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Research Paper

Inconvenient truth: unsafely managed fecal sludge after achieving MDG for decades in Thailand

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ABSTRACT

In most low- and middle-income countries, due to financial constraints and improper management practices, the expansion of conventional centralized systems to enhance wastewater management services is not practical. Despite the fact that the majority of the world population has met the Millennium Development Goals 7c (MDG7c) targets, more than 2.5 billion are still using unimproved sanitation facilities and affecting the safety of drinking water and public health. Because of this problem, a novel approach on 'Non-Sewered Sanitation' with decentralized treatment systems is being recognized as a promising alternative to accomplish the Sustainable Development Goal No. 6 (SDG6) targets on 'Safe Water and Sanitation' and bringing health benefits to the people. This study aimed to investigate the current status of access to improved sanitation facilities in relation to the MDG7c and SDG6 in Thailand and comparing with other countries, including the effects of unsafely managed fecal sludge (FS) on the prevalence of diarrhea and liver fluke infections. The prevailing constraints and weaknesses were identified, and effective sanitation management measures to accomplish SDG6 targets were recommended. Based on data collected from 20 cities located in the north and northeastern regions of Thailand during the period of 2015–2020, the sanitation facilities data on conventional centralized systems and FS management facilities that affect the prevalence of diarrhea and liver infections were analyzed and interpreted using statistical and response surface methodology techniques. The findings showed that most of the surveyed cities have achieved the MDG7c targets, but 70% of the FS generated from on-site sanitation systems are still unsafely managed, caused by limited expansion of sewage systems for wastewater collection and conveyance (with inadequate operation and maintenance) as well as the financial constraints, especially in areas outside of urban neighborhoods. The effective sanitation management practices to accomplish the SDG6 targets were proposed such as increasing the capacity of sanitation facilities to be 55,000 m^3/day/30,000 households, designing appropriate FS collection program and treatment technology, and providing more awareness programs for safe sanitation management and health risk protection.

Key words: effective sanitation measures, fecal pathogen infections, fecal sludge management, improved sanitation facilities, Millennium Development Goals, Sustainable Development Goals

HIGHLIGHTS

- This has identified an inconvenient truth after achieving MDG7c in relation to SDG6.
- This has identified the reasons why many countries could not achieve SDG6?
- This has identified the relationships between MDG7c and SDG6.
- This has indicated the relationships between the effect of unsafely managed FS and fecal pathogen infections.
- This has proposed an effective way to accomplish SDG6.

INTRODUCTION

Despite the fact that more than 70% of the world population has met the Millennium Development Goals 7c (MDG7c) targets, more than 2.5 billion people still lack improved sanitation facilities. The Joint Monitoring Program for Water Supply and Sanitation (JMP) of World Health Organization (WHO) and United Nations International Children's Emergency Fund (UNICEF) reported the progress of the MDG7c targets in which only 64 countries, mostly in Asia and Africa, met the

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MDG7c targets for sanitation facilities (UNESCO 2015; Adams *et al.* 2016; Satterthwaite 2016; UN 2017). In sub-Saharan Africa, for example Ethiopia, more than 40% of the Ethiopian population still practiced open defecation, while most people in slum areas (90%) used unsafe water and were without toilet facilities. Although Thailand and Vietnam are on track to meet the MDG7c targets for access to improved water and sanitation coverage, only 10–20% of the FS generated from on-site sanitation systems are safely managed (WHO/UNICEF 2015). These problems have caused environmental and health impacts such as diarrheal diseases and parasitic infections and were barriers to accomplishing the SDG6 targets (Bongartz *et al.* 2016; Holm *et al.* 2016; Jayathilake *et al.* 2019; Koottatep *et al.* 2021). In urban Cambodia, for example, 54% of people in urban poor areas still practice open defecation which usually causes contamination of the water resources and groundwater, affecting the prevalence of fecal pathogen infections (UNSECO 2015; Mills *et al.* 2018).

There have been several studies on monitoring progress to achieve the MDG 7c which focused on household-level inventories of toilet facilities, but ignoring improved sanitation facilities in relation to safe containment, collection, and treatment of FS. A novel approach on 'Non-Sewered Sanitation' with decentralized treatment systems is considered to be a promising alternative to achieve SDG6 targets and bringing health benefits to the people. Several studies have highlighted deficiencies of decentralized treatment systems in different countries, resulting in disposal of untreated FS into nearby storm drains and water resources (Taweesan *et al.* 2015a, 2015b; Arphacharus 2016; De La Brosses *et al.* 2017; Freeman *et al.* 2017; Bindra *et al.* 2021). These findings were confirmed by Weststrate *et al.* (2019) who mentioned that, to accomplish the SDG6 targets, consideration should be given to safe sanitation management from containment to adequate treatment facilities. In other cases, there is evidence of fecal pathogen infections in different cities in Asia and Africa caused by ineffective FS collection services and treatment (Bisung *et al.* 2015; Taweesan *et al.* 2015a, 2015b; Koottatep *et al.* 2021). In this respect, with the demand for sanitation facilities and public health protection, identifying the current status of access to improved sanitation facilities in relation to the MDG7c and SDG6 targets are increasingly important. The objectives of this study were: (i) to investigate the current status of access to improved sanitation facilities in relation to the MDG7c and SDG6 targets in Thailand and comparing with other countries, (ii) to analyze the effects of unsafely managed FS on the prevalence of diarrhea and liver fluke infections, and (iii) to identify prevailing constraints and suggest some effective measures to accomplish the SDG6 targets for safely managed sanitation and health risk protection.

METHODOLOGY

Information on the performance of sanitation management practices from various cities was analyzed to assess the achievement of the MDG7c and SDG6 targets (Hopewell & Graham 2014; Sabogal *et al.* 2014; Bisung *et al.* 2015; Malik *et al.* 2015; Weststrate *et al.* 2019; Wolf *et al.* 2019). The literature points to the importance of access to basic sanitation facilities (such as latrines) for measuring progress toward MDG7c. Another mention is that fecal sludge (FS) in latrines needs to be properly managed along the sanitation service chain to accomplish the SDG6 targets. Based on published literatures and key informants consultation (such as government authorities and service providers), the access to improved sanitation facilities was measured for monitoring progress toward the MDG7c in this study. While systematic assessment of 'safely' or 'unsafely' managed along the sanitation services chain was measured, the effective measures were proposed to accomplish the SDG6 targets.

Data on access to improved sanitation facilities were based on availabilities of on-site sanitation facilities and conventional centralized systems from containment to treatment. Information on improved sanitation facilities was collected from 20 cities located in the north and northeastern regions of Thailand that have relatively high diarrhea and liver fluke infections during the period of 2015–2020. Figure 1 shows locations of the 20 cities which are subdivided into 6 city municipalities, 43 town municipalities, and 256 subdistrict municipalities. These municipalities were classified based on a number of households ranging from 5,000 to 10,000, representative of local levels in Thailand.

Most data were obtained from the Department of Health, Ministry of Public Health in Thailand relating to sanitation facilities of the 305 municipalities which included: (1) containments (such as type of on-site sanitation facilities, open defecation, and direct FS discharges into open drains), (2) emptying and transport (such as number of households connected to conventional centralized systems per city, number of vacuum trucks, and frequency of FS collection services), and (3) treatment (such as type of treatment technology, capacity of conventional centralized systems, and FS treatment plants). A total of 198 responses were received which were sub-divided into 6 city municipalities, 43 town municipalities, and 149 subdistrict municipalities, with a response rate of approximately 65%. However, about 35% of these municipalities did not have

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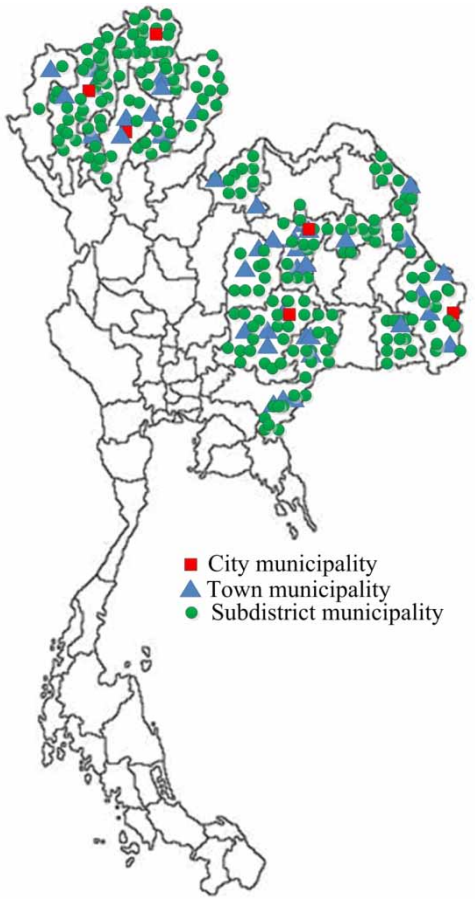

Figure 1 | Study areas in north and northeastern Thailand.

complete data of the above three categories, and the missing data were collected from questionnaire surveys and key informants consultation. The key informants who contributed to this study were administrators 25 (12%); utility providers 22 (11%); households 124 (62%); and others 29 (15%).

Descriptive statistics and frequencies were generated and analyzed to present fecal waste flow from containment to treatment, including the achievements on the MDG7c and SDG6 targets. Infection rates in this study were identified based on actual situations of the surveyed cities by comparing the recent nationwide survey conducted by the Department of Disease Control, Ministry of Public Health of Thailand during the period of 2015–2020. The infection rates were assigned 'high' if the prevalence of diarrhea and liver fluke infections was more than 20%, 'moderate' if the prevalence was from 10 to 20%, and 'low' if the prevalence was less than 10% (DID 2013; DDC 2020). The Response Surface Methodology (RSM) technique was applied to identify optimum conditions to achieve effective sanitation management practices for each city. To identify the effective sanitation management levels, data on the sanitation performance from various cities were applied (Taweesan *et al.* 2015a, 2015b; ADB 2016; De La Brosses *et al.* 2017; Bindra *et al.* 2021). A city is considered to have effective sanitation management practices (such as Tokyo, Japan and Nonthaburi, Thailand) if collection efficiencies were greater than 80%, 'moderate' if the collection efficiencies were between 50 and 80%, and 'poor' if the collection efficiencies were less than 50% (such as Malang, Indonesia; Punjab, India; and Kuala Terengganu, Malaysia).

RESULTS AND DISCUSSION

Current status of access to improved sanitation facilities in selected cities in Thailand

The results on improved sanitation facilities from containment to treatment from 20 cities located in the north and northeastern regions of Thailand are shown in Figure 2. Only 30% of the FS generated from on-site sanitation systems are safely managed, while about 70% of the FS generated from on-site sanitation systems are unsafely managed. About 52% of the

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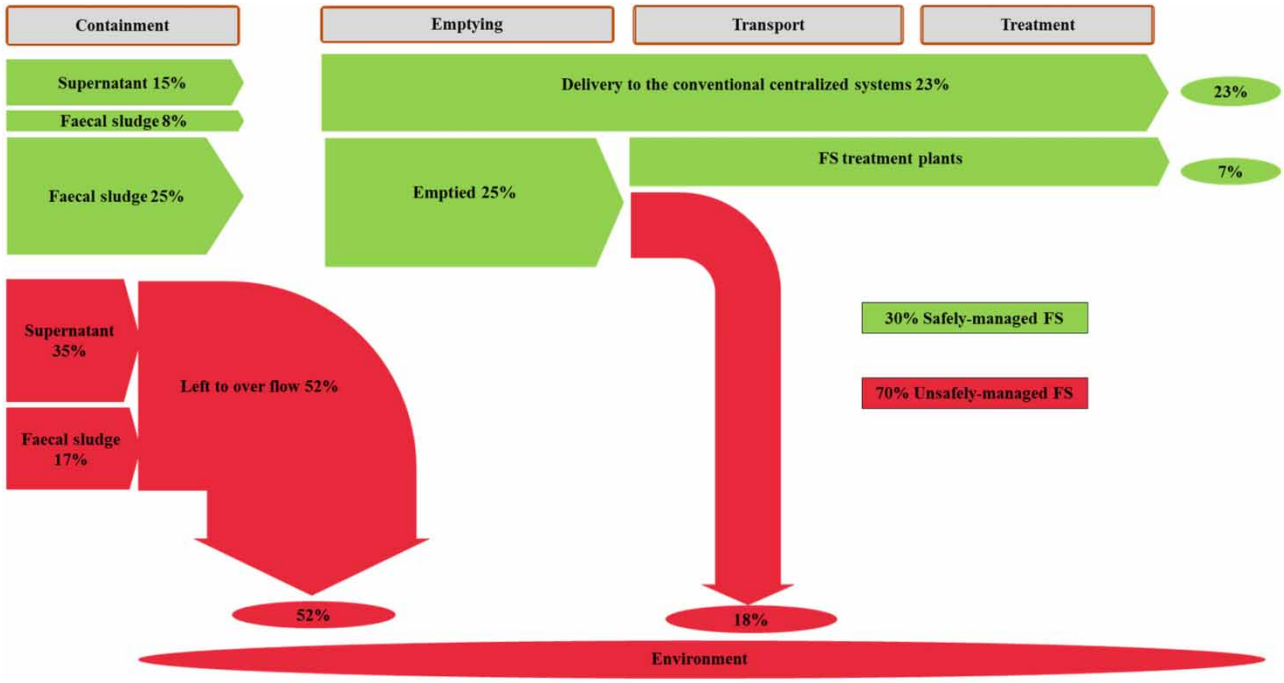

Figure 2 | Current status of access to improved sanitation facilities covering 20 cities in Thailand.

FS are not emptied but are connected/overflow to open drains or local sewers. For containment connected to a sewerage system, 23% of the FS (15% from supernatant and 8% from solids) are delivered to the conventional centralized systems. For the FS emptying and treatment services, it was found that 25% of FS generated from on-site sanitation systems are emptied by local government authorities (LGAs) and private operators; some are transported to treatment (7%), and 18% are illegally dumped to the nearby environment. Similar results documented by WHO/UNICEF (2017) and Wolf *et al.* (2019) referred to the inadequate FS collection and treatment facilities which hampered the efforts to achieve the SDG6 targets for safely managed sanitation and hygiene services.

Achievement of MDG7c and SDG 6 targets of Thailand and comparing with other countries

The detailed results on the achievement of the MDG7c and SDG6 targets of Thailand and comparing with other countries are shown in Figure 3. It can be seen that Thailand has achieved the MDG7c targets (99%), but not other countries in South Asia (India and Nepal) and Southeast Asia (Myanmar and Vietnam). The results of Figure 3 implied that although many countries have achieved the MDG 7c targets, safely managed FS is still a challenge to accomplish the SDG6 targets, especially in South and Southeast Asia. A similar finding was documented by UNESCO (2015) and Bindra *et al.* (2021), which reported that most urban cities in India still practice open defecation, causing not only environmental and economic impacts, but also public health problems. In Southeast Asia, for example in Thailand, about 19 million m^3 of FS from on-site sanitation systems (conventional septic tanks or cesspits/cesspools) are produced annually, but more than 90% of these FS are unsafely managed (Satterthwaite 2016; WHO/UNICEF 2017). This result was confirmed by Wankhade (2015) and Taweesan *et al.* (2015a, 2015b) who reported that access to improved sanitation in the low- and middle-income countries was usually too limited for adequate FS collection, treatment, and disposal, causing serious fecal pathogen infections.

Effects of unsafely managed FS on the prevalence of diarrhea and liver fluke infections

The effects of unsafely managed FS on the prevalence of diarrhea and liver fluke infections are shown in Figure 4. It can be seen that all the 20 cities surveyed were found to have high unsafely managed FS in which more than 90% of the untreated FS are directly discharged into nearby storm drains or watercourses. This result implies that unsafely managed FS had direct effects on the prevalence of liver fluke ($r = 0.65$) and diarrhea infections ($r = 0.82$), as previously documented by Koottatep *et al.* (2021). The findings indicated that unsafely managed FS had significant direct effects on the prevalence of fecal pathogen infections such as liver fluke and diarrhea infections. It was found that the significant factors such as type of on-site

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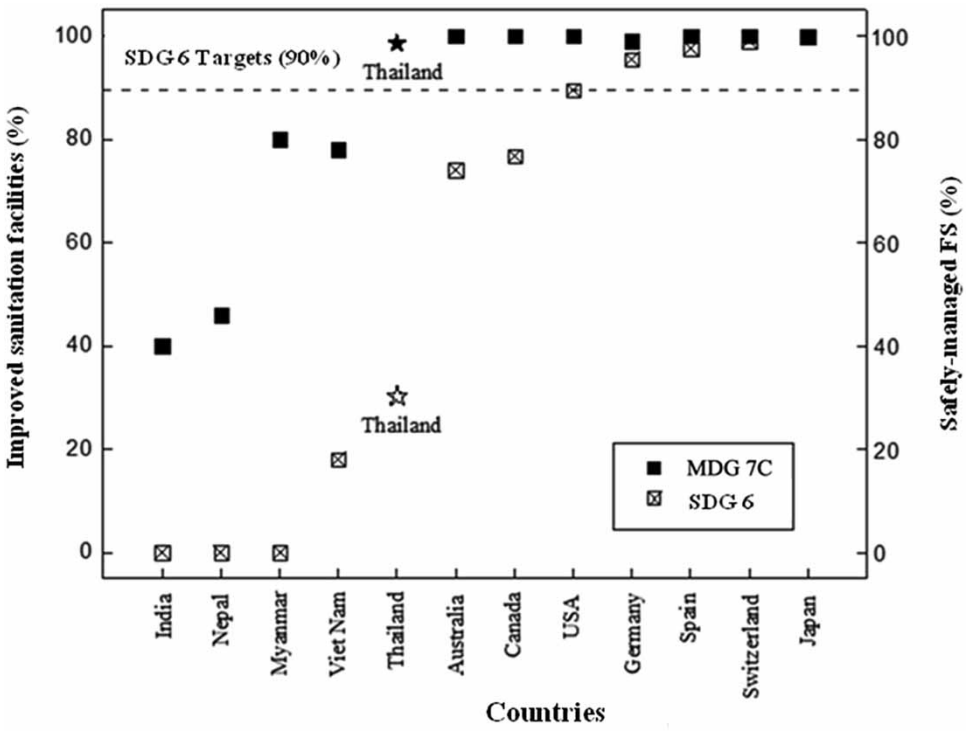

Figure 3 | Achievements of MDG 7c and SDG6 targets of Thailand and other countries. *Sources*: WHO/UNICEF (2015, 2017, 2021).

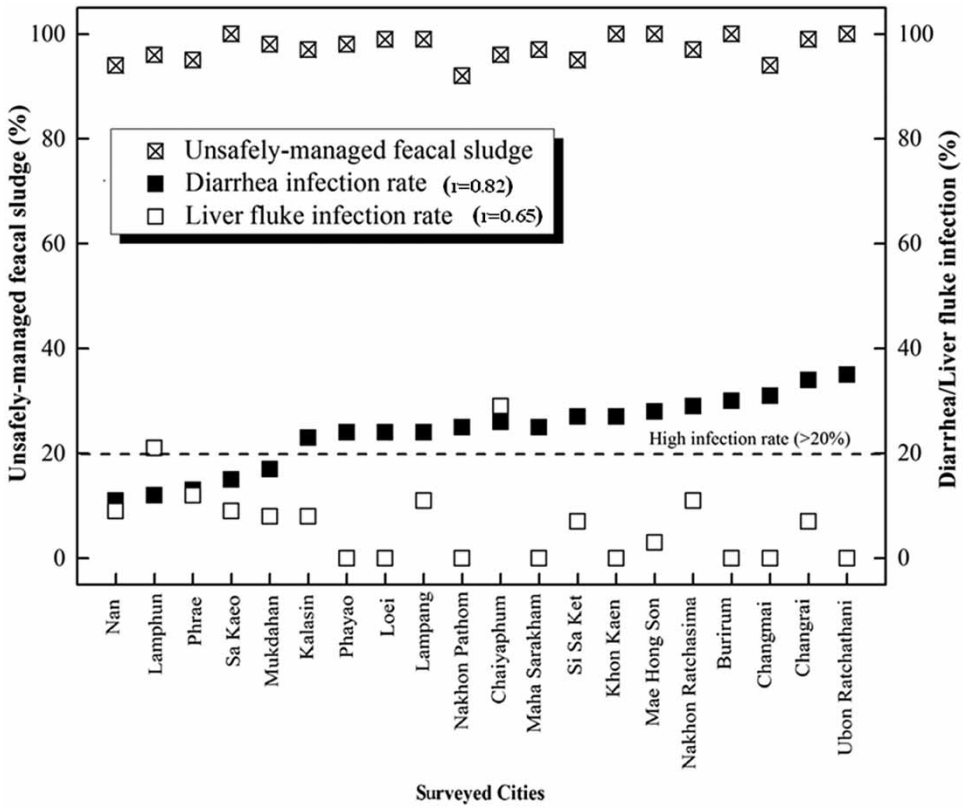

Figure 4 | Effects of unsafely managed FS on the prevalence of diarrhea and liver fluke infections of the 20 cities in Thailand.

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sanitation systems, frequency of FS emptying, and open defecation had significant direct effects on the prevalence of diarrhea and liver fluke infections. Similar findings were confirmed by Jung *et al.* (2017), showing the effects of unsafely managed sanitation on diarrhea morbidity. The results shown in Figure 4 indicate that 15 of the 20 cities surveyed were found to have a 'high' prevalence rate of diarrhea infections; 5 of the 20 cities surveyed were considered to have 'moderate' prevalence rate of diarrhea infections. The main reason for the high prevalence of diarrhea infections was inadequate FS collection and treatment facilities, poor personal hygiene, and unsafe drinking water. Other similar findings documented that the prevalence of diarrhea infections depends not only on the inadequate sanitation practices, but also on the personal hygiene and knowledge of consumption of unsafe drinking water and their relationships with diarrhea infections (Joob & Wiwanitkit 2015; León *et al.* 2018; Khadra *et al.* 2019). Often, inadequate FS management (FSM) facilities lead to contamination of natural resources and groundwater, causing infections of water-borne diseases, particularly in the absence of water resources and filtration (Ejemot-Nwadiaro *et al.* 2015; Wolf *et al.* 2019). To address these problems, there should be programs to raise people's awareness about diarrhea infections relating to consumption of unsafe drinking water and unsafely managed FS. Drinking water and water supply from natural resources should be properly treated before consumption in order to prevent diarrheal infections.

The prevalent rates of liver fluke infections of the 18 surveyed cities were less than 20%; only two cities were found to have 'high' prevalence of liver fluke infections which were Lamphun and Chaiyaphum, as shown in Figure 4. From the survey results, the LGAs responsible for FSM services in these two cities had no adequate FS collection trucks and treatment facilities. In addition, cesspools, the most prevalent toilets in these two cities (more than 95%) were found to function poorly with the partially treated effluents overflowing and contaminating nearby watercourses. It is evidenced that one of the most common causes of liver fluke infections in these two cities is the lack of safely managed sanitation, particularly the inadequate FS collection and treatment facilities, as confirmed by Baraki *et al.* 2019. Other studies have identified lacking improved sanitation facilities as the cause of fecal pathogen infections (Freeman *et al.* 2017; Bindra *et al.* 2021). In this respect, designing appropriate FS collection program and treatment technology is strongly recommended to reduce fecal pathogen contamination of the nearby environment which could reduce the prevalence of liver fluke infections, as reported by Koottatep *et al.* (2014) and Lindberg & Rost (2018).

Effective measures to accomplish SDG6 targets for safely managed sanitation and health risk protection

The effective sanitation management practices were proposed based on the actual data of the 20 surveyed cities in Thailand and using the scales of the collection efficiency and the sanitation facilities, as presented in Figure 5. A city is considered to

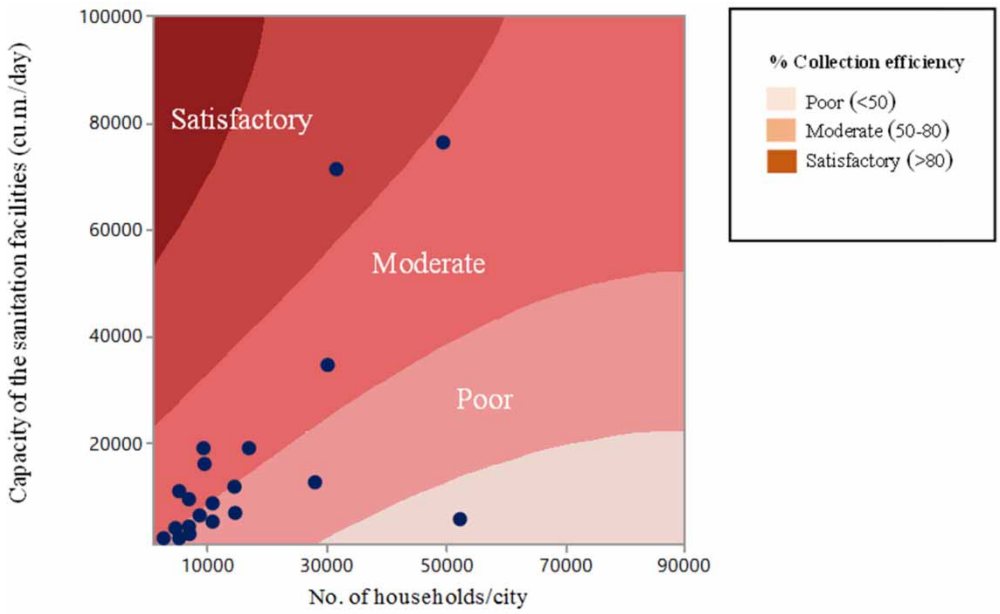

Figure 5 | RSM plot of sanitation facilities collection efficiencies.

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have effective sanitation management practices if collection efficiencies were greater than 80%. Figure 5 indicates the relationships among the collection efficiency, the number of households per city, and the capacity of the sanitation facilities. It can be seen that 12 of the 20 cities surveyed were found to have 'poor' collection efficiency; 7 of the 20 cities surveyed were found to have 'moderate' collection efficiency; and only one city surveyed was found to have 'satisfactory' collection efficiency. From the RSM plot of Figure 5, the capacity of the sanitation facilities should be at least 55,000 m^3/day/30,000 households to achieve a satisfactory collection efficiency of more than 80%. The 'moderate' and 'poor' collection efficiencies of about 50 and <20% would occur for cities having the ratios of the capacity of the sanitation facilities per number of households of 25,000:30,000 and 2,000:30,000, respectively.

It can be seen from Figure 5 that most of the surveyed cities were found to have 'poor' collection efficiency, except for Nakhon Ratchasima city in northeastern Thailand which was 'satisfactory'. From the survey results, it was found that the Nakhon Ratchasima city has subsidies from the central governments to support the sanitation management practices in both wastewater and FS collection and treatment facilities. Moreover, the Nakhon Ratchasima city promotes the participation of local communities and private sectors in the efficiency of sanitation management and sustainable sanitation development. The main reason for the poor collection efficiencies of the 12 cities surveyed was the limited expansion of sewage systems for wastewater collection and conveyance (with inadequate operation and maintenance) as well as the financial constraints. Despite the MDG 7c targets which aim to improve access to basic sanitation facilities, the access to improved sanitation facilities in Thailand has occurred at a very slow pace, especially on the collection services. To address these problems, access to improved sanitation facilities such as conventional centralized systems and FS treatment facilities should be properly implemented and managed to provide adequate wastewater and FS collection facilities for safely managed sanitation and health risk protection toward the SDG6 targets.

SUMMARY CONCLUSIONS

This study investigated the current status of access to improved sanitation facilities in relation to the MDG7c and SDG6 targets in Thailand, including the effects of unsafely managed FS on the prevalence of diarrhea and liver fluke infections. Based on the findings obtained from this study, about 70% of the FS generated from on-site sanitation systems are discharged directly into open drains and local sewers which indicated unsafely managed FS. Despite the fact that most of the surveyed cities have achieved the MDG7c target, safely managed FS is still a challenge to accomplish the SDG6 targets. Due to the limited expansion of sewerage systems for wastewater collection and conveyance (with inadequate operation and maintenance) as well as the financial constraints, these cities were found to have poor FS collection efficiencies. Some effective sanitation management practices to accomplish the SDG6 targets were recommended such as increasing the capacity of sanitation facilities to be 55,000 m^3/day/30,000 households, designing appropriate FS collection program and treatment technology, and providing more awareness programs for safe sanitation management and health risk protection.

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DATA AVAILABILITY STATEMENT

All relevant data are included in the paper or its Supplementary Information.

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