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Enhancing faecal sludge dewaterability and end-use by conditioning with sawdust and charcoal dust

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ABSTRACT

Faecal sludge (FS) treatment in urban slums of low-income countries of sub-Saharan Africa is poor or non-existent. FS contains over 90% water and therefore dewatering it within slums decreases transport costs, facilitates local treatment and end-use. This study was designed to enhance the dewatering efficiency of FS, using two locally available physical conditioners (sawdust and charcoal dust), each applied at dosages of 0%, 25%, 50%, 75%, 100% and 125% TS. The optimum dosage for both conditioners occurred at 50% and 75% for cake moisture content and capillary suction time, respectively. The dewatering rate improved by 14.3% and 15.8%, whereas dewatering extent (% cake solids) improved by 22.9% and 35.7%, for sawdust and charcoal dust, respectively. The dewatering in FS conditioned with sawdust and charcoal dust was mainly governed by absorption and permeation (porosity), respectively. The FS calorific value improved (from 11.4 MJ kg^{-1}) by 42% and 49% with 50% TS dosage of sawdust and charcoal dust, respectively. The FS structure also became porous after dewatering which hastens the subsequent drying and/or composting processes. Due to comparable performance in dewatering, sawdust or charcoal dust, whichever is locally available, is recommended to treat FS in low-income urban slum settlements.

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KEYWORDS
Calorific value; charcoal dust; dewatering; sawdust; urban slums

1. Introduction

Sanitation needs of over 80% of the urban population in sub-Saharan Africa (SSA) countries are met by use of some form of on-site sanitation technology, such as septic tanks and pit latrines [1,2]. Consequently, pit latrines are the dominant excreta disposal technologies in urban slums (densely populated areas in cities, inhabited by the poor) of low-income SSA countries [3,4]. When these pits are full, large quantities of semi-solid slurry material known as faecal sludge (FS) is generated, often mixed with non-faecal materials (solid wastes) that are deposited in the pits [2]. The users and/or owners face challenges, among which are the high costs of emptying and subsequent transportation of FS to treatment facilities outside of the slums due to high density of housing units and long haulage distances to treatment facilities [5]. A number of slum dwellers resort to emptying FS in the living environment, which is not only a high risk to public health, but also environmental pollution. Such costs and risks can be minimised by adoption of decentralised treatment of FS within urban slums [6]. However, dewatering (solid–liquid separation) forms a crucial part in decentralised treatment of FS since it contains >90% water [7]. Dewatering reduces solid fraction volumes and subsequently the costs of transportation and handling [8].

FS from lined pits (cement-mortar sealed containment pits to prevent liquid loss), used by over 75% of slum population in Kampala, Uganda [4], has a low dewatering extent (low percent dry solids in dewatered cake) [9]. Chemical conditioners and plant extracts have been used to improve the dewatering rate (rate at which water filters through the FS sample) [10], but no improvement in dewatering extent is reported. Physical conditioners such as coal fines, char, sawdust, bagasse, rice husks, rice bran and wheat dregs have been reported to improve dewatering extent of sewage sludge. They enhance the mechanical strength of sludge through formation of a rigid lattice structure to improve permeability within sludge solids, hence allowing water to easily flow out of the porous sludge structure [8]. Also, physical conditioners have a low moisture content compared to FS, which leads to reduction in cake moisture through absorption. They are generally more attractive from the economic and environmental points of view,

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since they are often waste materials from domestic and agricultural activities or cheap process by-products, therefore cost effective when applied in dewatering enhancement. Additionally, some of these physical conditioners are carbon-based, hence preferred if the dewatered sludge is to be used for energy recovery purposes [8,11]. Diener et al. [12] reported energy recovery from FS as a viable venture that can incentivise FS management to bear its own cost.

In this study, sawdust and charcoal dust were investigated as suitable physical conditioners for improving dewaterability and also improve energy potential of the resulting FS from urban slums. Sawdust and charcoal dust from the Bwaise slum (Kampala) were used because they are biodegradable and locally available at low or no cost. Since a large number of slum dwellers depend on wood charcoal as their major cooking fuel, there is production of high volumes of charcoal dust (a waste from wood charcoal). The other physical conditioners such as coffee, palm, ground nuts and rice husks, as well as bagasse were not considered because they are costly to transport since they are generated in areas with large-scale agricultural activities [13]. For example, these conditioners are obtained at long distances in relation to Kampala slums, where a lot of FS that needs localised handling to reduce haulage costs is generated. In addition, the current competition for these wastes as fuel sources to generate heat in a number of industries and agricultural production (e.g. poultry and piggery farming; some on a commercial scale) has made them expensive [12]. Also, application of sawdust and charcoal dust conditioners maintains potential utilisation value of the resulting FS cake after dewatering. Sawdust and charcoal dusts possess calorific values of about 20 and 28 MJ kg^{-1}, respectively [12], but FS has a slightly lower calorific value in the range of 12–17 MJ kg^{-1} [7,14], which is expected to be improved by sawdust and charcoal dust conditioning. The improvement in energy content could be a driver for sustained end-use, hence improved sanitation through management of not only FS, but also the sawdust and charcoal dust wastes from the surrounding environment of urban slums.

Over 70% of the urban households in a number of low-income countries of SSA rely on wood charcoal (carbonised wood product) as the main source of cooking fuel [15]. The population growth in SSA is likely to raise the demand of wood charcoal, yet about 5–20% of the charcoal volume is wasted in the form of charcoal dust, formed either during parking, transportation and/or storage [16]. Some charcoal dust is currently mixed with binders to make fuel briquettes, while the rest ends up in municipal solid waste [17]. Also, sawdust is a globally abundant organic waste from timber sawmills. In fact, the wood loss in the form of sawdust is estimated at 18–20% of the log volume in some SSA countries such as Uganda [18]. Part of sawdust is currently used to provide energy at household and industrial scale [12] as well as bedding layer in rearing of chicken, while a fraction of it joins the municipal solid waste stream [19].

Sawdust on the other hand has been used in a number of studies to remove toxic substances, such as heavy metals, colour and others, from water and wastewaters [20]. Furthermore, pre-conditioning of domestic and industrial wastewater sludge with sawdust to improve dewaterability has been studied [11]. However, charcoal dust is equally important but its potential as a conditioner in the treatment of wastewater sludge is untapped. Application of sawdust and charcoal dust in dewatering of FS is not yet reported.

The objective of the present study was therefore to determine how the dewaterability of FS from pit latrines in urban slums can be enhanced with sawdust and charcoal dust as physical conditioners. Additionally, characterisation of dewatered FS in terms of the energy beneficiation resulting from the use of these conditioners was done. The results provide information that could be used in the practice of FS conditioning while managing sawdust and charcoal dust wastes in urban slums.

2. Materials and methods

2.1. Collection and preparation of FS samples

FS samples were collected from Bwaise (00 21 00 N, 32 33 40 E), a typical urban slum in Kampala with limited access to mechanised pit emptying. FS from lined pit latrines (cement-mortar sealed containment pits that prevent liquid loss) was used in this study because lined pit latrines are used by more than 75% of urban slum population in Kampala [4]. Grab samples were obtained from various layers (top, middle and bottom) of a pit latrine through a squat hole by using a multi-stage sampler reported by Semiyaga et al. [9]. These were mixed into a composite sample that was collected in a 30 L HDPE plastic container and then transported to the Public Health and Environmental Engineering Laboratory at Makerere University, where they were stored at 4°C prior to further processing and analysis. The preparation of FS samples before analysis involved removal of extraneous material by passing it through a 5 mm sieve [21].

2.2. Collection and preparation of physical conditioners

Charcoal dust was obtained from charcoal outlets within the Bwaise slum, while sawdust was obtained from a timber sawing mill in the same slum area. Charcoal dust and sawdust particles were sieved to a size less than 2.36 mm, oven dried for 24 hours and stored in a vacuum desiccator, to keep it dry during analysis [11]. The particle size distributions of sawdust and charcoal dust used in the study were determined by gradation using standard sieves ranging from 2.36 to 0.075 mm (Table 1). The density of sawdust and charcoal dust was determined by packing a measured weight of the conditioner into a graduated cylinder. The cylinder was tamped on the bench top until no further volume reduction of conditioner was observed. This volume was recorded and the density was calculated.

2.3. Characterisation of FS

Raw FS from lined pit latrines was characterised for: total solids (TS), total volatile solids (TVS), pH, EC, moisture content, dewatered cake solids, bulk density, ash content, calorific value and crude protein (Table 2). TS, TVS and ash content were determined according to standard methods for examination of water and wastewater [22]. The TS concentration was determined gravimetrically by taking the weight of the oven dried sample at 105°C for 24 hours and expressed as a fraction of wet sample volume. TVS was determined by taking the weight difference between oven dried solids and the 2-hour muffle furnace ignited sample at 550°C and expressed as a percentage of TS. Ash content was the residue after ignition in the furnace at 550°C for 2 hours. Gross calorific value was determined on dry samples after TS analysis, where approximately 1 g of sample was combusted in an oxygen bomb calorimeter (IKA Model C2000, Germany). Crude protein, an indicator for extracellular polymeric substances (EPS), was determined by multiplying a factor of 6.25 to the difference between total nitrogen (TN) and ammonium nitrogen (NH_4–N) [23]. Three replicates were analysed for each sample to verify the reproducibility of the experimental results.

Table 1. Particle size distribution of sawdust and charcoal dust conditioners.

	Sawdust		Charcoal dust	
Particle size (mm)	Mass retained (%)	Cumulative mass passing (%)	Mass retained (%)	Cumulative mass passing (%)
2.360	0.0	100.0	0.0	100.0
1.180	36.6	63.4	31.4	68.6
0.600	37.4	26.0	22.6	46.0
0.425	11.6	14.4	9.4	36.6
0.300	7.2	7.2	8.9	27.7
0.212	3.6	3.6	6.4	21.3
0.150	1.6	2.0	5.2	16.1
0.750	0.8	1.2	7.2	8.9
Pan	1.2	N/A	8.9	N/A

2.4. Physical conditioning and dewatering of FS

The physical conditioner (sawdust or charcoal dust) was added to 500 mL of FS in dosages of 0%, 25%, 50%, 75%, 100% and 125% and the mixture was agitated at a speed of 60 rpm and time of 20minutes [11,24], using a Stuart flocculator (Jar test), model SW6. The sawdust or charcoal dust dosage was expressed as the weight ratio of conditioner to FS dry solids.

2.5. Dewatering performance of conditioned FS

Dewatering performance of conditioned FS was determined in terms of capillary suction time (CST) (time for water to filter through the FS sample) and percent moisture content in dewatered FS cake after centrifugation, representing dewaterability rate and dewaterability extent, respectively. A high CST value and high cake moisture content are reflections of poor FS dewaterability (rate and extent, respectively). CST was measured in triplicate using a CST instrument (Type 304M, Triton, England, UK) equipped with an 18 mm diameter reservoir funnel and chromatography paper, as described in the standard method [22].

Dewatering extent was determined using a batch type laboratory centrifuge (MISTRAL1000 type, UK), where 50 mL of FS sample was centrifuged at 3000 rpm for 20 minutes, corresponding to gravitational force of 1500 g [25]. After centrifugation, percent moisture content (wet basis) in centrifuged cake was determined from the wet and oven dried (105°C) cake weights. The volume and turbidity of decanted off supernatant (leachate) were determined using a measuring cylinder and a spectrophotometer (Hach DR 2800, UK), respectively. The other parameters, namely volatile solids and ash content of the centrifuge dewatered FS cake, were determined following standard methods [22]. In order to compare the microstructure of the original raw FS and the conditioned FS mixtures, a digital microscope was used. Micrographs were obtained by visualising the samples, placed on the microscope slide.

Table 2. Characteristics of raw FS samples.

Parameter	Unit	Range values
pH		7.6–8.5
EC	mS cm^{-1}	5.8–9.4
Total solids (TS)	g/L	15.0–32.2
Moisture content	%	96.7–98.4
Volatile solids (VS)	%TS	30.2–60.7
Ash content	%TS	39.3–69.8
Cake solids	%	14.0–28.2
Bulk density	kg m^{-3}	995–1002
Crude protein	mg/gTS	50.8[a]
Gross calorific value (dry basis)	MJ kg^{-1} (d.b)	11.4[a]

[a]Mean value.

2.6. Data analysis

Statistical analysis was carried out using SPSS version 21.0 for Windows. Data were tested for normality using the Shapiro–Wilk test and homogeneity of variance by the use of Levene's test in SPSS. Descriptive statistics were used to describe the characteristics of FS and conditioners. Significant differences in treatments using sawdust and charcoal dust were evaluated using the Analysis of Variance (ANOVA) at 5% significance level.

3. Results and discussion

3.1. Characterisation of sawdust and charcoal dust

Most of the characteristics of sawdust and charcoal dust used in this study were comparable to published literature from different tree species in different countries (Table 3). This implies that the results from this study are transferrable to similar conditioners in different locations. In cases of no literature for charcoal dust, wood charcoal literature was used, since charcoal dust is derived from wood charcoal. Charcoal dust had a higher calorific value than sawdust, mainly because of its higher fixed carbon content [26,27]. However, some charcoal dust can be mixed with extraneous materials like soil, depending on the source, which may increase the ash content and thus lower the calorific value. Volatile solids in charcoal dust are lower than in sawdust due to their possible removal during the wood carbonisation process.

3.2. Effect of physical conditioners on FS characteristics

There was an increase in TVS and a decrease in ash content for FS conditioned with both sawdust and charcoal dust (Figure 1(b) and (c)). However, sawdust-conditioned FS depicted higher TVS and lower ash content values than charcoal dust for all dosages. These are relevant trends if conditioned FS is to be used in energy recovery, as depicted by increasing calorific value of conditioned FS with increasing dosages (Figure 1(a)). The low calorific value of unconditioned FS in this study (11.4 MJ kg^{-1}) could be due to the presence of high ash content (~40%TS). This is comparable to a study by Seck et al. [14], whose calorific value of FS was 12.2 MJ kg^{-1} with an average ash content of 41.7%TS. The authors further realised an increment of 6% in ash content after dewatering of FS on sand beds. Therefore, avoiding FS contact with sand during dewatering reduces the ash content of the resulting cake. Additionally, usage of sawdust or charcoal dust significantly lowered the ash content through dilution effect, hence increment in energy potential of the resulting material.

FS conditioned with charcoal dust depicted higher calorific values, though not significantly different from sawdust ($p = .410$, .082, .388 and .122) for corresponding dosages (25%, 50%, 75% and 100%). This reflects a comparable performance in energy recovery when either of the conditioner is used. Additionally, multiple comparisons of average calorific values at different dosages using Tukey HSD revealed no significant difference ($p > .05$) beyond 25% and 50%TS dosage for charcoal dust- and sawdust-conditioned FS, respectively. The gross calorific value of FS improved by 42% and 49%, when conditioned with 50% TS dosage of sawdust and charcoal dust, respectively. Finally, increased conditioner dosages lowered crude protein content in FS (Figure 1(d)). Crude protein is a component of EPS, with a high water-holding capacity. Therefore, a reduced crude protein fraction in FS improves dewaterability efficiency [28].

3.3. Effects of physical conditioners on dewatering of FS

The cake moisture content decreased significantly with conditioner dosage of up to 50%TS. Beyond this dosage, charcoal dust-conditioned centrifuge cake had significantly lower moisture content than a sawdust-conditioned one ($p < .05$) (Figure 2(a)). The cake moisture content significantly decreased from 86% to 80.8% ($p = .000$) and 82.8% ($p = .001$), when conditioned with 50%TS of charcoal dust and sawdust, respectively. A linear regression showed a very strong positive relationship between cake moisture and crude protein content when conditioned with sawdust ($R^2 = 0.92$, $p = .009$) and charcoal dust ($R^2 = 0.96$, $p = .004$). The decrease in cake moisture with sawdust addition was comparable to results obtained by Lin et al. [24], who reported the sawdust dosages (0%, 90%, 100%, 200% and 300%) with sludge cake moisture contents of 88.6%, 85.3%, 80.4%, 77.2% and 74.8%, respectively. Additionally, Ding et al. [29] also noted a decrement in cake moisture from 91.3% to 88.5%, when sawdust was increased from 0% to 100%, respectively. Also, a decrease in filter cake moisture from 87% to 75% was reported when coal fly ash dosage was varied from 0% to 100% [30].

On the other hand, CST decreased (FS dewaterability rate improved) when the doses of sawdust or charcoal dust were increased to 75%TS (Figure 2(b)). In fact, CST

Table 3. Characteristics of physical conditioners (sawdust and charcoal dust).

	Unit	Present study		Published data	
		Sawdust	Charcoal dust	Sawdust	Charcoal dust[1]
Specific gravity		0.065	0.053	N/A	N/A
Bulk density (loose)	kg m^{-3}	173.9 ± 10.8	868.5 ± 7.8	180–635[a]	N/A
Water content (wet basis)	wt%	18.4 ± 1.3	11.6 ± 0.4	11–13[c]	5.2[d]
TVS	wt%	79.0 ± 1.0	61.3 ± 2.2	77–82[a,c]	20-23[b,d]
Ash content	wt%	2.5 ± 0.6	24.7 ± 3.1	0.4–2.8[a]	3.8[d]
Gross heating value (dry basis)	MJ kg^{-1}	19.7 ± 0.1	23.7 ± 0.7	14–21[a,c]	23–28[e]
Aluminum oxide (dry basis)	%	N/A	N/A	4.2–9.5[a,c]	10.8[d]
Silicon oxide (dry basis)	%	N/A	N/A	10.8–49[a,c]	29.5[d]
Crude protein	mg/g solids	2.6	10.3	N/A	N/A

[a]Demirbas [26].
[b]Pastor-Villegas et al. [27].
[c]Abreu et al. [37].
[d]Arthur et al. [38].
[e]Diener et al. [12].
[1]Values used are for wood charcoal since charcoal dust is a waste from wood charcoal, N/A – not available.

was reduced by 14.3% and 15.8% for sawdust and charcoal dust, respectively at 75% dosage, compared to non-conditioned FS. The presence of aluminium and silicon elements in sawdust and charcoal dust (Table 3) is responsible for increment in dewatering rate, since these are known to cause agglomeration and thus increase in rate of settling. However, an increase in CST beyond the 75% dosage was recorded. A similar trend was reported by Luo et al. [11], where optimal sawdust dosage for sludge from textile dyeing industry was 60%, beyond which an increase in CST was realised. Secondly, Jing et al. [31] reported a high dewaterability rate improvement of 60% when 170% dosage of sawdust was used. This high improvement could be due to higher doses and larger particle sizes of sawdust used (1–5 mm) as opposed to the one with high proportion of fines used in this study (<2.36 mm).

The results generally suggested that the added sawdust and charcoal dust created voids within the FS cake, which permitted the passage of water. This was supported by the visible voids in the microstructure of conditioned FS compared to raw FS (Figure 3). Therefore,

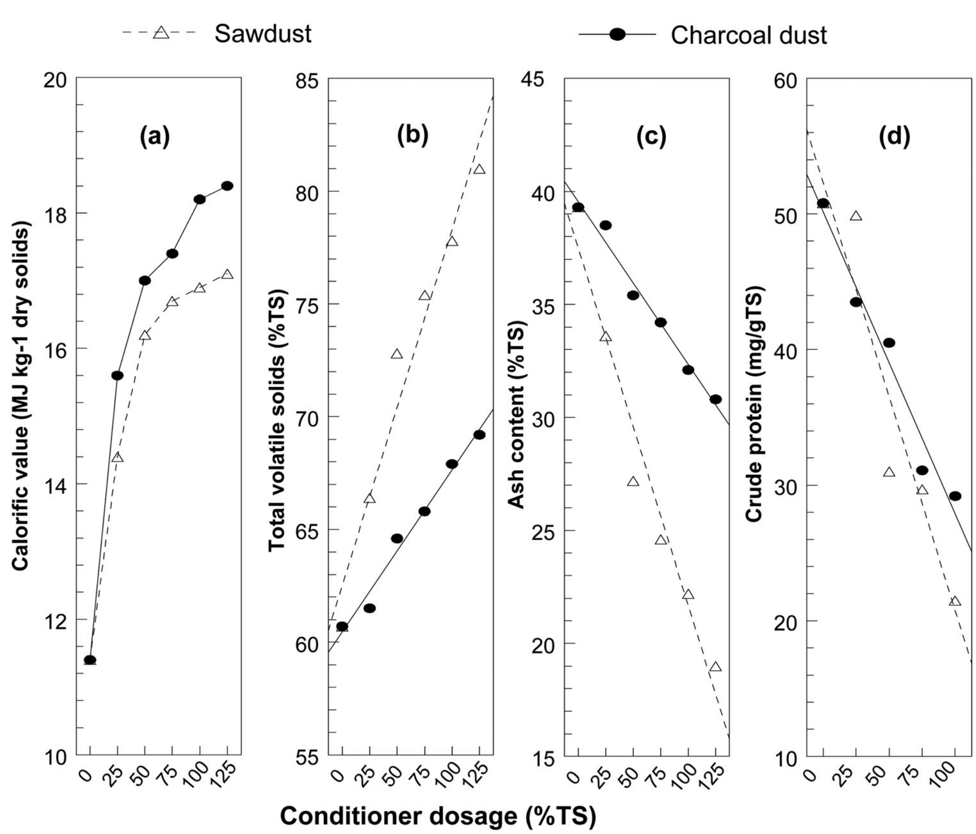

Figure 1. The effect of physical conditioner dosage on (a) calorific value, (b) volatile solids, (c) ash content and (d) crude protein of FS.

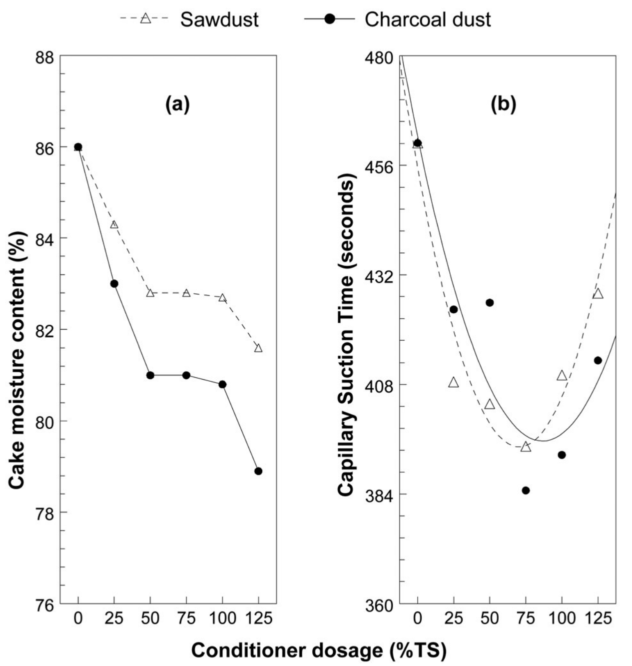

Figure 2. The effect of conditioner dosage on (a) dewatered cake moisture content and (b) CST.

the presence of physical conditioners improved the cake porosity by forming channels or pores between the sawdust or charcoal dust particles and FS particles because of different particle size distributions, thus also, the increased CST.

3.4. Effect of dewatering on leachate production

Increasing the dose of sawdust or charcoal dust decreased the cake moisture content, but did not increase volume of centrate/leachate (liquid stream after centrifugation) yielded (Figure 4(b)). These conditioners consistently reduced the volume of leachate recovered. Significant reduction ($p < .05$) in leachate production was realised after 50% and 75% TS dosage of charcoal dust and sawdust, respectively. This decrease with higher dosages could be attributed to permeation and subsequent absorption of free water from FS into sawdust or charcoal dust, hence less free water available for release from FS. A similar observation of decrease in leachate volume at higher sawdust dosages was reported by Lin et al. [24].

A linear regression revealed a very significant ($R^2 = 0.89$, $p = .000$) and a moderate positive ($R^2 = 0.56$, $p = .005$) correlation between cake moisture content and leachate volume when conditioned with sawdust and charcoal dust, respectively. This implied that more free water absorption took place in sawdust- than charcoal dust-conditioned FS. For example, at 50% dosage of charcoal dust conditioner, there was significant low cake moisture content and at the same time no significant reduction in leachate volume. Therefore, cake moisture content reduction in FS conditioned with charcoal dust was mainly governed by permeation due to the created rigid porous structure that allows escape of water.

It suffices to note that the leachate turbidity significantly decreased by 65.3% and 78%, when conditioned with sawdust and charcoal dust, respectively, at dosages of 50% TS (Figure 4(a)). Chen et al. [30] varied coal fly ash dosage from 0% to 1000% in conditioning sewage sludge and obtained least turbidity at 100% dosage. At a dosage of 50% and beyond, the turbidity for charcoal dust-conditioned FS was significantly lower than that of sawdust-conditioned FS because wood charcoal has potential of adsorbing toxic substances such as heavy metals and organic compounds [32]. More so, charcoal dust contained a higher proportion of finer particles (Table 1), leading to an increase in surface area, thus more adsorption potential for suspended solids, and hence the recorded low turbidity. The attained turbidity levels with charcoal dust conditioner were below the Ugandan effluent discharge standards of 300 NTU, implying improved quality of leachate after dewatering. However, at dosage higher than 100% TS, the turbidity slowly increased with increasing conditioner dosage.

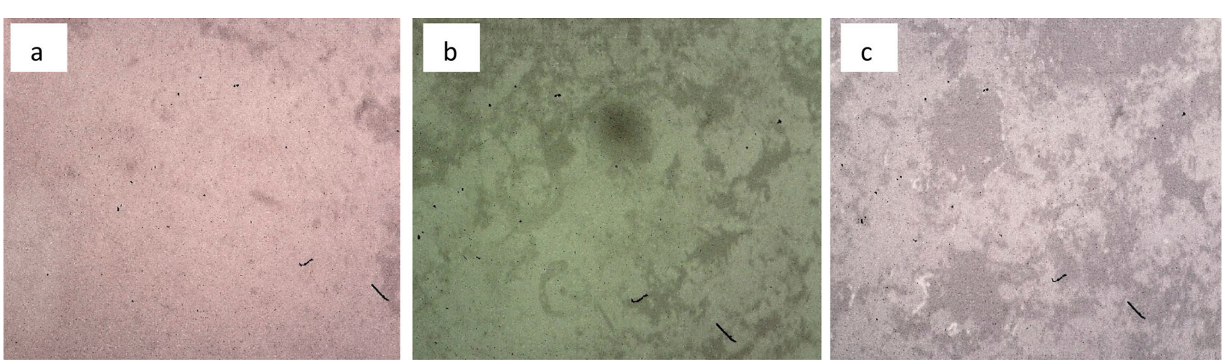

Figure 3. Micrographs of raw FS (a), FS conditioned with 75% sawdust (b) and with 75% charcoal dust, (c) magnification ×100.

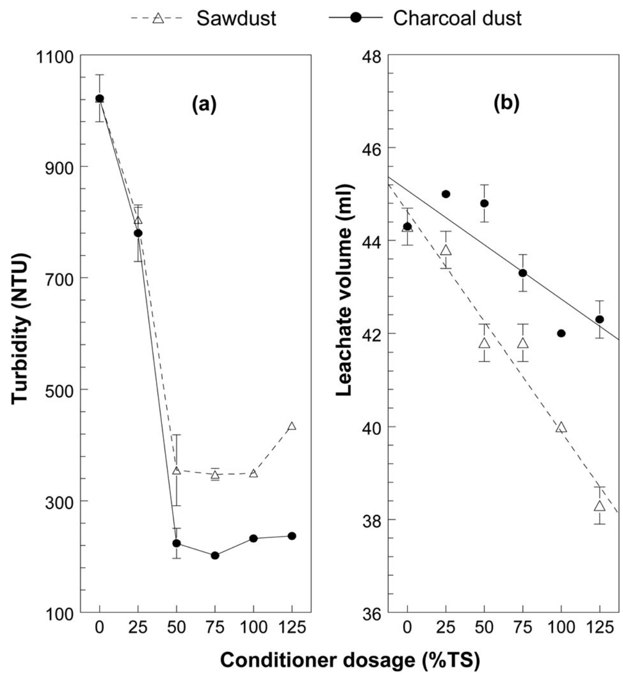

Figure 4. Effect of conditioner dosage on (a) leachate turbidity and (b) leachate volume.

3.5. Implications for subsequent FS management options in urban slums

Various FS management strategies in an urban slum setting are suggested based on the study findings (Figure 5). Semiyaga et al. [6] reported that if dewatered FS is to be used as a fuel, energy for drying is required and the dewatered cake could be transformed into briquettes for easy usage and handling. Fortunately, the created porous structure after physical conditioning means less energy is required to dry conditioned FS than the raw FS. The dried conditioned FS can be carbonised to produce char, bound and compacted into briquettes. Both the drying and carbonisation processes are very effective if one is to ensure destruction of pathogens present in conditioned FS, due to high temperatures involved [15,33], making such briquettes easy and safe to handle/use in homes. The emissions such as carbon monoxide, carbon dioxide, methane, hydrogen and ethane occur during different carbonisation stages, leading to reduced volatile compounds (organic compounds), increased fixed carbon, and hence increased calorific value of the resulting char [26]. Therefore,

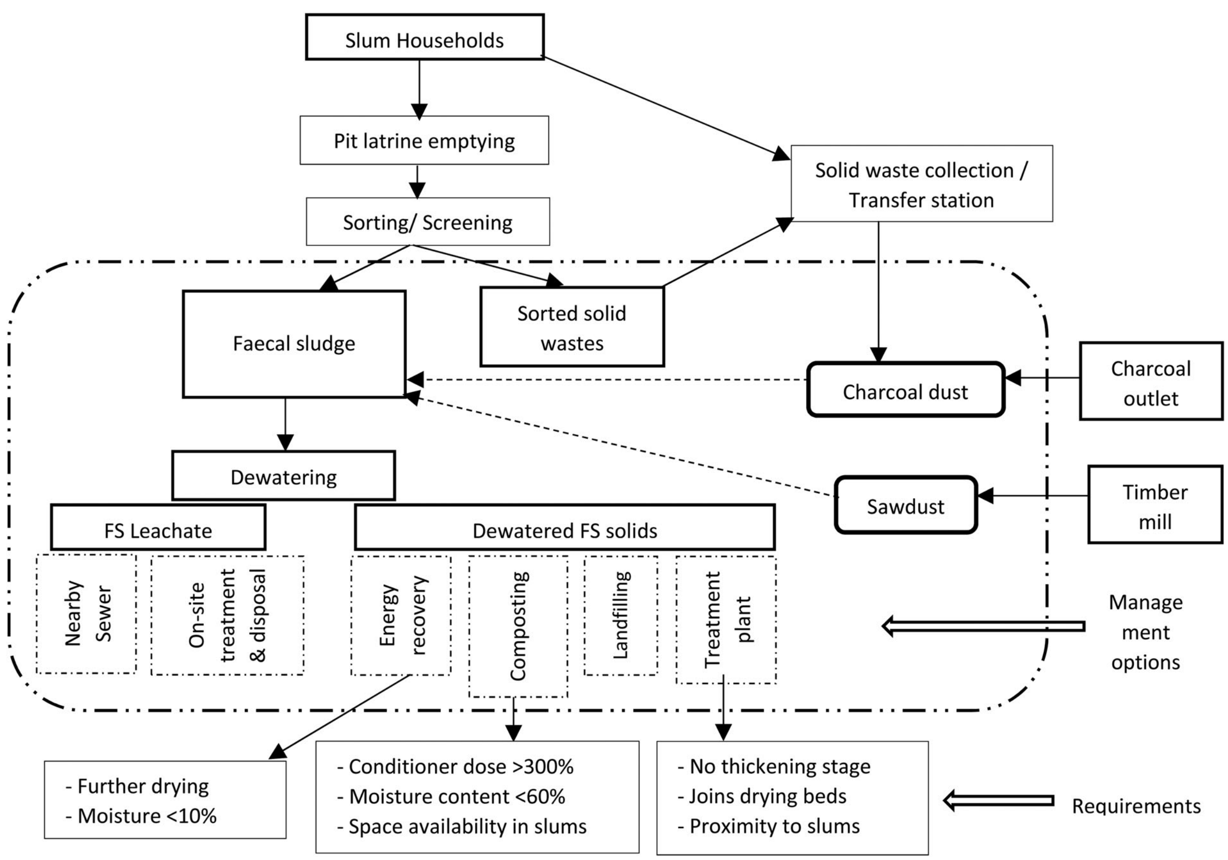

Figure 5. Propositional FS management system technology scheme in urban slum based on use of sawdust and charcoal dust conditioners.

usage of carbonised conditioned FS reduces the harmful emissions compared to burning of raw conditioned FS in home stoves. The resulting ash content of about 25 and 34% TS from sawdust and charcoal dust-conditioned FS, respectively, after energy recovery can be transported and sold to farmers to recover nutrients, such as phosphorus, potassium, calcium and magnesium for their crops. This can therefore improve soil physical and nutritional properties. Unlike, wastewater sludge, the concentration of heavy metals (such as copper, zinc, lead and arsenic) in FS from Ghana and Burkina Faso is significantly lower [34,35]. For Bwaise slum, the heavy metals from automotive garages are mainly disposed off in drainage trenches, than pit latrines [36]. Therefore, the resulting ash after recovering heat from FS can be safely used in soil improvement.

Increasing sawdust or charcoal dust dosages leads to increase in weight of resulting sludge. Therefore, dosages of >75% (dry weight) should be avoided if dewatered sludge is to be transported from urban slums and disposed of at either landfills or conventional treatment plants, whichever is nearer. Alternatively, if the space and time in the slums allow, then composting could be done. The increased porosity after conditioning of FS allows easy passage of air within the FS structure, hence increased rate of composting. However, this would require more bulking material (sawdust or charcoal dust) dosage to lower moisture content (<60%) to acceptable levels for composting. Addition of conditioners such as sawdust in dosages of >300% after dewatering has been found to be sufficient in achieving successful composting [24].

4. Conclusions

The effect of sawdust and charcoal dust conditioners in enhancing FS dewaterability has been investigated. The investigations demonstrate the potential of conditioning FS followed by dewatering as well as potential end-use, could make the use of FS products or their sales subsidise the costs of FS management, thereby reducing financial inputs by the low-income urban slum residents. The CST of FS decreased by 14.3% and 15.8% when conditioned with 75% of sawdust and charcoal dust, respectively. Additionally, the moisture content in dewatered cake decreased by 4.6% and 6.4% when conditioned with 50% sawdust or charcoal dust, respectively, and these are comparable to values in the literature when sawdust is used in conditioning sewage sludge. As a demonstration, 100 L of FS, with total solids concentration of 25 g/L at conditioner dosage of 50%TS, translates into a requirement of 1.25 kg solids of conditioner. The conditioned FS structure became porous after dewatering, and this potentially translates into less time and energy for subsequent drying, compared to unconditioned FS.

After dewatering, the leachate characteristics improved in terms of turbidity, due to the adsorptive nature of the conditioners. This could reduce the cost of treating the leachate to safe levels before discharge. Also, the calorific value of dewatered FS increased by 42% and 49% when conditioned with 50% TS dose of sawdust and charcoal dust, respectively, hence improvement in energy recovery potential. This may promote its use as an alternative fuel to increase the proportion of home-grown energy sources, and thus achieving the aim of energy conservation.

This study did not vary physical characteristics of conditioners such as particle sizes, hence their contribution to dewaterability should be studied. Different sources of conditioners may affect conditioner characteristics like charcoal dust from retail outlets may differ from that at households. Similarly, sawdust from different tree species may possess different characteristics. These may be studied and their contribution to FS dewatering determined.

Disclosure statement

No potential conflict of interest was reported by the authors.

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