement thatenhancespathogen removal. Pathogen removal was not affected during cold periods.

VII. CONCLUSION

The review 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. Pathogen reduction is also achieved but complete disinfection is not achieved by solar drying. The comparison of solar drying with thermal dryers shows huge savings in energy costs.

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