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Technologies for sanitation: how to determine appropriate sludge treatment strategies in Vietnam

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REFEREED PAPER

Developing appropriate technologies for the sanitation chain in low- and middle-income countries is crucial to protect public and environmental health. This includes treatment systems for the sludge produced in onsite and centralized systems (i.e., faecal and wastewater sludge). As the quantities and characteristics of sludge differ from city to city, this requires context-specific technologies. This case study was conducted to identify potential management strategies in five cities in Vietnam. The influence of the enabling environment, existing infrastructures, local sanitation practices and socioeconomic contexts on the selection of technology was assessed through literature reviews, household surveys and interviews. A checklist of influential aspects is presented to make best use of local opportunities and minimize the risks of technology failure. This approach is applicable to develop sludge management strategies in other cities.

Introduction

Sanitation coverage in Vietnam has increased significantly over the last 20 years. In urban areas 50 - 70% of all households are served by centralized or onsite sanitation systems (WHO and UNICEF 2013). However, only a negligible portion of the wastewater from the centralized network and of the faecal sludge (FS) from onsite systems is treated, resulting in significant negative impacts to human and environmental health (ADB 2009). There is currently no management plan in place for FS or wastewater sludge in Vietnam. Most households have onsite pre-treatment units (e.g., septic tanks) even if they are connected to sewers, but the management of FS remains entirely an informal endeavour. Therefore, faecal sludge management (FSM) will continue to be a challenging priority in this rapidly urbanizing country. There are also plans to construct more than 30 wastewater treatment plants in the near future (Le Duy, Nguyen et al. 2013).

Information on the quantity and characteristics of sludge is required to accurately design sustainable solutions for sludge management. FS characteristics are very dependent on the local context (Bassan, Tchonda et al. 2013). Solutions for comprehensive FS management (FSM) service chains include technologies for collection, transport, treatment and resource recovery, and need to be developed for each specific physical, institutional and socio-economic context (Tilley, Lüthi et al. 2009; Dodane, Mbéguéré et al. 2012).

The objective of this research study was to develop an understanding of the unique sanitation situation in mid-sized cities of Vietnam, in order to identify appropriate sludge management technologies. To achieve this, all context-related aspects that influence the production of FS and wastewater sludge were identified and analyzed in five cities, including the enabling environment, existing sanitation infrastructures and practices, and socio-economic and physical contexts.

Methodology

A review of available literature was combined with field studies to collect information related to water provision and waste management in the following areas:

- Existing drainage and wastewater management infrastructures,

- Enabling environment, including the regulatory framework and stakeholder organization, and
- Sanitation practices influencing the characteristics and quantities of sludge produced at the household and city level.

The information was cross-checked to ensure reliable and comparable data for the five cities. The field studies consisted of semi-guided interviews with local stakeholders, visits and household level surveys (June-Sept 2013). The stakeholders were selected if they had influence over the decision process at the state level (i.e., local authorities), or were directly involved in the management of wastewater, solid waste or FS (i.e., public or private companies). A questionnaire was used to discuss the regulatory framework in each city, the distribution of roles and responsibilities, the existing and planned infrastructures, and the sludge production and management. 100 households were surveyed in each city, and the questions included: number of residents, onsite sanitation technology design, operating and emptying practices. Households were selected based on:

- Location inside or outside the area of current sanitation projects,
- Connection or no connection to a sewer,
- Size of street (e.g., narrow lanes) and the ability of emptying trucks to access septic tanks, and
- Type of building (e.g., individual or multi-family).

The five cities have urban population ranging from about 60,000 to 100,000 inhabitants. They were chosen for this study because they are each undergoing drainage and wastewater treatment projects. Son La, Hoa Binh and Lang Son are situated in mountainous environments. Bac Ninh and Ba Ria are in the plains. The average rainfall in the five cities is between 1,350mm and 1,850mm. The mean relative humidity is about 80% and the mean temperatures vary between 20 and 27°C. The cities are all experiencing rapid industrialization and urbanization, but still have strong agricultural sectors. The mean per capita monthly income is 40 USD in Son La, Lang Son and Hoa Binh, and 80 USD in Ba Ria and Bac Ninh (1USD = 21,092 VND) (GSO 2011).

Results and discussion

Existing infrastructure

In most cities of Vietnam, combined drainage and sewerage networks exist, but do not cover all areas due to a lack of tertiary networks, especially in small alleys (WHO, VIHEMA et al. 2012). Urban households typically have septic tanks whether or not they are connected to a sewer. Untreated wastewater is generally discharged to water bodies. In each of the five cities, sewer upgrades mean that in the future wastewater will be transported to treatment plants. The current plan is that wastewater sludge will be landfilled following partial stabilization and dewatering. Unfortunately, solid waste landfills in the cities are either non-lined, operating over-capacity, or located far from the city centre. Moreover, transporting sludge is costly due to the high water content.

94-100% of the surveyed households had flush toilets with septic tanks. Therefore, FS mechanical emptying and transport will continue to be an important aspect of the environmental management. Septic tanks are typically located below the houses, and, hence, the floor of the house needs to be broken to access the tank for emptying. This partly explains the infrequent emptying of FS as households tend to not empty systems unless there is a problem (e.g., blockage causing backing up into the household). The volumes of septic tanks were mostly 3-5m^3, with around 20% below 3m^3 and 20% above 5m^3. The volume and the age of the tank affect the emptying frequency and characteristics of FS as the organic matter is stabilized with time.

In Ba Ria there is a FS treatment plant operated by a private company, (Dai Nam) with a capacity of 120 m^3/d. In Son La, FS is collected by a state-owned company and transported to a pre-treatment unit, consisting of a small settling tank and gravel filter. It is planned that the end-products will be used in aquaculture and tree plantations. In Son La, a composting plant for organic solid wastes is also being constructed. In Hoa Binh, Bac Ninh, and Lang Son, private or state-owned companies own landfills, and they discharge the FS they collect at their landfills.

Enabling environment

The current regulatory framework for sanitation management is not coherently designed and does not include reference to any type of sludge from sanitation systems (i.e., dredged from sewers, FS or wastewater sludge). National laws and regulations for the sanitation sector are set by the Ministry of Construction (MOC) in urban areas and the Ministry of Agriculture and Rural Development (MARD) in rural areas. The

Ministry of Natural Resource and Environment (MONRE) is responsible for groundwater, surface water, water pollution, and the environmental impact of landfills. Relevant regulations include:

- Decree 88 covers rainwater drainage and wastewater management, and states that pre-treatment at the household level is required in urban areas (i.e., septic tanks), even if households are connected to sewers. Direct connections to separated sewers are an exception (Government of Vietnam 2007).
- Decree 25/2013 sets a fee for the discharge of untreated wastewater into the environment, although this is not equally applied in all Vietnamese cities (Le Duy, Nguyen et al. 2013).
- Decision 06/2007-QD prohibits enduse of human wastes (e.g., FS) for agriculture, even though this is common practice in rural areas.
- The laws for solid waste management do not include any type of sludge, even though sludge is often discharged at landfills.

Strategies for sludge management are needed for each of the cities, but this requires a commitment at the national level regarding regulations, fees, and accepted management strategies. Currently, local governments have no incentive to promote sludge management. Provincial People's Committees are the local authorities and organize water supply and sanitation services to fulfil local demand. They distribute the responsibilities to state owned companies, joint stock companies (i.e., JSC, the state owns 50%), or private companies. Solid waste management is commonly done by state owned companies called URENCO (URban ENvironmental COmpanies). In the current system, private companies empty septic tanks in all five cities, but are actually discharging illegally, even though they are essentially providing a public service. They discharge sludge directly into the environment as there are no designated discharge or treatment facilities, other than some privately owned facilities (e.g., Ba Ria). Stakeholders and their roles in the five case study cities are presented in Table 1. Where one stakeholder manages all sludge (i.e., FS, wastewater and sewer sludge) the management of sludge can be readily centralized, which is the case in Son La and Hoa Binh.

Table 1. Stakeholder roles for sanitation, water and solid waste management in the five cities

<table>
<tr><th></th><th>Son La</th><th>Ba Ria</th><th>Hoa Binh</th><th>Bac Ninh</th><th>Lang Son</th></tr>
<tr><td>Water supply</td><td>Son La Water Supply JSC</td><td>Ba Ria - Vung Tau Water supply company JSC</td><td>Hoa Binh Water supply company JSC</td><td rowspan="2">Bac Ninh Water Supply and Sewerage Company (state)</td><td rowspan="2">Lang Son Water Supply & Drainage Company (state)</td></tr>
<tr><td>Wastewater and sewer management</td><td rowspan="2">Son La URENCO (state)</td><td>BUSADCO (state)</td><td rowspan="2">Hoa Binh URENCO JSC</td></tr>
<tr><td>Solid waste management</td><td>URENCO Ba Ria (state)</td><td>Bac Ninh URENCO (state)</td><td>Huy Hoang Ltd company (private)</td></tr>
<tr><td>FSM</td><td>URENCO + 3 private</td><td>BUSADCO + 6 private</td><td>URENCO + 1 private</td><td>URENCO + 4 private</td><td>Huy Hoang + 3 private</td></tr>
</table>

Sanitation management and practices

Management structures affect financial flows, type of implemented technologies, and human resources. In general, the Environmental Protection Fee or Wastewater Fee is insufficient to cover the operation and maintenance costs of wastewater infrastructure, and the budget for FSM is non-existent in Vietnamese municipalities. Additionally, local authorities invest scarce resources into operating the few existing treatment facilities, or supporting projects related to FSM (AECOM and Eawag 2010). The lack of policies and appropriate models to mobilize financial resources should be addressed to reduce the financial burden of the government and increase the coverage and quality of services (WHO, VIHEMA et al. 2012).

In general, septic tanks are built at the same time houses are constructed. In the five cities, the number of septic tanks that are over 20 years old was less than 5%, and an average of 73% were built less than ten years ago. This makes sense as the cities have undergone recent development. On average, two thirds of the surveyed households had less than five inhabitants, and one third had between five and ten inhabitants. The number of users per septic tank affects the rate of FS accumulation, and the emptying time.

Most of the households in the five cities discharge only blackwater from toilets into septic tanks. Greywater from the kitchen, cleaning and washing activities are generally directly discharged in the sewer network or into the environment. Operational recommendations for septic tanks loaded with blackwater include emptying them every two to three years. However, the actual average emptying frequency reaches ten years or more (Nguyen, Nguyen et al. 2011). In the five cities, only 12 and 29% of the septic tanks that were built less than five and ten years ago have been emptied, respectively. A very high percentage of households had never emptied their septic tanks (80-89%), except in Ba Ria, where 61% of the surveyed households had emptied them. More FS will need to be removed from the septic tanks over the next five to ten years. This points to an increasing need for FS management solutions. Also, households mostly empty their tanks during the last months of the lunar calendar, resulting in seasonal variations. In the five case study cities, FS is currently often discharged in rubber-tree fields, coffee plantations, and familial farmland or aquaculture ponds. In general, farmers do not pay for FS.

Technology selection

The assessment of the local context shows that various aspects need to be considered to select adequate treatment technology. Existing infrastructures can be expanded to optimize costs and land requirements. Aspects related to the enabling environment, socio-economic situation and existing management practices also determine available resources and influence the long-term operation and maintenance. A checklist with crucial aspects that need to be assessed to identify appropriate sludge treatment technology was developed, based on influencing aspects observed during this study (Table 2).

Table 2. Important aspects for sludge treatment and their influence on the technology selection

Aspects	Influence on technology selection
Wastewater infrastructures	• Characteristics and volume of wastewater sludge • Available technologies that can be used, upgraded or extended
Faecal sludge infrastructures	• Characteristics and volume of faecal sludge • Available technologies that can be used, upgraded or extended
Regulatory framework	• Type of technology promoted and sludge produced
Stakeholder organization	• Type and quality of existing services provided • Possible management system, and co-treatment opportunities
Management practices	• Financial flows for sludge management
Type of wastewater	• Requirement for treatment to allow safe disposal or end-use
FS age, emptying frequency	• Volume of faecal sludge to be treated over time
Resource recovery	• Value added end-products that allow revenue production in local context
Social context	• Type of onsite infrastructures and population density • Expected volumes of sludge that require treatment over years
Economic context	• Activities producing wastes, which could be co-treated with sludge
Physical context	• Spatial organization of the transport of the sludge and treatment plant based on topography and land use • Design of treatment infrastructures and operational modes based on climate (hydrology, humidity and temperature)

These aspects allow for an efficient assessment of the situation, and can be applied to the design of treatment technologies and strategies in other contexts. Based on the data collected in the five cities, recommendations were made for each of these aspects in terms of selecting treatment technologies (Table 3).

Table 3. Recommendations to develop sludge management in five cities

Aspects	General recommendation	Technology selection
Wastewater infrastructures	• Avoid landfilling of sludge • Use of existing treatment plants	- **All:** co-treatment of FS and wastewater sludge - **Son La:** co-composting of dewatered sludge with solid wastes is also possible
FS infrastructures	• Mechanical transport should be optimized • Centralized to semi-centralized treatment is possible	- **All:** treatment options need to be designed for partly stabilized FS - **Ba Ria:** transport to existing FS treatment plant - **Son La:** upgrade of existing FS treatment plant
Regulatory framework	• Enforcement of correct septic tank design and operation • FS and wastewater sludge co-treatment • Regulation should enable resource-recovery of treatment end-products	- **All:** national regulation needs to promote treatment strategies to allow for coherent technological solutions
Stakeholder organization	• Centralized treatment would optimize role distribution, including public- private partnerships	- **All:** the same stakeholder should be in charge of management of FS and wastewater sludge - **Son La, Hoa Binh:** co-treatment by URENCO
Management practices in city	• Financial mechanisms are required for operation of treatment plants	- **All:** treatment with resource recovery from end-products to offset treatment costs
FS age, emptying frequency	• Solutions are needed to treat FS from septic tanks over 5-10 years	- **All:** FS treatment needed within five years - **All:** Robust technology required to resist to varying loads
Resource recovery	• Resource recovery is well accepted and should be promoted • Pathogen reduction is required	- **All:** treatment technology should produce valuable and safe to use end-products, which can generate revenue

Conclusion

This study of the local context and sanitation systems in five cities provided useful information for the identification of appropriate treatment technologies for FS and wastewater sludge in urban Vietnam. A long term strategy should allow coherent sanitation development and avoid overlap of onsite and centralized systems. For the next 20 to 30 years, environmental and public health burdens could be reduced through the co-management of sludge, the efforts of stakeholders could be centralized, and treatment end-products could be used to offset treatment costs. Therefore, the anaerobic co-digestion of FS and wastewater sludge needs to be further evaluated. Possibilities for co-digestion with other organic wastes will also be assessed, together with local marked demand for end-products. For FSM projects in other contexts, the traditional engineering approach that considers only physical and socio-economic aspects needs to be complemented with the following aspects:

- FSM should be integrated in urban sanitation strategies, including rainwater drainage, wastewater treatment, and solid waste management,
- The enabling environment should include all the types of waste requiring treatment, and coherent strategies for the treatment of sludge,

- Analysis of the existing infrastructure would allow for better use of local resources, and the optimization of local waste flows,
- Understanding management practices in each city is important, as local organizations vary, and have differing influences over the available means and best strategies for sludge management,
- Sanitation practices at the household level provide key information about the estimation of the volumes and characteristics of the sludge that requires treatment, as well as their temporal and spatial variability,
- Specific studies, that are required to characterize FS and assess produced volumes in each city's treatment plants, are planned,
- Assessment of accepted resource recovery will allow for the development of treatment technologies that produce valuable end-products.

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