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# The main Factors in the Treatment of Faecal sludge: A mini review

**[Les principaux facteurs dans le traitement des boues fécales: une mini-revue]**

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## Abstract

The aim this research was to present an overview of the key aspects of faecal sludge treatment based on the research available over the last 5 and 10 years, in line with the context of developing countries on the African continent. This research is a literature review. The publications were collected mainly from the web databases of the 'reaserch gate', 'google scholar' and 'academia.edu' platforms, where articles, manuals, technical reports or other relevant documents were extracted. The variables or key factors to be considered in the treatment of faecal sludge that have been identified through this research are far from exhaustive. The few that have been retained have been classified as technical, environmental, economic and social factors. Research published on the subject over the last 5 and 10 years is a relevant source of information. The variables or key factors encountered have been grouped into 4 main categories: technical, environmental, economic and social. If faecal sludge treatment is to be sustainable, appropriate technology is needed, based on a sound knowledge of environmental requirements and a mastery of economic and financial aspects, without neglecting the needs and role of stakeholders.

**Key word:** faecal sludge, sustainable development, drying beds, circular economy, environment.

## Résumé

L'objectif de cette recherche était de présenter une vue d'ensemble des aspects clés du traitement des boues fécales sur la base des recherches disponibles au cours des 5 et 10 dernières années, en tenant compte du contexte des pays en développement du continent africain. Cette recherche est une revue de la littérature. Les publications ont été principalement collectées à partir des bases de données web des plateformes « research gate », « google scholar » et « academia.edu », où des articles, des manuels, des rapports techniques ou d'autres documents pertinents ont été extraits. Les variables ou facteurs clés à prendre en compte dans le traitement des boues fécales qui ont été identifies grâce à cette recherche sont loin d'être exhaustifs. Les quelques-unes qui ont été retenues ont été classées en facteurs techniques, environnementaux, économiques et sociaux. Les recherches publiées sur le sujet au cours des 5 et 10 dernières années constituent une source d'information pertinente. Les variables ou facteurs clés rencontrés ont été regroupés en 4 grandes catégories: techniques, environnementales, économiques et sociales. Pour que le traitement des boues fécales soit durable, il est nécessaire de disposer d'une technologie appropriée, fondée sur une bonne connaissance des exigences environnementales et une maîtrise des aspects économiques et financiers, sans négliger les besoins et le rôle des parties prenantes.

**Mots clés**: boues fécales, développement durable, lits de séchage, économie circulaire, environnement.

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## 1. Introduction

Faecal sludge refers to raw, muddy or partially digested excreta, whether or not combined with greywater, from on-sie sanitation systems, such as pit latrines, septic tanks and dry toilets. Faecal sludge resembles a solid and varies greatly in characteristics

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and consistency (Lindberg & Rost, 2018; Doglas et al., 2019).

The management of this sludge is a real challenge, especially in developing countries which often face a lack of adequate infrastructure (Manga et al., 2022).

In these countries, the urbanization process has not been accompanied by a commensurate expansion of adequate sanitation infrastructure or the rehabilitation of old infrastructure that has aged over time. Sanitation conditions have become particularly critical in peri-urban areas where adequate infrastructure and services are almost non-existent. Currently, access to sanitation in these peri-urban areas is generally provided by on-site sanitation techniques, namely pit latrines and septic tanks. In sub-Saharan Africa, approximately 65 to 100% of urban areas are served by these types of systems, which allow faecal sludge to be released into the environment without prior treatment (Moiambo et al., 2021).

The discharge of untreated faecal sludge into the environment poses serious health risks, as faecal sludge contains viruses, protozoa, bacteria, helminths and many other dangerous pathogens that can trigger an epidemic in the environment. Faecal sludge can also contain a very high concentration of heavy metals such as lead, mercury and cadmium that easily enter the food chain, leading to serious consequences for human health. In addition, faecal sludge contains a large amount of organic matter, which causes foul odors during the degradation process and further worsens environmental conditions. Faecal sludge also generates a significant volume of greenhouse gases (GHGs), which have a severe impact on global warming and natural ecosystems in general (Orugba et al., 2024). Solutions are needed to improve access to safely managed sanitation services for people in developing countries (Simiyu et al., 2021) and thus progress towards achieving the Sustainable Development Goals (SDGs) (Ward et al., 2019.).

Despite the emergence of existing faecal sludge treatment technologies, it is not easy to predict the key factors that enable the deployment of a sustainable faecal sludge management system (Mwamlima et al., 2024). In addition, "a comprehensive overview of the problems faced by Faecal Sludge Management system and new technologies for them is still lacking", believes Zewde et al. (2021). The existing works have focused on a single aspect such as technical performances (Mwamlima et al., 2023; 2024), the cost (Mbouendeu et al., 2022), the use of products resulting from the treatment (Muspratt et al., 2014) and social acceptance (Mkude et al., 2021). But a synthesis that attempts to address all these aspects from the perspective of sustainability as carried out by Orugba et al. (2024) is hard to find.

To encourage and increase the implementation of sustainable faecal sludge management in low-income sanitation facilities, faecal sludge could be viewed holistically as a resource that should be transformed into valuable resources instead of polluting the environment and posing a risk to public health (Kawata et al., 2024).

Unplanted sludge drying beds could then largely be the most appropriate technique because they have the particularity of being inexpensive and of relying on natural processes, namely evaporation and gravitational drainage (Cofie et al., 2006). Sludge drying beds are simple and cost-effective solutions that provide significant sludge volume reduction and hygiene improvements. The performance of unplanted drying beds is related to the duration of the drying cycle and depends fundamentally on the local climate and the characteristics of the sludge, namely its solids content and degree of stabilisation (Strande et al., 2014; Ssazipius et al.,2021). Can the success of faecal sludge treatment be achieved without societal acceptance and stakeholder participation throughout the entire chain, from production through treatment to final use and disposal? It is clear that the treatment of faecal sludge involves the consideration of several aspects that should require special attention. There are many factors to consider when selecting the best treatment configurations, including the end-use, treatment goals, potential benefits and limitations, and how to compare costs (Zewde et al., 2021).

It is with a view to clarifying the issue of key aspects of the proper configuration of faecal sludge treatment that this review has been undertaken.

The objective of the research is to present a synthetic view of the main factors of faecal sludge treatment based on the research work available in the last 5 and 10 years in line with the context of developing countries on the African continent. The study therefore aims to make a contribution to knowledge that aims to address the key aspects of faecal sludge treatment from a holistic perspective that includes technical, economic, social and environmental or ecological dimensions.

## 2. Material and methods

In this literature review, the publications were collected mainly from the web databases of the platforms as reaserchgate, google scholar,pubmed, central pubmed and academia.edu where articles, manuals, technical reports or other relevant documents were extracted. A total of 60 publications were selected in which 36 served as the main data sources. The other publications contributed to the deepening of the discussion. The keywords used for the article search were: “sludge treatment”, “sludge recovery”, “unplanted drying beds”, “biosolids utilization” and “environment”. No limitation on the years of publication has been set.

Data analysis was carried out using Excel software. The publications identified were classified in an Excel sheet, taking into account factors or variables relating to technical, environmental, social and economic aspects identified as being decisive in the treatment of sewage sludge by each publication. They were also classified according to the years of publication and finally according to the study environments.

## 3. RESULTS

Figure 5 shows the different plant families listed in the two privinces (Kuffour et al., 2019; Junglen et al., 2020; Cofie et al., 2021)

*Table I. Different plant families listed in the two privinces*

| N° | Factors or variables |
|---|---|
| 1 | Economy, (Costs, outlets, market, financial resources,) |
| 2 | Technique (dehydration method, filter type, conditioners, sizing) |
| 3 | Environment or ecological (Pollutant removal capacity, Characteristics, properties of sludge, Climate, Use of the final product, space) |
| 4 | Social (Pathogen destruction capacity, stakeholder involvement, social acceptance) |

The factors or variables listed in table 1 are grouped into four major categories: technical, environmental, social and economic. This is what emerges from the various publications used in this research. Out of a total of at least 36 publications, at least 16 highlight the technical aspects and 18 the economic dimension while 23 emphasize the environmental aspects and 8 the social aspect. In some publications, 2 or even three factors are highlighted at the same time that are found in the 4 major categories. By distributing them to observe their proportions through figure 1, it can be observed that the environmental aspect requires more than 30% while the technical and economic aspect are found at less than 30% and the social aspect at less than 15%.

Through this classification of factors, it is revealed that environmental factors constitute the most mentioned group, that is to say that a little more than three publications out of ten have noted the fact that variables such as the origin of the sludge, its characteristics before and after treatment as well as its elimination constitute major concerns in the treatment of faecal sludge. They are followed by the economic and technical aspects and in last position the social aspects. Figure 1 gives the distribution of the key aspects in the treatment of faecal sludge.

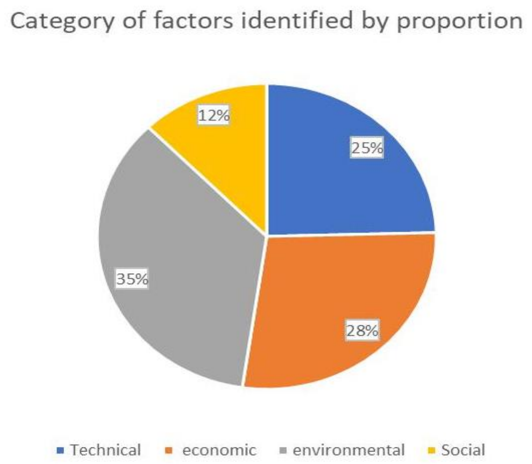


*Figure 1. Distribution of key aspects in sewage sludge treatment.*

Table II gives the classification of publications by year of publication

*Table II. Classification of publications by year of publication*

| Year | Time period | Number of publications | References |
|---|---|---|---|
| 2004<br>2006<br>2007<br>2009<br>2010<br>2012<br>2013<br>2014<br>2015<br>2016<br>2017 | Prior to last 5 years | 17 | Montangero et al., 2004 ; Cofie et al., 2006 ; Koné et al., 2007 ; Kuffour et al., 2009 ; Öğleni et al., 2010 ; Dodane et al., 2012 ; Kuffour et al., 2013 ; Diener et al., 2014 ; Singh et al., 2017 ; Ziebell et al., 2016 ; Seleman et al., 2016 ; Vuni et al., 2022 ; Sonko et al., 2015. Wijesekara et al, 2020. |
| 2019<br>2020<br>2021<br>2022<br>2023<br>2024 | 5 last years | 19 | Doglas et al., 2019 ; Ward et al., 2019 ; Orugba et al., 2024 ; An-nori et al., 2021, 2022 ; Giwa et al., 2023 ; Kawata et al., 2024 ; Simiyu et al., 2021 |
| Total | | 36 | |

Most of the countries where research has been carried out as listed in table II are developing countries in sub-Saharan Africa where non-collective sanitation systems predominate and the studies listed have been published most, 19 out of 36 in the last 5 years. This may reflect the interest and topicality of the issues addressed. Figure 2 gives the number of publications by study environment.

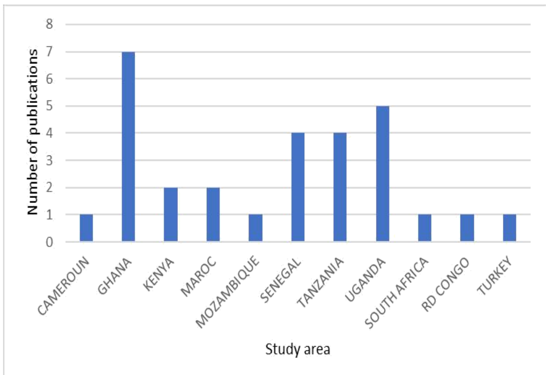


*Figure 2: Number of publications by study area*

Ghana, a developing African country located south of the Sahara, is at the top of the list of countries where research on the treatment and management of faecal sludge has been carried out with at least 7 publications listed in this journal (Cofie et al.,2006; Diener et al.,2014; Koné et al., 2007; Kuffour et al., 2009,2013,2019; Nsiah-Gyambibi et al., 2021). It is followed by Uganda with 6 publications (Diener et al., 2014; Ziebell et al., 2016 ; Manga et al., 2010:2022:2022; Ssazipius et al., 2021); Senegal (Diener et al., 2014; Sonko et al., 2015; Dodane et al., 2012; Ward et al., 2019) and Tanzania (Doglas et al., 2019;Seleman, 2016 ; 2021;Ward et al., 2019) with 4 publications; Kenya (Junglen et al., 2020, Simiyu et al., 2021) with 2 and finally the DR Congo (Kawata et al., 2024); Cameroon (Ekam-Ngohe et al., 2017),South Africa (Getahun et al., 2020)And Mozambique (Moiambo et al., 2021) with 1 publication each. Only 3 studies carried out respectively in Morocco (An-nori et al., 2021:2022) and in Türkiye (Öğlenı & Özdemı, 2010) are located outside the South Sahara region.

### *3.1. Technical factors or variables*

Technique refers to the treatment mode, the dehydration capacity, the materials (types of filters, dimensions of materials, types of conditioners etc.) As a technique, we can distinguish between unplanted drying beds, planted drying beds, solar drying beds, mechanical dehydration technique, and permeable membranes.

Faecal sludge constitutes complex mixture of human excreta, water, solid waste, pathogens and nutrients, which are dangerous to both human health and the environment (Doglas et al., 2019).

However, if faecal sludge is managed safely, it can be recovered and used for energy and agricultural purposes, contributing to community income (Doglas et al., 2019).

This complex, which generally contains a large amount of water, organic matter, pathogens and pollutants, requires, before being valorized, to ensure the reduction of the amount of water, the stabilization of the organic matter, the elimination of pathogens and pollutants. To do this, it is important to use appropriate techniques. The choice of technique arises from the analysis of many researchers listed as the key element that must guide the treatment of sewage sludge (Cofie et al.,2006; Ziebell et al., 2016; Moiambo et al., 2021; Seck et al., 2015; Manga et al.,2016; Sonko et al.,2015; Zewde et al. ,2021; Orugba et al.,2024). The space and size required for the treatment device have also been identified as a significant factor, as it is a constraint, especially for developing countries. (Junglem et al., 2020).

Among the existing techniques, drying beds are acclaimed as the technique best suited to treating sewage sludge. Drying beds are one of the most commonly employed technologies for sludge dewatering. They are appropriate technologies for low-income countries, as they have low-operational requirements, and low-capital and operating costs (dry et al., 2015). Two major mechanisms are at the heart of the operation of the drying bed, namely drainage and evaporation. The figures below show the two mechanisms described by Moiambo (2021).

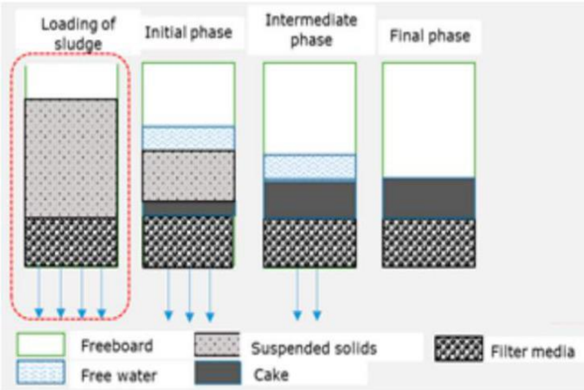


*Figure 3*. Schematic presentation of the phases that characterize the Sludge Driying Bed drainage process (Moiambo et al., 2021)

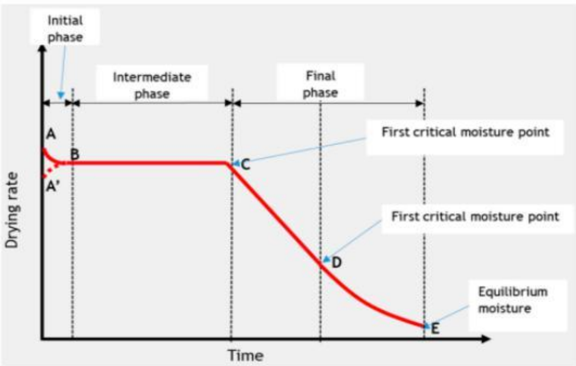


*Figure 4. Schematic caracterization of the different phases of sludge dewateringg at drying beds* (Moiambo et al., 2021).

Figure 3 shows the drainage process in four phases: loading, initialization, intermediate phase and final phase. Loading corresponds to the deposition of sludge on the drying beds. The initialization phase is the one during which the solid fraction forms a "cake" leaving a less dense liquid mass interface at the top. During the intermediate phase, the liquid that has started to separate with the solid fraction gradually passes through the biofilter. The final phase is characterized by the disappearance of the liquid mass on the surface and the formation of cracks inside the solid material (Moiambo et al., 2021).

Figure 4 explains the evaporation in three phases. The first (section A and B) is the initialization phase during which the evaporation rate increases or decreases depending on the sludge temperature; the second, called intermediate (section BC) during which the moisture transfer from the sludge to the free surface is sufficient to keep it completely free from moisture allowing evaporation at a constant rate, and finally a final phase (section CDE) which is characterized by a decreasing evaporation rate that begins when the free surface water of the sludge begins to dehydrate, thus showing a generally linear progression because the resistance to internal diffusion of the liquid is low compared to the resistance to internal diffusion of the liquid (Moiambo et al., 2021). In terms of infrastructure implementation, the unplanted drying bed appears as a basin inside which filter beds are arranged as shown in the figures below:

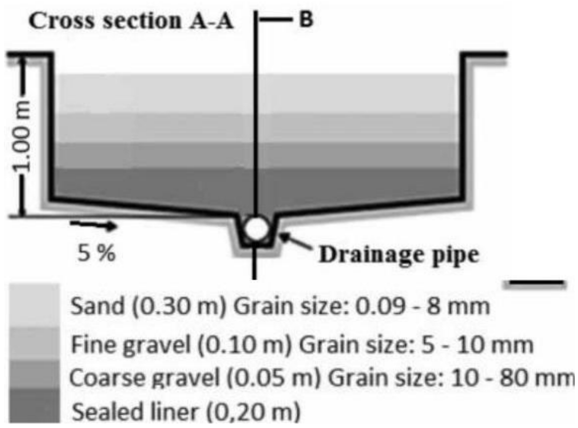


*Figure 5*. *Cross sections of the drying beds*. (Seck et al., 2015)

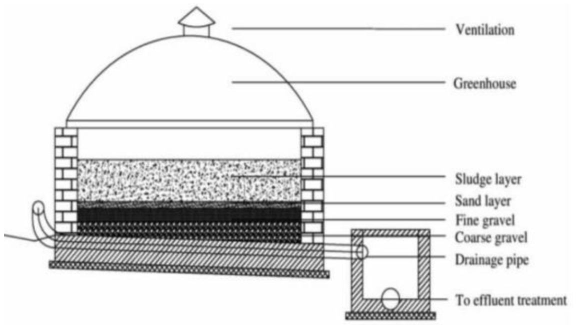


*Figure 6*: *Diagram of a drying bed*. (Sonko et al. 2015)

The common point of these figures is the filter consisting mainly of three layers plus a drain for evacuating the percolate.

The difference between them is that figure 6 is designed with a roof while the others are not. The roof can indeed be placed in order to prevent against rainwater but it can also be built as a greenhouse (An-nori et al., 2021; 2022). Instead of sand as a filter component, sawdust can be used. Similarly, in order to optimize the treatment and dehydration potential, the use of conditioners or even varying the dimensions of the filter components can be considered.

In some cases, another device consisting of tank is placed before dumping the sludge on the drying bed. This device helps in thickening the sludge. But due to cost and other maintenance requirements, Seck et al., (2015) recommends to do without such a device and to resort directly to treatment in the drying bed. One of the most important technical variables (factor) is the dehydration capacity. This is dependent on many other variables including conditioners, filter type, device size (Gold et al., 2016; Doglas et al., 2019). The choice and diameter of the filter media has also been identified as a key element in the dewatering performance. The commonly used media is sand. (Manga et al., 2016). Usually, sand is used as the filter media, but geotextile (Ziebell et al.2016) and sawdust (Kuffour et al., 2019) can also be used as filter media, gravel being maintained as a drainage medium. Sawdust is a by-product of sawmilling processes, with various uses (mulch, animal bedding and soil amendment, construction and soil conditioner, energy source. in construction and as an energy source. This resulted in reduction in the sludge dewatering times for different sludge to sawdust mixed ratios (Ssazipius et al, 2021). In this regard, 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 (Ssazipius et al, 2021).

The dimension of the filter used (Kuffour et al. 2009; Manga et al. 2016) is also a variable mentioned. Details on the importance of technical factors are also found in the research of Getahun et al., (2020); An-nori et al. (2021); An-nori et al. (2022); Cofie et al. (2006); Doglas et al. (2019); Ziebell et al. (2016); Ssazipius et al. (2021); Moiambo et al. (2021); Kuffour et al. (2009); Manga et al. (2016).

### *3.2. Economic and social factors or variables*

Social aspects mainly refer to health but also to the participation and role of stakeholders involved in the treatment of faecal sludge. The economic variables identified refer to the outlets for the treated products, the reduction of treatment costs and the gain of savings. The destruction of pathogens in order to preserve human health is one-dimension important demonstrated by Öğlen and Özdem (2010), Manga et al. (2016); Koné et al., (2006) then An-nori et al., (2022). Social acceptance and stakeholder involvement are described by Simiyu et al., (2021).

The world is increasingly experiencing resources crisis in recent years. Resource recovery from faecal sludge such as biogas, fire briquettes and soil conditioners are increasingly gaining interest of many researchers. These researchers have focused only on its yield, health hazard, technical aspect for collection and storage of these resources, but little has been done in low-cost resources recovery (Doglas et al., 2019, Mwamlima, 2023).

The economic aspects also concern the added value that the treated product brings once placed on the market but also the financial resources necessary for the implementation of the treatment plant. (Cofie et al., 2006 ; Doglas et al., 2019; Diener et al.2014; Bell et al., 2016; Ssazipius et al., 2021; Moiambo et al., 2021; Kuffour et al., 2019 ; Manga et al., 2016; Dodane et al.,2012; Murray et al.,2010; Zewde et al.,2021; Toilet Board Coalition, 2016; Simiyu et al.,2021 ; Orugba et al.,2024; Gold 2016; Mallory et al., 2020; Strande et al. 2014). It was noted by Junglem et al., (2020) the concern to discover options likely to have a considerable impact on the treatment cost by defining less expensive parameters to analyze in order to determine the characteristics of the sludge.

### *3.3. Environmental factors or variables*

The environmental aspects identified include climate, properties of sludge before and after treatment, destruction of pollutants, origin or source of sludge (public or private toilet, septic tank toilet or pit) as well as use and disposal of sludge (Cofie et al., 2006; Seck et al., 2015; Ziebell et al., 2016 ; Ssazipius et al., 2021 ; Moiambo et al., 2021 ; Manga et al., 2016; Getahun et al., 2020 ; Zewde et al.,2021 ; Orugba et al.,2024; Sonko et al., 2015; Ekam-Ngohe et al.,2017; Ward et al.,2019; Ward et al.,2022; Junglem et al., 2020 ; Manga et al., 2022).

Thanks to the characteristics of the product obtained after treatment, several uses have been cited in agriculture as organic fertilizer, in households as fuel or in the rehabilitation of sites and soils contaminated by pollutants. (Cofie et al.2006 ; Doglas et al., 2019 ; Seleman et al., 2016 ; Diener et al., 2014

; Kuffour et al.,2019 ; Murray et al.,2010 ; Dodane et al., 2012 ; Simiyu et al.,2021 ; Manga et al. (2016); Zewde et al., 2021; Orugba et al., 2024; Manga et al., 2022).

All of this summarizes the environmental aspects mentioned through the works and documents used in this review.

# 4. Discussion

The results obtained through this study showed that the treatment of faecal sludge involves taking into account several factors and/or variables which can be grouped under four main categories namely environmental, technical, economic and social.

It is indeed important to treat feacal sludge in order to prevent it from constituting a danger to public health and the environment (Vuni et al., 2022).

The environmental aspects considered in this study include climate, destruction of pollutants, physicochemical characteristics of sludge before and after treatment (Giwa et al., 2023), the source of sludge and finally the use and disposal of the products obtained after treatment.

The concern to save public health and the environment requires that faecal sludge be free of pathogens, chemical and organic pollutants. And thus have properties that make them usable without producing induced pollution. This explains why a good knowledge of the physicochemical characteristics of sludge before and after treatment is one of the major concerns. The source of production of faecal sludge (type of containment: pit latrine or septic tank) is also a relevant element. As through this study, Montangero & Strauss. (2004) lists the characteristics of faecal sludge as key variables. This is also evident in the research of Taylor et al., (2018).

It is important to know the physicochemical characteristics of the sludge before its treatment because this makes it easier to choose sludge treatment techniques and even to predict the quality of the products to be obtained after treatment (Ward et al., 2019). Empirical and qualitative observations in the field indicate, for example, that sludge from public toilets takes longer to settle and dehydrate than sludge from households, (Cofie et al., 2006; Heinss et al., 1999). It has been suggested that this is due to different degrees of stabilization (i.e. the extent of biodegradation of organic matter), although it is not yet clear how stabilization is related to the dewatering performance of faecal sludge (Ward et al., 2019).

However, it has also been observed that the type of containment (pit latrines or septic tanks) is an important predictor of the physicochemical characteristics than the source (domestic or public toilets) (Strande et al., 2014). Relationships between surface charge and conductivity and dewatering time have been observed in fecal sludge (Gold et al., 2016). These relationships could also be influenced by concentrations of extracellular polymeric substances (EPS) although it has been observed that they are 2 to 10 times lower in fecal sludge than in activated sludge (Ward et al. 2019). Technical obstacles to solid-liquid separation of faecal sludge are mainly related to its high variability and unpredictability of treatment performance, as well as the lack of fundamental knowledge on the factors influencing the settling and dewatering of fecal sludge. (Ward et al., 2022). Sludge dewatering depends on the initial total volatile matter (TVM) and total suspended solids (TSS) content, loading rate and loading frequency. Indeed, drainage is highly dependent on the applied sludge volume and the sludge concentration on suspended solids which influence the formation and characteristics of the sludge cake that settles on the drying bed (Sonko et al., 2015). It is required that after the treatment of the sludge, in addition to the presence of elements to be recovered (N, P, K, energy etc.), the main characteristics of the products obtained must be free of pathogens and pollutants as well as emerging contaminants (Wijesekara et al., 2020).

It is therefore of capital importance to have a good understanding of the properties of sludge before its treatment. This is also what is noted in more than 30% of the studies analyzed in the context of this research as shown in figure 1.

The characteristics that cover the products obtained after sludge treatment are also crucial in determining their use or disposal. What has been established through this review is attested by other research. The products obtained after treatment can thus be useful in agriculture as green manure and compost for soil fertility (Kawata et al., 2024), to carbon sequestration (Silvana et al., 2014), to the rehabilitation of mining sites (Wijesekara et al., 2020), to the decontamination of soils contaminated with polycyclic aromatic hydrocarbons (Kawata et al., 2024) or even as a source of energy (Orugba et al., 2024; Sanka et al., 2024).

The last two uses of products from the treatment of sewage sludge are particularly interesting.

The characteristics presented by the biosolids obtained by drying bed treatment during a study conducted in Kinshasa in the DRC led to the valorization of treated sewage sludge through the decontamination and fertilization of sandy soil contaminated by hydrocarbons. Which further shows that the interest resulting from the use of sewage sludge according to the characteristics of the by-products obtained is a significant parameter that justifies the importance of sewage sludge treatment. The study conducted by Kawata et al., (2024) highlighted both the role of biosolids obtained by treatment of sludge drainage in soil fertility (agriculture) as well as in the decontamination of sites contaminated by polycyclic aromatic hydrocarbons. Which is also a sustainable solution in the face of the limit resulting from the fear of the accumulation of treated sludge in particular as a source of greenhouse gases and as a source of induced organic pollution (Singh et al., 2017; Nsiah-Gyambibi et al., 2024).

As for the interest of the characteristics of by-products from the treatment of sewage sludge as a source of energy, it is important to mention the triple interest, namely as a source of green and alternative energy that contributes to the fight against deforestation, as a solution for cooking and finally as a source of both economic gain and income generation (Eliyan et al.,2022). Low-income countries face a severe shortage of energy for heating and cooking, often relying heavily on wood, leading to deforestation issues especially in Africa and South America. Approximately 1.6 million tons of charcoal are produced annually, leading to ecosystem destruction (Gachuri et al., 2015). Replacing wood-derived biomass with treated faecal sludge is not only cost-effective but also environmentally friendly. Faecal sludge is proving to be a viable biomass source for energy production (Laura et al., 2022; Sanka et al., 2024), its coal having an energy content comparable to that of charcoal (Onabanjo et al., 2016). Environmental factors are closely linked to technical considerations. The elements of understanding provided by these studies mentioned above meet those discovered through this review.

The environmental aspects developed above lead to the implementation of appropriate techniques. The technique then takes on a significant importance because obtaining products free of contamination and pollution as well as by-products offering properties useful to agriculture, to the rehabilitation of contaminated sites and as a source of energy depends on it. The choice of the appropriate technique recommended in the review carried out is also the concern of Montangero et al., (2004); Taylor et al., (2018) who respectively described the processing mechanism and provided a description of the choices to be made. Unplanted drying beds thus stand out as a suitable solution, especially for countries south of the Sahara with a humid tropical climate. Kawata's et al., (2024) conducted in Kinshasa in the DR Congo showed the effectiveness of using non-planted drying beds in the treatment of sewage sludge. Other researchers including Kuffour et al., (2019) and Orugba et al., (2024) also confirmed the effectiveness of unplanted drying beds.

In order to optimize the achievement of results, the review conducted within the framework of this study also largely supported drying beds as an appropriate technique in the treatment of faecal sludge. Figures 5,6,7 and 8 presented a description of them. However, it is essential to consider several technical options that improve the treatment technique using unplanted drying beds.

For example, consider using a type of filter other than sand such as sawdust and geotextile; varying the dimensions of the materials constituting the biofilter (Kouffur et al., 2010; Mwamlima et al., 2024)) but also the use of organic conditioners. The interest focused on the type of filter through this research is also found in the research of Mbouendeu et al., (2022).

However, of all the improvement proposals, the analysis of the data collected through this literature review highlighted the use of local Kuffour conditioners (2009; 2010; 2013; 2019) as the most decisive improvement for several reasons. Conditioners provide several advantages: The main advantage of some local conditioners is that their by-products are non-toxic and biodegradable, they are environmentally and health friendly and they do not significantly affect the pH and conductivity of the treated effluent. In addition, local conditioners such as Moringa oleifera have antimicrobial activity on pathogens and are highly effective against several bacteria and fungi (Padla et al., 2012). Conditioners contribute to the reduction of sludge treatment time, they increase the energy capacity of sludge, improve the settling of suspended solids. Local conditioners increase the calorific value of solids since they have a carbon-based calorific value of 20-28 MJ/kg, which allows solids to reach the calorific value required by energy fuels (Diener et al., 2014). The use of local conditioners allows the elimination of heavy metals and the destruction of pathogens in soils, thanks to the formation of a permeable and rigid structure (Diener et al., 2014). In addition, these conditioners have a coagulation capacity that allows small sludge particles to be agglomerated into larger particles prior to sludge dewatering. Local conditioners operate by means of an adsorption mechanism followed by charge neutralization with a bridging effect on sludge dewatering (Doglas et al., 2019). Local conditioners have the advantage of reducing sludge treatment costs by 50% due to the reduced volume of sludge they produce (Gold et al., 2016). Environmental and technical factors alone are not enough to justify the treatment of faecal sludge. The social and economic dimension plays a role that the review has brought out. The economic gain and the possibility of selling the products obtained through the treatment represent a very important link as well as the need for social acceptance. These concerns are widely found throughout the review carried out.

Murray et al., (2010) found that the financial burden of sanitation on households and governments can be shifted by creating new value propositions from human waste. One way to generate additional financial flows is at the back of the service chain, by tapping into a customer segment interested in resource recovery from waste by-products. Viable business models could emerge from designing faecal sludge management systems that focus on resource recovery, which would help ensure the sustainable provision of adequate sanitation. The findings from this study are largely supported by Muspratt et al., (2014). Through the use of treated sewage sludge as fuel, sewage sludge constitutes a clean and inexpensive source of energy Muspratt et al., (2014). Mwamlima et al., (2023). The consideration of sewage sludge as a resource to be valorized rather than simply as a problem to be solved is also found in Kawata et al., (2024). Establishing that sewage sludge is a resource to be valorized (Kawata et al., 2024), provides clear elements in the paradigm shift to be made through an epistemological revolution which consists of considering sanitation as a field of the circular economy rather than simply as an environmental or ecological and health issue.

Lack of funding for remediation and increased contamination of natural resources due to improper waste disposal have led to increased advocacy for a transition to circular economy approaches to sanitation that can produce nutrients for agriculture, protein for animal feed or clean energy. This aspect of the economic and ecological gain highlighted in this study is also supported by Mkudeet al., (2022) and Koottatep et al., (2001). Toilets provide a range of valuable resources that offer multiple circular flows for materials, energy and water (Mallory et al., 2020). Toilet resources are an important part of the biological cycle. Toilet resources can be mixed with food and agricultural "waste" as well as compostable items, such as packaging. (Toilet board coalition, 2016).

One way to generate additional financial flows is to tap into the customer segment interested in resource recovery from waste-derived products. This new value proposition of selling finished products after treatment would complement the existing value proposition, which typically consists of an emptying service for households. As part of a multi-stakeholder approach to sanitation, it is important to develop viable business models that move away from subsidy-based approaches to stand-alone or even profit-oriented business approaches, in which costs are fully recovered. This could potentially reduce the amount paid by households, thereby increasing their ability to pay for the service, thereby improving overall access to sanitation and the impacts on hygiene, health and well-being (Diener et al., 2014).

The (Reasons) challenges related to the treatment of sewage sludge therefore also cover the sphere of social acceptance. Hence the significant importance to be given in particular to the various stakeholders (Diener et al., 2014) and their customs and traditions.

Societal acceptability also requires a good understanding of the habits of the population (Mkude et al, 2021). Faecal sludge management systems require many interactions between stakeholders (e.g. the household, the collection and transport company, the treatment plant, the end use or disposal), (Diener et al, 2014). The question of the reasons for treating faecal sludge cannot therefore be addressed without integrating the issue of stakeholder interest and involvement. The issue of the treatability of faecal sludge is not only technical, environmental, ecological or economic. It is also social in that it concerns the actors. Top-down and technocratic approaches to sanitation planning are now giving way to participatory approaches, which focus on waste producers, i.e., households/communities as key actors in sanitation planning processes (Murray, 2010). Challenges such as dealing with populations who find the idea of handling faecal sludge, odours and other challenges related to customs and traditions repulsive must be addressed.

# 5. CONCLUSION

This research aimed to present the main factors as the key aspects involved in the treatment of fazcal sludge through a literature review. Research published on the subject in the last 5 and 10 years constitute relevant sources of information on this subject.

The key variables or factors encountered were grouped into 4 main categories, namely technical, environmental, economic and social.

For the treatment of feacal sludge to be carried out in a sustainable manner, appropriate technology is therefore required, based on a good knowledge of environmental requirements and a mastery of the economic and financial aspects without neglecting the needs and role of the stakeholders.

Thus, in terms of the technology to be deployed, it turns out that unplanted drying beds offer advantages that make them a well-suited technique for treating faecal sludge. Opting for unplanted drying beds as a technique requires a good knowledge of the characteristics of the sludge to be treated and the by-products obtained after treatment and taking into account the climate. It is then necessary to use the by-products obtained after treatment well in order to ensure that solutions are provided for the health of ecosystems and humans. In addition, it is strictly recommended to exploit the needs to be satisfied with the treated products in order to rationalize the cost of operations and seize opportunities in possible markets with a view to a circular economy. Finally, it is necessary to ensure that all stakeholders, from households to public authorities, including communities and private individuals, are involved.

However, although the results of this research are applicable to developing countries where non-collective sanitation is the mode, each country should have its own standards and properly contextualize the key aspects of faecal sludge treatment.

This review has mainly made it possible to realize that knowledge on the key aspects of the treatment of faecal sludge is available and that it is urgent to use it in order to find solutions to the problems of health, pollution, lack of energy and even lack of financial resources.

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## Ethical considerations

This literature review was conducted in accordance with the ethical principles of scientific research. No data was collected from human or animal participants. The sources used are exclusively academic publications, reports, and publicly available documents. References have been correctly cited to ensure compliance with copyright and intellectual property rights.

## Authors' contributions

K.D.P conceived the initial idea for the review, developed the methodology, and wrote the first draft of the manuscript.

I.L.C. and K.M.I. participated in the documentary research, article selection, and critical analysis of the content.

M.E.A.D. contributed to the revision, structuring, and final validation of the manuscript.

All authors have read and approved the final version of the document.

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## Bibliographical references

An-nori, A., El Fels, L., Ezzariai, A., et al., 2021. Effectiveness of helminth egg reduction by solar drying and liming of sewage sludge. Environ Sci Pollut Res 28, 14080–14091. https://doi.org/10.1007/s11356-020-11619-w

An-nori, A.; Ezzariai, A.; El Mejahed, K.; El Fels, L.; El Gharous, M.; Hafidi, M., 2022. Solar Drying as an Eco-Friendly Technology for Sewage Sludge Stabilization: Assessment of Micropollutant Behavior. Front. Environ. Sci.

Cofie, O. O., Agbottah, S., Strauss, M., Esseku, H., Montangero, A., Awuah, E., Kone, D. 2006. Solidliquid separation of faecal sludge using drying beds in Ghana: implications for nutrient recycling in urban agriculture. Water Res. 40(1), 75-82. doi: 10.1016/j.watres.2005.10.023. Epub 2005 Dec 15. PMID: 16343581.

Diener, S., Semiyaga, S., Niwagaba, C. B., Muspratt, A. M., Gning, J. B., Mbéguéré, M., Ennin, J. E., Zurbrugg, C. & Strande, L., 2014. A value proposition: Resource recovery from faecal sludge– Can it be the driver for improved sanitation? Resources, Conservation & Recycling 88 (0), 32–38.

Dodane, P-H., Mbéguéré, M., Sow, O., Strande, L., 2012. Capital and operating costs of full-scale faecal sludge management and wastewater treatment systems in Dakar, Senegal. Environ Sci Technol;46(7):3705–11.

Doglas, B., Mayo, AW., Gabrielsson, S., Kimwaga, R., 2019. The potentials of faecal sludge treatment using local conditioners in Tanzania: a review. Tan J Eng And Tech. 38(2):220–244. doi: 10.52339/tjet. v38i2.508

Ekam- Ngohe, Paul-Salomon, Sezawo, R., and Talla, A., 2017. Characterization of Depotted Faecal Sludge into the Environment and Design of a Suitable Treatment System: Case of Nomayos Area in Yaounde City, British Journal of Applied Science & Technology 21(2): 1-12, Article no. BJAST.32755 ISSN: 2231-0843, NLM ID: 101664541 DOI: 10.9734/BJAST/2017/32755

Eliyan, C., McConville, J. R., Zurbrügg, C., Koottatep, T., Sothea, K., and Vinnerås, B., 2022. Generation and Management of Faecal Sludge Quantities and Potential for Resource Recovery in Phnom Penh, Cambodia, Frontiers in Environmental Science, 10, 869009, doi: 10.3389/fenvs.869009.

Gachuri, W. G., 2015. Optimising the utilisation of sawdust of eucalyptus tree species; a fuel for teaindustry, Unpublished MSc Thesis University of Nairobi.

Getahun, S., Septien, S., Mata, J., Somorin, T., Mabbett, I., Buckley, C., 2020. Drying characteristics of faecal sludge from different on-site sanitation facilities. J Environ Manage. 261:110267. doi: 10.1016/j.jenvman.2020.110267.

Giwa, A. S., Maurice, N. J., Luoyan, A., Liu, X., Yunlong, Y., Hong, Z., 2023. Advances in sewage sludge application and treatment: Process integration of plasma pyrolysis and anaerobic digestion with the resource recovery. Heliyon. 49(9), e19765. doi: 10.1016/j.heliyon. 2023. E19765. PMID: 37809742; PMCID: PMC10559074

Gold, M., Dayer, P., Faye, MCAS, et al., 2016. Locally produced natural conditioners for dewatering of faecal sludge. Environ Technol. 37(21):2802–2814

Heinss, U., Larmie, SA., Strauss, M., 1998. Water Research Institute (Council for Scientific and Industrial Research, CSIR), Accra, Ghana. In Solids Separation and Pond Systems for the Treatment of Faecal Sludges In the Tropics: Lessons Learnt and Recommendations for Preliminary Design SANDEC REPORT No. 05/98. Vol. SANDEC Rep (Issue Second Edition). Duebendorf, Switzerland: EAWAG/SANDEC.

Junglen K., Rhodes-Dicker L., Ward J. Barbara, Gitau, E., Wali Mwalugongo, Strande L., and Thomas, E., 2020. Characterization and Prediction of Fecal Sludge Parameters and Settling Behavior in Informal Settlements in Nairobi, Kenya, Sustainability 12, 9040; doi:10.3390/su12219040 www.mdpi.com/journal/sustainability

Kawata, P. D., Pwema, V., Kibal, I., Kitadi, J. M., Biey Makali, M., & Musibono, D. E. A. 2024. Apport des biosolides dans la décontamination et la fertilité d'un sol sableux contaminé aux hydrocarbures aromatiques polycycliques

Kawata, P. D., Inkoto, C. L., Pwema, V., Kibal, I., Kitadi, J. M., Mimbwete, M., & Musibono, D. E. A. 2024. Contribution to the study of faecal sludge as a resource for the city and province of Kinshasa in the Democratic Republic of the Congo. Orapuh Journal, 5(3), e1121. https://dx.doi.org/10.4314/orapj.v5i3.21

Koné, D., Cofie, O., Zurbrügg, C., Gallizzi, K., Moser, D., Drescher, S., and Strauss, M., 2007. Helminth eggs inactivation efficiency by faecal sludge dewatering and co-composting in tropical climates. Water Research, 41(19), pp.4397-4402

Koottatep, T., Polprasert, C., Oanh, N. T. K., Montangero A., and Strauss, M., 2001. Sludge From On-Site Sanitation - Low-Cost Treatment Alternative. Paper submitted at the IWA Conference, Kuala Lumpur, Malaysia. October, http://ocw.unesco ihe.org/pluginfile.php/644/mod_folder/content/0/ Koottatep_sludges_from_on451 site_sanitation_systems.pdf?forcedownload=1

Kuffour, A. R., Awuah, E., Anyemedu, F. O. K., Strauss, M., Koné, D. and Cofie, O. 2009. Effect of using 453 different particle sizes of sand as filter media for dewatering faecal sludge. Desalination, 248(1–3), pp.308- 454 314. 455

Kuffour, A. R., Awuah, E., Sarpong, D., Anyemedu, F. O. K. and Koné, D. 2013. Effects of Different Solid Loading Rates of Faecal Sludge on the Dewatering Performance of Unplanted Filter Bed. Civil and 457 Environmental Research, 3(4), pp.39-48. 458

Kuffour, A. R., Awuah, E., Koné D. 2019. Effect of physical conditioners (sawdust) on the dewatering of faecal sludge using unplanted filter beds. Appl J Environ Eng Sci. 4:321–333.

Laura, M.S., Fløytrup, Sara Gabrielsson and Petro Mwamlima, 2022. Using energy justice to contextualise existing challenges of wood charcoal against faecal sludge derived briquettes as a future cooking fuel alternative in Dar Es Salaam, International Journal of Urban Sustainable Development 14(1):91-107 DOI: 10.1080/19463138.2022.2067166

Lindberg, E., & Rost, A., 2018. Treatment of Faecal Sludge from Pit Latrines and Septic Tanks Using Lime and Urea: Pathogen die-off with Respect to Time of Storage, p. 48. Available from: https://ltu.diva-portal.org/smash/get/diva2:1242729/ FULLTEXT01.pdf

Manga, M., Evans, B.E., Ngasala, T.M., Camargo-Valero, M.A., 2022. Recycling of Faecal Sludge: Nitrogen, Carbon and Organic Matter Transformation during Co-Composting of Faecal Sludge with Different Bulking Agents. Int. J. Environ. Res. Public Health, 19, 10592. https://doi.org/10.3390/ ijerph191710592

Manga, M., Evans, B E., Camargo-Valero, M A., Horan, N J (In press)., 2022. Effect of filter media thickness on the performance of sand drying beds used for faecal sludge management. Water Science and Technology Available Online 26 September 2016, DOI: 10.2166/wst.2016.45105293255

Manga, M., Evans, B., Camargo-Valero, A., Horan, N., 2016. The fate of helminth eggs during the co-composting of faecal sludge with chicken feathers and market waste view project ssessment of potential risks associated with chemicals in wastewater used for irrigation in arid and semiarid Zones: a review View proj. (December). Retrieved from http://www.wateratleeds.org

Mallory, A., Rochelle, Holm and Alison, Parker, 2020. A Review of the Financial Value of Faecal Sludge Reuse in Low-Income Countries

Mbouendeu, LS., Emmanuel, N., Sandrine, NDJ., Raissa, MT., 2022. Low-cost onsite selection of suitable unplanted sand drying bed structure for faecal sludge treatment in less developed countries: a case study of Yaounde in Cameroon. Water Pract Technol. 17(12):2614–2624. doi: 10.2166/wpt.2022.145

Mkude, IT., Gabrielsson, S., Kimwaga, R., 2021. Knowledge, attitudes and practices (kap) on faecal sludge resource recovery and reuse in Dar es Salaam, Tanzania. J Water Sanit and Hygi for Devel. 11(5):758–770. doi: 10.2166/ washdev.2021.249.

Mkude, IT., Kimwaga, R., Gabrielsson, S., 2022. Potential economic and environmental benefits of faecal sludge derived compost and Char Briquettes: the case of Dar es Salaam, Tanzania. Tanzan J Sci. 48(2):383–393. doi: 10.4314/tjs. v48i2.13.

Moiambo, O., Mutevuie, R., Ferreira, F., Matos, J., 2021. Modelling Faecal Sludge Dewatering Processes in Drying Beds Based on the Results from Tete, Mozambique. Sustainability, 13, 8981. https://doi.org/ 10.3390/su13168981

Montangero, A., and Strauss, M., 2004. Faecal Sludge Treatment [online]. Eawag, Swiss Federal Institute of Aquatic Science & Technology Sandec, Department of Water & Sanitation in Developing Countries. Available from: http://www.sswm.info/sites/default/files/reference_attachments/STRAUSS%20and%20MONTANEGRO%2 469 02004%20Fecal%20Sludge%20Treatment.pdf.

Murray, A., Ray, I., 2010. Commentary: back-end users: the unrecognized stakeholders in demand-driven sanitation. J Plann Educ Res;30(1):94–102.

Muspratt, AM., Nakato, T., Niwagaba, C., Dione, H., Kang, J., Stupin, L., Regulinski, J., Mbéguéré, M., Strande, L., 2014. Fuel potential of faecal sludge: calorific value results from Uganda, Ghana and Senegal. J Water Sanit and Hygi for Devel. 4(2):223–230. doi: 10.2166/washdev.2013.055.

Mwamlima, P., Mayo, AW. Gabrielsson, S., Kimwaga, R., 2023. Potential use of faecal sludge derived char briquettes as an alternative cooking energy source in Dar es Salaam, Tanzania "nexus between sanitation and energy (SDG 6 & 7. Hygiene And Environmental Health Advances. 7(June):100068. doi: 10.1016/j.heha.2023.100068

Mwamlima, P., Karoli, N., Njau, Mwemezi Rwiza & Nyangi Chacha, 2024. Evaluating the performance of faecal sludge dewatering technologies in urban settings of developing African countries: a review, International Journal of Environmental Health Research, DOI: 10.1080/09603123.2024.2349707

Nsiah-Gyambibi, R., Essandoh, H. M. K., and Asiedu, N. Y., 2021. "Valorization of fecal sludge stabilization via vermicomposting in microcosm enriched substrates using organic soils for vermicompost production", Heliyon7, e06422;

Öğleni, N., and ÖzdemiR, S., 2010. Pathogen reduction effects of solar drying and soil application in sewage 476 sludge. Turkish Journal of Agriculture and Forestry, 34(6), pp.509-515

Onabanjo, T., Kolios, A. J., Patchigolla, K., Wagland, S. T., Fidalgo, B., Jurado, N., and Cartmell, E., 2016a. An experimental investigation of the combustion performance of human faeces, Fuel, 184, 780-791. https://doi.org/10. 1016/j.fuel.2016.07.077.

Orugba, H. O., Osagie, C., Owamah, H. I., and Edomwonyi-Out, L. C., 2024. Sustainable Faecal Sludge Management in Internally Displaced Persons (IDPs) Settlements in Tropical Climate: A Review, Nigerian Journal of Technology, 43(1), pp. 172 – 188; https://doi.org/10.4314/njt.v43i1. 19

Samal, K., Moulick, S., Mohapatra, B.G., Samanta, b., Sasidharanc, S., Prakashc, B., et Sarangi, S., 2022. Design of faecal sludge treatment plant (FSTP) and availability of its treatment technologies, Energy Nexus 7 (2022) 100091, https://www.researchgate.net/publication/361290 910

Sanka, M.P., Germain, O., Khalifa, L., Komakech, H., and Magambo, H., 2014. Production of low emission briquettes from carbonized faecal sludge as an alternative source of cooking energy, Energy, Sustainability and Society 14:14 https://doi.org/10.1186/s13705-024-00449-0

Seck, A., Gold, M., Niang, S., Mbéguéré, M., Diop, C., and Strande, L., 2015. Faecal sludge drying beds: 481 increasing drying rates for fuel resource recovery in Sub-Saharan Africa. Journal of Water Sanitation and 482 Hygiene for Development, 5(1), pp.72-80

Seleman, A., and Bhat, MG. 2016. Multi-criteria assessment of sanitation technologies in rural Tanzania: implications for program implementation, health and socio-economic improvements. Technol Soc. 46:70–79. doi: 10.1016/J. TECHSOC.2016.04.003.

Seleman, A., Gabrielsson, S., Kimwaga, R., 2021. Faecal sludge containment characteristics and their implications on safe desludging in unplanned settlements of Dar es Salaam, Tanzania. J Environ Manage. 295(October):112924. 2020. doi: 10.1016/j.jenvman.2021.112924

Simiyu, S., Chumo, I., Mberu, B., 2021. Faecal sludge management in low-income settlements: case study of Nakuru, Kenya. Front Public Health. 9:9. doi: 10.3389/fpubh.2021.750309.

Silvana, I., Rodrigo, SC., Renella, G., 2014. Soil Carbon Sequestration Resulting from Biosolids Application.

Singh, S., Mohan, R. R., Rathi, S., and Raju, N. J., 2017. Technology Options for Faecal Sludge Management in Developing Countries: Benefits and Revenue from Reuse. Environmental Technology and Innovation, 2017; 7, 203– 218. doi: 10.1016/j.eti...02.004

Sonko, EHM., Diop, C., Mbéguéré, M., Seck, A., Guèye, A., Koné, D., 2015. Effect of hydraulic loading on the performance of unplanted drying beds treating low-concentrated faecal sludge. J Water Sanit and Hygi for Devel. 5 (3):373–380. doi: 10.2166/washdev.2015.103

Ssazipius, GJ. Miiro, MJ., Muzoora, D., Kpange, S., Babu, M., 2021. Sawdust as a filtering media in sludge drying beds. Int J Biol Chem Sci. 15(7):53–61. doi: 10.4314/ijbcs. v15i7.5S.

Strande, L.; Ronteltap, M.; Brdjanovic, D. Faecal Sludge Management: Systems Approach for Implementation and Operation; IWA: London, UK, 2014

Tayler, K., 2018. Faecal sludge and septage treatment. A guide for low and middle-income countries. In: Practical action publishing. UK: Rugby, Warwickshire. doi:10.3362/9781780449869

Toilet Board Coalition. 2016. Sanitation in the Circular Economy. Transformation to a Commercially Valuable, Self-Sustaining, Biological System; Toilet Board Coalition: Geneva, Switzerland.

Vuni, S. A., Holenu, M. H., Puela P. F., Kinsungila, W. E., Tshibuabua, M. F., Masamuna, P., L. N. F., Mola, M. J-P., Aloni, KJ., And Nzau, U-D-MC., 2022. Study of current urban waste management in Kinshasa by observation along university avenue. Environnement, Ingénierie & Développement. 88, 3-11. https://doi.org/10.46298/eid.2022.9250

Ward, BJ., Traber, J., Gueye, A., Diop, B., Morgenroth, E., Strande, L., 2019. Evaluation of conceptual model and predictors of faecal sludge dewatering performance in Senegal and Tanzania. Water Res. 167:167. doi: 10.1016/j.watres. 115101

Ward, BJ., 2022. Settling and dewatering of fecal sludge: building fundamental knowledge for improved global sanitation. 28520: doi: 10.3929/ethz-b-000581228.

Ward, BJ., Sam, S., Andriessen, N., Morgenroth, E., Strande, L., 2018. Research priorities and progress in faecal sludge dewatering. doi: 10.3929/ETHZ-B-000313083.

Wijesekara, H,. Bolan, NS., Kumarathilaka, P., Geekiyanage, N., Kunhikrishnan, A., Seshadri, B., et al., 2020. Biosolids enhance mine site rehabilitation and revegetation. Environmental Materials and Waste; p. 45-71.

Zewde, AA., Li Z, Xiaoqin Z., 2021. Improved and promising faecal sludge sanitizing methods: treatment of faecal sludge using resource recovery technologies. J Water Sanit and Hygi for Devel. 11(3):335–349. doi: 10.2166/ washdev.2021.268 .

Ziebell, F., Gold, M., Matovu, J., Maiteki, J., Niwagaba, C., Strande, L.,2016. Water N and eawag/Sandec. Dewatering of faecal sludge with geotextiles: results from laboratory and bench-scale experiments in Kampala, Uganda. Sludge To Energy Enterprises In Kampala (SEEK).