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Characterization of faecal sludge during dry and rainy seasons in Ouagadougou, Burkina Faso

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REFEREED PAPER

Faecal sludge (FS) management is a challenging problem in low-income countries where large parts of the urban population rely on onsite sanitation systems. The design of treatment plants relies on accurate knowledge of FS characteristics, but this information is lacking. The goal of this study, conducted between December 2010 and September 2011, was to determine physical and chemical characteristics of raw FS from collection and transport trucks in 5 discharge sites in Ouagadougou. Over 100 samples directly collected during truck discharge were analysed. Analyses included suspended solids, volatile suspended solids, total solids, total volatile solids, sludge volume index, chemical oxygen demand, biological oxygen demand, and heavy metals. The FS characteristics were highly variable, but had similar characteristics for FS collected during the dry and rainy seasons and at different discharge sites. The type of onsite system had an influence on FS characteristics.

Introduction

Sanitation is one of the most challenging issues in Sub-Saharan countries, which are not on track to meet the sanitation Millennium Development Goal (Unicef and WHO 2012). In urban areas of this region, 65 to 100% of households rely on onsite sanitation systems (Koottatep, et al. 2001, Strauss, et al. 2000). Onsite options can be more affordable and attainable than sewered systems to provide sanitation to urban populations (Dodane, et al. 2012, Koné 2010). However, for adequate environmental and public health protection, a management plan is required for the collection, transport, treatment, enduse, and disposal of the faecal sludge (FS) from onsite systems. Collection and transport companies already exist in most West African cities. However, there is a lack of proper infrastructure for the treatment of FS, and as a result, huge quantities of FS are disposed of directly to the environment (Cofie, et al. 2006).

The design of FS treatment plants requires accurate data on FS characteristics and quantities to properly size and select treatment technologies and operational parameters. However, in contrast to wastewater characteristics that are already well known, the availability of FS characteristics is very limited to unavailable. Results of studies that have been conducted are extremely variable, and are typically carried out over a short-term basis, not incorporating climatic effects over the year (Heinss, et al. 1999, Koottatep, et al. 2005, Vonwiller 2007). In West Africa, there has never been a comprehensive, city wide study conducted over more than one season. As a result, if FS treatment plants are built, they are frequently over- or under-designed for the actual conditions in the local context (Bassan, et al. Submitted).

In Burkina Faso, the national agency for water and sanitation (ONEA) is planning construction of three FS treatment plants in Ouagadougou. This study was conducted to fill the gap of knowledge concerning the temporal and special variability of FS in one city over one year, and at the same time provide accurate data for the design of future treatment plants. This paper presents results of the study, which was conducted between December 2010 and September 2011 to assess the physical and chemical characteristics of raw FS collected in five sites in Ouagadougou where FS collection and transport trucks currently discharge FS directly to the environment.

Methods

Study area

Ouagadougou is the capital of Burkina Faso. The climate is sahelo-soudanian and is characterized by a long dry season from October to May, and an intense rainy period from June to September. The average annual rainfall is 850 to 900 mm (UNHabitat 2007), whereas the mean evaporation exceeds 2000 mm per year. There is an unconfined aquifer with a depth between five and ten meters in the city center, that increases by up to two meters during the rainy season (Somda 2006). The population of Ouagadougou is about 1.5 million (INSD 2007), of which 80% use simple pit latrines and 20% use VIP latrines or septic tanks. Onsite systems are used by approximately 100% of the population, and 50% of these facilities have been emptied since they were built, 75% of which with a vacuum truck (DGAEUE 2011). The quantity of FS collected daily is estimated between 500 and 1000 m^3 (Dembele, et al. 2003, Koanda 2006, Pöyry 2010).

There is no FS treatment plant in Ouagadougou, so the FS that is collected is discharged directly into the environment. For this study, five sites were selected, which are located in open areas in the outskirts of Ouagadougou (Figure 1). Three of the sites, Yagma, Kossodo, and Zagtouli, were selected because they are well established, and are potential sites for future FS treatment plants. Pô road is utilized during the dry season, and Ouaga 2000 during the rainy season.

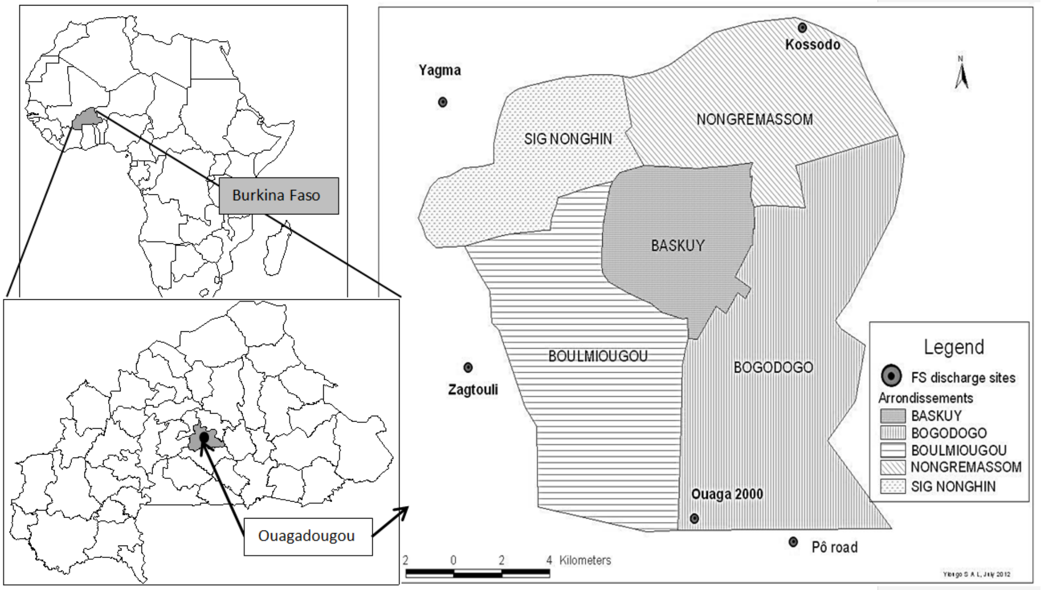

Figure 1. Location of Ouagadougou, its administrative sectors, and the permanent discharge sites where FS samples were collected

Assessment method

The present study was conducted from December 2010 to February 2011 (dry season), and from July to August 2011 (rainy season). It aimed to allow a comparison of collection and transport activity, a better understanding of FS characteristics between the seasons, and to facilitate accurate design of future FS treatment plants. In order to obtain a representative overview of FS, 28 collection and transport companies were involved in this study. The sampling periods and sites were coordinated with companies in order to increase access and to have the greatest number of samples possible. FS was sampled directly from the trucks during discharge, and a semi-structured questionnaire was used to record the type of onsite system (i.e. septic tank, pit latrines, ventilated improved pit latrines, cesspools), the customer profile (i.e. administration, household, commerce, military, medico-social organism), and location.

Sampling and laboratory methods

FS samples were taken at the discharge site directly from the trucks. Four samples of 0.5l were taken: one at the beginning of the discharge (at valve opening); two in the middle of the discharge; and one at the end (at flow reduction) (Klingel, et al. 2002). A composite was prepared with the samples collected per truck, preserved at the laboratory. One to three trucks were sampled per day. During the dry season 54 trucks were sampled, and during the rainy season 56 trucks. Kossodo is the most heavily utilized discharge site, and during the dry season 30 of the 54 samples were collected there.

Analyses were selected to understand FS characteristics influencing the solid/liquid separation, dewatering potential of treatment options and potential for beneficial use of treatment endproducts. Analyses were based on standard methods (Eaton, et al. 1995), and included: Total Suspended Solids (TSS), Volatile Suspended Solids (VSS), Total Solids (TS), Total Volatile Solids (TVS), Sludge Volume Index (SVI), Chemical Oxygen Demand (COD), Biological Oxygen Demand (BOD_5), and Ammonium (NH_4^+). Heavy metals (lead (Pb), iron (Fe), zinc (Zn), and copper (Cu)) where quantified with atomic absorption spectrometry at Eawag in Switzerland on two composite samples, one for all samples collected during the rainy and dry seasons, respectively. Results were analysed to understand the influence of the FS origin, the discharge site location and the season on the solid and organic matter content.

Results and discussion

FS transport and origin

The spatial analyses revealed that each site receives FS from the nearest city sectors. FS collected in the city center, which is far from all of the sites, is equally distributed among the five sites. Emptying is done much more frequently during the rainy season. It took 19 days to collect 56 samples during the rainy season, but it required 56 days to collect 53 samples during the dry season. The increase in emptying during the rainy season is most likely due to intrusion of rain water, and ground water in poorly designed and constructed systems, as heavy rains run off to directly into septic tanks without adequate covers, and the water table rises significantly. Many households empty their systems one or more times during the rainy season, and not at all during the dry season. Truck volumes were equivalent on average to 1.6 onsite systems, with a maximum of four. 80% of faecal sludge came from private households, and 20% from commercial and public establishments. The distribution of onsite technologies is presented in Table 1.

Table 1. Distribution of onsite technologies that were sampled

Type of onsite system	Percentage
Pit latrine (i.e. all types)	68%
Pit latrines only	45%
Pit latrines + shower	14%
Pit latrines + septic tank	9%
Septic tank	26%
Septic tanks only	17%
Pit latrines and septic tanks	9%
Not identified	10%
Cesspools	3%
Public latrines	2%

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FS characterization

The results of the characterization for the dry and rainy seasons are presented in Table 2. The analysis indicated that the FS is “low strength” for both seasons (Heinss, et al. 1998, Koottatep, et al. 2005). This is logical given the water intrusion, significant amount of septic tanks, and minimal amount of public toilets which typically contain “high strength” FS. The ratio of TVS to TS (53-61%), and VSS to SS (60-72%) illustrates that partial stabilization is occurring in the onsite systems, but that a significant amount of degradable organic matter still remains, requiring stabilization prior to enduse. The SVI of 26-29 mg/l indicates that the FS will settle well. The high proportion of SS (64-86% of TS) and settling ability, indicate that a significant volume reduction could be achieved with settling tanks.

The average COD:BOD ratio was greater than three, indicating a rather low biodegradability. However, there was a large variation in the samples, ranging from one to 26. The low biodegradability represented by ratio as high as 26 can be due to FS that is stored for long periods of time in onsite systems (Heinss, et al. 1998). It can also be a result of inorganic pollutants being added to onsite systems by users (e.g. motor oil).

The characteristics of FS collected only from traditional pit latrines (n=48), and only from septic tanks (n=18) are presented in Table 2.. The results illustrate that pit latrine FS is more concentrated than septic tank FS. This could be due to leaching of liquids to soils in unlined pits, partial degradation in septic tanks, or greater water consumption by households with septic tanks. The higher COD:BOD ratio of the septic tank FS indicates greater stabilization, probably due to longer storage periods.

Results of the metals concentrations in the two composite samples from the dry and rainy seasons are presented in Table 3. The concentrations exceed the regulatory limits for discharge of wastewater to water bodies in Burkina Faso. As only one composite sample was taken for each season, it is not known if the limits are regularly exceeded, or the high average values are due to peak loadings of contaminants. Peak loadings could be a result of collection trucks servicing industrial implementations, consistently high background concentrations could be due to the discharge of contaminants such as batteries, or used oil and grease into onsite systems. The results highlight the need to evaluate metals concentrations in FS on a case by case basis to verify the potential for beneficial enduses. FS treatment plants do not remove metals, so the contamination needs to be addressed by investigating and preventing the upstream causes.

Table 2. FS characterization for dry and rainy seasons, and pit latrine and septic tanks

	FS sampled during dry season		FS sampled during rainy season		Average of all samples collected (rainy and dry season)			FS from pit latrines only		FS from septic tanks only	
	Mean	σ	Mean	σ	Sample size	Mean	σ	Mean	σ	Mean	σ
SVI [ml/gTSS]	29	9	26	12	108	27	11	25	8	24	11
TS [mg/l]	10658	8264	12919	10989	108	11820	9781	13349	10755	8984	8926
TVS [% TS]	53	-	61	-	104	58	-	58	-	57	-
TSS [mg/l]	6826	5032	11084	10406	108	9014	8480	10982	10700	7077	7478
VSS [% SS]	72	-	60	-	108	64	-	64	-	74	-
COD [mg/l]	9355	6538	11973	11492	106	10725	9508	12437	12045	7607	6718
BOD_5 [mg/l]	1839	1236	1981	1454	89	1902	1332	2126	1480	1453	1237
COD:BOD_5	5.3	3.3	6.9	5.0	89	6.1	4.2	5.8	3.3	6.7	6.5
NH_4^+ [mg/l]	-	-	1230	732	25	1230	732	-	-	-	-

Table 3. Metals concentration in FS sampled during dry and rainy seasons

	Dry season composite sample (n=54)	Rainy season composite sample (n=56)	Discharge limit to water bodies for Burkina Faso
Zn (mg/l)	8.0	10.1	5
Cu (mg/l)	1.2	1.8	1
Fe (mg/l)	21.0	155.0	20
Pb (mg/l)	0.7	1.0	0.5

FS variability

As illustrated by the standard deviations in Table 2,, large variability was observed among the results for all the parameters and between all the samples. Due to this high variability, a statistically significant difference between the dry and rainy seasons was not detected. There was also no spatial variability detected among the three main discharge sites (i.e. Kossodo, Zagtouli and Yagma). These results indicate that in Ouagadougou, the location and season have a low influence on the variability, compared to the continual variability of characteristics that is observed with FS.

The variability of FS is illustrated by the results of other studies in West Africa, as presented in **Error! Reference source not found.**. FS variability is due to factors such as storage duration, climate, type of onsite system, and pump capacity of emptying truck. In addition, the lack of consistent methods for sampling can have a significant impact on the results.

Another study conducted in Ouagadougou, evaluating samples taken directly in septic tank, showed an average TS concentration of 19000 mg/l and COD of 13500 (Koné and Strauss 2004), which is 1.2-1.6 times as high as the average values in this study. A study conducted in Accra, Ghana, also evaluating only septic tank FS, observed a TS concentration of 11900 (mg/l), which is very similar to that observed in this study (Heinss, et al. 1999). Results from Dakar, Senegal are also highly variable with TS 4500 - 14000 mg/l, and COD 7100 - 15700 mg/l (Vonwiller 2007, Walker 2008). Higher values were obtained through direct sampling during truck discharge than through sampling in reception channel of the treatment plant.

It is possible that FS collected directly from onsite systems is not representative of FS being discharged at treatment plants, as vacuum trucks are frequently not powerful enough to collect all of the solids accumulated and compacted at the bottom of systems, and water is frequently added to dilute and aid in the extraction of FS. Sampling from a receiving channel could be skewed from solids settling in the channel, depending on the flow rate. These results emphasize the need in conducting precise assessments in each context, considering the effect of seasonality, and in developing consistent and accurate sampling methods.

Table 4. Comparison of TS, TVS, and COD characterization of FS in West Africa
(Source: [1](Koné and Strauss 2004), [2](Heinss, et al. 1999), [3](Walker 2008), [4](Vonwiller 2007))

Location	Sampling method	Sample size	TS (mg/l)	TVS (%TS)	COD (mg/l)
Ouagadougou (this study)	From discharging trucks, at the beginning, middle, and end	108(TS) 106(COD)	11820	48	10725
Ouagadougou[1]	From septic tanks	NA	19000	47	13500
Accra[2]	From septic tanks	60	11900	59	7800
Dakar (Rufisque)[3]	From discharging trucks, every 30 second	10	14000	NA	15700
Dakar (Cambérène)[4]	From the treatment plant receiving channel	35	4500	70	7100

Conclusions

This study offers for the first time an insight into the spatial and temporal variation of FS within a city. It reveals huge intrinsic variations between all the samples, without significant difference in FS characteristics between rainy and dry season, and between the different discharge sites. Important conclusions are:

- The selection of the FS sampling method influences the characterization results.
- Direct sampling of onsite systems does not necessarily provide reliable information for the design of treatment plants receiving FS from collection and transport trucks.
- Types of onsite systems need to be considered when designing FS treatment plants, as they have a direct impact on FS characteristics.
- The presence of heavy metals needs to be evaluated, and if present traced upstream to prevent contamination.
- FS characterization studies of the local context need to be conducted prior to designing FS treatment plants. Estimations based on literature values are not adequate due to high variations.
- Poor design of onsite systems and climatic variation can be responsible for variations in FS quantities that are collected, transported, and need to be treated, which should be considered when designing FS treatment plants.
- There is a need to further assess the type of solids in FS (e.g. sand vs organic matter), and to conduct further studies in different locations to gain a better overall understanding of the composition of FS, in order to also optimize the design and selection of treatment options.

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