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CASE STUDY

Sanitation situations in selected Southeast Asian countries and application of innovative technologies

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Abstract Sanitation coverages in selected Southeast Asian countries, namely Myanmar, Thailand and Vietnam, were increased from 1990 to 2015. The toilet coverage of 96, 100 and 99% was reported in Myanmar, Thailand and Vietnam, respectively. On contrary, incidences of waterborne disease and water pollution are still in existence. This situation is due mainly to poor design, performance and maintenance of the dominantly used on-site sanitation systems (OSS) such as septic tanks, cesspools. In addition, fecal sludge (FS), which has to be emptied from these OSS, is not properly managed. There are lacks in rules and regulation on FS management (FSM). Recent research conducted at the Asian Institute of Technology, Thailand, involved the development of innovative OSS, namely solar septic tanks, Zyclone cube toilet and septic tank effluent treatment units. The operation of solar septic tanks with increased temperatures of 40–50 °C could inactive *E. coli* by 4–6 logs in the effluent. The solar septic tanks enhanced the microbial degradability with increased methane gas production and reducing fecal sludge accumulation by 50%. The Zyclone cube toilet separated the toilet wastewater into solid and liquid portions, which were treated by heating and electrochemical disinfection, respectively. The septic tank effluent was further treated by a unit consisting of granular activated carbon coated with nano-silver resulting in *E. coli* reduction of 5–6 logs. These technologies should be applied for OSS in Southeast Asian and other developing regions for environmental improvement and public health protection.

Keywords Environmental pollution · Health protection · Innovative technology · Sanitation · Southeast Asia

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1 Introduction

Although the economy of Southeast (SE) Asia is growing rapidly, the environmental and health problems are also becoming more serious. At present, about 1.74 billion people in this region lack access to improved sanitation, among which 792 million people still suffer with the indignity of practicing open defecation (ADB 2013a). The poor sanitation situation has caused adverse impacts leading to diseases and premature death, polluted water resources, decreased time for daily activities and lost opportunities for the reuse of human excreta for energy or fertilizer production. Children, women and senior citizens are particularly vulnerable to this adverse impact, which considerably affects their quality of life. Poor sanitation has led to the significant economic losses due to related illnesses and lost income through reduced productivity. Over 9 billion US dollars was estimated as economic losses because of poor sanitation (based on 2005 prices) in Cambodia, Indonesia, the Philippines and Vietnam, accounting for 2% of their combined gross domestic products (GDP) (Hutton et al. 2007).

Even though government and development banks have been undertaking several initiatives to improve the sanitation situation in SE Asia, the situations are not well improved. Besides the limited access to improved sanitation, lack of technology options and poor performance of the existing technology has restricted the environmental and health improvement of the region. The system commonly employed for toilet wastewater treatment are on-site sanitation systems (OSS) such as septic tanks, cesspools, which in most cases are poorly designed, constructed and maintained, leading to system leakage or overloading (ADB 2013b; World Bank 2013). The need of innovative low-cost sanitary technologies and sustainable technological solutions is required to meet the sanitation targets (Moe and Rheingans 2006). Novel approaches to the design and operation of the OSS have potentials to bring benefits to people. For instance, energy or biogas can be produced from fecal sludge digestion, fertilizer can be produced from fecal solids, and reclaimed water can be reused in irrigation.

The main objective of this paper is to review sanitation situations in some SE Asian countries, which are the emerging economy with rapid urbanization such as Myanmar, Vietnam and Thailand (Fig. 1), and their related economic and health problems caused by improper sanitation. Innovative sanitation technologies recently developed are described including their application for OSS in these countries.

2 Sanitation situation in selected three countries

Sanitation refers to facilities and services for safe disposal of human excreta and urine (WHO 2016). An improved sanitation indicates the separation of human excreta hygienically from human contact (WHO and UNICEF 2016). It provides physically closer facilities and safe disposal of excreta (Van Minh and Nguyen-Viet 2011). Improved sanitation varies with collection and treatment systems of toilet wastewater. For example, the improved sanitation facilities include toilet units connected to public sewer, or OSS such as (1) septic tanks, (2) cesspools (3) pit latrines and (4) composting toilets.

2.1 Myanmar

Myanmar, formally known as Burma, has an area of 676,577 km^2 and population of about 60 millions. About 34.1% of the population live in urban area, which was reported to be increased annually by 2.5% during 2010–2015. The current toilet coverage is 96%

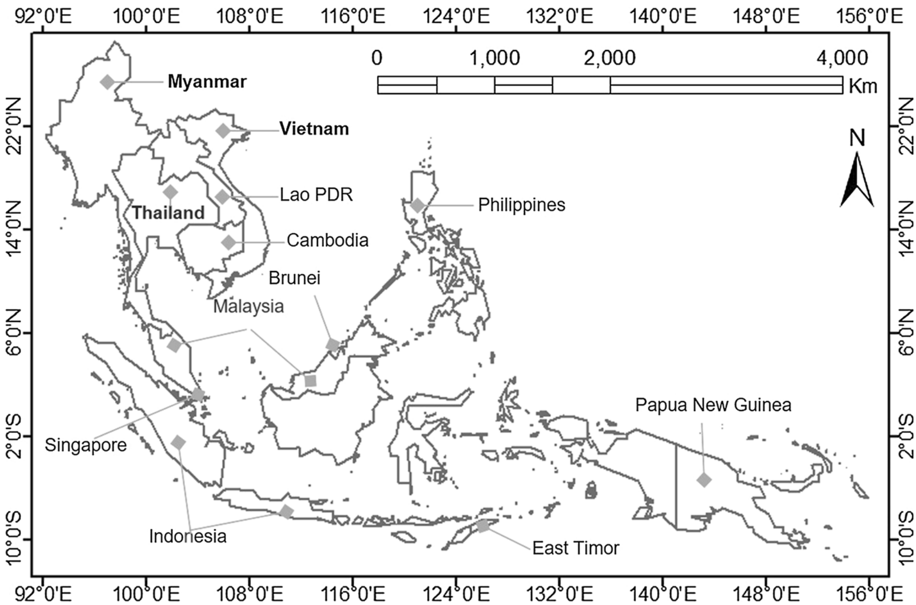

Fig. 1 Location map of Southeast Asia

(including shared and unimproved toilet facilities) which was progressively increased in the last decade (Fig. 2) (WHO/UNICEF JMP 2015). Except Yangon central business district, Myanmar lacks conventional central sewerage system and about 14% OSS such as septic tanks are used in households, while pit latrines with slab are used in more than 60% of the households (Table 1).

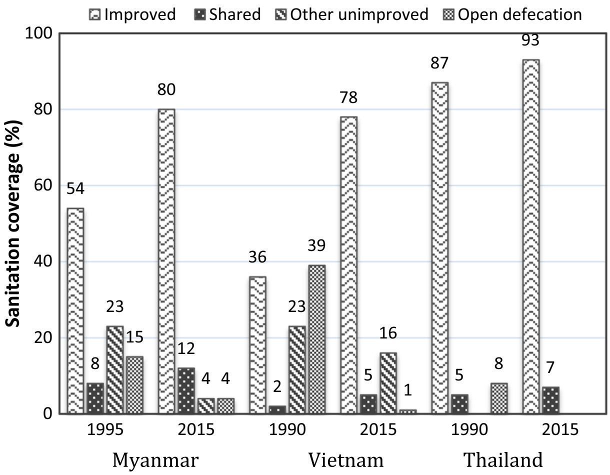

Fig. 2 Changes in types of sanitation facilities and its coverage. *Note* improved sanitation comprises toilet units connected to public sewers, as well as OSS such as (1) septic tanks, (2) pour flush latrines (3) simple pit latrines (4) pit latrines with slabs (5) ventilated improved pit latrines and (6) composting toilets. Toilet units connected to system other than improved ones, such as discharge of toilet wastewater in open land or ditches, hanging toilet, represent the unimproved toilet *data source* WHO/UNICEF (2015)

Table 1 Household populations (%) in relation to improved sanitation facilities types

Country	Improved sanitation facility Flush/pour flush to						
	Sewer System	Septic tank	Pit latrine	Unknown place/ not sure/DK where	Ventilated improved pit latrine	Pit latrine with slab	Composting toilet
Myanmar	1.1	13.9	–	–	3.6	64.9	1.1
Thailand	5.3	92.7	1.3	–	–	–	–
Vietnam	1.7	51.2	3.8	0.2	0.5	9.4	11.3

DK indicates do not know

Source (GSO 2011; NSO 2012; MNPED 2011)

The practice of fecal sludge (FS) collection and treatment is not systematic, and OSS are rarely serviced (ADB 2013b). The emptying of sludge is commonly practiced manually, and the collected FS from cities is usually dumped into agricultural lands or open lands. The incidences of diarrhea-related diseases including cholera, dysentery, typhoid and viral hepatitis were often reported (ADB 2013b). The health data of 2003 showed 45,095 cases of diarrhea, 4255 cases of hepatitis, 84 cases of cholera and 3162 cases of typhoid fever. The infant mortality rate of 46 per 1000 births was reported for 2010–2015. Gross domestic product (GDP) of the country was reported as 66,478 million US $ in 2014, whereas the total health expenditure was about 2.3% of the GDP for the same year (United Nations Statistics Division 2016a).

2.2 Thailand

Thailand has an area of 513,120 km^2 and population of about 68 millions (United Nations Statistics Division 2016b). Nearly half of population (50.4%) is urban population, which was increased by 3% during 2010–2015. Sanitation facilities are accessed by everyone in Thailand, where flush/pour flush toilets connected to septic tanks are dominantly used (Table 1).

On contrary to toilet coverage, there are increasing incidences of intestinal infectious diseases (Fig. 3), which indicates poor performance of the existing OSS and lack of appropriate FS management (FSM). It is reported that 20% of the collected FS is treated in well-maintained treatment plants and the remaining (80%) is disposed without proper treatment, due to either lack of treatment facilities or limited function of the treatment plants (AIT 2013). The country GDP in 2014 was reported 404,828 million US$, whereas 6.5% of total GDP was used for health expenditure during 2010–2015 (United Nations Statistics Division 2016b). Moreover, the economic loss resulting from waterborne diseases such as diarrhea, typhoid, and dysentery was estimated to be 23 million US $ in 1999 (AECOM and SANDEC 2010).

2.3 Vietnam

Vietnam has an area of 332,698 km^2 and population of about 90.5 millions. The majority of population live in rural area, whereas urban population constitutes only 33.6%. The average annual population growth was reported as 3% for 2010–2015 (United Nations

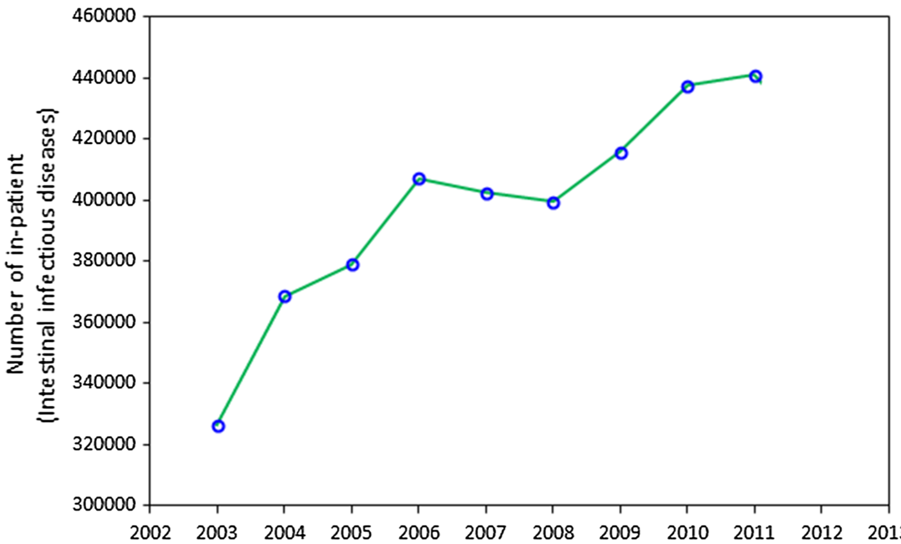

Fig. 3 Cases of water and food-borne infectious diseases incidence in Thailand. *Data source* MoPH (2014)

Statistics Division 2016c). The toilet coverage is reported as 99% (including shared facilities) in Vietnam (WHO/UNICEF JMP 2015). Similar to Thailand, flush/pour flush toilets connected to septic tank are mostly used in Vietnam (Table 1). The desludging of pits and septic tanks from households is poorly practiced, and removal of FS is largely unregulated in Vietnam. Only about 4% of the FS is treated, while the remaining is disposed of without treatment to nearby land and water resources (World Bank 2013; Smets 2014).

Annual diarrhea cases of about 7 millions in Vietnam and the main cause of death of about 4600 by poor sanitation and hygiene. The overall annual economic losses from poor sanitation are US$780 million that includes three major areas such as water costs (37%), health costs (34%) and environment cost (15%). About 0.5% of annual GDP was reported as the total financial losses due to poor sanitation (World Bank 2008), whereas the GDP of Vietnam was reported US $186,205 million in 2014 (United Nations Statistics Division 2016c).

According to Table 1, the differences observed in OSS types and their coverage among the three countries are possibly due to the government policy, socioeconomic, technical knowhow and geography of each country. For examples, flush/pour flush toilets connected to septic tanks, found mostly in Thailand and Vietnam (Table 1), were likely due to the government policy imposing construction of septic tanks in the premise of individual houses. Due to its lower cost, pit latrine with slab was found to have the highest coverage (64.9%) in Myanmar, while a limited coverage (i.e., 9.4%) was observed in Vietnam and absent in Thailand. On the other hand, composting toilet was used about 10% in Vietnam, probably due to the practice of applying composted feces to agricultural lands. With respect to geography, hanging toilets were found to be used in region of Mekong river delta in Vietnam (Table 2) in flood-prone area with high water level.

Sanitation coverage was progressively increased in the three selected countries of SE Asia during the last two decades (Fig. 2), but the extents of waterborne diseases, for example, in Thailand were also observed to be increasing (Fig. 3). Although septic tanks

Table 2 Household populations (%) in relation to unimproved sanitation facilities types

Country	Unimproved sanitation Facility					
	Flush/pour flush to somewhere else	Pit latrine without slab/open pit	Bucket	Hanging toilet/ latrine	Others	Open defecation/ no facilities/bush
Myanmar	1.1	6.4	0	0.3	0.5	7
Thailand	0.4 (in total all form of unimproved facilities except open defecation)					0.2
Vietnam	0.5	4.5	0.1	10.1	6.4	0.4

Flush/pour flush toilets connected to a septic tank refer to system that keeps all excreta disposal without overflow system for water or solid waste. When the tank is full, it needs to be emptied by suction truck. The tank may be located inside or outside the house. This type of toilet is mostly found in houses. A flush/pour flush to pit latrine refers to a system that flushes excreta to a hole in the ground and has a water seal

Source (GSO 2011; NSO 2012; MNPED 2011)

are widely used to collect and treat the toilet wastewater at households, these tanks are constructed without drainage trenches or leaching fields in most developing countries including SE Asia, resulting in the discharge of effluents rich in pathogens and organic contents into nearby waterbodies. Due to its limited treatment performance, there is high accumulation of FS which is not properly desludged or treated, causing serious environmental and health problems (Pussayanavin et al. 2015).

3 Fecal sludge management (FSM) situation

Because OSS is dominantly used, there is high quantity of FS generation. But FSM has not been prioritized and become a neglected field in many SE Asian countries. In Myanmar, the services of emptying and transportation are being offered by local authorities or private companies, with service charges on the amount of the FS volume desludged (Than 2010). However, there is a limited number of FS emptying trucks, while manual emptying of sludge is commonly practiced. The authorities have not executed systematic plans and policy on FSM. The regulation on environmental quality standard of FS treatment facility does not exist. Only, Mandalay, capital city, has developed laws and regulation on environmental conservation, but FSM regulation is not clearly stated (Naing 2016).

Thailand is striving for FSM, where local government authorities (LGAs) have an overall responsibility for FSM in their communities (Taweesan et al. 2015). FSM services such as emptying and transportation are provided either directly by LGAs or by private companies (license holder) under direct control of LGAs. FS collection fees are in the range of 5–9 US$/$m^3$, which cover mainly the collection and transportation costs. Treatment methods, namely anaerobic digestion coupled with sand drying bed, are widely used in FS treatment. Other methods such as disposal to landfill, co-treatment with wastewater, drying bed, activated sludge, stabilization pond, constructed wetland and covered lagoon are also being practiced (AIT 2013). Taweesan et al. (2015) reported that municipalities in Thailand are facing financial constraints to support FSM services, and FSM has not been placed in priority by many municipalities. Although the Ministry of Natural Resources and Environment (MNRE) and the Ministry of Public Health (MoPH) have responsibility to control and supervise FSM, the country still lacks proper guideline for implementation (AIT 2013).

Although Vietnam laws have specified on the design, construction and operation of septic tanks, it has not included the collection, treatment or disposal of FS. The local governments have no incentive to promote FSM (AECOM and SANDEC 2010), and wastewater enterprises have limited autonomy to deal with FSM operations or undertake FSM system development (World Bank 2013). A mix of state-owned, limited liability companies and private companies provide FS desludging but due to lack of treatment infrastructure, service providers usually dispose of FS in drains, fish farms and waterways (AECOM and SANDEC 2010).

4 Innovative sanitation technologies for health and environmental improvement

Reviews on sanitation and FSM situation presented in Sects. 2 and 3 indicate that due to lack of technology options, poor design, limited treatment capacity and poorly treated FS, the increase in sanitation coverage (toilet facilities) may not ensure the improvement of public and environmental health. In this regard, innovative sanitation technologies such as solar septic tanks, Zyclone cube toilet and post-treatment system developed by Asian Institute of Technology (AIT), Thailand, appear to be potential technologies to protect environmental pollution and improve the public health of this region. A brief discussion of each of these technologies is made below.

4.1 Solar septic tanks

Solar septic tank is an innovative technology that reduces the amount of sludge accumulation in septic tanks by utilizing the anaerobic digestion at high temperatures about 40–50 °C (Fig. 4). The high temperature normally increases microbial methanogenic activities occurring in the sludge layer of the septic tank, resulting in more organic degradation, less total volatile solids (TVS) or sludge accumulation and more methane (CH_4) production than in conventional septic tanks operating at ambient temperature (Table 3). A high intensity and diversity of Methanobacterium species was reported in solar septic tanks, operated at 40–50 °C, which has resulted the higher methane production (Pussayanavin et al. 2015). The reduction of sludge accumulation would further extend the frequency of desludging and subsequent treatment of FS. The increased biogas (energy) could be used for lighting and heating, while the effluents with low *E. coli* concentration would reduce the public health threat (Pussayanvin et al. 2015). The solar septic tanks are currently used in some areas of Thailand with satisfactory performance (AIT 2015).

4.2 Zyclone cube toilet

Zyclone cube toilet has been developed for the complete treatment the toilet wastewater on-site, which avoids the fecal sludge emptying, transportation and post-treatment. The toilet separates toilet wastewater immediately into fresh fecal matters (solid) and water (liquid) and disinfects the separated solid and liquid by heating and electrochemical methods, respectively. A schematic of Zyclone cube toilet is provided in Fig. 5.

The performance data of a Zyclone cube toilet (Table 4) show about 90% of solid–liquid separation. The separated solid is further treated by heating at 70 °C for 15 min before using as soil conditioner or safe disposal (Feachem et al. 1983). The electrochemical

Fig. 4 Schematic of solar septic tanks

Table 3 Comparative performance of laboratory-scale solar septic tanks and conventional septic tanks (Koottatep et al. 2014; Pussayanavin et al. 2015)

Parameters	Solar septic tank (40–50 °C)	Conventional septic tank (30 °C)
Sludge accumulation (m^3/year)	0.5	1
TVS accumulation in sludge (g/g TVS input)	0.26	0.50
CH_4 production (L/d)	1.5	0.9
CH_4 production (L/g TVS input)	0.027	0.016
E. coli in effluents (MPN/mL)	1.6×10^3 12.3 (50 °C)	4.6×10^3

TVS total volatile solid, CH_4 methane

unit could lower *E. coli* in the effluents to be lower than 10^3 CFU/100 mL, suitable for reuse in agriculture (WHO 1989).

4.3 Post-treatment unit of septic tank effluent

Post-treatment unit consisting of granular activated carbon coated with nano-silver (NS-GAC) has been developed (Fig. 6) to inactivate fecal microorganisms in the septic tank

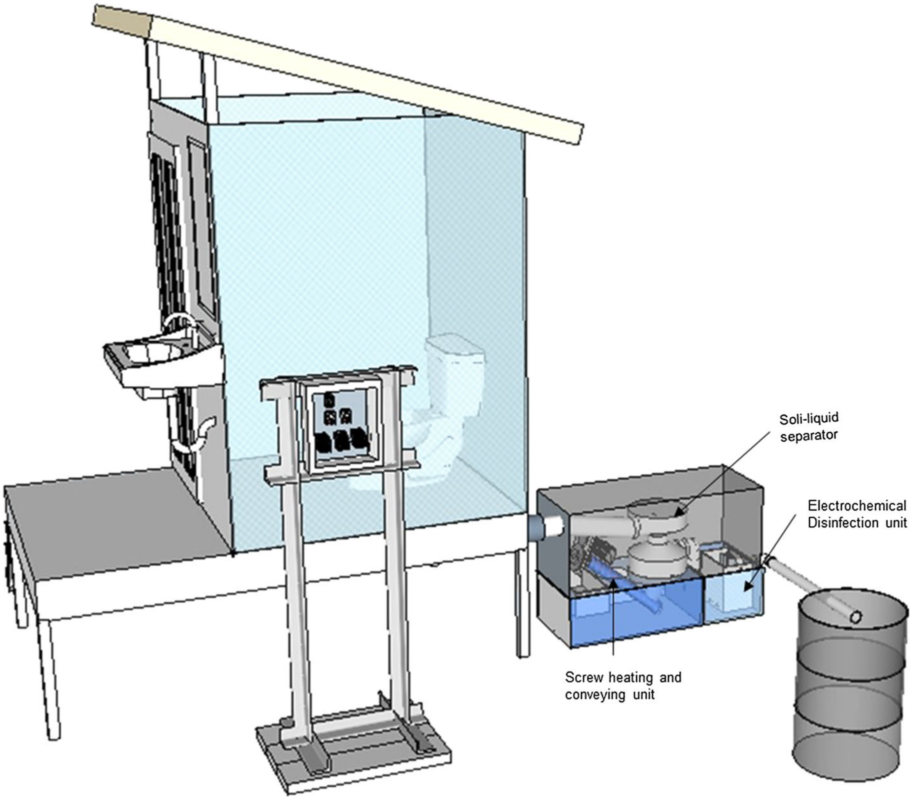

Fig. 5 Schematic of Zyclone toilet

Table 4 Key performance of Zyclone cube toilet (AIT 2015)

Parameters	Value	Remarks
Solid–liquid separation efficiency (%)	>90	Using specially designed double conical-shaped separator. It is calculated as Equation 1
E coli indicator (CFU/100 mL)		
Solid	ND	Heating of separated solid at 70 °C for 15 min
Liquid	$<10^3$	Electrochemical disinfection (supply of current at 12 V, 15 min, Ti electrodes)

Solid–liquid separation efficiency is calculated as Equation $\frac{\text{Separated feces (g, dry wt)}}{\text{Total supplied feces (g, dry wt)}} \times \frac{\text{Separated water (L)}}{\text{Total supplied water (L)}} \times 100\% \cdot \text{Eq. 1}$

ND indicates not detected

effluent. From the experimental data, the obtained NS-GAC unit could inactivate *E. coli* to be lower than 10^3 CFU/100 mL, suitable for agricultural reuse (WHO 1989). Analysis of the performance data (Koottatep et al. 2015) suggested that a septic tank effluent treating a

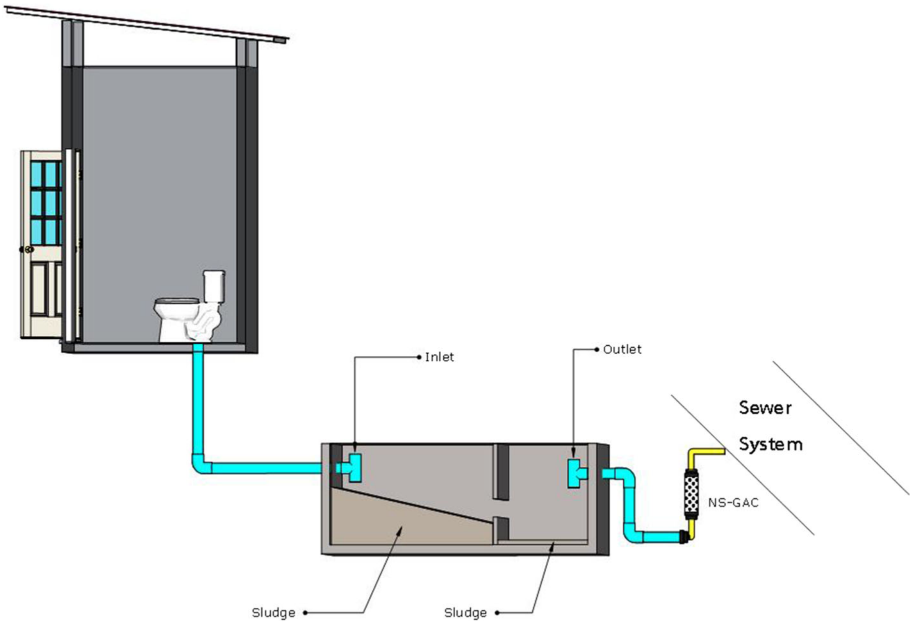

Fig. 6 Schematic of NS-GAC unit connected to a septic tank

single household wastewater should be installed with a 35 L NS-GAC unit which could function effectively for about 1 year before replacement.

5 Summary

SE Asian countries are progressing with rapid economic growth, but also facing a number of serious challenges in health and environmental protection. Toilet coverages are currently more than 95%, but water pollution and disease infections from toilet wastes are still significant. Due to improper design and inadequate maintenance of the OSS, there is leakage of the untreated OSS effluent into nearby water courses. In addition, the FS collected from OSS is not properly treated. There are lacks in rules and regulation on FSM in Myanmar; however, there are several organizations in Vietnam to deal with FSM, but FSM is not on the priority. Thailand possesses some rules and regulation on FSM, but FS treatment is still lacking, causing pollution and health problems.

Recent research conducted at the Asian Institute of Technology, Thailand, involved the development of innovative OSS, namely solar septic tanks, Zyclone cube toilet and septic tank effluent treatment units. The operation of solar septic tanks with increased temperatures of 40–50 °C could inactive E. coli by 4–6 logs in the effluent. The solar septic tanks enhanced the microbial degradability with increased organic matter degradation, methane gas production and reducing FS accumulation by 50%. The Zyclone cube toilet separated the toilet wastewater into solid and liquid portions, which were treated by heating and electrochemical disinfection, respectively. Post-treatment unit consisting of granular activated carbon coated with nano-silver resulting could reduce the E. coli of 5–6 logs from the septic tank effluent. These technologies show high potentials to be applied for OSS in

Southeast Asian and other developing regions for environmental improvement and public health protection.

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References

AECOM International Development, Inc. and Department of water and sanitation in developing countries (SANDEC) (2010). A rapid assessment of septage management in Asia: Policies and practices in India, Indonesia, Malaysia, the Philippines, Sri Lanka, Thailand, and Vietnam. http://pdf.usaid.gov/pdf_docs/Pnads118.pdf. Accessed 14 Sept 2015.

Asian Development Bank (ADB) (2013a). Asian water development outlook 2013. Measuring water security in Asia and the Pacific. http://adb.org/sites/default/files/pub/2013/asian-water-development-outlook-2013.pdf. Accessed 01 Aug 2015.

Asian Development Bank (ADB) (2013b). Myanmar: Urban development and water sector assessment, strategy, and road map. http://www.adb.org/sites/default/files/institutional-document/33976/files/myanmar-urban-dev-water-sector-assessment.pdf. Accessed 11 Sept 2015.

Asian Institute of Technology (AIT). (2013). *First progress report on sustainable decentralized wastewater management in developing countries: Design, operation and monitoring*. Klong Luang: Asian Institute of Technology.

Asian Institute of Technology (AIT). (2015). *Third progress report on innovative DEWAT technologies*. Klong Luang: Asian Institute of Technology.

Feachem, R. G., Bradley, D. J., Garelick, H., & Mara, D. D. (1983). Sanitation and disease: Health aspects of wastewater and excreta management. In: *World bank studies in water supply and sanitation* (Vol. 3). New York, NY: Wiley.

General Statistical Office (GSO) (2011). Viet Nam: Multiple indicator cluster survey 2011. http://www.childinfo.org/files/MICS4_Vietnam_FinalReport_2011_Eng.pdf. Accessed 14 Sept 2015.

Hutton, G., Rodriguez, U.E., Napitupulu, L., Thang, P. & Kov, P. (2007). Economic impacts of sanitation in Southeast Asia: Summary report. http://www.wsp.org/sites/wsp.org/files/publications/411200810059_EAP_ESI_summary.pdf. Accessed 01 Aug 2015.

Koottatep, T., Chapagain, S. K., Watanatanachart, J., & Polprasert, C. (2015). Application of nano-silver coated granular activated carbon for inactivation of septic tank effluent. *Journal of Water Sanitation and Hygiene for Development, 5*(4), 632–637.

Koottatep, T., Phuphisith, S., Pussayanavin, T., Panuvatvanich, A., & Polprasert, C. (2014). Modeling of pathogen inactivation in thermal septic tanks. *Journal of Water Sanitation and Hygiene for Development, 4*(1), 81–88.

Ministry of National Planning and Economic Development (MNPED) (2011). Myanmar: Multiple indicator cluster survey 2009–2010. http://www.unicef.org/myanmar/MICS_Myanmar_Report_2009-10.pdf. Accessed 14 Sept 2015.

Ministry of Public Health (MoPH) (2014). Office of the permanent secretary for public health. http://web.nso.go.th/index.htm. Accessed 15 Sept 2014.

Moe, C. L., & Rheingans, R. D. (2006). Global challenges in water, sanitation and health. *Journal of Water and Health, 4*(S1), 41–57.

Naing W (2016). Key determinants of fecal sludge management planning in Myanmar and Thailand: Case studies in Mandalay City and Nonthaburi Municipality. Dissertation Master of science in environmental engineering and management. Asian Institute of Technology.

National Statistical Office (NSO) (2012). Thailand: Multiple indicator cluster survey 2012. http://www.unicef.org/thailand/57-05-011-MICS_EN.pdf. Accessed 14 Sept 2015.

Pussayanavin, T., Koottatep, T., Eamrat, R., & Polprasert, C. (2015). Enhanced sludge reduction in septic tanks by increasing temperature. *Journal of Environment Science and Health Part A, 50*(1), 81–89.

Smets, S. (2014). Water supply and sanitation in Vietnam: Turning finance into services for the future. Water and sanitation program. Washington, D.C: World Bank Group. http://documents.worldbank.org/curated/en/588551468197392348/Water-supply-and-sanitation-in-Vietnam-turning-finance-into-services-for-the-future.

Taweesan, A., Koottatep, T., & Dongo, K. (2015). *Factors influencing the performance of faecal sludge management services: Case study in Thailand municipalities* (pp. 1–16). Development and Sustainability: Environment.
Than, M. M. (2010). Water and waste water management in Yangoon. Myanmar Ministry of Agriculture and irrigation, Irrigation Department. http://www.wepa-db.net/pdf/1003forum/9_myanmar_mumuthan.pdf. Accessed 29 Aug 2016.
United Nations Statistics Division (2016a). Country profile: Myanmar http://data.un.org/CountryProfile.aspx?crName=Myanmar. Accessed 19 Aug 2016.
United Nations Statistics Division (2016b). Country profile: Thailand. http://data.un.org/CountryProfile.aspx?crName=Thailand. Accessed 19 Aug 2016.
United Nations Statistics Division (2016c). Country profile: Vietnam.http://data.un.org/CountryProfile.aspx?crName=VietNam.Accessed 19 Aug 2016.
Van Minh, H., & Nguyen-Viet, H. (2011). Economic aspects of sanitation in developing countries. *Environment Health Insights, 5,* 63.
WHO (1989). *Health guidelines for the use of wastewater in agriculture and aquaculture*. Geneva: World Health Organization.
World Bank (2008). Economic impacts of sanitation in Vietnam a five-country study conducted in Cambodia, Indonesia, Lao PDR, the Philippines and Vietnam under the Economics of Sanitation Initiative (ESI). http://www.wsp.org/sites/wsp.org/files/publications/529200894722_ESI_Long_Report_Vietnam.pdf. Accessed 18 Nov 2015.
World Bank (2013). Executive summary. East Asia and the Pacific region urban sanitation review. Washington DC: World Bank Group. http://documents.worldbank.org/curated/en/385401468262139190/Executive-summary.
World Health Organization (WHO) (2016). Sanitation. http://www.who.int/topics/sanitation/en/. Accessed 28 Mar 2016.
World Health Organization and United Nations Children's Fund (WHO & UNICEF) (2015). Joint monitoring programme for water supply and sanitation. Estimates on the use of water sources and sanitation facilities. http://www.wssinfo.org/documents/?tx_displaycontroller[type]=country_files. Accessed 12 Sept 2015.
World Health Organization and United Nations Children's Fund (WHO & UNICEF) (2016). Joint monitoring programme for water supply and sanitation. Definitions & methods. http://www.wssinfo.org/definitions-methods. Accessed 28 Mar 2016.