

Short Communication

The potential application of non-sewered sanitation systems in healthcare facilities – a case study in Beijing, China

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ABSTRACT

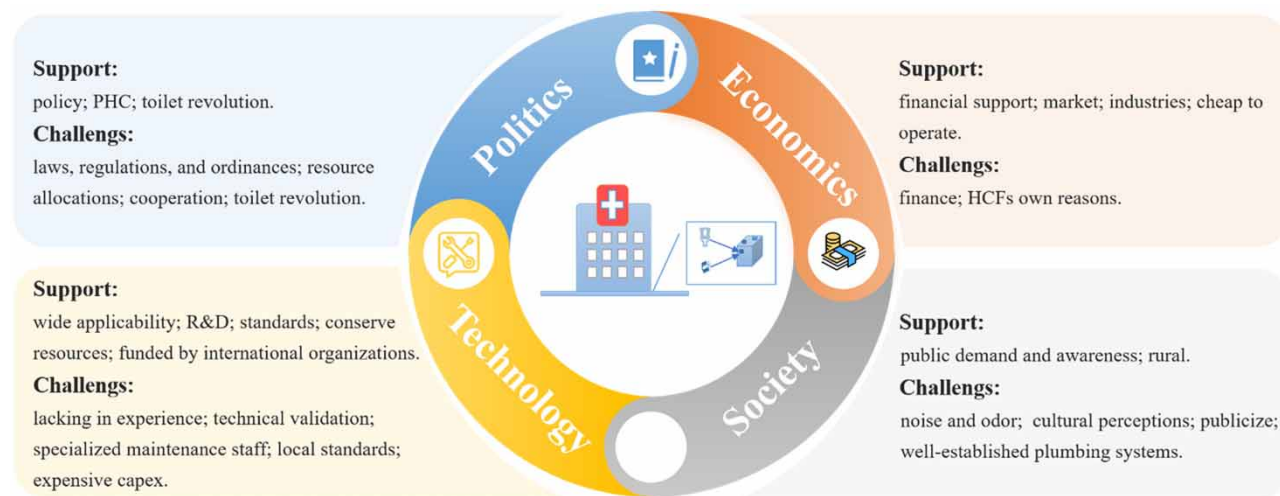
Non-sewered sanitation systems (NSSSs) could improve sanitation in healthcare facilities (HCFs) within urban areas of developing countries. However, they are not usually applied in these areas. In this study, the PEST analysis, which refers to analyzing the feasibility and potential of a project in terms of four factors – political, economic, social, and technological – was used to examine the practical application of NSSS in HCFs in Beijing, China. The results found that the support of NSSS applications in HCFs outweighs the challenges. Particularly in rural areas, NSSS has significant potential for application. Implementing these strategies would enhance sanitation in HCFs and reduce the spread of diseases.

Key words: healthcare facilities, PEST analysis, non-sewered sanitation systems, sanitation, sustainability

HIGHLIGHTS

- A total of 18 HCFs were visited onsite and stakeholders were interviewed in person in Beijing.
- PEST analysis was employed to study the application of NSSSs in HCFs.
- Support and challenges of application NSSSs in HCFs were identified.
- Application of NSSSs in HCFs is challenging but promising in LMICs.

GRAPHICAL ABSTRACT



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1. INTRODUCTION

Globally, illnesses caused by contaminated drinking water and poor hygiene practices are the main causes of child deaths (Hannah *et al.* 2020; WHO *et al.* 2023a). Global estimates show that there are nearly 1.7 billion cases of diarrhoeal diseases in children annually, resulting in the deaths of approximately 443,832 children yearly (WHO 2024). This problem is compounded by a lack of adequate sanitation in healthcare facilities (HCFs) predisposing children to diseases at the facilities (Mohamed 2024). Reports show that 3.85 billion, 1.7 billion, and 7.8 million people, respectively, lack basic water, hygiene, and sanitation (WASH) services at HCFs (WHO 2023b). For every 100 patients in acute care hospitals, 7 patients in high-income countries (HICs) and 15 patients in low- and middle-income countries (LMICs) will contract at least one health-care-associated infection (HAI) during their hospitalization (WHO 2022). There is a significant presence of pathogenic microorganisms (Ding *et al.* 2021) and various physical and chemical hazardous substances in the environment of HCFs, making them the most likely sites for HAIs to occur (Derso *et al.* 2023). Relevant data show that pathogens can remain on hands for several hours (Kampf and Kramer 2004) and on the surfaces of objects for several months (Bhalla *et al.* 2004), posing a high risk of HAIs. The provision of WASH services in HCFs, along with standard precautions, can significantly reduce the likelihood of children developing HAIs (Uprety *et al.* 2024) and surgical-site infection (Allegranzi *et al.* 2011). This is because WASH services help to prevent the spread of infections among healthcare workers, patients, and patients' companions (Gebremicael *et al.* 2024). Beyond the health implications, providing good sanitation is a sign of respect for the patients and a manifestation of the people-oriented service concept at HCFs (Sutherland *et al.* 2021).

China has been committed to the toilet revolution and many toilet technologies have been developed. Among them, non-sewered sanitation systems (NSSS) were developed to cater to half of the global population who are not connected to sewer systems (Michalak *et al.* 2023; Strande 2024). One of the most distinctive features of NSSS is that they dispose of their fecal matter without connecting to sewers (ISO 2018). The emergence and continued development of NSSS have opened up the possibility of providing safe and sustainable sanitation services to HCFs in areas without sewers (Michalak *et al.* 2023). However, despite the widespread use of NSSS in China, they have not been applied in HCFs. Given that the number of HCFs in Beijing, China reached 12,518 at the end of 2023, with the annual number of visitors reaching 29.09 million (BMHC *et al.* 2024), the importance of the fundamental sanitation services that toilets provide should not be overlooked. Therefore, it is important to have an in-depth study of the factors affecting the application of NSSS in HCFs. Studying these factors provides critical insights that aid in making strategic decisions about employing NSSS in HCFs.

2. MATERIALS AND METHODS

In this study, we assessed the feasibility of employing the NSSS in HCFs in Beijing, China using PEST analysis. PEST is an acronym that represents four sources of change: political (P), economic (E), social (S), and technological (T) (Sammut-Bonnici & Galea 2015; Buye 2021; Cox 2021). PEST analysis is a powerful and widely utilized tool for understanding strategic risks (Sammut-Bonnici & Galea 2015). The potential advantages of using PEST analysis include aiding in strategic decision-making, obtaining a competitive edge, aligning positively with external factors, and preventing mistakes that could hinder effective performance (Cox 2021). In addition, the importance of using PEST analysis lies in its ability to identify opportunities and respond to threats, establish goals, recognize key factors and forces, develop action plans, and set objectives to enhance performance (Buye 2021). The PEST analysis method examines applying NSSS in HCFs in Beijing, China four external macro-environmental influences: politics, economics, society, and technology. This PEST analysis method helps in identifying opportunities and challenges influencing applying NSSS in HCFs in Beijing, China, evaluating the market potential of NSSS in HCFs applications, and formulating a strategic development plan. We developed an interview outline consisting of 11 questions (Supplementary Material), and first-hand research information was obtained by interviewing individuals responsible for toilet management in 18 HCFs in Beijing (Figure S1). Through compiling interview materials and utilizing the PEST analysis method, we analyzed the factors influencing Beijing's potential for implementing NSSS in HCFs.

3. RESULTS AND DISCUSSION

Results of the PEST analysis of the application of NSSS in HCFs in Beijing are shown in Table 1.

Table 1 | PEST analysis for NSSS application in HCFs

| Items | For | Against |
|-------|---|--|
| P | <ol style="list-style-type: none"> 1. Favorable policy support. 2. Patriotic health campaigns (PHC). 3. Toilet revolution. 4. The government intends to promote the development of toilet revolutions in HCFs. | <ol style="list-style-type: none"> 1. The government's laws, regulations, and ordinances are not sufficiently developed. 2. Resource allocations need to be optimized. 3. There is a need for greater cooperation among government departments. 4. The toilet revolution undertaken by the government in HCFs has focused mainly on the front end. |
| E | <ol style="list-style-type: none"> 1. Financial support from the government. 2. HCFs have a market for NSSS applications. 3. It can promote the development of industries related to NSSS. 4. NSSS are cheap to operate. | <ol style="list-style-type: none"> 1. It isn't easy to finance in total. 2. HCFs are not interesting enough in sanitary systems. 3. Construction and disposal costs increase the budget of HCFs. 4. Most HCFs do not have enough funds to invest in the renovation. |
| S | <ol style="list-style-type: none"> 1. Public demand for a better toilet environment has increased. 2. NSSS can raise public awareness of safe and sustainable sanitation services. 3. NSSS have great potential for application in HCF in rural China. 4. There are many public complaints about HCF toilets. | <ol style="list-style-type: none"> 1. NSSS need to consider the impacts of noise and odor on surrounding residents during construction and operation. 2. Differences in public cultural perceptions hinder the application of NSSS in HCFs. 3. NSSS are not sufficiently publicized in society. 4. Many HCFs already have well-established plumbing systems and have no incentive to overhaul them. |
| T | <ol style="list-style-type: none"> 1. NSSS technology is suitable for a wide range of scenarios. 2. China has been encouraging research and development (R&D) in NSSS technologies. 3. Existing standards can fuel further R&D directions for NSSS technology. 4. Some of the NSSS technologies can conserve resources (water resources, power resources, etc.). 5. R&D is funded by international organizations such as the Bill & Melinda Gates Foundation (BMGF). | <ol style="list-style-type: none"> 1. There is a lack of implementation experience to draw upon. 2. NSSS technology requires further technical validation. 3. NSSS require specialized maintenance staff for operation and maintenance. 4. There are no local standards directly related to toilets in HCFs in Beijing, China. 5. The estimated capex of NSSS technology needs to be further reduced. |

3.1. Political analysis

The government has issued a series of policy documents to assist HCFs in making continuous improvements in sanitation (Table S1). PHC, promoted by the Chinese government, has been ongoing since the establishment of China and is still active today. The campaign focuses on the 'two managements and five improvements' in rural areas and sanitary cities in urban areas, emphasizing the continuous enhancement of the sanitation system. This initiative aims to improve the quality of sanitation services for Chinese citizens and reduce the spread of diseases. China's Toilet Revolution, which began in 2015, has laid the groundwork for using NSSS in HCFs, with increasing policy support and institutional optimization. Additionally, the government's Circular on Special Action on Toilet Tidying in HCFs issued in 2019 directly focuses on toilet refurbishment in HCFs, providing strong policy support for the toilet revolution in HCFs.

NSSS, as a new type of sanitation facility, is not yet well developed in terms of relevant laws, regulations, and ordinances. At present, Beijing's toilet revolution focuses on converting rural toilets and tourism facilities but does not give sufficient attention to HCFs, which necessitates policy support to optimize resource allocation. The construction and management of NSSS involve several government departments, such as the Beijing Municipal Finance Bureau (BMFB), Beijing Municipal Ecology and Environment Bureau (BMEEB), BMHC, Beijing Municipal Commission of Housing and Urban-Rural Development (BMCHURD), and others. In practice, coordination and communication between government departments are crucial. Insufficient coordination can result in slow project progress and inefficient use of resources. Additionally, the Beijing government's 'toilet revolution', aimed at promoting HCFs, has primarily focused on constructing and assessing the front end of toilet facilities (e.g. installation of accessible sanitary facilities and provision of toilet paper). However, insufficient attention has been given to the back end of the toilet, specifically the fecal waste treatment and disposal system, which requires enhancement in this aspect.

3.2. Economic analysis

The Ministry of Finance (MOF) and other departments provide annual financial subsidies to HCFs to enhance healthcare services and security capacity. For instance, Beijing receives annual subsidies of ¥54.39 million, ¥66.28 million, and ¥70.36 million from 2022 to 2024. Enhancing healthcare service levels in HCFs is part of healthcare security capacity building. Further, HCFs can also apply for special funds to upgrade the sanitation system. For instance, Beijing Children's Hospital has applied for ¥9 million in special funds to rectify safety hazards and upgrade the sewage treatment process. Beijing's year-on-year increase in the number of HCFs and the number of visits indicates that the demand for toilets remains high (Figure 1(a)). Hence, the construction and maintenance of sanitation systems in HCFs is important which means an existing market for NSSS applications. The promotion of NSSS will lead to the development of related industries. NSSS also has relatively low operating costs, mainly for the maintenance of excreta disposal equipment and the consumption of disinfectants.

Due to the longer payback period and higher risk of NSSS projects, it is often challenging to secure support from financial institutions (Zaqout *et al.* 2024). As for the HCFs, the lack of direct benefits from the operation and maintenance of the sanitation system often leads to a lack of interest on the part of HCF leaders in upgrading the sanitation system. The construction of NSSS, the treatment and disposal of fecal matter, and the consumption of toilet cleaning supplies increase the budget of HCFs and do not result in direct economic revenue. Unfortunately, most HCFs are underfunded in sanitary facilities and cannot afford to invest in renovation. These are serious challenges for the promotion of NSSS.

3.3. Social analysis

Nowadays, public demand for a better toilet environment is increasing. There are new demands for the effectiveness of fecal waste treatment at both the national and social levels. The popularization of NSSS helps raise public awareness of safe and sustainable sanitation services, enhance public health consciousness, reduce HAIs, and promote the progress of social civilization. Furthermore, the number of HCFs in rural China reached 651,390 in 2021, accounting for 63.2% of the total number (Figure 1(b) and 2(c)) (NHC 2022). In most rural areas, there are no sewer connections, which enables the potential application of NSSS. In addition, many public complaints about the toilet environment and dirty toilets still exist in some HCFs.

NSSS needs to consider the control of noise and exhaust emissions during construction and equipment operation. In some areas, especially those with a strong influence of traditional culture, there may be psychological barriers to the use of NSSS, which need to be gradually changed utilizing publicity and education. Besides, due to the novelty of NSSS compared with

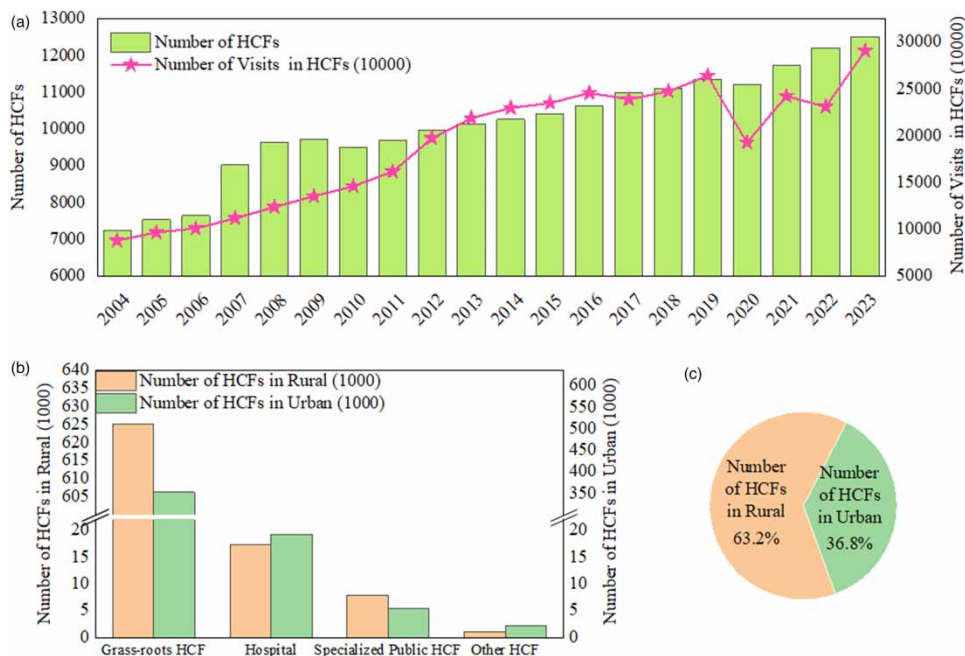


Figure 1 | (a) Number of HCFs (BMBS 2023; BMHC *et al.* 2024) and visits to HCFs (BMHC *et al.* 2014, 2024) in Beijing from 2004 to 2023, (b) number of HCFs (NHC 2022), and (c) the ratio of HCFs (NHC 2022) in rural and urban areas of China in 2021.

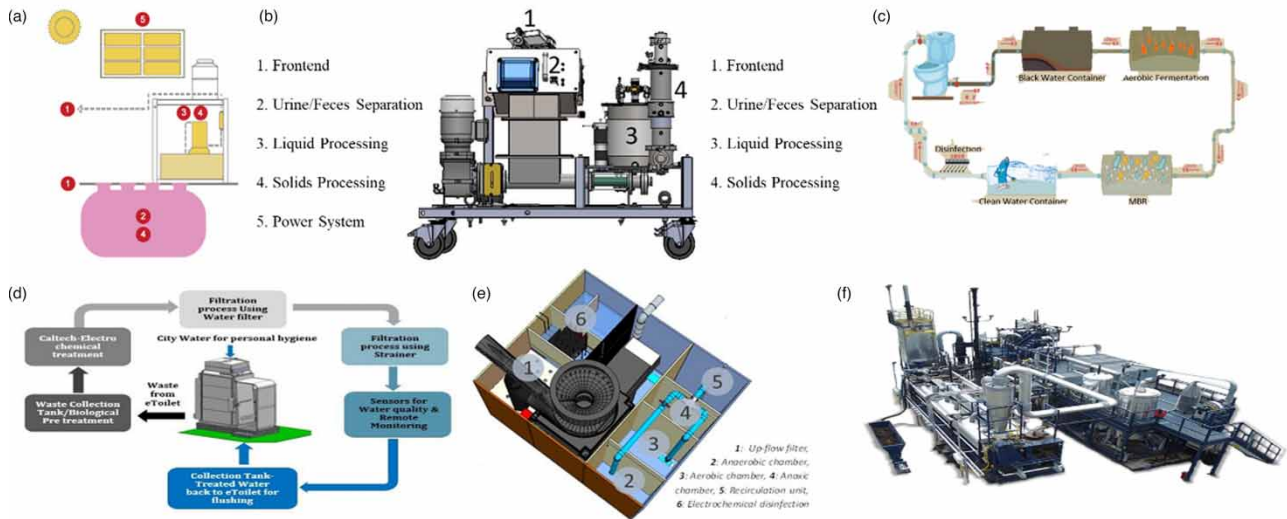


Figure 2 | Schematic of six NSSS applicable to HCFs (ANSI Sanitation 2024): (a) electrochemical reinvented toilet, (b) dry combustion reinvented toilet, (c) biological reinvented toilet, (d) electrochemical reinvented toilet, (e) biological and physicochemical reinvented toilet, and (f) omni-processor (SEDRON® TECHNOLOGIES 2024).

traditional sanitations, NSSS are not sufficiently publicized in society. Some people may have doubts and concerns about them. From the perspective of HCFs, many HCFs already have mature sewerage network systems, resulting in no incentive to carry out the construction and renovation of NSSS.

3.4. Technological analysis

Six NSSS technologies, developed with investment from the BMGF (Table S2 and Figure 2), have been deemed suitable for HCFs (Cid *et al.* 2022). NSSS in general are highly adaptable and can function effectively in various harsh environments, including extreme cold, high temperatures, drought, and other challenging conditions. The Chinese government is also encouraging the R&D of toilet technology. By examining a series of standards issued by the Chinese government regarding the construction of toilets in HCFs (Table S3), it is evident that the Chinese government has established specifications and requirements for the construction, management, and upkeep of toilets in HCFs to advance NSSS technology, thereby fostering the progress of NSSS technology. The study identified five out of six technologies (Figure 2(a), 2(b), 2(c), 2(e), and 2(f)) that can be powered entirely by solar energy or use solar energy for power generation. Three of these technologies (Figure 2(a), 2(b), and 2(c)) do not require an external water supply, enabling the NSSS to be widely utilized across the country. This can help expand the coverage in HCFs. The NSSS requires a low economic cost to treat fecal waste effectively. Thankfully, the development of NSSS technologies has been funded by relevant national organizations such as BMGF.

Although NSSS has many advantages, large-scale application in HCFs is limited, and there is a scarcity of implementation experience to reference. Moreover, since the NSSS technology has not been deployed on a large scale in HCFs, further technology validation work is needed. Additionally, maintaining NSSS poses challenges and requires professional maintenance personnel for regular upkeep and cleaning; without this, hygiene conditions may deteriorate, negatively impacting user experience. It is important to note that although the government has introduced many relevant standards, national, industrial, and provincial standards for toilets in HCFs have not yet been introduced (Cheng *et al.* 2024). This poses a challenge when applying NSSS in HCFs in Beijing, China. Finally, the estimated capex of NSSS technology (Table S3) needs to be reduced, which is an important factor in adopting NSSS in HCFs.

4. CONCLUSION

This study analyzed the potential application of NSSS in HCFs in Beijing, China, in terms of support and challenges from four perspectives: political, economic, social, and technological. The results found that the support of NSSS application in HCFs exceeds the challenges in Beijing, China. Particularly in rural areas, NSSS has significant potential for application due to the numerous HCFs, accounting for 63.2% of the total. To realize the widespread application of NSSS in HCFs, it is essential to

reduce the construction costs of NSSS and ensure that the NSSS technology effectively eliminates pathogenic bacteria, thereby reducing the risk of infection. Therefore, efforts need to be made from political, economic, social, and technological standpoints to promote the large-scale application of NSSS in HCFs.

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DATA AVAILABILITY STATEMENT

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

CONFLICT OF INTEREST

The authors declare there is no conflict.

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