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- Energy Optimisation Sludge treatment (EOS) at the Vienna main wastewater treatment plant
- Sludge treatment for sewage sludge of an activated sludge wastewater treatment plant in Montenegro using sludge drying reed beds
- Financing Sanitation: Resource Recovery from Faecal Sludge in Sub-Saharan Africa

Sludge treatment

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Cover Photo / *Titelbild*

Editorial

In Issue 21 of SSP we present three papers on „Sludge treatment“, i.e. presented:

- In the first paper we describe the new sludge treatment line that is currently implemented at the Vienna main wastewater treatment plant (the contribution summarises public available material),
- Markus Lechner describes the design of the first sludge drying reed bed in Montenegro, and
- Magdalena Bäuerl et al. present results of the project FaME on resource recovery from faecal sludge in Sub-Saharan Africa.

The thematic topic of the next issue (Issue 22, January 2015) is „Energy/heat recovery“. If you are interested to submit a contribution please inform the SSP editorial office (ssp@ecosan.at). Contributions are due to 1st December 2014, the guide for authors is available from the journal homepage (www.ecosan.at/SSP). Please feel free to suggest further topics for issues of the journal to the SSP editorial office (ssp@ecosan.at). Also, we would like to invite you to contact the editorial office if you volunteer to act as a reviewer.

SSP is available online from the journal homepage at the EcoSan Club website (www.ecosan.at/SSP) for free. We also invite you to visit SSP and EcoSan Club on facebook (www.facebook.com/SustainableSanitationPractice and www.facebook.com/EcoSanClubAustria, respectively).

With best regards,
Günter Langergraber, Markus Lechner, Elke Müllegger
EcoSan Club Austria (www.ecosan.at/ssp)

Content

Energy Optimisation Sludge treatment (EOS) at the Vienna main wastewater treatment plant

This paper briefly describes the sludge treatment concept that is currently implemented at the Vienna main wastewater treatment plant.

Authors: Günter Langergraber and Norbert Weissenbacher

Abstract

The paper describes the new sludge treatment concept of the Vienna main wastewater treatment plant. The current design of the plant for 4 Mio p.e. is described. For the description of the Energy Optimisation Sludge treatment (EOS) public available material has been used.

The Vienna main wastewater treatment plant

The Vienna main wastewater treatment plant was designed for carbon removal with a design capacity of 2.9 Mio p.e. and went into operation in 1980 (von der Emde, 1982). The original design was

- primary sedimentation: 28‘500 m³ (2 x 14‘250 m³)
- aeration tanks: 42‘000 m³ (4 x 10‘500 m³)
- final clarifiers: V=65‘400 m³ (8 x 8‘175 m³)

A few years after the start up discussions on the necessity of nitrification for further improvement of the river water quality began. After frequent changes of the legal standards including the implementation of nitrogen removal requirements and the adaptation of the Austrian ordinances to the EU legislation the final plant design was developed. The new plant design had to scope with additional requirements regarding nitrification and nutrient removal.

The plant was extended by addition of a second biological stage to the original plant (Kroiss et al., 2004). The tank volumes of the plant extension amount to

- aeration tanks: V ~ 175‘000 m³ (15 x 11‘700 m³)
- final clarifiers: V ~ 200‘000 m³ (15 x 13‘300 m³), diameter = 64 m, mean depth = 4.1 m

The plant now fulfils the Austrian effluent standards according to 1.AEVkA (1996). The requirements are BOD_5 = 15 mg/L, COD = 75 mg/L, total nitrogen removal rate = 70 % in average over all periods with temperatures T > 12°C, maximum NH_4-N = 5 mg/L in daily composite sample at temperatures T > 8°C, and maximum total phosphorus effluent concentration = 1 mg/L as yearly average of daily composite samples.

The extended 2-stage plant has a capacity of 4.0 Mio p.e. and went into operation in 2005. The first biological stage is designed for a maximum flow of 12 m³/s, the second for 18 m³/s (Wandl et al., 2006).

Key facts:

- Currently the Vienna main wastewater treatment plant has capacity of 4 Mio p.e. and consumes 60 GWh electricity per year (about 1 % of Vienna‘s total energy demand).
- The EOS (Energy Optimisation Sludge treatment) project aims to cover its entire demand of electricity and heat demand through energy generated on site by utilizing gas from anaerobic digestion of sludge.
- After finalisation of the EOS project in 2020, GHG emissions of Vienna will be reduced by 40‘000 t CO_2 per year (equivalent to the GHG emissions of a small town with 4‘000 people).

Figure 1: The Vienna main wastewater treatment plant (http://www.ebswien.at/hauptklaeranlage/service/presse/)

Sludge disposal at the Vienna main wastewater treatment plant is undertaken by gravity thickening, centrifugation and incineration of raw sludge. Raw sludge is pumped directly to the nearby incineration plant. The sludge age in the original plant was 1 day, i.e. a large part of organic matter is removed in the first stage with the excess sludge. In the new plant, under normal operating conditions, the excess sludge is withdrawn from the first stage only. The excess sludge of the second stage is pumped into the first stage. Sludge containing nitrifying bacteria from the second stage enters the first stage and thus enables nitrification in the first stage. Raw sludge incineration contributed to 40% nitrogen removal in the two stage concept (Kroiss et al., 2004).

Energy Optimisation Sludge treatment (EOS)

Currently the Vienna main wastewater treatment plant consumes 60 GWh electricity per year (about 1 % of Vienna‘s total energy demand). Since 2008 measures to increase energy efficiency and the use of renewable sources (solar and wind) the energy demand could be already reduced by 11 %.

In 2012 the city of Vienna decided to utilise the energy in sewage sludge for the generation of electricity and heat and started the project EOS (Energy Optimisation Sludge treatment) with the objective to cover its entire demand of electricity and heat through energy generated on site. It is projected that about 20 Mio m³ methane gas per year will be produced. The gas will be converted into electricity and heat in a co-generation plant.

Methane gas from sewage sludge is recognised as renewable energy source that is available reliable all around the year. The GHG emissions of Vienna will be reduced by 40‘000 t CO_2 per year.

The space required for the sludge treatment plant is created by renewing the pre-sedimentation stage and the first biological stage (tanks are made smaller but deeper). The tanks are renewed step by step while the plant remains in full operation. An EOS pilot plant has confirmed project assumptions and has led to the first results based on which design the mechanical engineering equipment for the sludge digester could be optimised.

The construction of the EOS project will start in 2015 and should be finalised end of 2020 (Figure 2). Estimated costs are about 200 Mio EUR (100 Mio EUR for rehabilitation of the first stage of the treatment plant and 100 Mio EUR for the new digesters).

Figure 2:The Vienna main wastewater treatment plant in 2020 (ebs, 2014).

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Sludge treatment for sewage sludge of an activated sludge wastewater treatment plant in Montenegro using sludge drying reed beds

This paper presents the design of sludge drying reed beds for sewage sludge of an activated sludge wastewater treatment plant with a load of 2500 PE in Montenegro.

Author: Markus Lechner

Abstract

As an alternative to an existing sludge treatment system in the form of a belt filter press at an activated sludge wastewater treatment plant of the municipality of Mojkovac in Montenegro sludge drying reed beds were designed, aiming at simplifying operation of the sludge treatment system as well as at improving the quality of the sludge before reuse. The project was also designed as a pilot system for the Ministry of Sustainable Development and Tourism with the support of UNIDO in order to gain more experience and knowledge on sludge drying reed beds for sludge treatment in Montenegro.

Introduction

Sewage sludge generated in wastewater treatment plants, comprising primary sludge from mechanical pre-treatment as well as surplus sludge from biological treatment, requires further treatment for a number of reasons. On the one hand depending on the wastewater treatment process the sludge has to be stabilised and depending on the planned reuse or disposal option reduced in volume. These objectives may be achieved by a number of different technical options. Sludge drying reed beds have been applied for more than 20 years as an option requiring low operation and maintenance cost. The municipality of Mojkovac in Montenegro is operating an activated sludge wastewater treatment plant for app. 2´500 PE. Primary and surplus sludge are first reduced in water content in a static thickener and should then be dewatered using belt filter presses. For technical reasons – a too small pipeline from the sludge thickener to the feed pumps for the belt filter presses – as well as the planned reuse of the treated sludge, the Municipality of Mojkovac, together with the Ministry of Sustainable Development and Tourism with the support of UNIDO decided to design and implement sludge drying reed beds for the treatment of the sludge of the wastewater treatment plant.

Process Description

Sludge drying reed beds use common reed (*Phramites australis*) which is planted into a substrate layer on top of a substrate / drainage system. The reed penetrates the layers of sludge which are fed intermittently into the sludge drying reed bed and increases dewatering. An annual increase in sludge layer of up to 15-20 cm is possible.

Typical characterisitics

Typically sludge drying reed beds are designed for sludge loading in intervals of 2-3 weeks, the sludge volume to be loaded depending on the TSS concentration. The design storage period of the sludge is between 8 and 12 years, followed by a secondary treatment (composting either inside the reed be or externally). This process achieves a final product with a dry solid content of more than 40 %, which is suitable for reuse.

Key facts:

- The first sludge drying reed bed in Montenegro is designed for 2‘600 p.e
- Design criteria of sludge drying reed bed in similar climatic regions have been used for sizing the beds
- Required surface area of the beds is 880 m², i.e. about 0.35 m²/p.e.

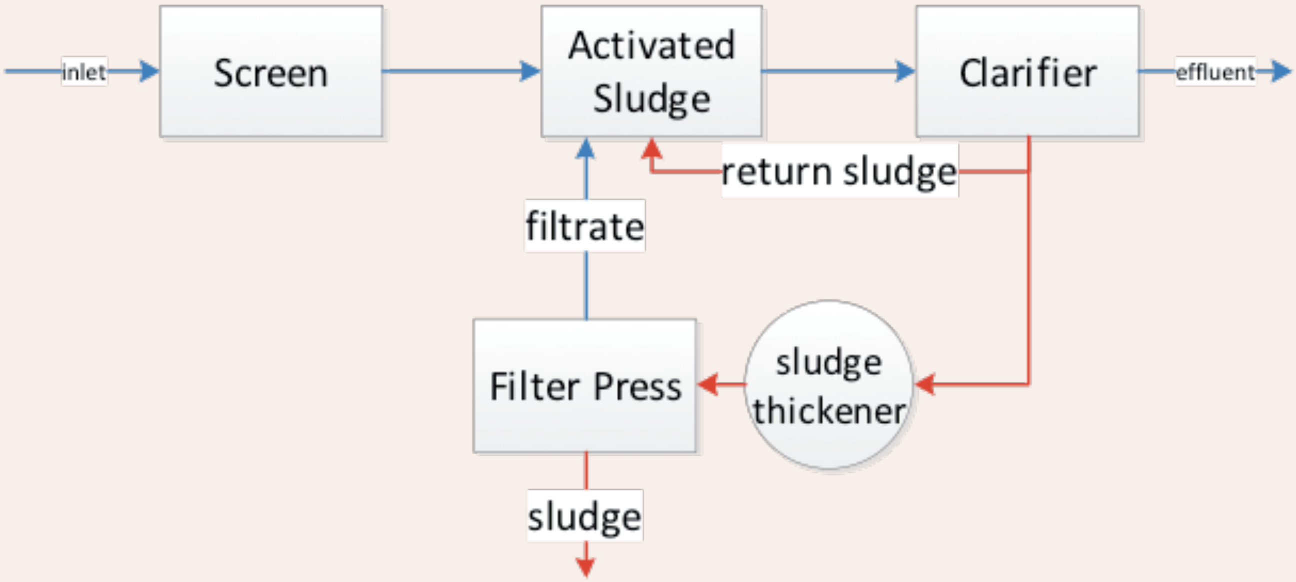

Figure 1: Current flow scheme

Process

Sludge drying reed beds typically use the combined effects of reed, microorganisms in the root zone, sewage sludge and the filter material at the bottom of the bed. Generally, the same processes as in constructed wetlands for wastewater treatment take place:

Dewatering
- Transpiration
- Evaporation
- (Infiltration)

Oxygen Supply
- Roots
- Pores
- Cracks

Stabilisation and isolation during cold times
- vegetation dieback

Microorganisms
- aerobic decomposition

Objectives

Objectives of the process described above are the reduction of the sludge water content below 50%, going hand in hand with a reduction of volume by 90%. This volume reduction has a direct impact on cost for energy, operation and maintenance and transport of the sludge. A final secondary composting phase of 1 year shall assure sanitation (disinfection). In addition to these objectives a major benefit of sludge treatment in sludge drying reed beds is the production of valuable compost (Kołecka and Obarska-Pempkowiak, 2013).

Current situation

Process

The current flow scheme is shown in Figure 1 below. Although designed for 5‘250 PE using two parallel treatment lines, currently only a capacity of 50 % is installed. Sludge is withdrawn from the return sludge lines manually depending on the MLSS concentration in the activated sludge reactor and pumped to a sludge thickener. From the sludge thickener the sludge should be pumped to a filter press for dewatering, however due to a too small intake line from the sludge thickener to the pump (DN50) the filter press cannot be operated.

Design

General

Sludge drying reed beds may be realized as concrete basins or basins sealed with synthetic sheets (rubber, PE, PP). Commonly the depth is between 1.2 and 1.7 m.

Leachate will be recirculated to the wastewater treatment plant (inlet activated sludge tank).

As a rough estimate the required specific surface area can be assumed with 0.25-0.50 m²/PE (Kainz, 2006). This assumption results in a total required (net) area of 1‘300 to 2‘600 m² for 5.250 PE.

Climate

Climatic data – precipitation and temperature – are shown in Figure 2. The data was used to select design assumptions from countries with comparable climatic conditions.

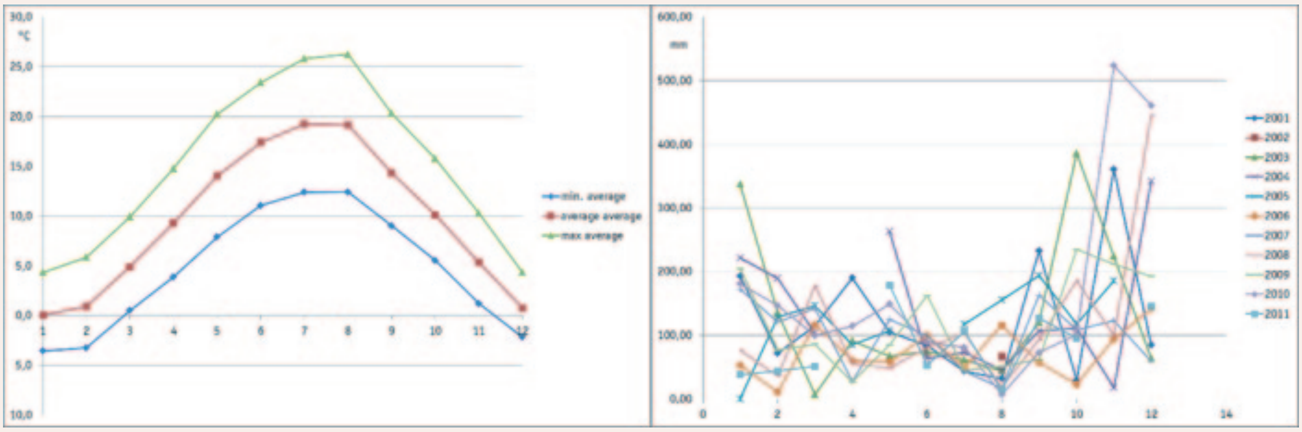

Figure 2: Temperature and precipitation

Design Assumptions

Currently the wastewater treatment plant has a nominal capacity of 50 % of the design capacity, i.e. app. 2‘600 PE. For this reason the sludge treatment was designed for a capacity of 2‘600 PE.

The design assumptions are summarized in Table 1. Although the treatment plant is in operation no monitoring data on wastewater quality at inlet or outlet, respectively operational parameters (TSS, vTSS, etc.) are available and the design assumptions had to be based on literature values, resp. experience.

Considering the solids retention time at design capacity and an assumed TSS inlet concentration the surplus sludge generation was assumed to 80 g/PE/d with a volatile share of 2/3 and a water content of 99 %. Relative sludge generation by precipitation of phosphates was assumed to be 15 g/PE/d with a small share of 3g vTSS / PE/d.

The existing thickener with slow turning mixer and a theoretical retention time of app. 30 days was assumed to generate a reduction in water content to 95 %, equivalent to a volume reduction of 80 %.

Load	2600	PE
relative sludge generation activated sludge	80 g/PE/d	TSS
	55 g/PE/d	vTSS
	99 %	water content
Relative sludge generation P-precipitation	15 g/PE/d	TSS
	3 g/PE/d	vTSS
	99 %	water content

These design assumptions result in a design load of 247 kg sludge per day and a volume of 4.9 m³/d after the sludge thickener.

Sludge drying reed bed

The design of sludge drying reed beds is based on empiric design recommendations which have been proven to be successful in the past. Design assumptions are frequently based on maximum permissible loading rates – Troesch et al. (2009) gives a range from 40 – 250 kg TSS/m²/a – depending on the origin of the sludge, the degree of stabilisation as well as the climatic conditions.

Based on relative sludge generation assumptions this approach is equivalent to defining a minimum required area of sludge drying bed per PE (e.g. 0.25-0.5 m²/PE according to Reinhofer, 2000).

For this project, the design has been based on a maximum permissible increase in sludge layer per year. This approach is consistent with the basic requirement of providing sufficient oxygen for rapid composting in the top layers of the sludge drying bed. The assumed maximum permissible annual increase in sludge layer of 0.20 m is equivalent to a loading rate of 80 kg/PE/d, respectively 0.43 m²/PE and as such well within literature recommendations. This results in a total required area of 880 m², which is divided onto two sludge beds for operational reasons. As shown in Figure 4 thickened sludge will be withdrawn from the existing sludge thickener and discharged via a sludge pumping station to one of the sludge beds. The discharge will be done alternately, allowing a sufficiently long resting period for each bed.

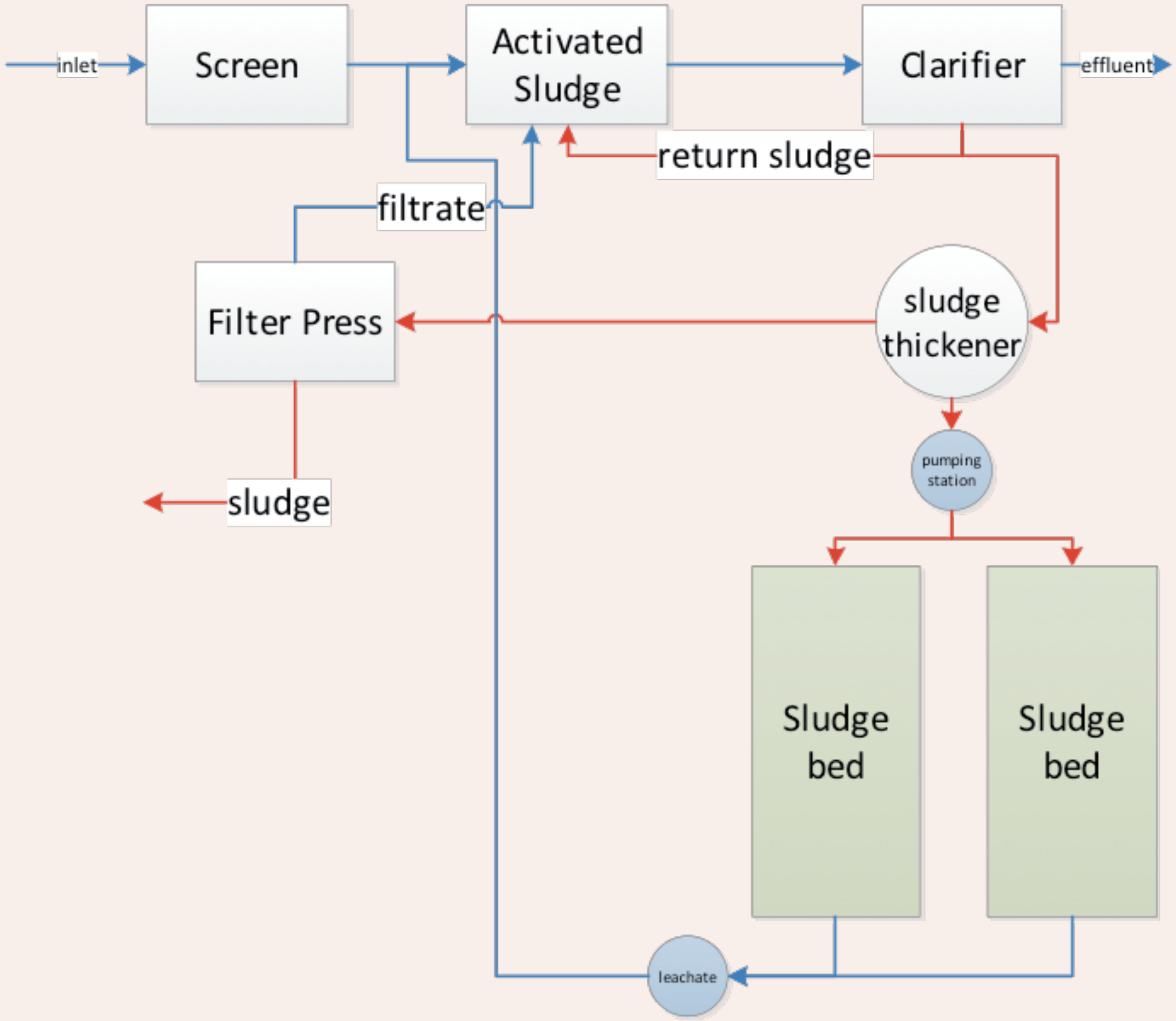

Figure 3: Proposed new flow scheme

The cross section of the sludge drying reed beds is shown in Figure 4. Leachate is collected at the bottom of the sludge drying reed beds and returned to the wastewater treatment plant.

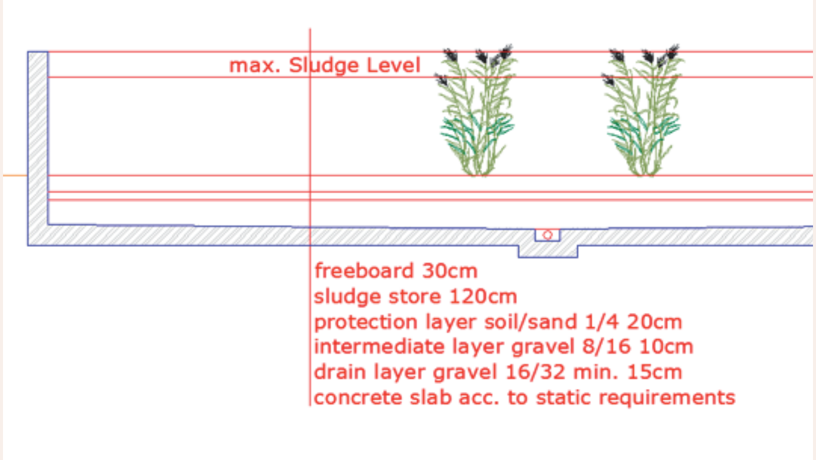

Figure 4: Sludge drying reed bed – cross section

Operational Issues

The sludge drying reed beds will be used for a total design period of 8-12 years. At an interval of 2-3 weeks (depending on the season and the actual progress of dewatering) sludge will be pumped to one of the sludge drying reed beds, the quantity designed to achieve a maximum increase in sludge level of 20 cm per year.

After reaching the maximum design sludge level a resting period of 12 months starts, during which no sludge will be added and the composting process completed. After this period, the sludge will be removed from the sludge drying reed bed and the process starts afresh.

Depending on the actual quality and the intended utilization, an additional storage period of the sludge may be required after removing it from the sludge drying reed bed.

Construction & performance monitoring

Construction of the sludge drying reed beds will start in 2014. Being the first sludge drying reed bed of this kind in Montenegro the Ministry will design and implement a performance monitoring system.

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Financing Sanitation: Resource Recovery from Faecal Sludge in Sub-Saharan Africa

Revenues related to resource recovery from faecal sludge treatment products could provide a financial incentive to enhance faecal sludge management services.

Authors: Magdalena Bäuerl, Martin Edthofer, Marie-Alix Prat, Sophie Trémolet and Manfred Watzal

Abstract

Without a developed sewer system, the majority of the urban population in Sub-Saharan Africa remains dependent on onsite sanitation technologies. Rapid population growth is increasing pressure on these already very inefficient systems, resulting in a large amount of faecal sludge being dumped untreated into the environment. Without sufficient capacities of faecal sludge collection, transport and treatment, faecal sludge is seriously threatening public and environmental health. The lack of financial incentives is often seen as one of the main reasons for malfunctioning faecal sludge management. Providing incentives and cash-flow to be re-invested in order to enhance the service chain, requires to understand how value can be created from faecal sludge treatment products. In cities such as Accra, Dakar and Kampala, investigations through financial modelling showed that financially sustainable production of faecal sludge treatment products is possible under certain conditions. Modelling results are thereby intended to support strategic decisions in urban sanitation planning.

Background

In many fast growing cities throughout Sub-Saharan Africa, population growth is increasing pressure on sanitation services. While onsite sanitation technologies are most commonly used to meet sanitation needs of the urban population, inefficient faecal sludge management services result in large amounts of faecal sludge being dumped untreated into the urban environment. Poor collection and transport services are working in an uncontrolled manner, often too expensive for poor households, which are left with no option but to abandon their onsite sanitation facility as in Figure 1, or employ manual faecal sludge collector, which frequently results in dumping of the the collected faecal sludge into the immediate environment (Günther et al., 2011). But even where onsite sanitation technologies are accessible

Key findings:

- Identified inefficiencies along the poorly working faecal sludge management service chain could be overcome by providing incentives and cash-flow from selling dried faecal sludge as a solid fuel to industries.
- It is presumed that the financially sustainable production of faecal sludge treatment products is possible under the conditions that treatment capacities are created or increased, households are financially supported and mechanical collection and transport businesses receive assistance, also implementing innovative ways of increasing the accessibility of onsite sanitation facilities in dense urban settlements.
- Kampala's current faecal sludge treatment capacity holds a revenue potential of an estimated USD 54,000 per year, if dried faecal sludge was sold at an industrial pick-up price of USD 15 per tonne. Meanwhile, if a faecal sludge treatment plant was realised in Accra, it could annually generate around USD 781,000 at current levels of supply, selling the product to a plastic factory that expressed interest at approximately USD 85 per tonne. In Dakar, project-internal research conducted in 2012, indicated that the volumes discharged at the faecal sludge treatment plants could produce revenues of around USD 90,000 annually if sold for about USD 59 per tonne. Industrial revenues have hereby shown to be about 2 to 17 times higher than revenues from selling dried faecal sludge to farmers for agricultural use.
- Industries will only be interested in using dried faecal sludge in their production process, if supply could be guaranteed at an improved level of quantity and quality

Figure 1: Abandoned toilet in an informal settlement in Kampala.

Figure 2: Faecal sludge discharge at the Bugolobi waste water treatment plant in Kampala.

and households can afford mechanical collection and transport, there is often only insufficient treatment capacity available, Figure 2 hereby showing how faecal sludge is inappropriately dumped at the waste water treatment plant in Kampala. The lack of appropriate collection, transport and treatment is posing a serious threat to public and environmental health (Blackett et al., 2014).

Accra is presenting itself in an especially dark light without any faecal sludge treatment capacity available (Ackon, 2013). Currently, collected but untreated faecal sludge is dumped at a central discharge point into the sea. A high dependency on expensive public toilets (GSS, 2013) is forcing over 10% of the population (Harris, 2013) to resort to open defaecation, further polluting the immediate environment. In Kampala on the other hand, the construction of the first faecal sludge treatment plant can be observed in Figure 3. An enlargement of at least half of its current capacity, would though be required to meet the estimated volumes of faecal sludge that could currently be delivered. In Dakar, once realised, rehabilitation of the existing faecal sludge treatment plants could enable treatment of capacities that exceed the estimated volumes of collected faecal sludge.

Faecal sludge collection and transport services are furthermore limited by low accessibility of dense urban settlements and inefficient mechanical emptying technologies, unable to collect all of the material settled in the onsite sanitation technology (Chowdhry and Koné, 2012).

A lack of financial incentives is often seen as one of the main reasons for the malfunction of faecal sludge management (Steiner et al., 2003).

While cities seem to struggle with the amount of faecal sludge required to be collected, delivered and treated to secure a safe living environment, rising prices for combustibles are forcing industries to search for fuels available at sufficient quantity and quality.

The FaME Project

With respect to the above mentioned circumstances, a project consortium joined forces to launch the Faecal Management Enterprises (FaME) project. This project aims to develop solutions for scalable end-use oriented faecal sludge management, that provide a financial drive in order to enhance service along every step of the value chain. The focus was hereby laid on the Sub-Saharan African cities of Accra (Ghana), Dakar (Senegal) and Kampala (Uganda).

The FaME market demand study showed that untapped markets exist for faecal sludge treatment products (Diener et al, 2014). Energy producing options showed the highest market potential. The FaME calorific value study indicated that dried faecal sludge has a calorific value competitive to other solid biomass fuels, which was demonstrated for two industrial applications (Murray Muspratt et al. 2014).

Figure 3: Drying beds in construction at the new faecal sludge treatment plant in Kampala.

The financial viability of end-use of dried faecal sludge was then assessed together with the broader economic costs and benefits of this process, showing the financial potential of this untapped market. End-use as soil conditioner or as solid fuel, were hereby chosen as two innovative ways of resource recovery that responded well to the market demand for treatment products.

Throughout the entire project, the research findings were disseminated to decision makers and other stakeholders, including the aim to raise interest of industrial users, as in progress in Figure 4.

Financial Flow Modelling Approach

As part of the FaME project a consortium led by hydrophil GmbH aimed to develop a tool that can be used to evaluate the financial viability of end-use oriented faecal sludge management with respect to the broader economic costs and benefits. Therefore an end-use oriented financial flow model was developed, adapted and implemented for the three cities of Dakar, Accra and Kampala.

The financial viability of faecal sludge products was analysed, based on a generic stepwise approach set out in Figure 5:

Figure 4: Raising interest of industrial users for alternative biomass fuels in Kampala.

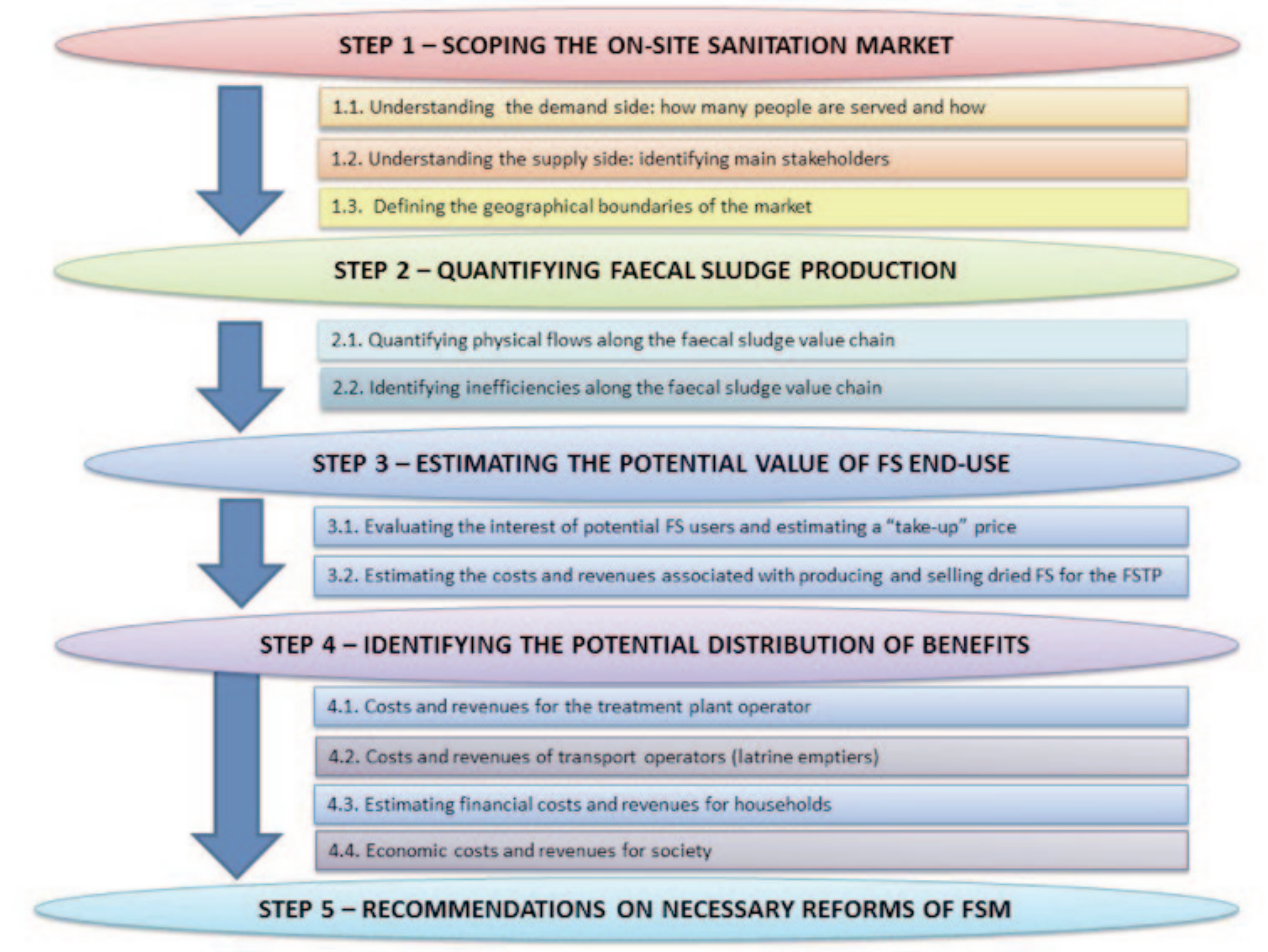

Figure 5: Approach to evaluating the potential value of faecal sludge end-use (Bäuerl et al., 2014a).

The analysis was hereby conducted with data from an in-depth literature research, referring to scientific articles and surveys, as well as reports from local and national institutions, official authorities' development plans or project-internal pieces of work. As reliable data or sufficient information was not always available and finances are perceived as a sensitive issue, semi-structured interviews with key stakeholders were conducted additionally. These represent a sensitive method of investigation, allowing to receive more detailed information and better understanding the prevailing circumstances (Davis Case, 1990). Local FaME project partners hereby helped to identify the most important key stakeholders.

The expert team then included the received data into an excel-based financial flow model, hereby basing their decisions and estimations on their long-term experience within the field of sanitation and economics, as well as benchmarks of other countries or projects.

Based on the collected data, the analysis was then conducted in the following steps:

1. Establishing the frame under economic and financial assumptions, including a reasonable pick-up price for the product;
2. Quantifying the amount of faecal sludge that is produced onsite and then carried along the service chain to reach the designated faecal sludge treatment plant and hence would be available for valorisation through end-use;
3. Estimation on the potential revenue from valorisation of faecal sludge end-products for different scenarios, including a "business as usual" scenario;
4. Identifying the potential distribution of these revenues among the stakeholders to see whether the establishment of a financially sustainable service chain is feasible;

As no complete or reliable data on costs of faecal sludge treatment could be collected in the investigated cities, a full viability calculation for this section of the value chain could not be performed. A sensitivity analysis was therefore conducted for different volume-scenarios. Based on the results, recommendations which could help to increase financial flows from end-use were then formulated.

Specific guidance on how to use the developed financial flow model is presented in Annex 1 of the project report, available for download under: http://www.tremolet.com/publications/report-financial-viability-faecal-sludge-end-use-dakar-kampala-and-accra

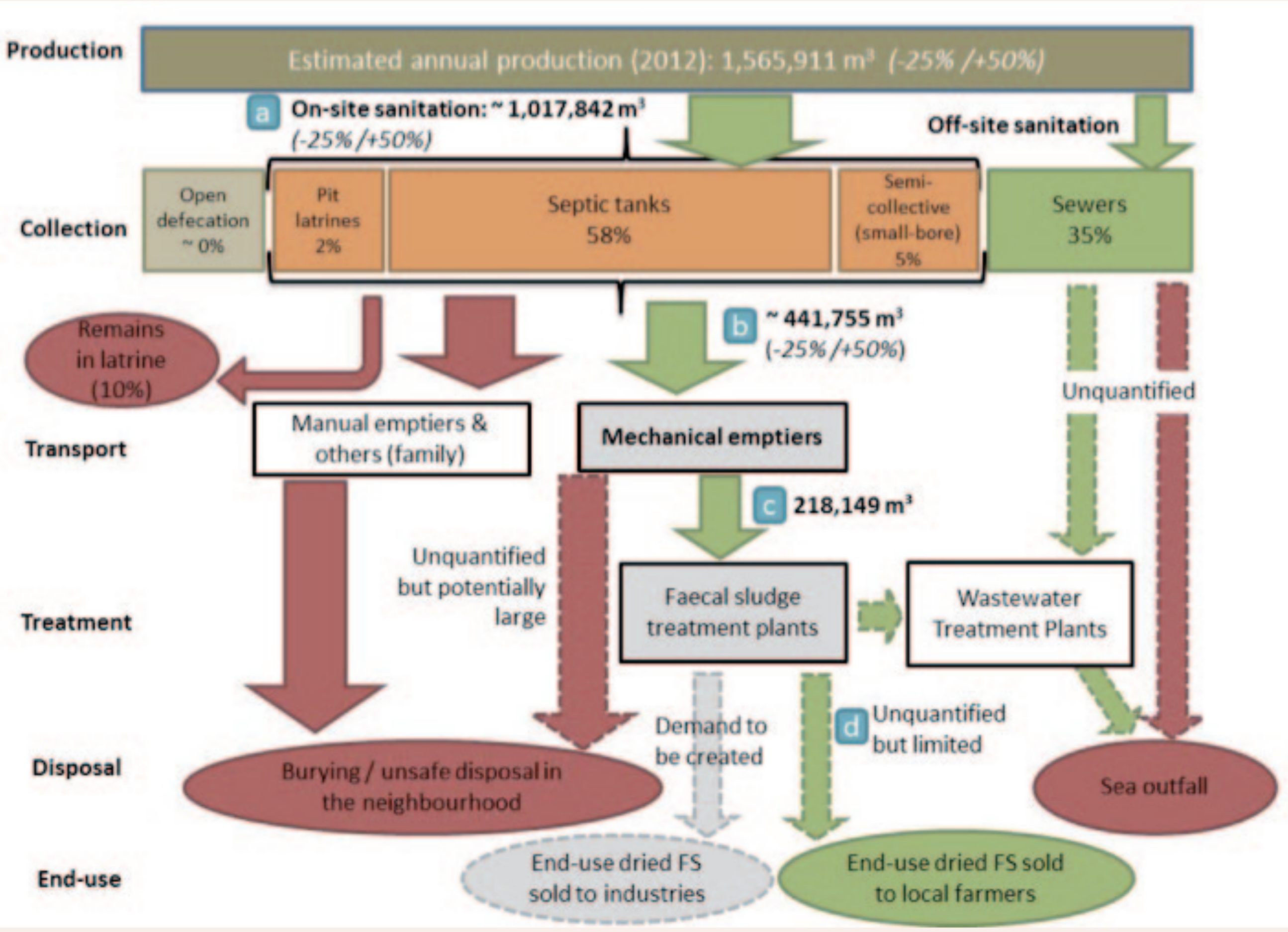

Figure 6: Flow of faecal sludge (in m³/a) along the faecal sludge management service chain in Dakar, Senegal (Bäuerl et al., 2013b)

Results from the Analysis

As a representative example of the results, Figure 6 shows the volumes of faecal sludge along the faecal sludge management service chain of the most certain scenario used as a reference in Dakar.

The analysis of volumes and cash-flow along the faecal sludge management value chain, revealed the following inefficiencies that avert a potentially viable system:

- Unavailability of sanitation technologies. In Accra, up to 40% of the population are still dependent on expensive public toilet services (GSS, 2008), while almost 11% still have no access to sanitation facilities (Harris, 2013). Therefore people have to resort to open defaecation, which makes the produced volumes unavailable for end-use.
- Inaccessible onsite sanitation technologies. A large amount of onsite sanitation facilities remain inaccessible for mechanical emptying. Hence households have to abandon their facilities, once they fill up or employ a manual scavenger who would then presumably dump the matter into the immediate environment (Günther et al., 2011).
- Inefficient faecal sludge collection. Poor organisation of expensive mechanical collection services averts the efficient collection of faecal sludge throughout the city. Furthermore emptying technologies used are not advanced enough to empty the settled material at the bottom of the pit, causing many facilities to fill up faster and requiring more frequent emptying.
- Insufficient treatment capacities. In Accra no treatment capacity is currently available, while Kampala and Dakar are only providing treatment for a part of the faecal sludge volume that could actually be collected and delivered.

Potential revenues

At present it was not possible to identify immediate industrial interest for faecal sludge product in any of the three cities. This is most likely due to the fact that the supply of dried faecal sludge could not be guaranteed at the level of quantity and quality required by the industries. Hence companies are not willing to make initial investments for the adjustment of their combustion process.

Still, based on estimated industrial pick-up prices, financial modelling indicated the potential of different revenue scenarios. The preliminary price quote was hereby set at half of the price of the fuel in relation to their calorific value, to imitate a realistic market scenario and make the process more attractive for industrial users.

At current levels of 1,455m³/d being delivered to the dumping site in Accra (Anum, 2013), an annual revenue of USD 781,000 was calculated, assuming that a tonne of dried faecal sludge could be sold for USD 85. The content of total solids was set at 22 g/l, based on field test conducted for the project in Kumasi and the statistical distribution of sanitation facilities in the city (GSS, 2008). Given that the planned faecal sludge treatment plant is realised with a capacity of 626,000 m³/a (Kabe, 2013), revenues could rise by half.

Sales of current faecal sludge volumes of 697 m³/d delivered to the faecal sludge treatment plants in Dakar could generate around USD 90,000 annually, if sold to industrial users for USD 59 per tonne and given an amount of 7 g/l of total solids, which was indicated by a project-internal study at the Cambérène faecal sludge treatment plant in Dakar. The industrial use would hereby allow to generate revenues 17 times higher than if sold to farmers as soil conditioner for around USD 4 per tonne (Diener et al., 2014). If the old and inefficiently operating faecal sludge treatment plants were successfully rehabilitated to reach a capacity of 1,360 m³/d, revenues around USD 176,000 could be generated.

Fully established, the treatment capacity in Kampala allows to treat 125,200 m³ annually, selling at a price of USD 15 to industries or USD 8 to farmers (Diener et al., 2014) thereby creating revenues of USD 54,000 or 29,000 respectively. These calculations further refer to an amount of 29 g/l of total solids (KSP, 2008). These revenues could be about four times higher if all faecal sludge produced was effectively collected and delivered to a faecal sludge treatment plant of sufficient capacity, given an estimated overall mechanical collection of 212,000 m³/a (Matuvo, 2013).

Mentioned revenues could significantly offset operational costs of the faecal sludge treatment plants and outweigh government subsidies or household fees. The revenue could also be reinvested to increase the efficiency of faecal sludge management, resulting in an overall improvement of environmental and public health.

Required Measures

Following measures have been identified to have the biggest potential in increasing the faecal sludge valorisation potential:

Create and increase treatment capacity

The lack of a functional faecal sludge treatment plant in Accra, as well as current treatment capacities in Dakar and Kampala, do not seem to allow producing enough dried faecal sludge to raise the interest of big industries like clay or cement factories. Accra is planning to build a large faecal sludge treatment plant that could treat estimated future amounts of faecal sludge collected, while Kampala is aiming to increase its current treatment capacity to 40% of what is produced, through another small faecal sludge treatment plant. In Dakar rehabilitation of the

Figure 7: Delivery of mechanically emptied faecal sludge in Dakar, Senegal (picture credits to Sophie Trémolet)

faecal sludge treatment plants should increase capacities to 96% of faecal sludge that is currently discharged at the faecal sludge treatment plants, as can be observed in Figure 7. In all cases the production of more dried faecal sludge through the introduction of larger and more efficiently working treatment plants, would be required to attract big businesses. Clay and cement factories have hereby shown to provide a fuel demand that could have a significant financial impact on the process. If a long-term supply of dried faecal sludge at sufficient quality and quantity could be assured through proper operation and maintenance, it is likely that the cities hold the capacities to meet the fuel-demand of larger businesses. Of course, onsite conditions would have to be assessed individually and the combination of several smaller industries could also present a solution.

Support mechanical emptiers businesses

Mechanical collection and transport services are inefficient in various ways. Improving the overall performance of these systems would require support on all levels in order to increase the amount of faecal sludge that is actually collected and reaches the designated site.

Heavy traffic and high distance-related costs to the faecal sludge treatment plants pressure many collectors to dump closer elsewhere. These costs could be reduced through enhancing logistics e.g. through truck routing, zoning the city for different operators or establishing centralised bidding systems through mobile phones. Transport costs could furthermore be reduced if technologies were implemented that allow to empty the solidified matter on the bottom of the systems, avoiding to add dilution water. Such technologies would also substantially increase the biomass portion and hence the energy content per trip, which in turn would raise the cash value of the load if it were hypothetically paid by the treatment plant.

Besides improving logistics, lowering discharge fees or outright payment for faecal sludge at treatment plants could incentivise more emptiers to deliver the collected faecal sludge to the facility. Paying trucks for the delivery of faecal sludge would most likely efficiently close the gap between collection and treatment, but it seems difficult as a quality-dependent check and payment system would have to be established.

Increase accessibility of dense urban settlements

Dense informal settlements being home to a major proportion of the population served by onsite systems, it is essential to make these systems accessible for mechanical emptying at a price that poor households can afford. Preventing uncontrolled manual emptying and the abandonment of sanitation facilities is not only essential to make the volumes available for valorisation through end-use but also to secure a safe living environment. Innovative emptying technologies such as VacuTugs or Gulpers (visible in the centre of Figure 8) should therefore be supported as they would allow collecting faecal sludge from dense settlements. The implementation of innovative emptying technologies, as well as the establishment of small profitable businesses behind it (Sudgen, 2013) would through require even more support from local authorities and NGOs.

Financially supporting households

Employing a mechanical emptier poses a major financial burden to many poor households. Under certain modelling assumptions, it is shown that a poor household in Dakar would annually have to spend between 1.5% and 4.5% of their income (dependent on the number of required emptyings per year) (Mbeguere et al., 2011). In Accra the annual emptying costs for poor households amount to about 0.7% of their annual income, while extremely poor households would have to spend about 1% (Wassel et al., 2005). In Kampala a poor tenant's monthly household income of about USD 39 equals the costs of one mechanical emptying service (Günter et al., 2011).

Additionally, in places such as Dakar where inadequate septic tank designs and high water tables lead to a higher frequency of required emptying, financial support should be given to poor households to build improved systems. Again, this could increase the concentration of total solids within the collected faecal sludge. Micro-loans pose a potential financing solution, based on the assumption that savings would be created by reducing the required emptying trips. In Accra and Kampala increasing the amount of private toilets could also increase the concentration of total solids within the collected faecal sludge.

Financing the Reforms

Funds to improve faecal sludge collection, transport and treatment, cannot initially be provided through revenues of selling dried faecal sludge to industries, but referring to the fact that the enhancement of the sanitation system could (partly) offset the costs of inadequate sanitation

Figure 8: Delivering faecal sludge that has been emptied with a Gulper

for society, initial investments could be financed through public money or cross-subsidies from other services. Only once a reliable industrial demand for faecal sludge has been established, could the costs be carried by the revenues themselves. Another option would be to provide dried faecal sludge for free during an initial testing phase, giving industries the chance to realize the benefits without bearing extra-costs. However, further research should be conducted to increase the energy content of dried faecal sludge and allow to produce faecal sludge in any form that would be demanded by users. Interesting research is also provided by the question of how faecal sludge could be co-processes with other waste streams in order to increase fuel quantities.

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