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Sawdust as a filtering media in sludge drying beds

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ABSTRACT

Conventional wastewater treatment is a common method of domestic wastewater treatment in Sub Saharan Africa. Lubigi wastewater treatment plant (LSTP) in Kampala – Uganda is a unique wastewater treatment system combining treatment of on-site faecal sludge and domestic wastewater. High solids content of on-site faecal sludge mean large volumes of the same, thus limited sludge drying space. This means need to optimize sludge drying bed use (improving the sludge drying efficiency) by reducing their drying times. This study investigated use of wood sawdust as a filtering layer in the faecal sludge drying process. Comparison of performance between sand, fine and coarse sawdust as a filtering media was conducted at LSTP. Sludge shrinkage depth (cm) and moisture content (%) were key parameters used to analyze and determine the most ideal media for sludge dewatering. The study was conducted during both wet and dry seasons to determine the impact of seasonal changes. Dry season results showed a drastic decrease in the sludge depth (shrinkage) for all the three media types after a period of 8 days followed by a gradual decrease in sludge depth up to 28 days. This implies that effective dewatering happens for the first 8 days, which goes on for the rest of the remaining days. Overall, the best performing media was fine sawdust, coarse sawdust and lastly sand. Independent two sample t-tests assuming equal variances show that there is a significant difference between the mean sludge depth of sand and fine sawdust t(df) = 56, $P<0.05$). There was no significant difference in the mean sludge shrinkage depth of fine sawdust and coarse sawdust. Similar results were obtained during the wet season. Comparisons of similar media types during the dry and wet seasons shows that the mean sludge shrinkage for the dry season were significantly lower than that of the wet season ($P<0.05$). This implies that seasonal changes significantly affect the sludge dewatering. In terms of moisture content (MC), the results for dry season showed that fresh fine and fresh coarse wood sawdust achieved MC of 28% and 31% respectively after 28 days. Sand produced faecal sludge with a higher MC of 49% after 28 days. Similar results of the performance of the three types of media was observed during the wet season. In conclusion, fine sawdust performs better than coarse sawdust and sand media in faecal sludge dewatering. Sludge dewatering is affected by seasonal changes.

Keywords: Coarse sawdust, fine sawdust, moisture content, sand, Sludge shrinkage.

INTRODUCTION

Demographic trends world over indicate increase in population. This has translated into an ever-increasing pressure on the available resources which without a doubt has led to an increase in volumes of waste generated. Wastewater with its component of feacal sludge is one of the wastes generated in

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large quantities. This means challenges as far as its management is concerned, which translates into both an environmental pollution and public health threat. These large sludge quantities, if not well managed well, call for vast storage space. Such space is not readily available making the accumulating sludge a public nuisance. To properly dispose it off, strict regulations must be adhered to, to meet environmental standards (Andreoli et al., 2007).

Treatment techniques will vary from plant to plant depending on the raw sewage quality received (Yeqing et al., 2013). These may involve characterisation, stabilisation, dewatering, thermal processing, agricultural reuse (for that whose content of organic matter and nutrients is high and thus beneficial) and or its eventual disposal (Metcalf and Eddy, 2004).

One of the techniques used in sludge management is the unplanted drying beds as case is at LSTP. This employs natural drying techniques of evaporation and percolation, driven by the area's temperature and humidity (Strande et al., 2014). From the above it is clear that large Sludge volumes are generated which require innovative mass and volume reduction treatment techniques.

Ordinarily, sand acts as a filtering media for which this research studied sawdust as its potential replacement with gravel maintained as the draining medium. Sawdust, a by-product of the sawing processes has various agricultural uses (mulching, animal bedding, and soil conditioner), construction and as an energy source (Forest laboratory services, 1969).

According to Kufour (2010), sawdust has exhibited abilities to act as a sludge conditioner in the dewatering process on sand sludge drying beds. This resulted in reduction in the sludge dewatering times for different sludge to sawdust mixed ratios. The sludge drying period of about 2 months taken to dewater the sludge at LSTP is longer than the design period of 1- 1.5 months. This is despite the beds having plastic roofing sheets to enhance the dewatering process. The need to reduce this long drying period coupled with sawdust availability (from the prior mentioned sawing processes), presented the opportunity to beneficially dispose it off and informed the decision and need to conduct this research.

The importance of sludge management under the environmental management of solid waste, emphasising waste minimisation and increased reuse/recycling as strategies is clearly outlined in Agenda 21 (Andreoli et al., 2007). From this conference, innovative sustainable treatment and disposal methods in the management of sludge were deemed necessary.

With the feacal sludge source majorly being the human gut, presence of pathogens with potential to pose a public health risk (cause disease), or be hazardous/toxic due to presence of/interaction with organic and inorganic contaminants is a must. All these factors deem it environmentally harmful (McGhee, 1991), for which, its treatment and proper handling cannot be underestimated. Goal 6 of the globally set Sustainable Development Goals (SDGs) earmarks sludge management as a means of availing sustainable yet manageable water and sanitation for all. The impact of this would have a direct bearing on goal 12 targeting waste recycling through sustainable consumption and production patterns.

Article 3 of the Bamako convention stipulates banning of the importation of hazardous wastes to Africa, aided by their management through transboundary movement controls. It further emphasizes proper treatment measures as a means to minimize their generation. This would lead to a healthier environment through reduced pollution. Presence of pathogenic as well as other environmentally contaminating constituents in the sludge, renders it as a hazardous waste, for which this convention predominantly addresses itself.

Mathney and Jennifer (2011), according to U.S. Environmental Protection Agency (EPA), defines sewage sludge as the solid, semi-solid, or liquid residue formed after domestic sewage treatment. This residue can comprise the beneficial by-product referred to as bio-solids or suspended solids or liquids requiring treatment after removal from the liquid stream before disposal (Jenkins and Nolasco, 2015).

Faecal sludge (FS) is obtained from onsite sanitation technologies, with the transportation means being cesspool emptier trucks, aquavacs, etc. and not through sewer lines. It takes on the form of raw or partially digested, slurry or semisolids, and formed after the faecal sanitation chain (storage, collection, transportation and treatment) of combinations of excreta and black water, with or without greywater (Strande et al., 2014), as shown in Figure 2 below. Examples of onsite sanitation technologies include pit latrines, sewered public ablution blocks, septic tanks, aqua privies, and dry toilets (onsite sanitation appurtenances). It doesn't have a uniform composition, nor is it of the same quantity and concentration. The sludge comprises of a solid and liquid fraction as in studies by Garg and Neeraj (2009), Yeqing et al. (2013) and Jenkins and Nolasco (2015).

Five groups of pathogenic organisms are majorly known, namely; bacteria, fungi, viruses, protozoa and helminths. These are mostly found in faecal matter of animal and humans which means that they are present in human systems. The treatment process concentrates most of these pathogens initially present in the incoming wastewater into the sludge. Therefore, how this sludge is handled is of utmost importance (Andreoli et al., 2007).

Reduction of sludge volume and alteration of its properties prior to its transport, disposal and or use are the main objectives of treating it, for which several technologies are employed. Some of these technologies for which the sludge is treated before it is disposed off include but not excluded to digestion, thickening, stabilisation, drying and de-watering. During these processes, excess water and heavy metals are removed as well as killing off the pathogens.

It employs physical processes such as evaporation, evapotranspiration, filtration, gravity, surface charge attraction, centrifugal force and pressure (Strande et al., 2014). As a process, it reduces the moisture content and volume of the sludge, which increases its solid content. This enables considerable amounts of sludge to be treated/dried, transported and hence disposed of.

With the reduced dried sludge volumes (cake), means transportation of a product with a more relevant solids content, otherwise impossible in its liquid form. By this, through pathogen reduction, stabilization of organic matter and nutrients, and the safe end use or disposal of treatment end products, the objectives of ensuring environmental protection and public health safety are achieved (Strande et al., 2014). Key targets of odour and putrescible control, are achieved by this method which is undertaken before most disposal methods (Metcalf and eddy, 2004). Several dewatering techniques exist, either mechanical or natural, but all being physical processes.

These involve natural processes of evaporation and percolation which include lagoon and drying beds which may be planted or unplanted. The natural dewatering method used was one of the Conventional sand drying beds, which is the most used sludge drying technique worldwide. Several factors affect and therefore are key in informing their design and usage. Among these are weather conditions, sludge characteristics, land values, closeness of the residents to the site, as well as conditioning aid use (US EPA, 1974). These beds can be open or covered.

The general drying bed lay out usually consists of a rectangular tank, of masonry or concrete walls and a concrete floor, with the details as elaborated by Wang et al. (1986). The natural process of evaporation and filtration are the main drivers of dewatering and drying of the sludge in the sand drying beds. As a multi-phase process dewatering consists of the liquid, plastic and solid phase. For much of the dewatering period, the water easily percolates through the draining bed (liquid phase) up to the moment when the sludge changes into a thick pasty mass, the plastic phase (Andreoli et al., 2007). This is further aided by the additional exposure of the sludge area through the developed cracks in it.

Good weather and the sludge condition can enable to obtain a cake of 40-45% solids in 2-6 weeks (Wang et al., 1986). It however, must be noted that drying beds, besides achieving dewatering, do not aid stabilisation, nor pathogen removal, although biodegradation may occur to some extent (Strande et al., 2014). As a result, presence of any pollutants within the sludge would remain in it and or the resultant leachate.

According to Manga et al. (2016) research in Uganda, it was realised that it 100% helminth eggs removal efficiency from the percolate was attained meaning that the dewatered solids retain them. As such further treatment of the dewatered dry sludge is required before its use. Total solid (TS) content of at least 25% is fit for removal regardless of the different sludge treatment technologies.

Also referred to as wood dust, is among the wood processing by products besides chippings, slabs, off cuts and shavings (Tiough, 2016). It is a tiny – sized powdery wood waste in saw milling and wood industries with their particle size largely dependent on the wood type, saw teeth and purpose for which it is to be used (Maharani et al., 2010). Such industries are quite numerous in Uganda from which varying shape and sizes of sawdust can be obtained. What endears the sawdust for its use are its absorptive, abrasive, bulky and fibrous, nonconductive and granular properties (Forest product laboratory, 1969), for which challenges as far as its disposal as a waste are negated. This study investigated use of wood sawdust as a filtering layer in the faecal sludge drying process.

MATERIALS AND METHODS

This involved setting up model beds of 1 m^3 volume capacity with 1 m^2 effective drying area covered with tarpaulin structure. The study was carried out in the wet and dry seasons.

Three of the beds were used for the first cycle (dry season) while five were used in the second cycle (wet season).

In first cycle, all model beds comprised of course and fine aggregates, but differing in filtering layers (sand, course sawdust and fine sawdust); while in second cycle, besides the known media, also reused course and fine sawdust were included as filtering layers.

Bed construction consisted of a raised plinth wall approximately 1 m from the ground surface. The drying beds contained a supporting layer of gravel (fine and coarse) with a depth of 30 cm and sizes ranging from 5-10 mm and 10-19 mm. This was placed on the under drains which consisted of a PVC pipe. The sand-sawdust mixture serving as a filtering media, was placed on the gravel at a depth of 20 cm. The sand was washed and dirt free, having an effective size of 0.2-0.6 mm with a uniformity coefficient of 2.833. Sludge was pumped into each bed to a height of 30 cm. Each of the beds was constructed in triplicate and arranged in a randomized block design.

The change in depth of the sludge layer was measured after every 24 hours, using a 2m long tape measure to determine reduction in depth of sludge due to filtration and evaporation. Samples from the bed were collected with an interval of 7 days for monitoring moisture content and initial total solids. This was done until the desired moisture content of the cake at which harvesting occurs was achieved.

Phase changes of the sludge in the beds were monitored i.e. liquid, plastic and solid phase. Sludge changed from liquid to plastic phase when the percolation stopped. A change from plastic to solid phase was realized when cracks formed on the surface of the sludge. These which were deep to an extent that the filtering media could be seen.

The total number of days taken for complete dewatering was noted and recorded. Dewatering was considered complete when the solid phase was reached, moisture content for dried solid was reached (30%-40%) and the percolate from the drying bed stopped. At this point, the dewatered sludge could be easily removed with a spade. Two dewatering cycles were conducted and monitored for a period of 1 month each.

Moisture content determination

The moisture content of the sludge was determined using the gravimetric method. This is done to determine the variation of the moisture content of the sludge before and after drying and was done in a laboratory. It is expressed by weight as the ratio of the mass of water present to the dry weight of the sludge sample. The materials used included: a drying oven, analytical balance, aluminium weigh tins, Auger or tool to collect sample and a Crucible.

Moisture content is the mass fraction determined as the loss on mass after the specified drying process. It is expressed as a Percentage or in milligrams.

Calculation

The percentage moisture content (MC) is expressed as below:

Moisture content (%) = (Mw-Md)/ Mw*100

Mw= mass of wet sample

Md= mass of dry sample

The procedure involved:

Placing the crucible in an oven for 30 minutes to remove all moisture, weighing the crucible, and recording its weight.

Placing a sample of about 10g in the crucible and record this weight as (wet sludge + crucible).

Placing the sample in the oven at 105^{o}C for at least 7 hours.

Weighing the sample, and recording this weight as weight of (dry sludge + crucible).

Return the sample to the oven and dry several times between intervals of 30-60 minutes, and determine the weight of (dry sludge +crucible).

Repeat above step until there is no difference between any two consecutive measurements of the weight of (dry sludge and crucible).

Figure 1: Sludge being dried in one of the unplanted covered sludge drying beds at LSTP, Kampala, Uganda.

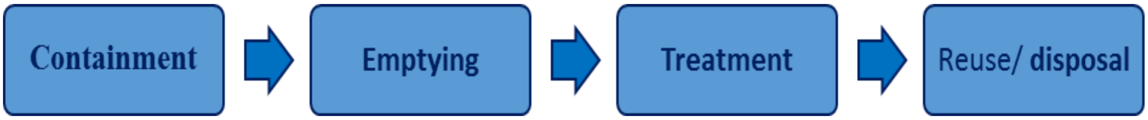

Figure 2: Faecal sludge management chain.

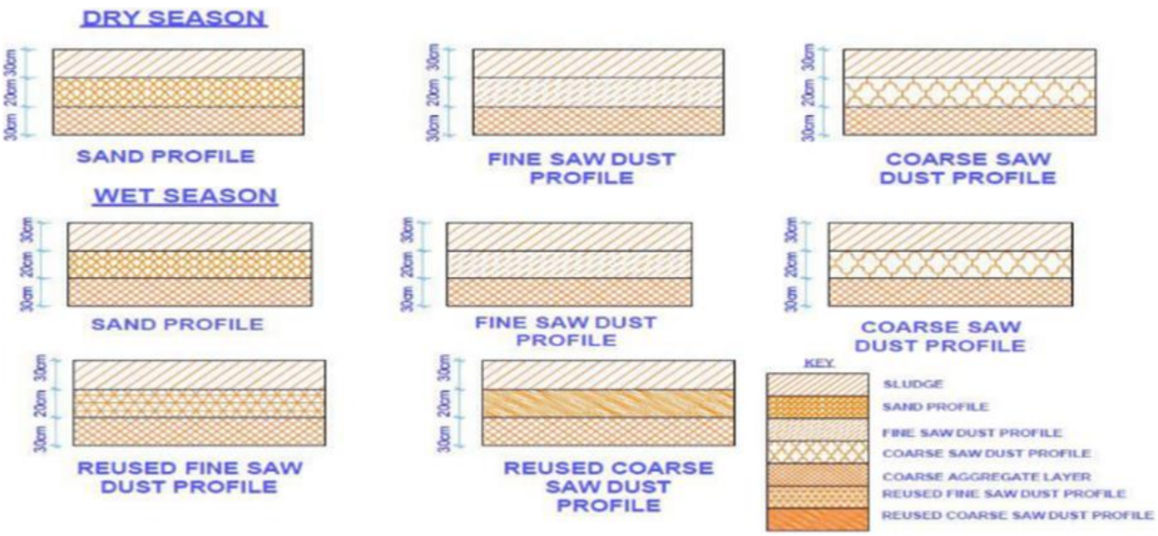

Figure 3: Layout of different filtering profiles of model drying beds.

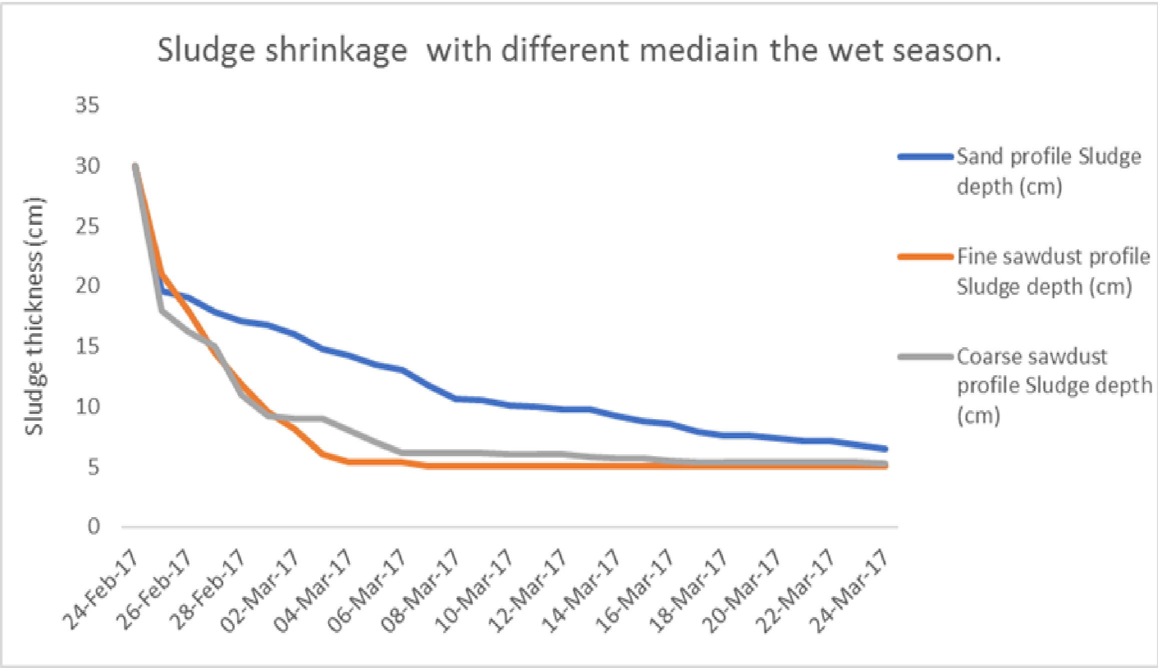

Figure 4: Graph showing trend of sludge dewatering process in the different filtering bed profiles (Wet season).

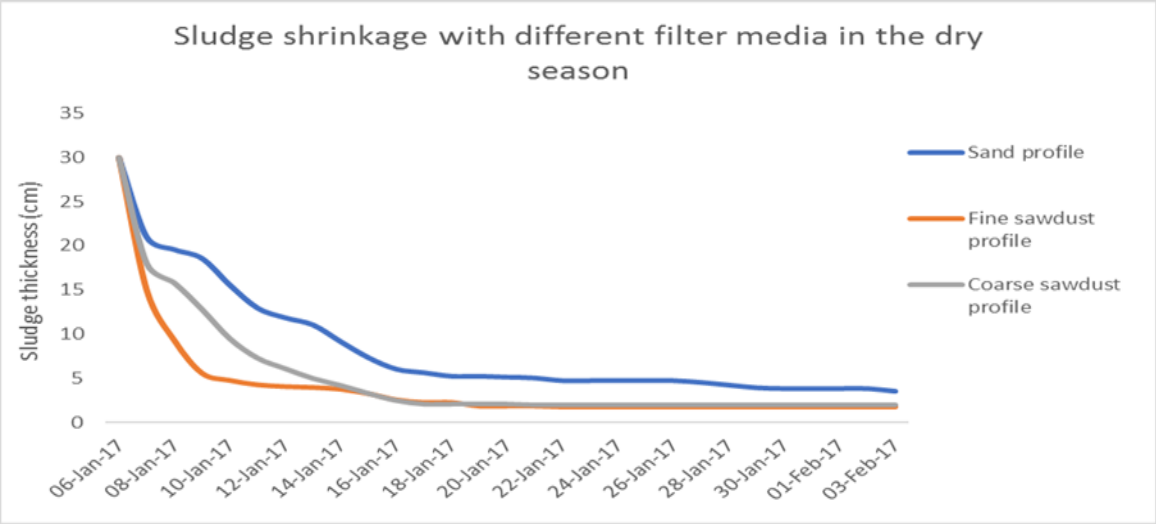

Figure 5: Graph showing trend of sludge dewatering process in the different filtering bed profiles (Dry season).

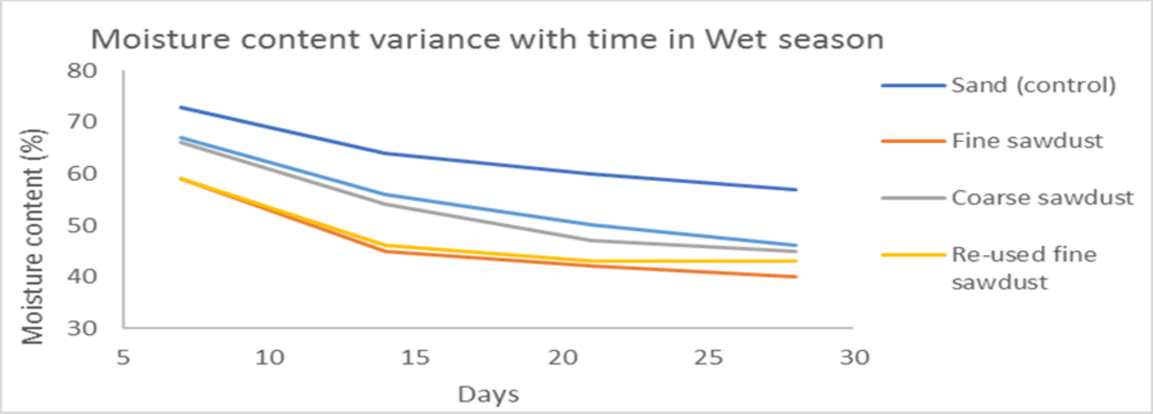

Figure 6: Graph of moisture content values for sludge (Wet season).

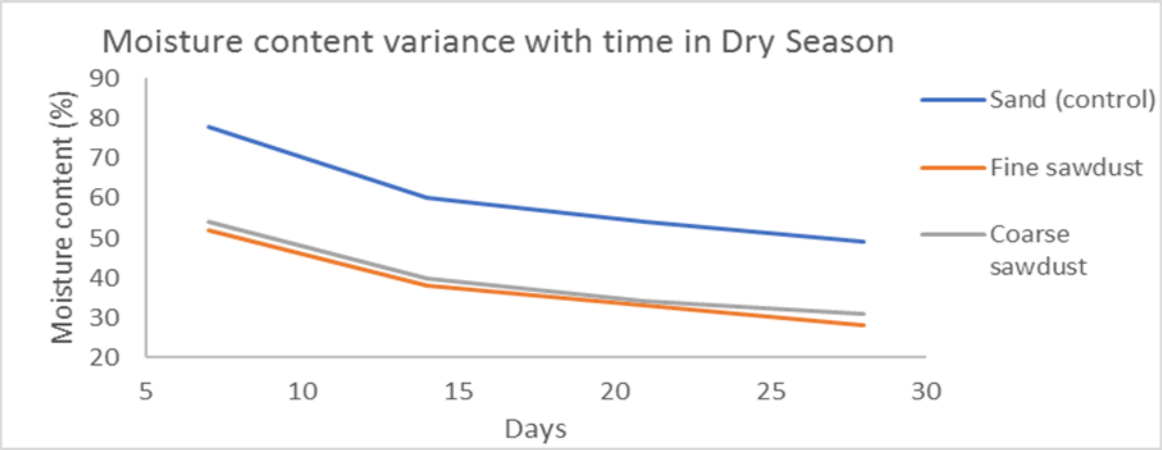

Figure 6: Graph of moisture content values for sludge (Dry season).

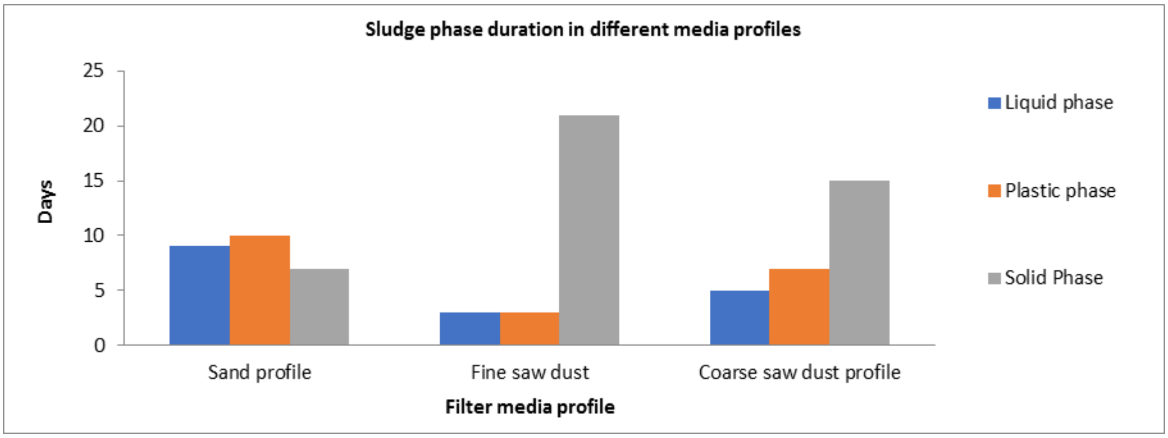

Figure 8: Sludge phase duration in different filtering profiles (dry season).

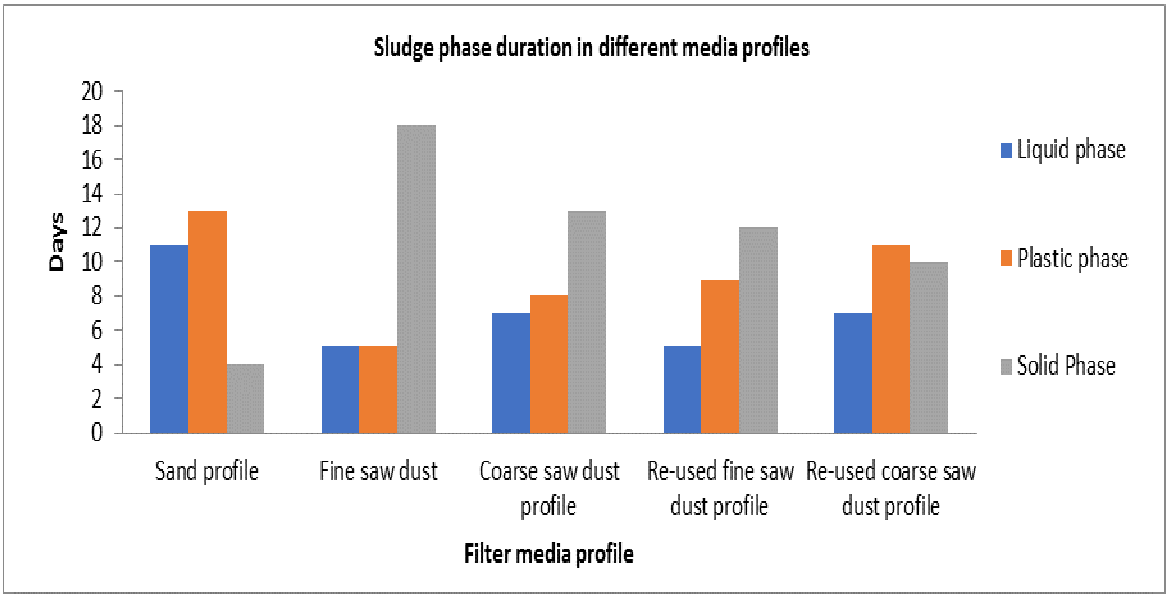

Figure 9: Sludge phase duration in different filtering profiles (dry season).

RESULTS AND DISCUSSION

Results for the dry season show that there was a drastic decrease in sludge depth (shrinkage) for all three media types after a period of 8 days followed by a gradual decrease in sludge depth up to 28 days. The mean sludge depth of sand, coarse sawdust and fine sawdust after 8 days were 14.9±7 cm, 10±8.3 cm and 7.9±8.2 cm respectively. This implies that effective dewatering happens for the first 8 days with the best performing media being fine sawdust, coarse sawdust and lastly sand. Sludge depth of sand, coarse sawdust and fine sawdust after 28 days of study were 8.5±6.6 cm, 5.2±6.5 cm and 4.2±5.7 cm respectively. Independent two sample t-tests assuming equal variances shows that there is a significant difference between the mean sludge depth of sand and fine sawdust t(df) = 56, $p<0.05$). There was no significant difference in the mean sludge shrinkage depth of fine sawdust and coarse sawdust. Similar results were obtained during the wet season. Comparisons of similar media types during the dry and wet seasons show that the mean sludge shrinkage for the dry season were significantly lower than that of the wet season ($p<0.05$). This implies that seasonal changes significantly affect the sludge dewatering.

In terms of moisture content (MC), the results for dry season showed that fresh fine and fresh coarse wood sawdust achieved MC of 28% and 31% respectively after 28 days. Sand produced faecal sludge with a higher MC of 49% after 28 days. Similar results for the performance of the three different media types were observed during the wet season.

Conclusion

In conclusion, fine sawdust performs better than coarse sawdust and sand media in faecal sludge dewatering, and should be adopted as a filter media in sludge drying beds within sludge treatment plants as a suitable replacement of sand. Sludge dewatering is affected by seasonal changes.

COMPETING INTERESTS

The authors declare that they have no competing interests.

AUTHORS' CONTRIBUTIONS

All authors participated in the project design, data collection and data analysis. They produced and approved the final submitted manuscript.

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