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FAQ: faecal sludge quantification and characterization – field trial of methodology in Hanoi, Vietnam

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Characterizing and quantifying faecal sludge (FS) at a city-wide scale in low- and middle-income countries is essential for designing and planning appropriate FS treatment facilities. However, there currently is no accurate methodology for the estimation of these values. The FAQ (faecal sludge quantification and characterization) study developed a methodology, and is validating it in Hanoi, Vietnam and Kampala, Uganda. The method utilizes spatially analysed demographic data as a predictor of FS characteristics. Extensive sampling has been conducted to field test the presented method. This paper presents results of collected and analysed secondary data, and preliminary results of the TS, VS, COD and SCOD concentrations from household septic tanks in Hanoi, which were on average 26,471, 19,395, 37,541 and 713 mg/L respectively, and ongoing data analysis is being conducted.

Introduction

The management of onsite sanitation technologies (e.g. septic tanks, pit latrines) in low- and middle-income countries has been disregarded for many years. Faecal sludge (FS), the slurry or semi-solid waste from these technologies needs to be collected and transported away from households to designated discharge locations to ensure adequate protection of human and environmental health. Emptying and transport service providers exist in most south-east Asian cities, but treatment facilities for safe treatment and disposal or enduse of FS are largely lacking. Before adequate FS treatment facilities can be designed and built, context specific FS quantities and characteristics need to be well understood. However, at this time there is no method for the accurate quantification and/or characterization of FS on a city-wide scale.

Several attempts have been made to calculate the accumulation of sludge in septic tanks. Some of the methods calculate the accumulation of settled and digested anaerobic sludge at the bottom of septic tanks. Elmitwalli (2013) employed a mathematical model based on the theoretical influence of hydraulic retention time (HRT), temperature and chemical oxygen demand (COD) influent values to estimate sludge production. They conclude that 0.13 to 0.15 l/cap/d accumulate when the tank receives blackwater only, and is desludged every two to four years. Gray (1995) determined the mean sludge accumulation rate to be 0.254 l/cap/d based on 28 septic tanks in Ireland. The rate was determined by measuring the sludge volumes over a period of three weeks and calculating the accumulation rate for the specific age of the sludge on a per capita basis. Accumulation was then modelled from this data over a five year period.

However, in low- and middle income countries, septic tanks are typically not emptied on recommended desludging intervals, and only when problems arise, such as backing up of FS from the septic tank into the household. At this time, the entire tank volume is emptied, which is not equivalent to quantities estimated based on accumulation rates (Harada et al. 2008, Koottatep et al. 2004). In contrast, if tanks are emptied at regular intervals, on average only one third of the volume of the tank is emptied, and some anaerobic sludge is left to ensure proper functioning, which is also not reflective of the estimated values (Harada et al. 2004). In this case sludge is estimated by the number of households using septic tanks and multiplying it with the volume of the tank and then dividing it by the desludging interval (Nguyen et al. 2013). For the design of FS treatment plants it is essential to predict the expected volumes, as there is a high risk of technology failure if the incoming quantities are over- or underestimated (Bassan et al. 2014).

FS characteristics are highly variable and are influenced by a wide range of factors, such as the diversity and management of onsite sanitation technologies, mixed greywater and blackwater systems, cistern toilet or pour-flush system, the number of users per system, average desludging interval and physical factors (e.g. soil, permeability, water table). Examples of the high variability include: Koottatep et al. (2013) observed TS from 2,202 to 67,200 mg/L and COD from 1,108 to 76,075 mg/L with septic tank sludge monitored over six years (n=256) in Thailand. Vonwiller et al. (2007) observed TS from 4,500 to 14,000 mg/L and COD from 7,100 to 15,700 mg/L with septic tank sludge in Dakar, Senegal. Bassan et al. (2013) observed TS 8,984 ± 8,936 mg/L and COD 7,607 ± 6,718 in Burkina Faso, Ouagadougou when evaluating the influence of dry and rainy season. Although these studies identified the high variability of FS, they did not evaluate factors contributing to the variability. They also focused on the household level, whereas in low- and middle-income countries significant amounts of FS are generated at public toilets, administrative buildings and restaurants and hotels. A statistically representative city-wide characterization study that incorporates all possible technologies, sources, and variabilities would be too resource and time intensive to carry out, and hence representative and feasible methods need to be developed.

This paper presents the FAQ method (faecal sludge quantification and characterization) which has now been field tested in Hanoi, Vietnam and in Kampala, Uganda. In addition to the method, preliminary results from Hanoi, where the majority of the population utilizes septic tanks and little is known about FS characteristics, are presented (Nguyen et al. 2013, Anh et al. 2013). Extensive data has been collected, and is being analysed for presentation. This will provide information on how to use predictors to design sampling campaigns that accurately quantify and characterize FS.

Methodology

Secondary data collection and interviews

The first step in the FAQ method is to collect and analyse secondary data of city demographics and to conduct interviews to understand the local context. Analysing demographic data spatially allows to develop and design a representative sampling scheme for the characterization of FS at a city-wide scale. Understanding the existing situation requires a step-by-step approach to secondary data collection and interviews as this information is otherwise non-existent in regards to FS. This, includes:

1. Definition of city boundaries
2. Identification of types and numbers of onsite sanitation technologies in use within the boundaries
3. Identification of types of implementations (e.g. single households, multiple households, public toilets, businesses)
4. Identification of collection and transport service providers (e.g. private companies, public utilities)
5. Identification of FS discharge points (e.g. FS treatment plants, channels, drains, illegal dumping)
6. Identification of demographic data by spatial distribution (i.e. income categories, population density, age of house, informal settlements, institutional, commercial, industrial areas)
7. Identification of physical data (i.e. soil type, elevation, water table, land-use)

Data was obtained through national census, sanitation master plans, urban development plans and stakeholder interviews. Data needs to be analysed regarding time it was collected, reliability, validity of future projections, and sensitivity analysis applied to understand the influence these factors.

Characterization

Spatial analyses of demographic data is then used to design the sampling plan based on its ability to predict FS characteristics. For example: the impact of income level through diet and/or quality of construction; informal settlements through types of technologies and emptying frequencies; and physical data by direct influence on FS characteristics.

Secondary data was then entered into a database and analysed by spatial distribution (e.g. with ArcGIS, or existing data set maps). A sampling plan was then defined to ensure representative sampling from each of the identified demographic categories. A spatial analysis of the data was undertaken to identify locations that are most representative, interviews results were used to incorporate the expertise of local FSM stakeholders. Results from the sampling in Hanoi and Kampala is being used to validate this methodology.

Sampling and analyses

In this case, the available budget was the constraining factor for the total number of samples, which will typically be the case. The number of samples that can be collected also needs to be considered as it will be a limiting factor. In this case it ranged from four to 16 samples per week with a team of three people. The goal during this validation was to take as many samples as possible with the given time and resources, to identify the minimum number for future implementations.

In Hanoi, the samples were taken directly from the holding tank of collection trucks, immediately following collection of the FS, with a sampling device that was developed in collaboration with the Laboratory for Environmental Biotechnology at École Polytechnique Fédérale de Lausanne (EPFL). Whereas in Kampala, samples were taken directly from the truck discharge valve. This was not possible in Hanoi due to inaccessibility. The influence of the sampling methodology on FS characteristics is also currently being analysed, but within one study it is imperative to always use the exact same method to ensure consistency of the results. A questionnaire was implemented at the household level during emptying to fully understand factors that contribute to the variability of FS.

All analyses were performed at the Institute of Environmental Science and Engineering (IESE) at Hanoi University of Civil Engineering (HUCE) and conducted as described in (APHA,1997).

Quantification

The amount of FS that accumulates in septic tanks is based on factors such as the rate of anaerobic digestion, tank design, number of users and desludging interval, and is different than the total amount of FS being produced or from the total amount that is collected. Theoretical accumulation rates should only be used if emptying is strictly carried out on regular or predictable intervals. In the Hanoi study, quantities were estimated with collected city specific data on number of households using septic tanks, the average volume of the tank and the desludging interval. In this case it was assumed that septic tanks only get emptied once they are overflowing and the total volume is emptied. In Kampala, FS quantities were also estimated with a truck counting study as official discharge locations exist, which also included a questionnaire to record the volume of FS being delivered to official sites, and specific information at the household level (e.g. type of building, onsite sanitation technology, number of users, size of septic tank). For future implementations, all three methods should be considered. Sludge accumulation is based on mathematical estimations, sludge production includes more context specific patterns, and a truck counting study can be used to cross-check any existing information and collected data.

Results and discussion

Analysis of secondary data

In Hanoi the city boundaries were set to be the nine urban districts of Historic Hanoi prior to the expansion of its boundaries in 2008. The population of these districts is 40% of the whole administrative area which has a total population of 6,844,000 The total volume of wastewater was estimated to be 650,000 m3/d (HSDC, 2013), of which 20% is treated in wastewater treatment plants (HSDC, 2013). 10% of the generated wastewater flows through open channels and undergoes no treatment. 90% of the wastewater flows into septic tanks at the household level and is transported in a combined rainwater and wastewater sewer system (Harada et al. 2008). 99% of septic tanks receive only blackwater (Nguyen et al. 2012), and almost 100% of the urban population utilizes flush toilets connected to septic tanks, with other technologies such as VIP latrines being almost non-existent.. Due to the high utilization of septic tanks, management and regular desludging of septic tanks plays a very important role. It is recommended that septic tanks in Hanoi are desludged on a yearly basis to prevent overflowing of solids into the combined sewer system (Harada et al. 2008). However, 90% of septic tanks in Hanoi have never been desludged as households only empty them when problems arise. The actual desludging period for household septic tanks is estimated to be six to eight years (Harada et al. 2008, Nguyen et al. 2012).

The design and size of septic tanks in urban areas is set by the National Design Standard of Vietnam for Wastewater Systems. However, the enforcement capacity to ensure compliance of these regulations is lacking (AECOM, 2010). The Urban Environmental Company (URENCO), a state-owned company, is responsible for providing environmental services, including septage management (i.e. FS collection and transport). In addition to URENCO, there are currently 112 trucks that belong to private emptying companies offering desludging services in Hanoi (Nguyen et al. 2012). URENCO is responsible by mandate of the Peoples Committee to empty the septic tanks of public toilets in four of the nine urban districts and is the only service provider that has permission to discharge FS at the Cau Dien cocomposting facility, the only designated FS treatment plant in Hanoi (URENCO 7, 2013). An unknown, but relatively small quantity of untreated FS is sold to farmers for direct application as a soil amendment and fish ponds, while the majority of private emptying companies dump FS illegally into open channels, lakes and rivers (Nguyen et al. 2012).

Design of the sampling plan

In addition to households, apartment blocks, office buildings, public toilets and restaurants and hotels were identified as major contributors to FS quantities. Difficulties were experience in collecting more detailed demographic data as it is mostly state-owned and difficult to access without authorization. Within Hanoi distinctive distribution of populations based on income category were not discernible, and informal settlements do not exist. These were the main challenges when implementing FAQ in Hanoi, whereas in contrast, demographic data in Kampala was widely accessible. Data on population densities at the level of wards was the most reliable data collected in Hanoi and was hence used to design the sampling plan. The nine urban districts are broken up into 128 wards which are sub-sections of administrative units that play an important political role in Hanoi. For the sampling plan, it was hypothesized that higher population densities have an influence on the number of users per system, emptying cycles and therefore characteristics of FS.

Population densities were divided into four categories as presented in Table 1, each category containing 25% of the population of urban Hanoi, and 88 samples were allocated for each density. This included 36 samples from single households, 24 from apartment blocks, 12 from office buildings, eight from public toilets and eight from restaurants and hotels based on the analysed spatial data, together with stakeholder interviews. Apartment blocks currently produce a significant fraction of the FS in Hanoi, and this trend is expected to continue as population growth is resulting in increased density and less single family homes. The density of office buildings are also increasing as the labour force continues to change from agricultural to industrial and service based sectors. Public toilets are also significant contributors to the total volume of FS as in four urban districts a total of 190 public toilet facilities were identified.

Table 1. Categories of population density categories for sampling plan in Hanoi.

Category	very low (VL)	low (L)	medium (M)	high (H)
Range (persons/km2)	1,000 – 13,000	13,000 – 23000	23,000 – 38,000	38,000 – 100,000
Number of wards	36	26	28	38

Characterization

The sampling program in Hanoi has now been carried out. Preliminary results of the first ten household samples are presented in Table 2. They represent three samples from very low density population areas, two from low density, two from medium density, and three from high density. The results are highly variable with standard deviations between 67% and 85%. The TVS to TS ratio of 66-83% indicates that the sludge undergoes some stabilization in the septic tanks, but also that a high amount of bio-degradable organic matter is still remaining in the sludge. This ratio is higher than values reported in other comparable studies, with TVS to TS ratio of 53-61% (Bassan et al. 2013). The observed soluble COD concentrations were also low, indicating that most of the degradable organic matter is in the solid fraction.

When sludge is not removed from septic tanks as frequently as the design interval, it results in increased TS and COD washing out in the effluent. The average sludge removal period in this study was 8.75 years, but only two out of ten households had ever had sludge removed. This is indicative of the poor treatment performance of septic tanks in Hanoi where a correlation has been observed between an increased desludging period (1 to 20 years), resulting in higher concentrations of COD in septic tank effluent (Harada et al. 2008). Studies characterizing FS from septic tanks in West Africa have observed much lower concentrations of TS, VS and COD than this study. For example 11,820 mg/L TS, 6,855 mg/L VS and 10,725 mg/L COD (Bassan et al. 2013), potentially indicating that septic tanks in West Africa are emptied more frequently than in Hanoi. Another study in Da Nang, Vietnam observed similar characteristics to this study of 31,470 ± 24,081 mg/L COD for cistern-flush toilets and 48,990 ± 12,808 mg/L COD for pour-flush toilets (Anh et al. 2012), indicating similar management and construction to Hanoi.

Table 2. Faecal sludge characterization for ten household septic tanks in Hanoi.

Parameter	Average $mg \cdot L^{-1}$	Standard deviation	Min $mg \cdot L^{-1}$	Max $mg \cdot L^{-1}$
TS	26,471	20,786	5,020	71,007
VS	19,395	14,029	3,421	47,440
COD	37,541	25,283	4,233	83,000
SCOD	713	604	73	1,850

The characterization results by population density are presented in Table 3. Concentrations of TS, VS and COD were highest in the categories of high and medium densities. The average number of users per system was four, and higher population densities did not have an increased number of users. Even though a trend of higher concentrations can be seen in higher population densities, no correlation can be determined based on the small size of the data set. As the collected data is analysed, more conclusions will be drawn on the influence of population density on FS characteristics.

Table 3. Faecal sludge characterization for four population densities (see Table 1).

Parameter	VL (n=3) $mg \cdot L^{-1}$	L (n=2) $mg \cdot L^{-1}$	M (n=2) $mg \cdot L^{-1}$	H (n=3) $mg \cdot L^{-1}$
TS	11,740	17,616	48,514	32,411
VS	9,063	14,431	33,450	23,668
COD	16,717	32,329	53,584	51,144
SCOD	317	882	1,114	731

Quantification

The results of a previous quantification study in Hanoi following expansion are presented in Table 4. However, the preliminary results of this study indicate that the actual volume of collected FS is greater than what was reported (Nguyen et al. 2012). The previous study area included both urban and peri-urban areas, and 10% of the FS was from pit latrines, which, when emptied, is directly used at the household level in peri-urban areas.

Table 4. Faecal sludge quantification for Hanoi, including peri-urban areas after expansion in 2008. (Nguyen et al. 2012)

Quantification method	FS $m^3 \cdot d^{-1}$
Sludge generation	1,574
FS production (current desludging interval)	768
FS production (desludging interval: 2 years)	1,656
Current FS collected (based on survey)	388

Conclusions

How to adapt FAQ to other locations based on analysed data will be presented. Important lessons that have been learned from the implementation of FAQ in Hanoi include:

- FAQ requires access to adequate demographic data to develop hypothesis for the sampling plan, and test the validity of predictors of FS characteristics.

- Access to FS samples, for example if samples can not be collected during discharge due to the lack of legally designated discharge sites, then adaptations need to be developed for sampling methodologies.
- Collecting a representative sample of FS is very important for ensuring consistent characterization results, which can be complicated by trucks making multiple trips to the same household during an emptying operation. Methods for standardization of FS sampling and analysis are currently being developed.
- In Hanoi, preliminary results indicate that demographic distribution is not a strong predictor for the variability of FS characteristics, however analyses of the collected samples will provide verification.
- Based on available data, other predictors should be incorporated in the methodology to better understand FS characteristics.

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References

AECOM International Development, Inc. and Eawag/Sandec (2010), A Rapid Assessment of Septage Management in Asia: Policies and Practices in India, Indonesia, Malaysia, the Philippines, Sri Lanka, Thailand, and Vietnam

Bassan, M., Tchonda, T., Yiougo, L., Zoellig, H., Mahamane, M., Mbéguéré, M., Strande, L. (2013), Characterization of faecal sludge during dry and rainy seasons in Ouagadougou, Burkina Faso. 36th WEDC International Conference, Nakuru, Kenya, 2013.

Bassan, M., Mbéguéré, M., Koné, D., Holliger, C., Strande, L.(2014), Success and failure assessment methodology for wastewater and faecal sludge treatment projects in low-income countries (submitted to Environmental Planning Management), in press

Elmitwalli, T. (2013), Sludge accumulation and conversion to methane in a septic tank treating domestic wastewater or black water. Water Science and Technology Vol 68, No 4, pp. 956-64

Harada, H., N.T. Dong, S. Matsui (2008), A measure for provisional and urgent sanitary improvement in developing countries: septic tank performance improvement. Water Science and Technology Vol 58, No 6, pp.1305 – 11.

HSDC (2013), Personal Communication, Hanoi, Vietnam

Koottatep, T., et al. (2004), Treatment of septage in constructed wetlands in tropical climate – Lessons learnt after seven years of operation. Water Science and Technology Vol 51, No 9, pp 119-126.

Nguyen Viet Anh, Nguyen Hong Sam (2013), Business Model assessment in faecal sludge management in selected Vietnamese cities. 36th WEDC International Conference, Nakuru, Kenya, 2013.

Nguyen Viet Anh, Nguyen Hong Sam, Dinh Dang Hai, Nguyen Phuoc Dan, Bui Xuan Thanh (2012), Landscape Analysis and Business Model Assessment in Fecal Sludge Management: Extraction and Transportation Models in Vietnam. Final Report. For Bill & Melinda Gates Foundation

URENCO 7 (2013), Personal Communication, Hanoi, Vietnam

Pham Nguyet Anh, Hidenori Harada, Shigeo Fujii, Nguyen Pham Hong Lien, Huynh Trung Hai, Shuhei Tanaka (2013), Investigation of water use and discharge characteristics in Hanoi, Vietnam. Unpublished

Pham Nguyet Anh, Hidenori Harada, Shigeo Fujii, Tran Van Quang, Hoang Hai, Shuhei Tanaka, Chinagarn Kunacheva (2012), Effects of septic tank management on septage composition: A case study in Da Nang, Vietnam. Journal of Science and Technology (Japanese) Vol 50, No 1C, pp 1-8.

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