# Behavioural determinants of landlord decisions on household wastewater management in urban Dhaka, Bangladesh

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# Intellectual Property and Publication Statements

I confirm that the work submitted is my own, including the work which has formed part of jointly authored publications. My contribution and the other authors of this work have been explicitly indicated below. I confirm that appropriate credit has been given within the thesis where reference has been made to the work of others.

The work presented in Chapters 4, 5, and 6 was considered to be a contribution to knowledge and practice, warranting timely publication in peer-reviewed academic journals. It was therefore rational and appropriate to submit an alternative format thesis. These three publications are detailed below, including the contributions of each author.

The work in Chapter 4 of this thesis has appeared in publication as follows: Alam, M. U., Rahat, M. A., Nawaz, S., Neeher, N., Tabassum, K. F., Upoma, T. A., Kamal, A., Evans, B., and Hutchings, P. (2025). Behaviour change interventions to promote household connectivity to sewer: a scoping review. *Global Health Action, 18*(1). https://doi.org/10.1080/16549716.2025.2476335
Contribution: MUA prepared the first draft of the manuscript together with AR and SN. BE and PH provided their technical insights to improve the draft manuscript. BE, PH, and MUA were involved in reviewing the study design and the data extraction plan. AR, SN, and AK developed the search strategy and data extraction plan with the guidance of MUA. AR, SN, TAU, KFT, NN, AK, and MUA extracted the data from the included articles and prepared the data matrix. AR, SN, NN, KFT, and TAU reviewed and edited the draft manuscript.

The work in Chapter 5 of this thesis has appeared in publication as follows: Alam, M. U., Rahat, M. A., Neeher, N., Tabassum, K. F., Nawaz, S., Evans, B., and Hutchings, P. (2025). Barriers to sewer connection in urban Dhaka: Individual and organisational challenges. *Journal of Water, Sanitation and Hygiene for Development. 15*(4), https://doi.org/10.2166/washdev.2025.281
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# Abstract

Access to safe sanitation remains a challenge in urban areas globally, particularly in low-and middle-income countries. In cities like Dhaka, Bangladesh, despite efforts to expand sewer connections, uptake among households remains low. This PhD synthesises findings from primary and secondary data to explore the drivers and motivators to sewer connection, identify enablers and barriers to sewer connection, and develop interventions to increase sewer connections in urban Dhaka.

I conducted a mixed-methods cross-sectional study across five Dhaka zones operated by the Dhaka Water and Sewerage Authority (DWASA). I surveyed 384 landlords, conducted 8 Key Informant Interviews with DWASA and other stakeholders, 10 In-Depth Interviews, and 2 Focus Group Discussions with landlords. Survey participants included households whose toilets were connected to the sewer, and those whose toilets were connected to stormsewer or drainage. I used the Risks, Attitudes, Norms, Abilities, and Self-regulation (RANAS) framework to examine socio-demographics, and psychological factors determining connection behaviour. I followed the thematic analysis technique for qualitative data analysis.

Evidence from the literature review indicated that behaviour change campaigns alone had limited effectiveness unless combined with financial incentives and community engagement strategies. Evidence from primary data indicated that individual-level barriers to sewer connection included the lack of knowledge about connection procedures and perceived low risks of disease transmission among households without sewer connections. Organisational-level barriers included complex administrative procedures, high installation costs, bureaucratic delays, inadequate support from DWASA, and outdated infrastructure, thus impeding the uptake of sewer connections.

To improve uptake, an integrated intervention model is proposed, which includes targeted educational campaigns to improve health knowledge, role model-based interventions to shift social norms, and technical support to facilitate the connection process. A holistic approach that combines educational efforts, behaviour change strategies, active community participation, and infrastructural improvements, can successfully overcome barriers to sewer connections.

Since the traditional behaviour change theories are more individual-focused, I also propose a broader, more integrated framework for sewer research and practice, a ‘behavioural informed system approach’ - that considers the complex interplay of infrastructural availability, financial investment, institutional trust, and social relations.

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# Abbreviations

| | |
|---|---|
| BCT | Behaviour Change Technique |
| BCD | Behaviour-Centred Design |
| CBO | Community-Based Organisation |
| CLTS | Community-Led Total Sanitation |
| DNCC | Dhaka North City Corporation |
| DSCC | Dhaka South City Corporation |
| DWASA | Dhaka Water Supply and Sewerage Authority |
| DALY | Disability-adjusted life years |
| FSM | Faecal sludge management |
| GVMR | Greater Vitória Metropolitan Region |
| GPOBA | The Global Partnership on Output-Based Aid |
| GDP | Gross Domestic Product |
| GPS | Global Positioning System |
| HBM | Health Belief Model |
| ITN- BUET | International Training Network Centre - Bangladesh University of Engineering and Technology |
| icddr,b | International Centre for Diarrhoeal Disease Research, Bangladesh |
| JMP | Joint Monitoring Programme |
| LIC | Low-Income Community |
| LMICs | Low-and Middle-Income Countries |
| LPP | The Lodhran Pilot Project |
| MODS | Maintenance Operation Distribution and Service |
| NGP | Nirmal Gram Puraskar |
| OBA | Output-Based Aid |
| PSTP | Pagla Sewage Treatment Plant |
| PRISMA | Preferred Reporting Items for Systematic Reviews and Meta-Analyses |
| PRISMA-ScR | Preferred Reporting Items for Systematic Reviews and Meta-Analyses extension for Scoping Reviews |
| RANAS | Risks, Attitudes, Norms, Abilities, and Self-regulation |
| RCT | Randomized Controlled Trial |
| STP | Sewage Treatment Plant |
| SBM | Swachh Bharat Mission |
| TPB | Theory of Planned Behaviour |

| | |
|---|---|
| UNICEF | United Nations Children's Fund |
| UN | United Nations |
| WSUP | Water and Sanitation for the Urban Poor |
| WHO | World Health Organisation |
| WASH | Water, Sanitation, and Hygiene |
| Water-WISER | Water and Waste Infrastructure Systems Engineered for Resilience |

# Chapter 1: Introduction

## Context

The lack of safely managed sanitation services in urban areas represents a significant global challenge, with only 47% of the population utilising such services (JMP, 2019). The issue is particularly prevalent in Low and Middle-Income Countries (LMICs) (JMP, 2020), where only 25% of household wastewater in the Central and South Asia, and Sub-Saharan Africa regions is safely treated, highlighting significant regional disparities (Graham et al., 2021). According to the WHO-UNICEF Joint Monitoring Program (JMP), safely managed sanitation facilities must hygienically isolate excrement from human contact, not be shared among families, and appropriately treat and dispose of the treated excrement (WHO, 2018). These facilities are a prerequisite to preventing exposure to excreta and ensuring hygienic management and disposal of the treated excrement (WHO, 2018).

The health burden of inadequate sanitation is especially heavy on urban residents living in close proximity, leading to negative health outcomes (McMichael, 2000), adverse effects on overall well-being (Bisung and Elliott, 2017), decreased economic output (Hutton, 2013) and insufficient security measures (Lee, 2017). On top of that, households that are not connected to a functioning sewer often produce untreated wastewater (Jiao, 2021). This wastewater frequently contaminates water bodies due to inefficiently built and poorly managed septic tanks or pit latrines (Nyenje et al., 2013) and through storm drainages, which lead to open water bodies (Nyenje et al., 2010; Nyenje et al., 2013). The contamination of water through untreated wastewater is significantly associated with the spread of various diseases (Kimmelman, 2017; JMP, 2018), posing a threat to both human and animal health (Nyenje et al., 2010). While Sustainable Development Goal Indicator 6.3.1 aims to reduce water pollution through improved wastewater treatment, a recent UN progress report reveals that only 56% of global household wastewater was safely treated in 2020 (Graham et al., 2021).

To alleviate the burden of managing household-level wastewater in cities of Low and Middle-Income Countries (LMICs), there is an increasing interest in connecting households to sewer systems, enabling authorities to manage wastewater more safely (World Bank, 2020). A sewerage system comprises a network of pipes designed to transport household blackwater (human excreta and toilet flush water) and greywater (water from kitchens, laundry, and bathing) to treatment facilities, where

the wastewater is cleaned and safely discharged into the environment (Tilley et al., 2014). Sewers are typically constructed in urban areas where on-site sanitation solutions are difficult to manage due to limited space. However, connecting households to these systems poses challenges in LMICs, as many households do not opt for connections, even when the sewers are in close proximity (Kennedy-Walker et al., 2020).

The decision to connect households to sewerage systems is influenced by a range of social, financial, policy, and technical issues (Kennedy-Walker et al., 2020). Many individuals remain unconnected to available sewers due to various barriers, including affordability, uncertainty about community perceptions of the program, satisfaction with existing sanitation solutions, concerns about appearing affluent, doubts about construction quality, fears of property damage during the connection process, and the lack of government mandates (Tuy, 2003). For instance, a study in Zambia found that many households were hesitant to pursue sewer connections due to past incidents of sewer backups caused by obstructions and flooding, which resulted in property damage (World Bank, 2016). In Latin America, resistance to sewer connection has been attributed to concerns about paying tariffs, high upfront connection costs, and lack of proactive government efforts to facilitate connections (Kennedy-Walker et al., 2020).

In Bangladesh, the sewer system is only limited to Dhaka City, which serves only 20% of residents, mostly from high-income communities. Alarmingly, only 2% of the sewage generated is treated effectively (Ross et al., 2016; Mansour et al., 2017). The majority of households rely on on-site sanitation, leading to untreated wastewater being released into the environment (Mansour et al., 2017). On top of that, institutional challenges, such as leaking sewers and dysfunctional pumping stations, further complicate the situation (Ross et al., 2016). Additionally, the low uptake of household sewer connections results in the under-utilization of wastewater treatment facilities, which diminishes the efficiency of treatment plants from both operational and financial perspectives. This under-utilization also has negative repercussions for environmental and public health (Kennedy-Walker et al., 2020).

In Dhaka, the Dhaka Water Supply and Sewerage Authority (DWASA) is implementing a city-wide sewerage network funded by a USD 900 million loan from the World Bank (World Bank, 2019). This initiative includes the construction of sewers in high-income areas, as well as provisions for slums and low-income housing (World Bank, 2020). Additionally, the project involves the establishment of wastewater treatment plants in the Pagla and Dasherkandi catchments, targeting a 65% household

uptake rate for connections to the network (DWASA, 2016). Given the significant expansion of sewer infrastructure aimed at increasing household connectivity, it is crucial to understand the determinants that influence individuals' decisions, especially landlords' decisions who own the house and make decisions on behalf of tenants, those from low-income areas - regarding sewer connections. Identifying these determinants will provide implementers with the evidence needed to make informed decisions about facilitating household connections.

Thus, this research aims to identify the behavioural determinants of landlords influencing decisions regarding sewer connections, which can be targeted to design future interventions, ultimately increasing the uptake of sewer connections among the urban low-income community.

## Research Gaps

In many cities across sub-Saharan Africa and South Asia, sewerage system coverage remains below 25%, primarily due to limited network expansion and the absence of mechanisms that facilitate connections for poorer families (Yoshino et al., 2019). The World Bank explored the reasons behind the persistent challenges in sewer connection despite increased investments in trunk infrastructure. Even now, many households located near existing sewer networks, which could have been feasibly connected, remain excluded and unconnected to the system and raise concerns about equitable access to sanitation (Dhawan et al., 2001). These low connection rates are particularly prevalent among the poorest households, often due to a lack of information on the connection process (Dhawan et al., 2001). For example, in Argentina, El Salvador, Guatemala, Honduras, Mexico, Nicaragua, and Uruguay, sewer connection rates were more than 40% lower for the lowest-income quintile compared to the highest-income group (Gray, 2020). However, well-designed connection initiatives have demonstrated success in improving access, as seen in Tamil Nadu, India, where approximately 1.5 million households gained access to sewer systems (Gray, 2020). These findings highlight the importance of targeted interventions to increase sewer connectivity, particularly for low-income populations.

To increase sewer connections, many programs focused on addressing the financial, social, and legal barriers. Financial incentives and subsidies have been introduced to encourage more rapid and sustainable investment in sewer infrastructure and safely managed sanitation, though outcomes have been mixed (Andres, 2019). Evidence shows that the poorest populations did not fully benefit from improved sanitation without addressing these barriers (Kar, 2003; Kar and Bongartz, 2006; Chambers et al., 2015). Programs also focus on activities that reduce transaction costs for

households and improve customers' willingness to pay, increase revenue, enhance service providers' credibility, and set them on a path toward delivering universal, sustainable sanitation and sewerage services (World Bank and UNICEF, 2017). Social programs and other communication strategies were also considered in other settings to improve safely managed sanitation (Freeman et al., 2009; Devine and Kullmann, 2011; Bongartz and Fox, 2016). On the other hand, some water and sanitation authorities initiated legal mechanisms, such as penalties for failing to connect to sewer systems, or legal action against those discharging faecal waste into water bodies, canals, or rivers (WSUP, 2012). However, such regulatory approaches raise questions about whether enforcement alone is an effective strategy for increasing connections.

Decisions to connect to sewer systems are influenced by both individual and community-level factors (Chambers et al., 2015; World Bank and UNICEF, 2017). Individual barriers and motivators include convenience, willingness to pay, status, privacy, and dignity (Dhawan et al., 2001; Robinson, 2011; Yoshino et al., 2019; Gray, 2020). At the community level, factors such as collective action for using the ‘common pool resource’ (Ostrom, 2008), and social norms like disgust and shame (Kar and Bongartz, 2006) might play a role in shaping sanitation behaviours. While extensive research has examined common-pool resources in sectors like forestry, fisheries, and irrigation systems, poor sanitation and the associated contamination of land and water resources have been largely overlooked. Pathogen-free environments are common-pool resources that are often compromised by open defecation and the discharge of untreated wastewater in many regions. There is an opportunity to analyse how collective action can contribute to the sustainable management of local sanitation systems.

Despite the continuous effort from the government of Bangladesh and other development partners, the connection to sewers in low-income communities remains low. Existing studies often take a fragmented approach, lacking a holistic understanding of user and community perspectives on sewer connections (Alam et al., 2020). The decision to connect to a sewer depends on economic, social, environmental, behavioural, and psychological factors, but most studies failed to integrate these dimensions comprehensively.

This research focused on people from low-income communities and their 'behavioural determinants’, identifying key factors that facilitate sewer connections based on empirical evidence. By applying the Risks, Attitudes, Norms, Abilities, and Self-regulation (RANAS) behaviour change

framework (Mosler, 2012) this research seeks to address existing gaps and provide insights for improving sewer connection uptake.

In addition to addressing broader gaps, this research specifically focuses on the following novel issues:

- Identification of connected and not-connected households: Differentiating between low-income households that connect to the sewer (doers) and those that do not, despite availability (non-doers), using principles of behaviour change.
- Patterns of Uptake: Analysing patterns of uptake among various categories of connected households from low-income urban areas and identifying the factors that influence their decision to connect to sewer.
- Reasons for Non-Connection: Investigating the reasons behind not connecting with sewers for not connected households.
- Influencing Community Norms: Exploring strategies to influence community norms that can motivate households to connect with the sewer.
- Behaviour Change Interventions: Identifying effective behaviour change interventions aimed at increasing sewer connection uptake among low-income households.

## Overarching aim

Identify the behavioural determinants of landlords' decisions regarding sewer connections, which can be targeted to design interventions, ultimately increasing the uptake of sewer connections among the urban low-income community.

## Objectives

**Objective 1:** To understand the drivers and motivators to connect with available sewer in low-income urban countries

**Objective 2:** To understand the individual and organisational level barriers to connecting with an available sewer in low-income urban areas.

**Objective 3:** To develop a behaviour change intervention to promote sewer connection in a low-income urban community

# Institutional context of urban sanitation governance in Dhaka

**The role of DWASA**

The Dhaka Water Supply and Sewerage Authority (DWASA) is the principal agency mandated to provide water supply and sewerage services in Dhaka under the WASA Act 1996. DWASA's responsibilities include planning, construction, operation, and maintenance of water and sewerage networks across its jurisdiction (DWASA, 2020). While DWASA operates one central wastewater treatment plant at Pagla and several new facilities under construction, only around 20% of Dhaka's population is connected to a formal sewer network (ADB, 2020). The rest rely on on-site sanitation systems such as septic tanks, pits, and open drains, leading to widespread leakage of untreated effluent into the environment. Rapid and unplanned urbanisation, limited coordination with other agencies regarding sewer connection and onsite sanitation, and encroachment on canals and open water bodies have further constrained DWASA's operational efficiency. Consequently, DWASA's role in ensuring universal sewer connectivity depends heavily on behavioural, institutional, and land-use dynamics, particularly the decisions of landlords and local authorities.

**The role of City Corporations (DNCC and DSCC)**

Dhaka's two City Corporations - Dhaka North (DNCC) and Dhaka South (DSCC), are responsible for a range of urban environmental health functions, including solid waste management, street cleaning, drainage maintenance, and sanitation promotion, especially onsite sanitation (Local Government Division, 2022). Although sewerage is formally under DWASA, City Corporations oversee on-site sanitation services, faecal sludge management (FSM), and hygiene campaigns in collaboration with development partners and NGOs (World Bank, 2025). For example, both DSCC and DNCC have desludging services in Dhaka, especially for low-income settlements not connected to the sewer system. However, fragmented responsibilities and lack of a unified sanitation regulatory framework often cause overlap and inefficiency between DWASA and the City Corporations (ADB, 2020). This institutional misalignment undermines enforcement mechanisms for household-level sanitation, especially when landlords fail to provide adequate wastewater management systems for tenants.

**The role of RAJUK**

Rajdhani Unnayan Kartripakkha (RAJUK), the Capital Development Authority, is responsible for urban planning, zoning, and building control in Dhaka. RAJUK implements and enforces the Dhaka Metropolitan Development Plan (DMDP) and the Detailed Area Plan (DAP), which guide land use, density, and infrastructure development (RAJUK, 2022). In principle, RAJUK's building approval process includes verification of sanitation facilities and wastewater management provisions in new

constructions. However, widespread informal housing, illegal developments, and inadequate enforcement capacity mean that many buildings are constructed without approved plans or proper sanitation arrangements. Moreover, coordination gaps between RAJUK and service delivery agencies such as DWASA and the City Corporations limit the integration of urban planning with sewerage infrastructure. As a result, even areas with planned sewer lines often lack actual household connections due to mismatched implementation, regulatory loopholes, and weak accountability systems.

**Institutional fragmentation and governance complexity**

The overlapping mandates of DWASA, City Corporations, and RAJUK illustrate the fragmented institutional landscape of urban sanitation governance in Dhaka. Each organisation operates within its legal and functional domain, yet effective wastewater management requires coordinated planning, financing, and regulation across these boundaries. Weak horizontal coordination among agencies, limited enforcement of building codes, and the absence of a unified sanitation policy framework exacerbate the challenges of achieving citywide inclusive sanitation (World Bank, 2025). This fragmentation particularly affects informal and rented housing, where landlord decisions are shaped by economic incentives, land tenure, and institutional ambiguity. Understanding the behavioural determinants of such decisions, therefore, requires situating them within the broader governance and political economy context of Dhaka's urban development.

## Positionality statement

In this section, I share a positionality statement. The aim of producing the statement was to reflect on how the research was designed and the results interpreted (Vong, 2021), and on whether this project has perpetuated inequalities (Gani, 2024). The statement covers my personal and professional background relevant to the research, beliefs, attitudes towards the topic, the background to the research project, ontological and epistemological perspectives, and an explanation for terminology used in the thesis (Vong, 2021).

I am a 43-year-old Bangladeshi male from a middle-class background, fluent in Bengali, and residing in Dhaka. My educational journey and friendships along the way have shaped my worldview; I enjoy participating in a global community. At the same time, I recognise my privilege of being a professional researcher for the last 16 years and the relationship this has on my positionality and this work.

After graduating, I joined the International Centre for Diarrhoeal Disease Research, Bangladesh (icddr,b) in 2008 as a Research Officer. In 2012, I joined the MPH program at the BRAC James P Grant School of Public Health, and after completing my MPH, I joined as a Research Investigator at icddr,b, which is equivalent to the implementation manager or coordinator of a study. Since then, I have led and coordinated 22 research studies before I joined the Water-Wiser PhD program. I was recruited as a Research Assistant at icddr,b, and gradually, I became a leader who guided a team of more than 150 staff. This experience taught me the nuances of working in a research institution and the funding acquisition process, where we have to navigate power imbalances between researchers from the North and South. At the same time, we must accept working within structural conditions that are beyond our influence.

To this topic, I bring a combination of my professional experience and personal and political views. Professionally, I am agnostic about the role of the private and public sector towards providing and delivering sanitation services because whilst sanitation is an essential public service and a human right, it cannot be understood without considering the social, economic and political context in which it is situated. I am broadly critical of the global capitalist economic system and the power structures that it maintains and extends. I view international development as being problematic and in practice a mechanism that maintains the relationship and power structures between the so-called Global North and Global South (Dambisa and Baroness, 2010; Kahn, 2010). And with respect to research, I recognise that Global North institutions and researchers often repackage knowledge for consumption in the Global South (Luseka, 2020).

At the same time, there are arguments for collaboration between the Global North and South to attempt to redistribute, lessen damage and resolve imbalances (Tan, 2010). For this research, this suggests that locally driven development should be the objective, that it should promote underrepresented perspectives, and that it should rather support than lead. In response, the research questions were not exclusively driven by literature from the Global North but emerged from my direct experiences working with urban sanitation systems in Bangladesh. I used the resources available to me to promote collaborators and our research. But sometimes, this backfired, such as when I was foreseeably (Lue et al., 2023) unable to obtain visas to travel to the Global North, and they presented our work alone.

In this thesis, I take a critical realist ontological perspective, which when applied, suggests that what can be known about sanitation services is not entirely objective and that critical examination can capture what can be understood, and something remains not understood. Aligned with this is a constructivist epistemological perspective where society constructs knowledge through the relationship between society and the topic. When applied to sanitation services this suggests that the creation of knowledge is socially constructed rather than being inherent to the topic. This contrasts with generally positivist thinking around engineering and economics - I acknowledge that what can be known and how knowledge is constructed about sanitation services is partial and socially constructed because the service is a function of complex human behaviours and realities.

Throughout the thesis, I choose the terminology low-income countries as opposed to, for example the Global South, developing or industrialised countries. This is in acceptance that no terminology choice is perfect; that 'Global South' implies a global political relevance to the work that is less helpful for understanding the topic at the service level; in contrast 'developing countries' I consider inaccurate for the topic as all countries continue to develop sanitation services; and that industrialised misses the importance of power in the country's history. I opted for the low-income terminology because it is most relevant to organising funding at the service level and is suitable for working with research partners.

## Thesis structure

The remaining thesis is structured as follows. Chapter 2 reviews the literature on urban sewer services. In Chapter 3, I discussed the approach of this work, and methodology as a whole. In Chapter 4, the uptake of behaviour change interventions to promote sewer connection in LMICs from secondary data are presented. In Chapter 5, the organisational and individual level barriers to sewer connection from primary research are presented. In Chapter 6, we proposed a combined intervention to increase the uptake. Lastly, in chapter 7, the findings from the previous three chapters are synthesised, the main findings are discussed within the context of the urban sanitation literature, and opportunities for further research are presented.

# Chapter 2: Review of Literature

## Why is a sewer connection important?

### Urban sanitation situation and current practices around wastewater

Globally, inadequate sanitation and poor household sanitary practices contribute significantly to water pollution and public health risks. According to the Joint Monitoring Programme (JMP, 2014), approximately 88% of diarrheal deaths are attributed to unsafe sanitation. However, in 2017, only 47% of urban populations in countries with available sanitation data had access to safely managed sanitation (JMP, 2019). Additionally, the rapid urbanisation and population expansion in the majority of cities in the global South have outpaced the expansion of sanitation infrastructure, leading to critical gaps in service provision (Berendes et al., 2018; Mara and Evans, 2018). In many cities across Asia and Africa, septic tanks or cesspools are still predominantly used to handle toilet wastewater (Strande and Brdjanovic, 2014). Furthermore, grey water, that is wastewater from baths and kitchens, is often dumped untreated into storm drains or nearby waterways. It is commonly known that extremely toxic faecal or septic tank sludge is frequently dumped on public land, either with or without the landowners' consent (Strauss et al., 2006; JMP, 2012). These practices pose significant public health risks and have significant environmental and economic impacts on nearby communities.

On the other hand, the widespread use of on-site sanitation systems in Southeast Asia has been well documented. Unfortunately, many of these systems are subpar and are situated in areas with highly impermeable soils (clay), where the partially treated effluents typically overflow and contaminate nearby canals and rivers (Ludwig et al., 2005). A study in Vietnam has proved that on-site sanitation systems and disease outbreaks, such as diarrhoeal illnesses, are connected to contaminated groundwater (Dan and Truong, 2006).

The urban sanitation systems in low- and middle-income countries (LMICs) are very different from one another. Some cities have relatively well-functioning urban sanitation systems, while others face significant issues. The discrepancies are influenced by the degree of sewer network coverage, the efficiency of faecal sludge management (FSM), and the ability of local authorities to supervise sanitation services.

Santa Cruz, Bolivia provides an example of a partially functional urban sanitation system. Nearly half of the city’s population is connected to a sewer and most of the sewage from this network is

processed successfully and safely released into the environment. The remaining half use on-site sanitation systems, and some of these homes use a private operator-run pit emptying service that carries and releases the faecal sludge to the same sewage treatment facilities. Although this FSM service is limited, most of the faecal waste produced by families employing on-site sanitation is kept in containment systems of varying quality, many of which cannot be emptied or do not safely contain the faecal waste (Peal et al., 2015).

On the other hand, in Honduras, only a tiny portion of the sewage is safely handled and disposed of, making Tegucigalpa's sanitation system a failing sanitation service chain. An estimated 81% of the sewage is controlled and conveyed by a sewage system, which releases primarily untreated effluent into the environment (JMP, 2022). FSM services are also inadequate, with many pit latrines and septic tanks failing to contain waste properly. Additionally, sludge removed from these systems is neither treated nor safely disposed of, further exacerbating public health risks.

Similarly, sanitation facilities in Maputo, Mozambique, are still lacking, especially in low-income areas. Approximately 90% of households rely on on-site sanitation facilities, including septic tanks and latrines of varying quality, many of which contribute to environmental pollution. Only 10% of the city’s population has access to a sewer network. The high water table in the city further complicates the management of on-site sanitation systems, increasing the risk of groundwater contamination (Peal et al., 2015).

Kampala, Uganda, encounters similar difficulties. The sewer network accommodates only a limited number of residents, while the majority depend on on-site sanitation systems. Nevertheless, the Kampala City Council lacks the capability and resources to adequately regulate and assist these systems, resulting in numerous households lacking appropriate waste containment or treatment (Peal et al., 2015).

In Bangladesh, a study by Ross et al (2016) found that 52% of households in Dhaka reported having pits or tanks illegally connected to storm drains. In some slum areas (e.g., Kamrangichar LIC) pit latrines and septic tanks are connected with drains and the drainage system connected to the Buriganga river (Ross et al., 2016). A case study by ITN-BUET revealed that most of the houses in Baridhara, a high-income area in Dhaka, do not have a septic tank and none have a soakage pit. Thus, the greywater produced within the houses is being directly discharged into storm drains; the storm drains subsequently discharge into the nearby Baridhara lake (Rahman et al., 2016).

Moreover, 21% of households do not even have a pit or tank- their latrine empties directly to a drain or ditch without intermediate containment. For instance, most of the latrines are constructed above the drain in one of the largest slums in Dhaka (i.e. Mohakhali Shat Tola Bostee), the faecal waste ends up in the drain (Ross et al., 2016).

## Existing wastewater management in Dhaka

The first step of sewerage treatment is the transportation of wastewater from various sources or the point of generation. The pipes that convey the wastewater away from its point of generation are called sewers. The network of sewer pipes is a sewerage system.

The sewer system of Dhaka developed in 1923 (Figure 1), was designed to transport wastewater from domestic premises, commercial establishments, and industrial facilities while excluding stormwater or surface runoff, which is managed separately through drainage channels or khals (Naziruzzaman, 1999; Thøgersen, 2012). The residents of Dhaka generate approximately 2 million cubic meters of wastewater daily. However, the city's only sewage treatment facility, the Pagla Sewage Treatment Plant, has a capacity of treating only 120,000 cubic meters per day. Recently, the Dasherkandi sewage treatment plan started it’s operation in 2023, however, the plant was built without being connected to any local sewer network. It currently receives wastewater from a limited number of canals and lakes, not the sewer network from the service areas in Dhaka. Although the plant has a capacity of treatment of around 500 million litres per day, more than 40% of that capacity remains unused even years after its inauguration.

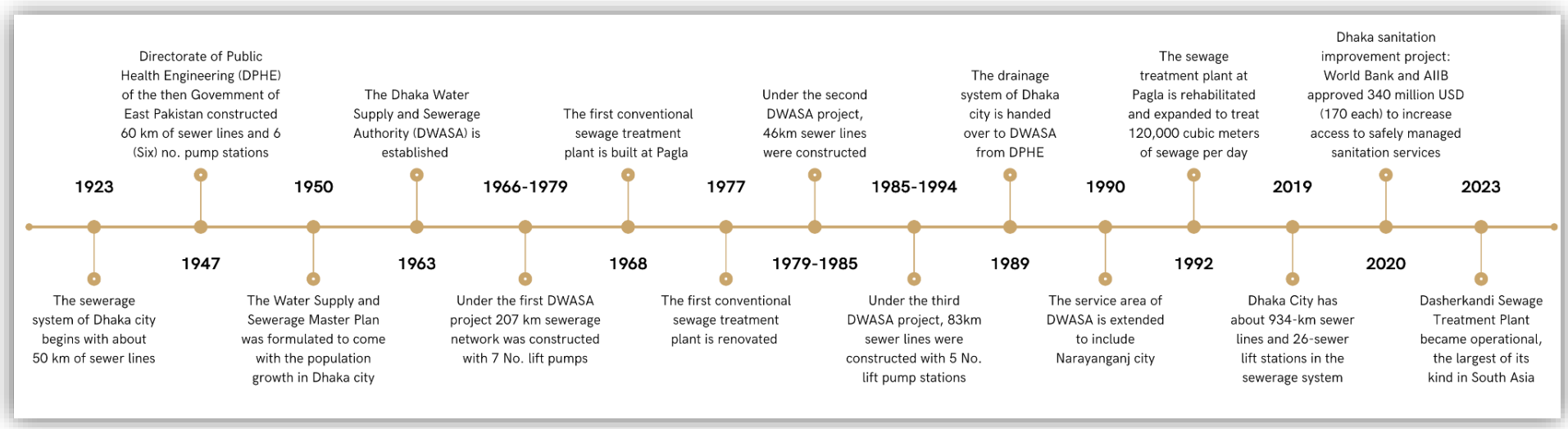


*Figure 1: Historical journey of Dhaka sewer*

DWASA has 49,000 domestic sewer connections, 882 km of sewer lines of different diameters, 27 sewer lifting stations, one central pumping station and three trunk sewers. The sewer networks of the Pagla Sewerage Treatment Plant (PSTP) are made by varying pipe materials and sizes, ranging from 100mm to 1350 mm. The larger pipe size is an equivalent diameter to a circular pipe as the larger trunk sewers are of a semi-circular type, usually described as brick-arch or horseshoe (Thøgersen, 2012). PSTP also has sewage lifting stations required when the sewer depth exceeds 7-8 meters. Above this depth, it is risky to lay pipes and difficult to maintain the sewers.

In Dhaka city, there are no facilities for treating greywater discharged into the open drain from households. However, it should be noted that to some degree primary treatment of wastewater occurs in the septic tank, which remains contaminated. In the pit latrine, almost no effective treatment occurs (Cisneros, 2011), and often connected to drainage.

In Dhaka city, currently, two sanitation systems exist:

Broadly, Dhaka's sanitation system can be categorised into on-site and off-site sanitation. In an on-site sanitation system, excreta and wastewater are collected and stored at the point of generation, whereas off-site sanitation comprises a sewer network and a centralised wastewater treatment plant (Tilley et al., 2014). DWASA is responsible for the water supply and sewage disposal within its service region, which encompasses the megacities of Narayangonj and Dhaka, covering a total area of more than 360 square kilometres. In terms of volume, on-site sanitation systems are predominant in the DWASA service region. Within the DWASA Service Area, about 25% of the population uses a septic tank, whereas 22% of the population utilise a pit directly connected to drainage (Thøgersen, 2012).

The on-site sanitation system in Dhaka city involves septic tanks and pit latrines, which are connected with the drainage system either directly or after initial containment in a sealed tank (JMP, 2022). Almost all the faecal sludge generated from households in Dhaka city ends up in the drains or the environment one way or another (Ross et al., 2016). According to the case study by Ross et al, more than 80% of on-site sanitation infrastructure in Dhaka does not properly confine faecal matter, leading to its direct discharge into surface water bodies (Ross et al., 2016). Moreover, due to the low porosity of the soil in some areas of Dhaka city, septic tank effluent drains away, and the overflow is discharged to a nearby drainage system (Thøgersen, 2012), exacerbating public health risks. Additionally, informal settlements such as slums frequently do not receive DWASA sanitation

services due to disputed land tenure status (Cawood, 2018). Most slum areas are situated in low-lying areas; therefore, faecal matter from pit latrines, communal latrines, and septic tanks often overflows into their households after heavy rainfall (Alam et al., 2020), leaving them particularly vulnerable to inadequate sanitation and environmental contamination.

In addition to its predominant reliance on on-site sanitation, Dhaka also has an off-site sewer system. Dhaka currently has one sewage treatment plant, the Pagla sewerage treatment plant (PSTP) (Sharmin, 2016). Household's greywater or wastewater are either discharged directly into the sewer network or first pass through septic tanks or pits before entering the sewer system. Due to the flat topography of Dhaka, the gravity-based sewer system is utilised. In this system, pipes are placed about 1 m below ground level, gradually sloping to a depth of six meters at a gradient of 0.66% and effluent is accumulated in a slump. This accumulation is lifted by the pumping and lifting station and is discharged to an intake at 1 m depth from the ground surface, and this process continues until the wastewater reaches the treatment facility. Ultimately, the treated effluent is discharged to the nearby Buriganga river (Sharmin, 2016).

At present, only 30% of Dhaka's total area is connected to the sewer system. For better operation and maintenance, DWASA has divided the total service area into 11 Maintenance, Operation, Distribution and Service (MODS) zones. Among them, ten are inside the city and one is a subzone, in Narayanganj, which is a nearby district of Dhaka city (Thøgersen, 2012). However, it is estimated that only around 20% of the population within the DWASA service area is potentially served by the centralised separate sewerage system. Moreover, in Dhaka, 25% of the population's excreta discharge directly to sewers, and then a further 3% of the population first contain excreta in sealed tanks before releasing it into the sewer system. However, of this combined 28% of the population, only 2% of the collected wastewater is ultimately treated at the Sewage Treatment Plant (Furlong, 2016).

## Environmental impacts of wastewater discharge in open water bodies

Access to adequate sanitation remains a critical global challenge, particularly in Sub-Saharan Africa and several tropical islands, where more than 50% of the population lacks access to any form of sanitation (JMP, 2019). Even in nations with a high penetration of modern sanitation facilities, poorly designed infrastructure and a lack of maintenance commitment can result in significant contamination through discharge into surface and ground waters. In the United States, for instance, overburdened wastewater treatment facilities result in the annual discharge of more than $4.54 \times 10^9$

$m^3$ (1.2 trillion gallons) of untreated sewage, stormwater, and industrial waste into water bodies (Ahuja, 2014).

Similarly, in Bangladesh, the discharge of grey and black water into natural water bodies is a considerable environmental and public health issue. This practice results in elevated concentrations of pathogens and coliform bacteria in rivers, canals, and ponds, endangering human health and aquatic ecosystems. Moreover, manual disposal of faecal matter through informal channels, such as adjacent sewer manholes, surface drains, aquatic bodies, municipal waste collection sites, roadways, and low-lying regions, exacerbates environmental contamination (Thøgersen, 2012; Rahman et al., 2016; Jakariya et al., 2018).

In addition to microbial contamination, the discharge of untreated wastewater also contributes to the nutrient and chemical pollution. Surplus nitrogen and phosphate from sewage induce eutrophication, resulting in oxygen depletion in aquatic environments, causing fish mortality and disruption of ecosystems (Jakariya et al., 2018). These challenges are intensified during the rainy season, as runoff from overfilled open drains mixes with untreated wastewater, spreading contaminants over a wider area and increasing the risk of waterborne diseases. Without significant improvements in wastewater management and treatment infrastructure, the continued spread of pathogens and chemical contaminants will further jeopardise public health and environmental sustainability (Thøgersen, 2012).

The impact of inadequate human sanitation is particularly severe in heavily populated metropolitan areas, where the disposal or leakage of untreated pit latrines, inefficient septic tanks, and underground sewers leads to groundwater contamination (Nyenje et al., 2013). The surface water contamination is also significantly linked to the spread of the parasite disease filariasis, and can occur via flooded pit latrines, broken sewers, and open defecation (Kimmelman, 2017; JMP, 2018). Additionally, there is a connection between the discharge of untreated human waste into rivers, streams, and lakes and the development of eutrophication. Eutrophication is the process by which natural water bodies become excessively rich in plant biomass as a result of elevated levels of nitrogen and phosphorus (Nyenje et al., 2010; Nyenje et al., 2013). This results in numerous adverse effects, such as water hyacinth blooms, the extinction of indigenous fish species, and the rapid development of phytoplankton blooms (Nyenje et al., 2010). In severe circumstances, this can lead to the bloom of mono-species like cyanobacteria, which is harmful to both human and animal health (Nyenje et al., 2010).

## Health risk among urban people due to sewerage discharge in the open

Faecal pathogen contamination of surface waters is simply one aspect of the pollution issue. Wastewater discharge contains a complex mix of contaminants, including endocrine disruptors, heavy metals, medicines, pathogens, human waste and faecal viruses (Wear and Thurber, 2015). Like faecal pathogens, these substances serve as reliable indicators of sewage contamination. For instance, researchers found that 25 of the 80 distinct contaminants found in water bodies receiving effluent from sewage treatment plants in Puget Sound, Washington, originated directly from wastewater discharge. This demonstrates the complexity of sewage pollution, where both chemical and biological contaminants cause threats to the environment and human health (Meador et al., 2016).

Pathogen-laden wastewater is a major driver of infectious diseases, including diarrheal diseases, rotavirus, cholera, and typhoid, which collectively caused 1.6 million deaths globally in 2017 (Dadonaite and Roser, 2018). These diseases cause severe dehydration and malnutrition leading to impaired growth and mental development in children (Pickering et al., 2015). Additionally, wastewater contaminated food elements like oysters and other shellfish cause 4 million cases of Hepatitis A and E every year, with roughly 40,000 deaths and another 40,000 cases of long-term disability from chronic liver damage (Shuval, 2003).

Furthermore, the increase in antibiotic-resistant pathogens, or “superbugs,” is the most concerning human health impact caused by wastewater pollution. Antimicrobial resistance is responsible for more than 700,000 deaths annually, and is escalating because of poor antibiotic stewardship (i.e., over-prescribing antibiotics), lack of sanitation, insufficient wastewater treatment, and discharge into the environment (O'Neill, 2016). The total global health impact of the thalassogenic diseases and human infectious diseases associated with pathogenic microorganisms from land-based wastewater pollution of the seas, is estimated to be about 3 million 'disability-adjusted life years' (DALY)/year, with an estimated economic loss of 12 billion dollars (Shuval, 2003) . LMICs like Vietnam are predicted to lose about US$780 million annually in related health, environmental, and economic expenses due to a lack of local capacity to manage and improve techniques for managing faeces (World Bank, 2008).

## Health risk perception and faecal waste management behaviour

Health-related risk perceptions are important determinants of health behaviours and components of behaviour change theories (Anthonj et al., 2022). Risk perception is how individuals or groups think and feel about the potential risks they face, which is an essential determinant of their willingness to adopt protective behaviour (Renner et al., 2015). It also plays a crucial role in designing effective risk communication strategies and supporting preventive public health interventions (Karki et al., 2020).

The level of risk perception is closely linked with prevention strategies. A high level of risk perception suffices for the required intervention, whereas a low level of perception hinders the process (Jerie, 2016). Risk perceptions are associated with individual, social and cultural factors (Anthonj et al., 2022), thus, are different from the actual risk, predicted risk, or tolerable/acceptable risk. A mismatch between actual risk and perceived risk can lead to inappropriate behaviours and suboptimal compliance with recommended public health measures (Gentili et al., 2020).

Inappropriate behaviours and suboptimal compliance with recommended public health measures can arise from several factors, including low risk perception, misinformation, and socio-cultural influences. When individuals or communities perceive the risk of a health threat as minimal, they are less inclined to adopt protective behaviours, such as proper sanitation and hygiene practices (Ali and Robele, 2023). Misinformation and a lack of awareness about the severity and consequences of health risks can further exacerbate this issue. Socio-cultural factors, such as traditional beliefs and practices, also play a significant role. For instance, in some communities, open defecation is culturally accepted, leading to resistance against adopting improved sanitation facilities (Patil et al., 2014).

## Urban Sanitation and Behaviour Change Strategies

Urban sanitation improvement initiatives have concentrated on three main strategies: Community-Led Total Sanitation (CLTS), urban sanitation marketing, and behaviour change interventions for pit emptying. CLTS, initially intended for rural environments, has been modified for urban contexts to promote community collaboration in eradicating open defecation and enhancing sanitation infrastructure (Myers, 2016). Urban sanitation marketing focuses on enhancing the demand for improved sanitation infrastructure by increasing the accessibility, affordability, and desirability of latrines, toilets, and faecal sludge management services (Devine and Kullmann, 2011). Targeted behaviour change interventions for pit emptying seek to mitigate the reluctance to safely manage faecal waste by promoting hygienic emptying practices and facilitating small-scale entrepreneurs in

delivering safe and efficient emptying services (Capone et al., 2020).

Different countries have adopted these strategies with significant success. For instance, India's Swachh Bharat Mission (SBM) has achieved notable progress in eradicating open defecation via extensive toilet construction and comprehensive awareness initiatives (Behera et al., 2021). Similarly, in Kenya, urban CLTS has effectively mobilised communities to enhance sanitation practices, leading to a significant decrease in open defecation rates (Wasonga et al., 2023). Meanwhile, Brazil's Program de Aceleração do Crescimento (PAC) emphasised the enhancement of urban sanitation infrastructure, specifically wastewater treatment facilities, in order to enhance public health outcomes (IDB, 2015). Additionally, in Bangladesh, urban sanitation marketing has been utilised to motivate households to adopt improved sanitation facilities (World Bank, 2014). Likewise, in Ghana, focused behaviour change interventions for pit emptying, whereby safe faecal sludge management has been promoted through providing training and financial incentives for local service providers (Still et al., 2012).

While progress has been achieved through these interventions, the focus has predominantly been on non-sewered sanitation solutions, including pit latrines and septic tanks, with insufficient attention given to encouraging household connections to sewer networks. The existing literature on urban sanitation behaviour change primarily focuses on decentralized sanitation models, highlighting a significant gap in the comprehension of the factors that affect household decisions regarding connections to sewer systems. Considering that sewerage is a more sustainable long-term solution for urban sanitation under certain conditions (Mara and Evans, 2017), particularly in densely populated regions addressing this gap is essential for developing comprehensive and resilient urban sanitation systems, especially in low- and middle-income countries where sewer networks frequently remain underutilised.

## Behaviour Change Theories

Numerous accepted behaviour change theories have been utilised in sanitation interventions, each providing distinct perspectives on influencing and maintaining behaviours. The Health Belief Model (Rosenstock, 1974) underscores perceived risks and benefits, which are essential for encouraging individuals to embrace healthy sanitation practices. The Theory of Planned Behaviour (Ajzen, 1991) emphasises the influence of attitudes, subjective standards, and perceived behavioural control on sanitation-related choices, including toilet utilisation and pit emptying. Social Cognitive Theory (Bandura, 2001) emphasises observational learning and self-efficacy, which have been utilised to

design peer-influence techniques aimed at enhancing sanitation practices. The Diffusion of Innovation Theory (Rogers et al., 2014) discusses the dissemination of novel sanitation technologies and practices across social networks.

Alongside these comprehensive behaviour modification theories, various models have been explicitly formulated for sanitation and hygiene treatments. The Behaviour Change Wheel (Michie et al., 2011) offers a systematic method by integrating many behavioural theories into a cohesive intervention design framework. The FOAM (Coombes and Devine, 2010) and SaniFOAM (Devine, 2009) models emphasise elements including opportunity, ability, and motivation to enhance sanitation-related behaviours. IBM-WASH (Dreibelbis et al., 2013) employs a multi-tiered strategy by targeting individual, family, and institutional factors influencing behaviour. The RANAS framework (Mosler, 2012) delineates five principal behavioural determinants - risk, attitude, norm, ability, and self-regulation - each utilised to formulate tailored WASH interventions. The Behaviour-Centred Design (BCD) paradigm (Aunger and Curtis, 2016) combines behavioural science with environmental and contextual elements to facilitate enduring behaviour modification in sanitation initiatives. Understanding these models and their uses facilitates the development of more efficient and context-specific sanitation change programs.

## Existing programs to increase sewer connections for LICs

Some existing programs or interventions have been implemented previously to connect the households to sewer in LMICs, such as financial incentives, subsidies, social campaigns, communication, legal actions, and reduction of transaction costs.

**(i) Financial incentives and subsidies:**

Adequate sanitation financing is a critical component of sanitation development, as it encourages more rapid and sustainable progress to higher levels of service while providing incentives for communities and households to invest in sanitation and hygiene improvement. Several nations, especially India, with its "Clean Village Award," the Nirmal Gram Puraskar (NGP), have given financial incentives and political recognition for attaining group sanitation goals. Additionally, in the peri-urban area of Cajamarquilla, Lima, Peru, the sanitation campaign achieved high uptake, with 98% of households connected to sewer, which was possible by targeting both households and service providers, including door-to-door visits, engagement with community leaders, promotional events, financial products and credit schemes for household ensure connections were completed (McGranahan and Mitlin, 2016). These coordinated incentives and support mechanisms

demonstrate that when sanitation service providers actively facilitate connections and reduce cost or informational barriers, household sewer uptake can be substantially increased. Some researchers found significant benefits from these incentive systems (such as significantly increased government and development partner engagement in community cleanliness), while others found mixed outcomes (Robinson, 2011). Although the topic of subsidies has long been divisive within CLTS (Community-Led Total Sanitation), it is becoming more and more clear that those who are poorest and most disadvantaged will not always be able to get improved sanitation and move up the sanitation ladder without some kind of outside help (Kar, 2003; Kar and Bongartz, 2006; Chambers et al., 2015). Similarly, people from Bangladesh's low-income communities are willing to connect their toilets to the sewerage, if five conditions are met: no installation cost for sewerage connection, household type/size-based service charges, area-based subsidies, income-based subsidies, and financial support for toilet improvement (Alam et al., 2020). However, this paper lacks user/household perspectives regarding connecting their toilets to the available sewerage. While that study provided valuable stakeholder perspectives from low-income settlements, it was limited to communities not yet connected to sewers and did not quantify the sewer connection issues.

(ii) **Social programs and other communication strategies**:

The main lesson from the most successful 2003–2006 sanitation campaign in Bangladesh was the importance of coupling governmental mandates with programs that boost community mobilisation (Bongartz et al., 2016). The national sanitation campaign in Bangladesh was a collaborative effort between the government, NGOs, and the private sector, aimed at a rapid, large-scale improvement in rural sanitation which focused on changing social norms and behaviours related to open defecation, leading to significant progress. Social marketing efforts to promote safe drinking water, good hygiene, and remedies for water-related ailments, including diarrheal disease, have been seen to show promising success (Freeman et al., 2009; Devine and Kullmann, 2011).

To improve sewer connections in Low-Income Communities (LICs), programs frequently employ social activities such as community engagement efforts and awareness campaigns, as seen in Pakistan and Brazil. The Connect to the Network program in Parana, Brazil, emphasised community engagement initiatives that promote the program's advantages (Sachet, 2020). In Pakistan, the program involved the community in the construction and management of the sewer system and offered social guidance (Robinson, 2005). Utilising this strategy, both programs successfully connected households in regions where the sanitary conditions were critical.

(iii) **Legal mechanisms:**

Some water and sanitation authority includes a provision for a penalty if customers fail to connect with the sewerage, or sometimes the government takes legal action if the faecal matter is discharged into the waterbodies, canals, or rivers (WSUP, 2012). Tamil Nadu's regulatory regulations mandate that a house service connection must be established when a sewerage line is installed and accessible within 100 meters of a residence. This establishes the legal foundation for urban local bodies to compel homes to connect to sewage systems. Furthermore, since 2002, connection to a sewerage network has been obligatory in São Paulo, provided such a network is accessible (Kennedy-Walker et al., 2020). Both programs showed a significant uptake in sewerage connections in those cities. This may have served as a motivating element for families to join the sewer system.

(iv) **Activities that reduce the transaction costs for households**:

Governments are heavily involved in incentivising service providers to increase their technical and financial effectiveness so that savings can be used toward better services (Kingdom and Saltiel, 2018). This will ultimately improve customers' willingness to pay, augment the revenue base, enhance the credibility of service providers, and set them on a path toward delivering universal, sustainable services (World Bank and UNICEF, 2017).

## Current knowledge and gaps in sewerage connection uptake

The sanitary coverage offered by current sewerage systems in cities in sub-Saharan Africa and South Asia is often less than 25% due to issues including limited network extension across the city and a lack of mechanisms to favour connection by poorer families (Yoshino et al., 2019).

The World Bank investigates why, despite increasing investments in the trunk infrastructure, so many households that are close to sewer lines and might reasonably connect nevertheless get left behind and stay disconnected from current or new sewer networks. The report concludes that barriers that prevent households from connecting to sewer lines that frequently pass directly in front of their homes include a lack of information from service providers about the importance of connecting, people's inability to pay the sewer connection fee or subsequent monthly bills, and social norms that work against change (Kennedy-Walker et al., 2020). The safe disposal of wastewater is a crucial component of community physical and economic wellbeing as well as the

environmental health of towns and cities, thus progress with sewer connections is important (Dhawan et al., 2001).

The majority of disconnected households are among the poorest, as they lack the necessary information to connect. For instance, access rates are more than 40% lower for the lowest fifth of the population than the richest fifth in Argentina, El Salvador, Guatemala, Honduras, Mexico, Nicaragua, and Uruguay (Gray, 2020). Households that can connect frequently choose not to do so; 34% of households in Peru do not connect to sewer close to their residences. Additionally, well-crafted connection initiatives are important; as a result, around 1.5 million households in Tamil Nadu, India, now have access to sewers (Gray, 2020).

In many situations, service providers provide insufficient, unclear, or unhelpful instructions, and customers are often unaware of the benefits and disadvantages of having a domestic sewerage connection. Even though many homes are just a few meters away from an existing sewage line, more than a quarter of urban dwellers in Latin America and the Caribbean still aren't connected (Dhawan et al., 2001).

## Definition of terms

**Stormsewer**

A stormsewer, also called a storm drain, is a drainage system whose purpose is to collect and carry away stormwater (rainwater and surface runoff) from streets, roofs, parking lots, sidewalks and other impermeable surfaces. It does not carry household sewage or industrial waste but only water resulting from precipitation or surface runoff. Stormwater refers to water from precipitation (rain, etc.) that flows over the ground or hard surfaces rather than being absorbed, and this water is what storm sewers are meant to drain. In Bangladesh, where urban drainage and rain-runoff management are important, this type of drainage system is essential for managing stormwater. In Dhaka, DSCC and DNCC are responsible for the construction and maintenance of stormsewers.

**Sewer**

Sewer refers to foul-water sewerage; a system of pipes designed to carry household blackwater (human excreta and toilet flush water) and greywater (water from the kitchen, laundry, and bathing) to a treatment facility prior to discharge to the environment (Tilley et al., 2014). Connecting households with foul water sewers can reduce the burden of managing household-level wastewater and allow authorities to manage the wastewater safely (World Bank, 2020). In Dhaka, DWASA is responsible for the construction and maintenance of sewer.

**Drainage**

In the context of Dhaka city, “drainage” refers to the integrated network of constructed channels which includes open drains and covered drains, subsurface pipes and culverts, designed for the collection, conveyance, and discharge of household graywater, ensuring that water is removed efficiently to prevent flooding and waterlogging. This system does not collect faecal sludge or faecal wastewater. In Dhaka, DSCC and DNCC are responsible for the construction and maintenance of drainage.

**Graywater**

Graywater in Dhaka refers to non-toilet domestic wastewater from bathing, washing, and kitchen activities, which is usually discharged into surface drains and canals without treatment. Graywater is the relatively clean wastewater that comes from household activities, excluding toilet waste or faecal sludge. In Dhaka, this typically includes water discharged from: bathing and showers, hand-wash basins, laundry (washing clothes), and kitchen sinks.

**Wastewater**

Household wastewater in Dhaka refers to both blackwater and graywater produced from domestic activities such as toilet use, bathing, washing, cooking, and cleaning, which is typically discharged into the sewer and drainage.

**Pit latrine effluent**

Pit latrine effluent in Dhaka is the liquid wastewater, containing dissolved toilet waste and pathogens, which often infiltrates soil or enters nearby drains due to inadequate lining and limited sewer connections.

**Landlords**

A landlord is defined as someone who receives rent from tenants for a house they own or manage, including those who own the house, have allocated land use rights, or bought land and built houses. These landlords are noted to hold significant power in urban low-income communities and often reside with tenants in the same compound. Landlords provide housing or commercial space to tenants under rental arrangements and are responsible for maintaining the premises and collecting rent.

**Tenants**

In the context of housing in Dhaka, tenants are any person paying rent for premises or a person remaining in possession after tenancy agreement. Research highlights that these tenants typically lack formal land ownership, experience limited tenure security, often belong to low-income and middle-income groups who have migrated for work, and are particularly vulnerable in informal settlements.

**Community management**

Community management is a clear example of how people, organised together, can bring about improvement in their lives that would have been unattainable individually. However, experience has taught us that there is no one correct response and that the system must be modified to consider the social, cultural, and institutional context of any given population group. The core principle of community management is that all other actors play supporting roles while the community manages its water and sanitation systems (Alhanaqtah, 2019). Involvement of the community in planning, decision-making, and maintenance of the sewer promotes a sense of ownership, which enhances compliance with sanitation guidelines and facilitates better infrastructure monitoring. Furthermore,

it could help in bridging service delivery gaps, especially in informal settings where expanding centralized sewerage can often be difficult.

**Collective Action**

Many have used the term "collective action" to describe strategies that encourage participants in the water or sanitation sectors to exchange knowledge and work together to find answers. Others used the word more broadly to refer to "people working together" or to describe any strategy for addressing what political scientists refer to as a "collective action problem," or a situation in which there are obstacles that prevent people from working together to achieve a common objective (Peabody, 2019). People who live in regions with poor sanitation have significant difficulty because of the collective character of sanitation issues: actions and practices of other locals that worsen the environment (Winters and Martawardaya, 2014; McGranahan, 2015). For example, others gain indirect benefits when a home builds a latrine because the surrounding land and water supplies are less contaminated, which is crucial in more densely populated places (Spears and Cumming, 2013). Collective action may help in overcoming common obstacles to sewerage uptake, such as budgetary limitations, a lack of confidence in public services, and fragmented infrastructure construction, by encouraging cooperation between governments, development organisations, and communities.

**Social Norms**

Social norms are the perceived informal, frequently unwritten guidelines that outline what is suitable and acceptable behaviour within a certain group or society, hence influencing how people behave (Cialdini et al., 1991; Cislaghi and Heise, 2017; Sood et al., 2020). They are made up of the things we do, the things we think other people do, and the things we think other people expect us and approve of. Social norms are thus located at the point where behaviour, beliefs, and expectations interact (Sood et al., 2020).

**Social Capital**

The institutions, connections, and standards that influence the amount and quality of social contacts in a society are referred to as social capital. Increasing amount of data demonstrate the importance of social cohesion for sustainable growth and economic prosperity in civilisations. The glue that keeps a society together is social capital, which is more than just the total of the institutions that support it (World Bank, 2011). Social capital contributes to the sharing of information about sanitation as well as the building of community infrastructure. By securing funding and ensuring that projects cater to local requirements, a state-civil society partnership can enhance infrastructure

design and upkeep (World Bank, 2011). Urban sewerage projects can be more robust, inclusive, and economical by utilising social capital, which will ultimately increase access to safe sanitation and lower public health hazards in quickly expanding cities.

**Risk Perception**

People's subjective assessments of the likelihood of unfavourable outcomes like harm, illness, disease, and death are referred to as risk perception. The way people perceive risk affects which hazards they prioritise and how they respond to them, making it crucial to both health and risk communication. There are two basic components to risk perception: the cognitive component, which deals with how much individuals are aware of and comprehend hazards, and the emotional component, which deals with how they feel about them (Paek and Hove, 2017). The operation of a sanitation system may involve risks related to waste collection, transportation, treatment, disposal, and reuse. Sanitation safety planning is a preventive risk management strategy that recognises these potential risks (ADB, 2016).

**Self-efficacy**

The concept of self-efficacy describes a person's belief in their capacity to carry out a task or realise a goal (Hopper, 2021). When self-efficacy is presented as a behavioural factor without much explanation of its environmental factors, the reader is left to infer what factors led to self-efficacy and how it should be increased (Seimetz et al., 2017). Some people have questioned whether the behaviour is a factor in self-efficacy (Aboud and Singla, 2012). For instance, getting all of the students to wash their hands before lunch was proven to increase self-efficacy more than getting students to wash their hands after using the restroom alone (Rosen et al., 2009).

**Common-pool resources**

Ostrom (2008) defines common-pool resources as those that are ‘sufficiently large that it is difficult, but not impossible, to define recognised users and exclude other users altogether (Ostrom, 2008). Further, each person’s use of such resources subtracts benefits that others might enjoy. In case of poor sanitation, it is difficult to exclude people from contaminating land and water quality through open defecation or unsafe sanitation practices. In addition, contamination by some residents practising open defecation is difficult to remediate and puts other residents’ health at risk (Sarker et al., 2008).

# Chapter 3: Methodologies

## Research approach in brief: Realist Perspective

The research is based on a critical realist ontology, which maintains that reality exists outside and independently of human knowledge but can only be partially and inadequately constructed through our multiple discourses (Bhaskar, 1975). Realism thereby helps to overcome the gap or separation between positivism and constructivism by recognising an objective reality that is filtered through socially, culturally, and cognitively mediated frameworks in our understanding (Bhaskar, 1978). In this view, phenomena result from real but often unobservable mechanisms or structures that can be estimated if we have access to systems and use careful research designs.

In a realist paradigm, however, researchers are interested in causal mechanisms and theoretical generalisability (or more specifically the contextual factors that produce observed outcomes) (Bhaskar, 1978). This approach is particularly suited to complex social phenomena, as it considers both the material and interpretive dimensions of reality. While positivist paradigms focus on uncovering universal laws and constructivist paradigms prioritise subjective meaning-making, realist research seeks to understand how mechanisms interact with specific contexts to produce particular outcomes (Sayer, 2000).

In this research, a realist perspective is employed to explore sewer connections, examining not only its observable manifestations but also the hidden mechanisms and structural influences that shape it. The aim is to generate practical insights that account for both individual experiences and systemic factors, thereby informing the design of equitable and contextually appropriate sewer services in Bangladesh. By emphasising the interplay between structure and agency, realism provides a robust framework for understanding and addressing complex challenges in the sanitation sector.

## Methods

This PhD project involves multiple methodological steps, combining both qualitative and quantitative techniques, are needed to address the research objectives. The information base for drawing evidence to conduct research in the following phases is established in the initial stage of setting the research gaps and getting insight into acceptable research methodologies through the literature

review. In turn, this demonstrates a clear link between the many methodological stages of this PhD study.

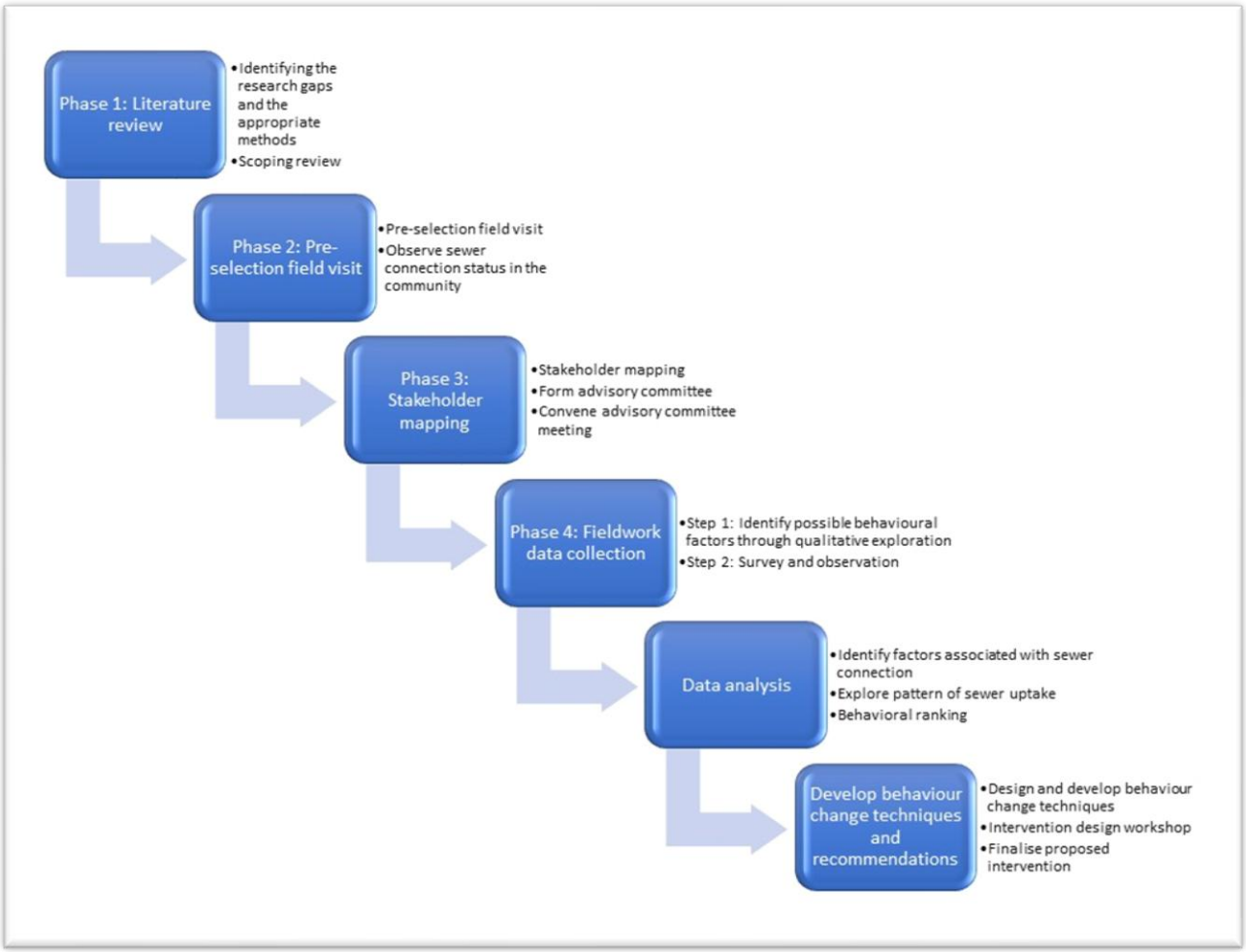


*Figure 2: Diagram of the methodological components for the PhD research project*

**Phase 1: Literature review- identifying the research gaps and the appropriate methods**

A comprehensive literature review has been conducted on recent studies addressing the behavioural factors influencing household wastewater management among urban populations. The primary objective of this phase was to explore and analyse existing research to gauge the extent of work done in this area and to identify any research gaps. Given the interdisciplinary nature of this topic, I reviewed a range of relevant subjects, including the urban sanitation situation, health risks faced by urban residents, and public perceptions regarding connection to existing sewerage systems. This approach aims to develop a coherent understanding of how these issues interconnect. As an outcome of the literature review, a scoping review has been conducted (Chapter 4) and published

titled ‘Behaviour Change Interventions to Promote Household Connectivity to Sewer: A Scoping Review’.

The findings from the literature review informed the selection of the most suitable experimental methods and tools to identify factors affecting individuals' wastewater management behaviour in low-income urban areas. Furthermore, the literature review was an ongoing process throughout the PhD, allowing me to continuously deepen my understanding of related topics and further refine my data collection methods.

**Phase 2: Pre-selection field visit**

The primary objective of this preliminary field visit was to assess the number of households, existing toilets, wastewater disposal methods, and to gather information on sewer connections through informal discussions and routine observations. We visited ten low-income communities in Dhaka city to determine the presence of a sewerage system in the area and whether residents are connected to it. Based on these preliminary observations and the current status of the sewers, I finalised the field sites, prepared the study tools, and developed a plan for local stakeholder engagement.

**Phase 3: Stakeholder mapping and forming an advisory committee**

I conducted stakeholder mapping to identify relevant stakeholders, their roles, and engagement strategies for this research, as well as their influence on implementing the sewer plan or related programs and activities. I formed a key advisory committee comprising stakeholders identified through this mapping process, emphasising the inclusion of policy influencers and decision-makers from a diverse range of relevant groups.

At the start of data collection, I organised an advisory committee meeting with the selected stakeholders. During this meeting, I consulted with the committee regarding our approach and target areas, allowing for input and feedback to enhance our research strategy.

During the stakeholder meeting, I conducted a stakeholder power analysis through consultation with all stakeholders. We, as a group, listed all stakeholders' names and their roles, and after that, placed the names according to their power and interest. We discussed the reasons for stakeholders' power and interest in sewer connection activities. Our analysis showed that development partners have much interest, but less power than DWASA and DNCC/DSCC. On the other hand, landlords showed the highest interest, while tenants had no power or interest. Landlords showed the highest interest

if there were no monetary implications, which means if the connection service is free/subsidized. Tenants showed less interest, as they perceived that if the households are connected to a service, the service charge might be collected from them, which would ultimately increase the monthly rent.

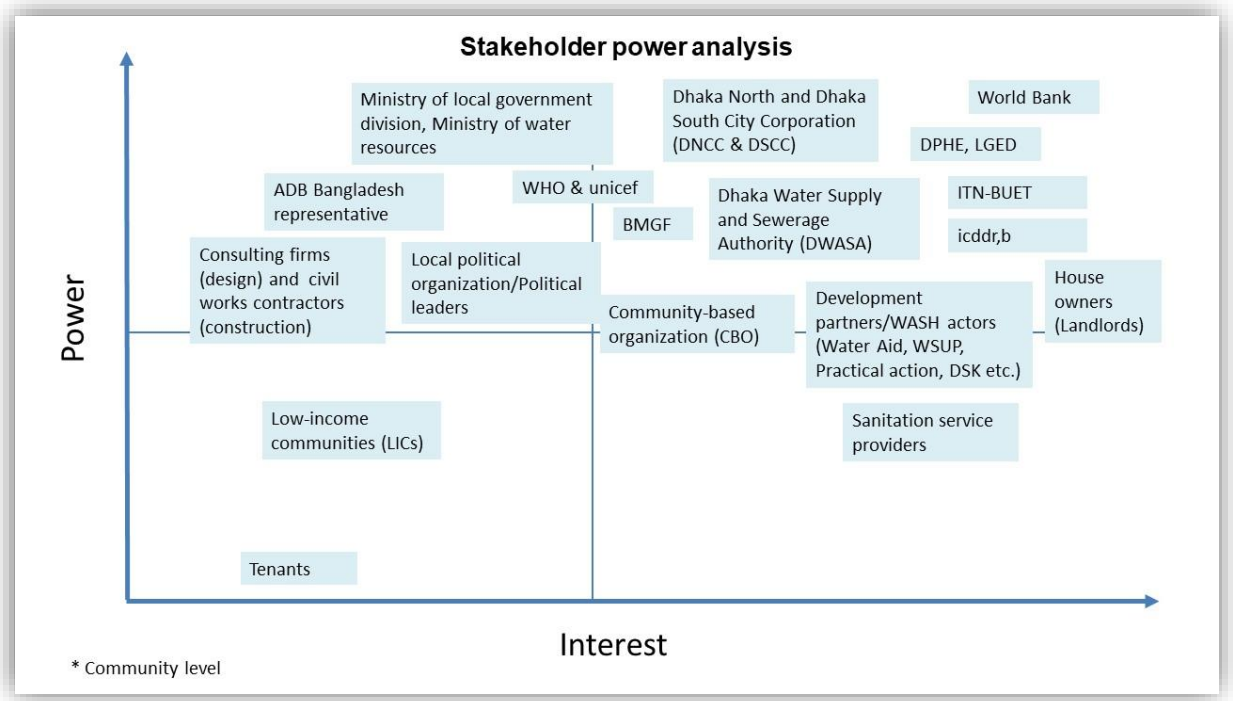


*Figure 3: Stakeholder power analysis in relation to sewer connection*

The stakeholder power analysis illustrates a structurally imbalanced governance landscape in the sanitation sector in Dhaka: where high-power actors such as the Ministry of Local Government, DWASA, DNCC/DSCC, development partners, and major donors showed strong influence over decisions, financing, and infrastructure planning, yet their direct interest in ensuring sewer connections in low-income communities remains variable. In contrast, the actors most affected by inadequate sanitation, low-income communities, and landlords, hold comparatively low power, despite having high or medium interest in sewer improvements. Mid-level actors, including local political leaders, community-based organisations, and sanitation service providers, have moderate interest and limited influence, constraining their ability to advocate for inclusive service. This shows a systemic governance gap: responsibility for sewer expansion is centralised within high-power institutions, while accountability for connection uptake falls on low-power actors who lack resources and formal recognition.

This result was used later to interpret how these structural imbalances shape the limited range and quality of sanitation services available in the study areas, and why interventions targeting only households are insufficient. It informed and supported the recommendation that effective strategies must address upstream governance barriers, such as coordination failures between DWASA and city corporations, weak incentives for service providers, and the exclusion of informal settlements from formal planning, to create an enabling environment so that behaviour change interventions for sewer connection can succeed.

**Phase 4: Conducting fieldwork in five LICs of Dhaka city using the RANAS framework**

In this phase, I carried out fieldwork in five LICs of Dhaka city. I approached the issue from a behavioural science perspective since this approach can help us all understand how we participate in decision-making and how to overcome implementation challenges by addressing bottlenecks related to people's biases, beliefs, motivations, group dynamics, and organisational processes (Lourenco et al., 2022). The behaviour science approach allowed me to explore individual, group, and institutional contexts for certain decision-making and adoption. There were some well-known theories around behaviour change i.e., the health belief model (Rosenstock, 1974), diffusion of innovation theory (Rogers et al., 2014), social cognitive theory (Bandura, 2001), theory of planned behaviour (Ajzen, 1991), transtheoretical model (Prochaska and Johnson, 1998), social norms theory (Berkowitz, 2005) and others. In addition to those, nudging (Thaler and Sunstein, 2009), behaviour change wheel (Michie et al., 2011), FOAM (Coombes and Devine, 2010), SaniFOAM (Devine, 2009), IBM-WASH (Dreibelbis et al., 2013), BCD (Aunger and Curtis, 2016), and RANAS (Mosler, 2012) used for specific behaviour change in water, sanitation, and hygiene programs. Among those, I used the Risks, Attitudes, Norms, Abilities, and Self-regulation (RANAS) model, as this model allowed me to understand the beliefs, motivations, and abilities of doers (connected) vs non-doers (Not connected).

I used the RANAS model to structure the interviews and to conduct the study; however, I was open to adopting or modifying the approach based on research. My data collection approach often went beyond the RANAS model, and especially the qualitative data collection technique (KIIs, IDIs, and FGDs).

The RANAS approach to systematic behaviour change is a well-known technique for formulating and assessing behaviour modification plans that concentrate on and alter the behavioural drivers of a particular behaviour in a particular population (Contzen and Mosler, 2015). The RANAS model is a

recognised framework for comprehending behaviours and has been extensively utilised in both developmental and emergency settings, especially for interventions aimed at changing WASH-related behaviours (Inauen and Mosler, 2014; Contzen and Mosler, 2015; Tumwebaze and Mosler, 2015). Our analytical approach established a clear connection between the significant psychosocial determinants derived from RANAS and the corresponding behaviour change techniques from the RANAS BCT catalogue (Mosler and Contzen, 2016). This process entailed systematically aligning each identified factor with evidence-based techniques that address it, facilitating the design of targeted interventions. This study advances previous research (Alam et al., 2025) by employing a systematic approach to convert behavioural determinants into practical behaviour change techniques (BCTs). BCTs were proposed for the general population but can be adapted to specific local contexts. Interventions addressing vulnerability (risk), behaviour and status (attitude), personal importance (norms), knowledge and confidence in performance (ability), as well as action and barrier planning were prioritised according to the factor analysis.

I used this approach that consists of four steps: (i) identify possible behavioural factors; (ii) measure the behavioural factors identified and determine those steering the behaviour; (iii) select corresponding behaviour change techniques (BCTs) and develop appropriate behaviour change strategies; and (iv), implement and evaluate the behaviour change strategies. My study scope covered the first three steps of the RANAS approach.

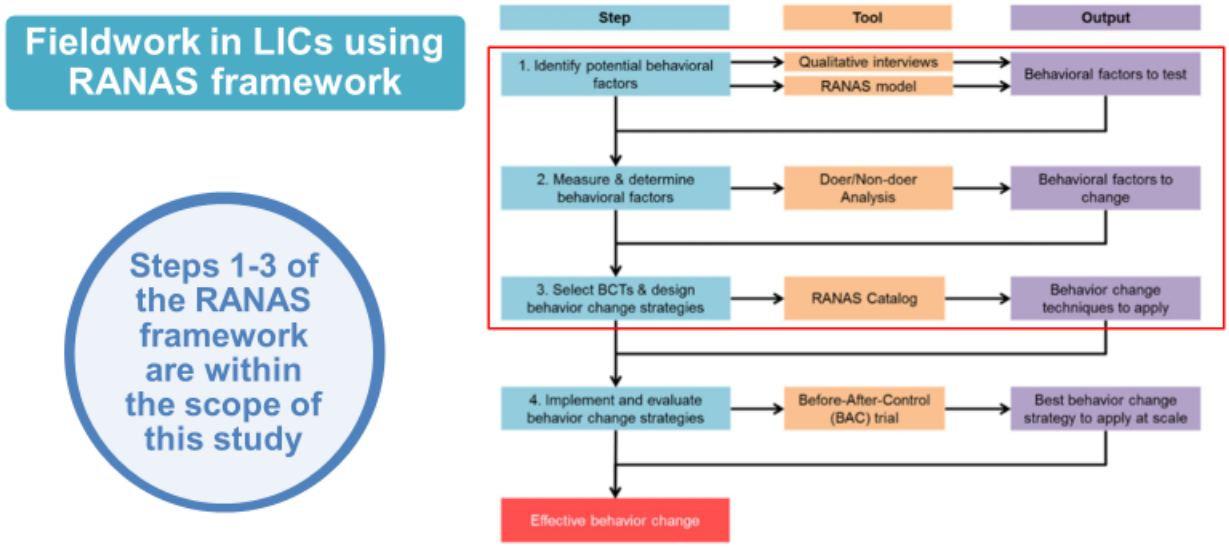


*Figure 4: RANAS approach for this research*

### Step 1: Identify possible behavioural factors through qualitative exploration

For the data collection, I selected low-income communities in Dhaka city as my target population. Initially, to collect information on psychosocial and contextual factors that might influence people to connect with the sewerage, I conducted 8 key informant interviews (KII) with key persons from Dhaka Water Supply and Sewerage Authority (DWASA), Dhaka South City Corporation (DSCC), Dhaka North City Corporation (DNCC), RAJUK, and Community Based Organisation (CBO), and 10 In-depth Interviews (IDI) and 2 Focused Group Discussions (FGD) with landlords from the selected LICs. Key personnel from DWASA, including engineers involved in strengthening the sanitation infrastructure, were included.

I conducted KIIs with officials who are directly involved with Dhaka Sanitation Improvement Project (DSIP) and are actively engaged with the existing and proposed sewer. I also interviewed representatives from a non-governmental organisation involved in urban sanitation service delivery. I selected key personnel from an Engineering Research Institute with experience implementing urban sewer solutions, and DWASA engineers from Maintenance, Operation, Distribution, and Service (MODS) zones involved in strengthening the sanitation infrastructure. The interviewees were selected based on their experience and knowledge regarding the Dhaka Sewerage Master Plan and those closely involved with the Dhaka Sanitation Improvement Project. The qualitative approach helped me identify the factors in urban areas that influence household wastewater management behaviour and to explore the pattern of uptake of sewer across Dhaka city among the low-income population.

For IDIs, I selected residents of LICs who were house owners (landlords). I also chose CBO/community leaders responsible for monitoring/decision-making for LICs' utilities or who previously participated in various implementing activities. For FGDs, I conducted 2 FGDs with the landlord group.

*Table 1: Data collection technique used for qualitative exploration*

| **Data collection technique** | **KII** | **IDI** | **FGD** |
|---|---|---|---|
| **Participant types** | Dhaka Water Supply and Sewerage Authority (DWASA)<br>Dhaka South City Corporation (DSCC)<br>Dhaka North City Corporation (DNCC) | Landlords<br>CBO leaders | 2 FGDs with Landlords |

| | | | |
|---|---|---|---|
| | Community-Based Organisation (CBO) | | |
| **Total number** | 8 | 10 | 2 |

### Step 2: Measure the behavioural factors and determine those steering the behaviour

*Activity 1: Survey*

For the second step, I prepared a questionnaire and performed surveys with a sample size of 384 households to measure the behaviour and the potential behavioural factors, and a protocol to conduct observations of the target behaviour by adopting the local context.

I conducted a household survey with two types of respondents categorised as connected to sewer (doers) and not connected to sewer (non-doers), and included adult participants (above 18 years old). Survey participants resided in any Low-Income (LICs) area within Dhaka city. Within each LICs, I collected information regarding the number of total households, total population, land ownership (government, private, etc.), duration of living in that area, LIC management characteristics, the total number of toilets, toilet location (with GPS), toilet types, whether it was shared or communal, improved or unimproved, water point types, service provider and responsible parties (NGOs, community leaders, etc.) involved with the sanitation system and, LIC's preferences regarding toilet facilities and sewer connection status.

The survey consisted of behavioural (perceptions, thoughts, feelings, and beliefs which influence the practice) and contextual factors. The contextual factors were divided into three categories: the social, the physical, and the personal. It helped me to understand the current water, sanitation, and sewerage conditions, information about existing service delivery mechanisms, satisfaction level regarding the sanitation system, and reasons that influence individuals to connect with the available sewer.

A doer/non-doer analysis was conducted to specify which behavioural factors were most critical. These were the factors to be addressed through behaviour change techniques. A doer/non-doer analysis compares the responses of people who do a behaviour (doers) to the responses of those who do not (non-doers); in this research ‘who took the sewer connection’ and ‘who did not’. A large difference between doers and non-doers in responses to a question about a behavioural factor indicates that the factor is critical. A doer/non-doer analysis involves three steps; (i) the sample is

divided into doers and non-doers, (ii) mean scores are calculated separately for doers and non-doers, and (iii) the mean scores are compared between doers and non-doers.

A sub-group analysis was done for years of education, age of respondents, and monthly household income to explore further; however, sub-group analysis may not be powered enough to provide a statistically significant outcome.

As an outcome of these activities, a paper has been published (Chapter 5) titled 'Barriers to Sewer Connection in Urban Dhaka: Individual and Organizational Challenges'.

*Activity 2: Behavioural Ranking*

After identifying behavioural determinants of individuals to connect with the sewer, I conducted the ranking exercise with connected and not-connected and asked them to rank the statistically significant/most valued (based on analysis from Step 2) determinants from most to least important for them to influence them to connect/not connect with sewer. I also asked them to provide reasons why they consider this specific behaviour.

**Step 3: BCT (Behaviour change technique)**

*Activity 1: Develop the initial behavioural change technique*

I compared the mean scores of doers and non-doers for each behavioural factor. Based on the larger difference in mean scores between doers and non-doers, I specified the behaviours through BCTs. I also considered the contextual drivers and enablers of individuals' waste management behaviour based on the qualitative findings, and behavioural ranking. Based on the analysis, I developed the initial behavioural change technique.

Behaviour change techniques (BCTs) are the core elements of an intervention plan aimed at altering or redirecting the systems that regulate behaviour. BCTs are identifiable, replicable, and indivisible, meaning they cannot be broken down further. When various BCTs are combined and delivered through one or more communication channels, they form intervention strategies. In this context, communication channels represent how the intervention is implemented, while BCTs represent what is being delivered. To achieve maximum effectiveness, BCTs should be tailored to address the behavioural traits that distinguish doers (those who adopt the desired behaviour) from non-doers (those who do not). While many BCTs can influence multiple behavioural factors, each primarily targets a dominant behavioural component. An exception is the technique of "exploiting persuasive

attributes," which involves leveraging the persuasive qualities of the message and its source. These attributes may include the source's credibility, expertise, empathy, notoriety, and public profile, as well as the length and number of arguments presented in the message. Incorporating persuasive features alongside each BCT can enhance the intervention's impact, as every BCT represents a specific message delivered from a particular source.

Behaviour change techniques (BCTs) are selected for behaviour change strategies based on their potential to influence the key behavioural characteristics identified in step 2. To facilitate this, a catalogue of BCTs has been compiled, drawing on research from environmental psychology and health psychology, which outlines which BCTs are likely to impact specific behavioural aspects. To ensure effectiveness, the mode of delivery for BCTs should be tailored to the local context by combining them with appropriate communication channels. This pairing of BCTs and communication channels forms a comprehensive behaviour change strategy. In practice, BCTs and communication channels are closely intertwined, as the channels serve as the means of delivering the BCTs. It is crucial to recognise that while BCTs represent what is being delivered, communication channels represent how the delivery takes place.

*Activity 2: Validate and update BCT with stakeholders*

After developing the draft BCT, I conducted a few KIIs with key persons and validated the BCT with key stakeholders through a stakeholder engagement workshop. I shared the BCT with the advisory committee to get their feedback. I finalised the BCT after all the above activities.

As an outcome of these activities, a paper has been published (Chapter 6) titled 'Sewer Misconnection: Recommendations for Increasing Sewer Connections in Low-Income Urban Communities in Dhaka, Bangladesh.

Table 2: Summary of Methodological phases and the tasks carried out

| **Objectives** | **Research Questions** | **Data Collection Method** | **Tasks** |
|---|---|---|---|
| To understand the drivers and motivators to connect with available sewer in low-income urban areas | What are the drivers and motivators of individuals and household to connect with an available sewer | Systematic literature review | Conduct a preliminary search of the literature to get an overview of the research topic |

| | | | |
|---|---|---|---|
| | in low-income urban areas? | Scoping review | Develop inclusion and exclusion criteria and a search strategy for scoping review<br><br>Search relevant databases including Google Scholar, PubMed |
| | | Key Informant Interviews with professionals and CBO leaders | Conduct Key Informant Interviews with policymakers, professionals, and citizen groups in urban Dhaka |
| To understand the barriers to connecting with an available sewer in low-income urban areas | What are the barriers to connecting with an available sewer in low-income urban areas? | Key Informant Interviews with professionals and CBO leaders | Conduct Key Informant Interviews with policymakers, professionals, and citizen groups in urban Dhaka |
| | | IDI with landlords | Conduct IDIs with landlords |
| | | Household survey<br><br>Observation of facilities | Develop and conduct surveys and observations in the low-income community |
| To develop behaviour change intervention to promote sewer connection in a low-income urban community | What are the behaviour change indicators that can influence an individual to connect with a sewer | Focus Group Discussion with users | Develop behaviour BCT components using RANAS |
| | | Stakeholder engagement workshop | Validate with stakeholders |
| | | Advisory committee meeting | Finalisation of BCT |

## Sample size calculation

I considered the following formula for the sample size calculation

$n = (Z\alpha/2+Z\beta)2 * (p1(1-p1)+p2(1-p2)) / (p1-p2)2,$

where $Z\alpha/2$ is the critical value of the Normal distribution at $\alpha/2$ (for a confidence level of 95%, $\alpha$ is 0.05 and the critical value is 1.96), $Z\beta$ is the critical value of the Normal distribution at $\beta$ (for a power of 80%, $\beta$ is 0.2 and the critical value is 0.84) and p1 and p2 are the expected sample proportions of the two groups (Wang and Chow, 2007).

I considered a confidence level of 95%, a power of 80% and a maximum uptake among the connected to sewer group is 65% (according to the DWASA estimates), and a maximum non-connection among the not-connected to sewer group is 80% (according to the current estimates for Dhaka); and the sample size is 136 for each group. I considered 20% non-response as LICs have a high level of migration in and out, and the sample size per group is 164. Considering the calculation, the total sample size would be 328 (connected- 164, and not-connected 164).

## Expected Outcomes

This research project contributed to new knowledge that helps to explain the extent to which determinants of sewer connection in low-income communities, especially among landlords. In the end, the PhD will support the government and city planners in taking action to solve household wastewater management issues in peri-urban and urban areas. A set of outcomes is:

- Factors that influence households to connect with the available sewer
- A context-specific behaviour change intervention to promote sewer connection in a low-income urban community

## Dissemination and stakeholder engagement

| **Date** | **Conference/Workshop** | **Purpose** |
|---|---|---|
| Jun ‘22 | Water-Wiser Early Career Conference | Sharing initial PhD topic with peers |
| Aug ‘22 | Stakeholder workshop | Sharing PhD research idea with stakeholders in Dhaka |

| | | |
|---|---|---|
| May ‘23 | DWASA Workshop | Workshop with DWASA stakeholders |
| Oct ‘24 | Impact workshop | Discuss with impact partners on the future implementation of BCC |
| Nov ‘24 | Stakeholder engagement workshop | Develop BCT with stakeholders |
| April ‘25 | Dissemination | Present results to stakeholders in Dhaka |
| Oct ‘25 | UNC Water & Health Conference | Present final outputs and results |

## Risk statement

Due to recent turmoil in Bangladesh, we could not conduct planned supervisory meetings as internet connectivity was an issue. There was an internet shutdown from 19-29 July, 2024 and then poor network for another two weeks. My supervisor and I communicated via WhatsApp or email after that period. However, the turmoil impacted my study progression, and I took two months of extension to recover from that loss.

At the beginning, the most significant risk was that pertaining to the Covid-19 pandemic and travel uncertainties due to new variant outbreaks. It has been the case that countries have previously announced spontaneous travel restrictions when infection cases were high, including Bangladesh, where I was carrying out my fieldwork. Although the risk of travel restrictions in the 2nd year was low, and I planned to mitigate this by hiring research assistants from icddr,b, my impact partner, to carry out the data collection. The other risk was political instability due to the national election in December 2023 in Bangladesh, which delayed quantitative data collection for two months. To mitigate this risk, I hired more research assistants to complete the survey and observation.

## Ethical Approval and Research Governance

Considering the ethical implications of the research is vital, both in the research design and the management process of the PhD. As my research entailed carrying out primary data collection with human participants and local communities, both in the preliminary field visits and during field work in Dhaka, ethical approval was required.

An ethical approval was received from the Faculty of Engineering and Physical Sciences Faculty Research Ethics Committee (EPS), University of Leeds on 7$^{th}$ June 2023 (MEEC 22-022). Another

ethical approval was received from the Ethical Review Committee of icddr,b on 21 October 2023 (protocol number PR-23088).

## Data Management

In line with the requirements of the University of Leeds' Information Protection Policy, data was collected, organised, documented, shared and stored ethically and securely throughout the PhD research and beyond.

The following principles proposed by the University Safeguarding Data Policy were adhered to:

- Confidential and critical data encryption
- Data was backed up on several locations i.e., OneDrive, local files & network source
- Use of email was not used to share classified content
- Use of removable media (e.g. memory sticks) was minimised where possible
- An encrypted laptop and passwords were used for access to confidential data
- Potential partners were made aware of, and made to follow the University management policy.

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# Chapter 4: Behaviour Change Interventions to Promote Household Connectivity to Sewer: A Scoping Review

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## Abstract

Households without access to a functioning and well-managed sanitation system produce untreated faecal waste. While connecting households to sewers is ideal in densely populated low-income areas, the connection rates often remain low. Most interventions to increase connectivity focused on addressing financial, social, and legal barriers; there is limited evidence on the effectiveness of behaviour change interventions in promoting sewer connections. Thus, we aim to understand the effectiveness of behaviour change interventions in increasing the uptake of sewer connections. We developed a review protocol with key search terms relating to households, sewers, behaviour change interventions, promotion, and effectiveness. We aimed to identify both the types of interventions deployed and their impact on increasing household sewer connections. Eleven articles met the eligibility criteria and were included in the review. Findings indicate that changes in rates of connection were associated with interventions that included a blend of indirect financial subsidy in the form of a free connection and community-engagement activities. There was limited evidence that behaviour change campaigns without financial incentives led to changes in sewer connection rates. A multi-component package involving financial subsidies with community engagement are likely to improve the sewer connection rate.

## Background

Nearly half of the global population still lacks access to safe sanitation services, and the majority of those without access are poor (JMP, 2021). In 2020, only 34% of the global population had safely managed sanitation through sewer connections, which were mostly prevalent in urban areas and in higher-income countries (JMP, 2021). The WHO-UNICEF Joint Monitoring Programme for Water Supply, Sanitation and Hygiene (JMP) defines safely managed sanitation services as use of improved facilities that are not shared with other households and where excreta are safely disposed of *in situ* or removed and treated off-site (JMP, 2023). A safely managed sanitation facility is a prerequisite to prevent exposure to excreta and ensure hygienic management and disposal of the treated excrement (WHO, 2018). Households without connection to a functioning and well-managed sanitation system produce untreated faecal waste and domestic greywater (hereafter referred to as 'wastewater') (Jiao, 2021). This wastewater is typically collected in poorly constructed and improperly maintained pits and tanks, from where it is discharged either directly into storm drains or into the subsoil (Nyenje et al., 2010; Nyenje et al., 2013). Overall, more than 80% of wastewater created by human activities is disposed into rivers and oceans without treatment, causing eutrophication, water quality deterioration, biodiversity loss, and physiological and behavioural change in existing aquatic species, which results in environmental degradation (Sami Ullah and Umara, 2021). The release of untreated wastewater also contributes to the global burden of disease related to inadequate WASH, which Wolf et al. (2023) estimate is associated with 69% of diarrhoea, 14% of acute respiratory infections, and 10% of undernutrition, and approximately 100% of the burden of soil-transmitted helminthiasis (Wolf et al., 2023). There are many places where sewers exist and could convey waste to treatment but the connection rates remain low, so the benefits of the sewers are not realised (Kennedy-Walker et al., 2020). Therefore, in these areas whereby sewers are underutilised, interventions to encourage households to connect are practical options to improve public and environmental health (World Bank, 2020).

Conventionally, the terms on-site and off-site sanitation systems are used widely to define excreta and wastewater management processes. In an on-site sanitation system, excreta and wastewater are collected and stored where they are produced, as opposed to off-site sanitation, which comprises of a sewer network which conveys sewage to a wastewater treatment plant (Tilley et al., 2014). Sewers may be 'separate' or 'combined' – carrying wastewater exclusively in the former case, or also conveying stormwater in the latter (Kennedy-Walker et al., 2020). 'Conventional sewer design uses standard hydraulic assumptions and safety factors which result in relatively large sewers and deep excavation. Costs can be reduced through the use of 'simplified hydraulic designs'

(simplified sewers, sometimes known as condominial sewers) or the inclusion of a settling tank at the household level ('settled' sewers). In both these latter cases, the resultant networks have reduced depth, smaller diameters, and on shallower hydraulic gradients (Kennedy-Walker et al., 2020). However, where connecting households to off-site sanitation (sewer) is regarded as an appropriate waste management system, especially for densely populated areas, even though the sewers exist, many households choose not to connect to them (Kennedy-Walker et al., 2020) in many areas due to a multitude of factors.

The household connection rate to sewer is associated with a range of factors, including social, financial, policy, and technical considerations, alongside individual sanitation behaviours, with reported barriers to connection comprising cost, potential property damage, absence of government mandates, and dissatisfaction with current wastewater management facilities (Dhawan et al., 2001; Tuy, 2003; Davis et al., 2010; Robinson, 2011; Yoshino et al., 2019; Kennedy-Walker et al., 2020). For example, in Latin America, people were unwilling to connect to the sewer due to the monthly tariff and high cost of connection, along with not being motivated by the government (Kennedy-Walker et al., 2020). The coverage of sewer in cities of South Asia and sub-Saharan Africa was less than 25% due to issues including limited network extension and a lack of mechanisms to involve poorer households (Yoshino et al., 2019). Another study in Zambia showed that a considerable number of households were hesitant to take sewer connections due to a history of sewerage obstructions and flooding (World Bank, 2016). In Dhaka, the capital of Bangladesh, only 20% of the total population is connected to a sewer, mostly from high-income communities (Alam et al., 2020). The majority of households use some form of on-site storage to collect wastewater , and wastewater is typically released untreated into the environment largely untreated (Mansour et al., 2017).

Some sewerage authorities have attempted to develop interventions that target behaviour change to encourage connection where sewer lines exist. These include financial incentives and subsidies to drive sustainable investment into building a sewer and motivating households to connect (Melo, 2005; Robinson, 2011; Patil et al., 2014a; Kennedy-Walker et al., 2020). Social programs and other communication strategies were also considered to improve sanitation (Melo, 2005; Freeman et al., 2009; Davis et al., 2010; Bongartz et al., 2016; Kennedy-Walker et al., 2020; Giannazi, 2022). By contrast, water and sanitation authorities in certain areas implement a penalty if households fail to connect with the sewerage, or in some cases the government can take legal action if the faecal matter is discharged into the water sources (WSUP, 2012). The aim of this review is to summarise available evidence for the effectiveness of different behaviour change interventions across the globe

in increasing the uptake of sewerage connections in households. The findings of this review can be used for implementing context-specific appropriate tailored interventions to be given as a comprehensive package in different regions of the world to increase the uptake of sewerage connection among households.

## Methods

### Overview

The aim of this scoping review was to summarise the available evidence for the effectiveness of behaviour change interventions in promoting better household connectivity to sewers. We followed the PRISMA guidelines and incorporated the following steps during the review process (Figure 5) (Tricco et al., 2018).

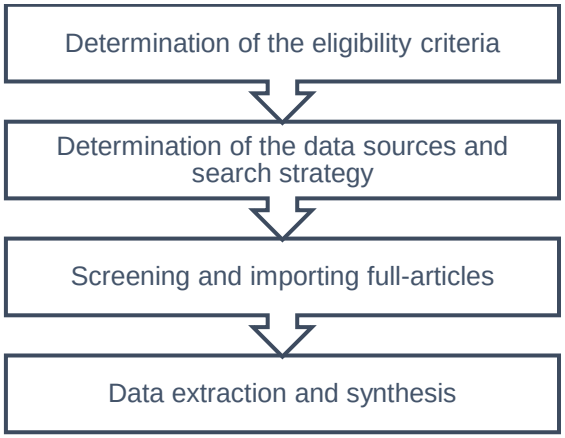


*Figure 5: Flow diagram of the steps for conducting the scoping review*

We developed a protocol that specified the research questions, inclusion/exclusion criteria, data sources and search engines (Supplementary Table 1). We followed the Preferred Reporting Items for Systematic Reviews and Meta-Analyses extension for Scoping Reviews (PRISMA-ScR) checklist to conduct the review (Tricco et al., 2018).

### Types of publications, population, and interventions

We included journal articles and organisational or institutional professional or technical reports written in English in the review. In the latter category, we selected publications that focus on aspects of off-site sanitation involving sewer and behaviour change interventions provided to increase sewer connectivity (Supplementary Table 2). All eligible studies conducted across the globe covering both urban and rural populations were included.

Behaviour change intervention is defined as “a coordinated set of activities designed to change specified behaviour patterns” (Michie et al., 2015). All the included articles mentioned different interventions to connect the households to the sewer while implementing their projects. These interventions comprised subsidies, promotional activities, educational interventions (trainings/workshops/educational kits), and community engagement (Foster, 2001; Melo, 2005; Robinson, 2005; Beauchêne, 2009; Kennedy-Walker et al., 2020; Sachet, 2020). Therefore, these were considered as behaviour change interventions in this review.

We considered two types of subsidies: direct and indirect. Direct subsidies take the form of a monetary transfer to a specific beneficiary or household. The household are then able to spend that money on the goods or services of their choice. Indirect subsidies are those where the household or individual receives something which has monetary value but does not receive cash. The most common form of indirect subsidy of concern here is the reduction of the cost of necessary products or services such as costs of connecting to a network (Scott, 2024). Subsidies may equal the full cost of the goods or services, in which case they are provided ‘free at the point of use’. A common example of this is that connection fees are waived for specific households. Therefore, we are referring to this indirect subsidy as a free connection that was received by the household owners while providing the sewer intervention.

**Outcome measures**

The change in the percentage of households connected to the sewer after implementing behaviour change interventions was selected as the outcome measure.

**Inclusion and exclusion criteria**

A set of specified inclusion criteria was determined that was used for searching studies relevant to the research objectives. The inclusion criteria involved selecting any journal article, organisational or institutional report and materials from websites that were related to behaviour change interventions for increasing sewer connection across the globe. The specified time frame used for searching relevant published studies was from 1st January,1980 to 31st December 2022, as the study protocol was developed in January 2023.

A set of exclusion criteria was developed and applied to the search (Supplementary Table 1). Articles that were not related to off-site sanitation and focused on on-site sanitation were excluded. Articles

and reports published in any other language than English were not selected for further screening. Furthermore, any type of review article was excluded. We also excluded any article that did not contain full details of the programme design and outcome. The study eligibility criteria are summarised in Supplementary Table 1.

***Data Sources and Search Strategies***

Two reviewers (AR and SN), under the guidance of MUA developed a search strategy and independently searched PubMed, Cochrane, Scopus, and ProQuest through Hinari databases for peer-reviewed literature published from 1st January 1980 to 31st December 2022. For grey literature, Google, Google Scholar, and the websites of the World Bank, WSUP, Practical Action, and WaterAid were searched. The first 300 results were screened for grey literature search in Google and Google Scholar (Haddaway et al., 2015). Manual searching of the reference list of the included articles was conducted for additional relevant publications.

We conducted a preliminary search for published scientific literature on the topic of interest to identify keywords for developing an advanced search. Afterwards, we developed key search terms related to households, sewers, behaviour change interventions, promotion, and effectiveness. A librarian working at the International Centre for Diarrheal Disease Research, Bangladesh (icddr,b) was invited to review the search strategy, and according to his suggestion, the search strategy was modified. A detailed search strategy with results is presented in Supplementary Table 2.

***Screening and importing full articles***

According to the PRISMA guidelines, we selected articles in three phases: (i) identification, (ii) screening, and (iii) inclusion. The literature identified by the search terms was imported to EndNote (version 20), and duplicates were removed. The updated list was then imported into Rayyan's online software.

MUA, AR, and SN collaboratively reviewed the articles by screening the titles and abstracts according to the study inclusion and exclusion criteria. The reviewers conducted a second review of each article that was excluded after the screening process to ensure that no pertinent papers had been inadvertently rejected. Studies that did not meet the criteria due to insufficient information in the title and abstract were referred to the reviewers for further discussion prior to a determination of

inclusion. After that shortlisted articles were screened in full text. Disagreements regarding eligibility were resolved through discussions among the two reviewers, with approval from the third reviewer. Corresponding authors were contacted in the situation when full-text articles were not found.

***Critical appraisal of the included studies***

For our scoping review, we adapted the JBI Critical Appraisal Checklist for Case Reports to better fit our study (JBI). The modified tool assessed eight key aspects: (1) population demographics, (2) history of sewerage conditions with a timeline, (3) current household connections, (4) clarity of methods and results, (5) description of interventions, (6) post-intervention conditions, (7) adverse events or limitations, and (8) key lessons. Two (AR, SN) reviewers assessed each case report against these criteria to ensure reliability and minimize bias. Any discrepancies between the reviewers were resolved through discussion and a consensus score was reached for each study. This critical appraisal allowed us to evaluate the overall quality and completeness of the included case reports, providing insights into the methodological strengths and limitations within the existing literature.

Each criterion was rated as "Yes" (1 point), "No" (0 points), "Unclear" (.5 points), or "Not Applicable (N/A)", with N/A responses excluded from the final score calculation. In the context of each study, a score of 1 or ‘yes’ considered as good quality, a score of 0.5 or ‘unclear’ considered as fair quality and a score of 0 or ‘no’ considered as poor quality (Munn et al., 2020). The NHLBI defines a study as "good" when it exhibits low bias, resulting in enhancing the likelihood that its results are accurate and genuine. A "fair" study recognises certain biases; yet, these biases are insufficient to invalidate its conclusions. A "poor" rating suggests a significant risk of bias, consequently questioning the accuracy of the results (Risk Assessment Working Group, 2013). The overall critical appraisal for each study was determined by summing the individual scores assigned to the eight criteria. Case report quality was classified as high quality (≥6), moderate quality (4–5), and low quality (<4) based on the total score.

***Data Extraction and Synthesis***

A data extraction form was created. The data were extracted based on the initial author's last name, the article category, the guiding criteria, and the number of checklist items. The review checklist was extracted into an Excel spreadsheet. Title, objectives, methodology, results, references, and recommendations were the section categories that were used for the review checklist.

This data matrix was disaggregated into two key themes with relevant sub-themes, including (i) interventions provided to increase sewerage connection among households and (ii) the impact of the interventions for sewerage connection among households. Two reviewers extracted data on each theme under the guidance of MUA. Subsequently, a narrative synthesis of the extracted data was performed.

***Ethical approval***

The study involved summarising existing published data from the literature. No ethical issues arose from the execution of this work.

## Results

The initial literature search yielded 10,017 unique articles, of which 109 were duplicates. These were assessed to determine against the inclusion criteria, resulting in a set of 33 relevant articles. Of these 33 articles, only 11 met the eligibility criteria and were included in the review (2). Reason of the exclusion of the articles was mentioned in the supplementary Table 3.

The studies were conducted in diverse locations, both upper- and low-income countries, including Ecuador, Colombia, Bolivia, multiple cities in Brazil, Kenya, Morocco, India, and Pakistan. One report from the World Bank (Kennedy-Walker et al., 2020) included several case studies from multiple locations. Among those case studies, five met the inclusion criteria of this review (Kennedy-Walker et al., 2020) and were included as five distinct studies. The selection process is summarised in Figure 6 below. The studies are summarised in Table 4.

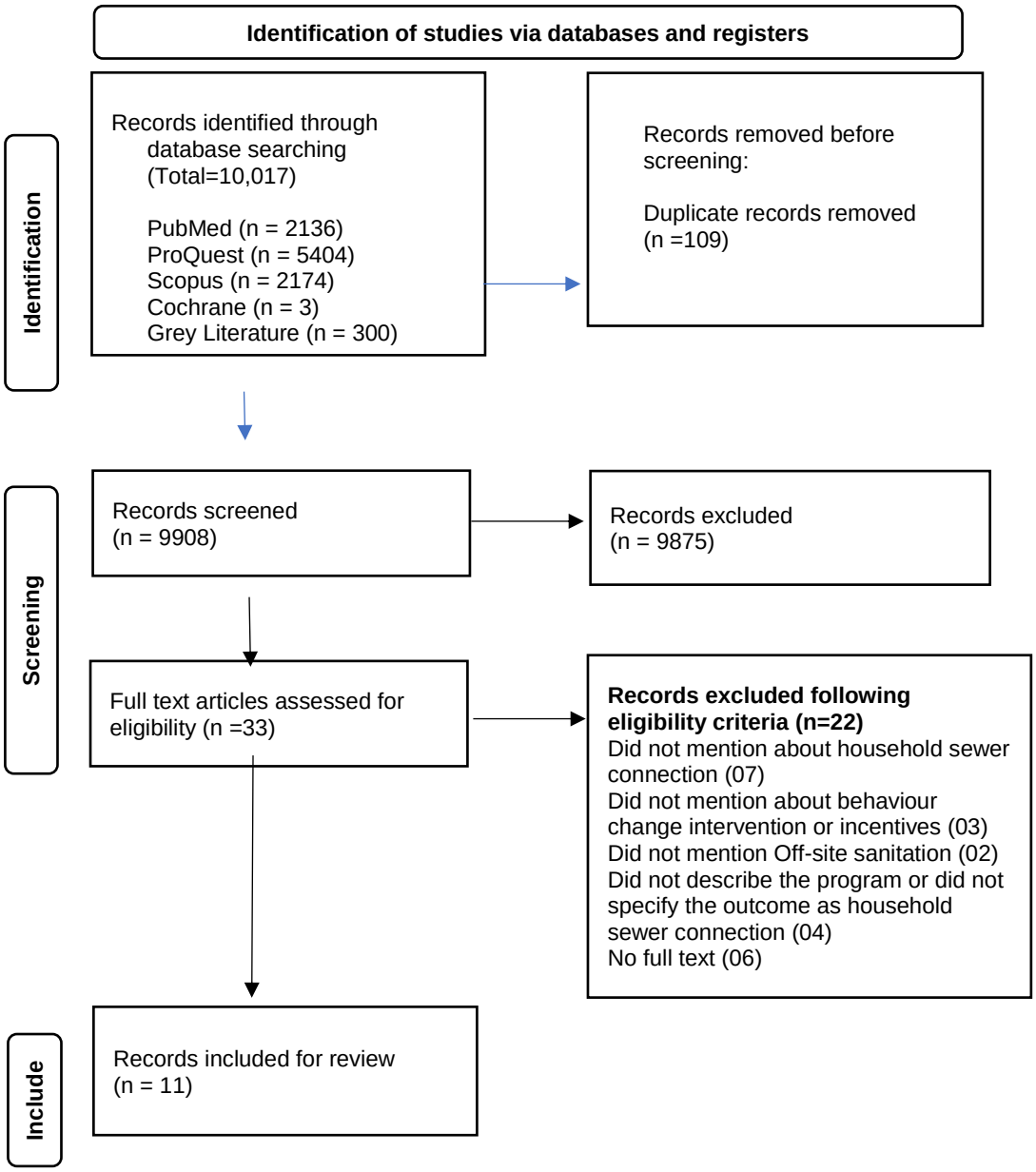


*Figure 6: PRISMA flowchart illustrating the study selection process*

The quality assessment of 11 studies was classified as good, fair, and poor quality according to their total critical appraisal ratings. Of these, six studies were assessed as high quality, with ratings between 6.50 and 7.50. Four studies were classified as fair quality, with scores ranging from 5.00 to 6.00. One study was deemed of poor quality, obtaining a score of 3.50 (Figure 7). The distribution reveals that the majority of research was categorised within the good to fair quality range, but only

one study exhibited poor methodological rigour. The full assessment can be found in Supplementary Table 4.

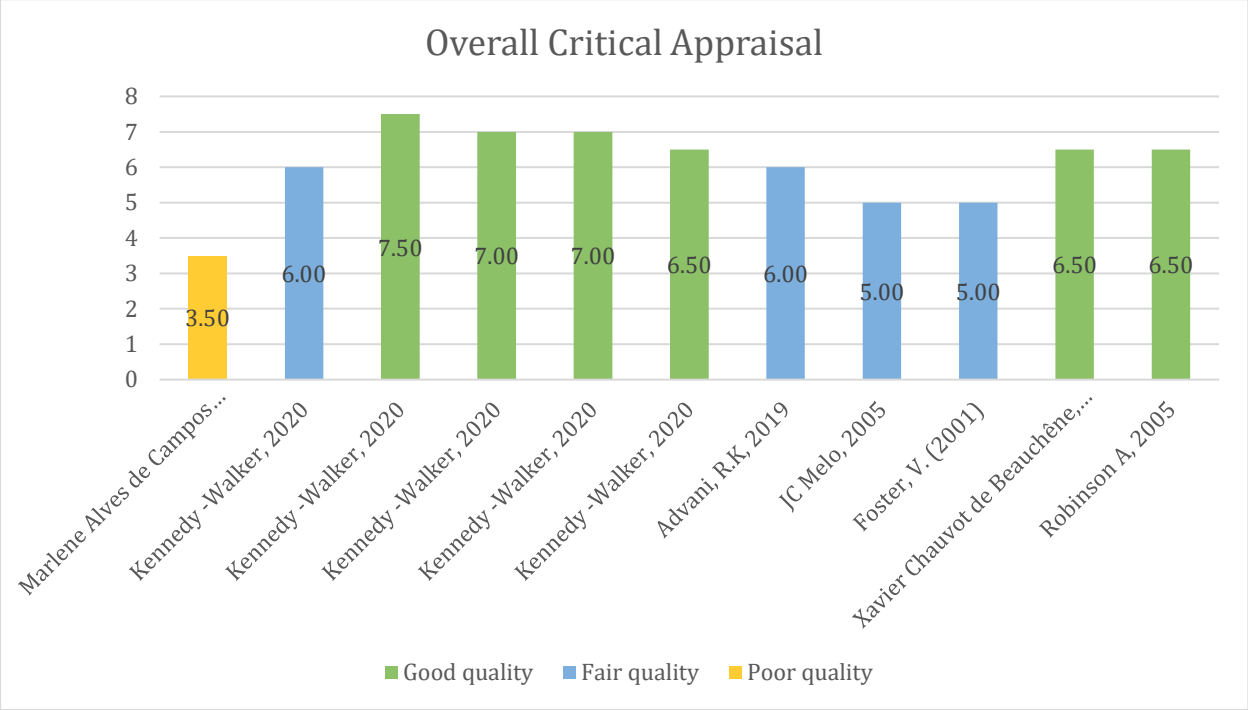


*Figure 7: Distribution of overall study quality appraisal*

***Design and settings of included projects***

The majority (9 out of 11) of the studies were in professional or technical project reports, with all being overviews of implemented projects. Among the included studies, six (55%) were conducted in upper-middle-income countries (Kennedy-Walker et al., 2020) of the region of Latin America, and the remaining five studies (45%) were conducted in low-income countries of different regions of the world. Ten (90%) of the included studies were implemented in urban settings, and only one (10%) was implemented in rural settings.

***Summaries of included projects***

The case study from Lodhran, Pakistan, the local NGO Lodhran Pilot Project (LPP) implemented a low-cost sewerage schemes project in Punjab in 2001 to connect rural households to the sewer across 12 villages which had equal or less than 1200 households (Robinson, 2005). The project focused on connecting households to sewers in these villages that had no existing sewer connection. In India, Tamil Nadu was the most urbanised state of the country, where 75 per cent of households

had access to on-site sanitation, and only one-fifth of the population of the state's capital had a connection to the sewer (Kennedy-Walker et al., 2020). Thus, A project called Third Tamil Nadu Urban Development Project (TNUDP III) targeted to connect 1,551,995 households to sewers in 25 cities state-wide between 2005 and 2014.

Among the studies in Brazil, one followed a mixed-method design to review the implementation barriers of the “Connect to the Network” programme in the state of Parana. “Connect to the Network” encompasses 17 projects and primarily focuses on establishing guidelines for social and environmental interventions to increase the uptake of sewer connections (Sachet, 2020). Another programme called “Se liga na rede” in the western and southern parts of the Sao Paulo metropolitan region was designed to connect around 192,000 households to the new sewer between 2012 and 2018. In 2012, this programme, which the state enterprise started, was designed to accelerate the expansion of sewer connections in the Greater Vitória Metropolitan Region (GVMR) of the state of Espirito Santo. This pilot programme ran for three years (2012-2015) and aimed to connect 20,000 households to the sewer. One of the aspects of the program was that they specifically targeted low-income households to increase sewer connections from the existing 13,000 connections (Kennedy-Walker et al., 2020).

A condominial sewerage approach was initiated under the “Bahia Azul” (Blue Bahia) umbrella programme in the state’s capital city of Salvador and 11 other cities between 1995-2004. The programme aimed to enhance solid waste, water, and sewerage solutions for all urban residents, with special attention paid to those residing in low-income informal settlements where traditional sanitation methods could not be used. In Salvador, only 26% of the population had access to sewer prior to the programme. At the beginning of the programme, the condominial sewerage approach was only used for low-income areas; however, with its success, the model was adopted for all areas of the city (Melo, 2005).

A similar approach was initiated in the urban cities of La Paz and El Alto, Bolivia. Learning from Brazil, the El Alto Pilot Project (EAPP) aimed at implementing the condominial sewerage and tested its applicability in the context of private sector participation in service provision. The short-term pilot project's objective was to provide water and sanitation connections to 5,000 poor households, where 60% of the households lived below the poverty line. The pilot project was implemented from 1998 to 2000 (Foster, 2001).

In the urban area of Guayaquil, Ecuador, a simplified sewerage pilot project enabled connections in hard-to-reach areas and got beyond the technical difficulty of joining households to a sewer. The target audience for the programme resided in the most impoverished areas, where the number of residents living in poverty ranged from 55% to 70%, and 18% to 32% of households experienced extreme poverty. The duration of the pilot project was two years (2013-2015) (Kennedy-Walker et al., 2020).

The National Administrative Department of Statistics (DANE) of Columbia estimated that 93% of Colombia's urban population has access to sewer, with 78% of those in the poorest quintile having sewer access. In 2011, the government approved the National Development Plan, which authorised subsidies for household connections. This initiative led to the "Connect-with-water program", aimed to connect 90,000 poor families by providing subsidies. The programme installed sewer connections in households across 20 municipalities from 2012 to 2014 (Kennedy-Walker et al., 2020).

The Global Partnership on Output-Based Aid (GPOBA), a World Bank-administered programme, piloted an innovative Output-Based Aid (OBA) method with the goal of increasing access to water and sanitation services among the underprivileged living in urban and peri-urban areas of Morocco. The project launched in 2007 and aimed to connect 11,300 households (approximately 56,000 people) to piped water and sanitation services in poor peri-urban neighbourhoods in the three cities (Casablanca, Tanglers, Meknes) (Beauchêne, 2009).

Another Output-Based Aid (OBA) Programme (2012–18) was launched in the Nairobi City of Kenya, to facilitate sewer connections among low-income households living in informal settings. New household sewer connections were constructed under the project, and the programme targeted around 167,000 people or 13,000 households to connect to the sewer to provide better sanitation (Advani, 2019).

***Interventions provided to increase sewer connections among households***

The included projects used different behaviour change interventions that influenced the uptake of sewer connections among households in different communities (Table 3). The interventions involved indirect subsidies (free connection) to increase connectivity, promotional activities (door-to-door campaigns, awareness campaigns, promotion of programme benefits), education (training or

workshop, or educational kit distribution), and community engagement activities (mass mobilisation for construction and maintenance).

*Table 3: Interventions provided for increasing sewer connection among households*

| **Reference** | **Country** | **Interventions** | | | | | |
|---|---|---|---|---|---|---|---|
| | | **Indirect subsidies (Free connection)** | **Promotional activities** | **Education** | | | **Community engagement** |
| | | | | Training | Educational kit | Workshop | |
| Marlene Alves de Campos Sachet, (2020) (Sachet, 2020) | Brazil (Parana) | | | ✓ | ✓ | | ✓ |
| Kennedy - Walker, 2020 (Kennedy-Walker et al., 2020) | Brazil (Espirito Santo), | ✓ | ✓ | ✓ | ✓ | | ✓ |
| Kennedy - Walker, 2020 (Kennedy-Walker et al., 2020) | Colombia | ✓ | | | | | |
| Kennedy - Walker, 2020 (Kennedy-Walker et al., 2020) | Ecuador | ✓ | ✓ | ✓ | | | ✓ |
| Kennedy - Walker, 2020 (Kennedy-Walker et al., 2020) | Brazil (Sao Paulo) | ✓ | ✓ | | | | |
| Kennedy - Walker, 2020 (Kennedy-Walker et al., 2020) | India (Tamil Nadu) | | ✓ | | | | |
| Advani, R.K, 2019 (Advani, 2019) | Kenya | ✓ | ✓ | | | | ✓ |

| Reference | Country | Interventions | | | | | |
|---|---|---|---|---|---|---|---|
| | | Indirect subsidies (Free connection) | Promotional activities | Education | | | Community engagement |
| | | | | Training | Educational kit | Workshop | |
| JC Melo, 2005 (Melo, 2005) | Brazil (Salvador) | ✓ | ✓ | ✓ | | ✓ | ✓ |
| Foster, V. (2001) (Foster, 2001) | Bolivia | ✓ | | | ✓ | | ✓ |
| Beauchêne, Xavier Chauvot de, 2009 (Beauchêne, 2009) | Morocco | ✓ | ✓ | | | | |
| Rural, S.U., 2005. Sanitation in South Asia (World Bank, 2005) | Pakistan | | | | | | ✓ |

**Free connection from households to sewer network**

Seven projects (Table 4) mentioned providing a free connection from households to the sewer and maintenance fees with other interventions to increase the number of households connecting to the sewer (Foster, 2001; Melo, 2005; Robinson, 2005; Beauchêne, 2009; Advani, 2019; Kennedy-Walker et al., 2020; Sachet, 2020). In Espirito Santo and Morocco, households were connected to the sewer free of charge (Beauchêne, 2009; Kennedy-Walker et al., 2020), whereas in Salvador, with free connection, technical assistance was given (Melo, 2005).

In Colombia, government entities received permission to cover the total cost of household access to sewer. This initiative influenced all types of households to connect to the sewer. Consumers received an upgrade of internal and external sanitation facilities, with an investment of US$2500 per targeted household from the service provider. This intervention connected 75% of the targeted households without sewer connection (30,159 among 40,000 households) across 20 municipalities of the country (Kennedy-Walker et al., 2020).

**Free connection and promotional activities**

Two studies conducted in Sao Paulo, Brazil and Morocco provided a free connection from households to sewers and promotional activities to motivate people to connect their houses to the sewers (Beauchêne, 2009; Kennedy-Walker et al., 2020). All of these countries have unique and different socio-economic and geographical contexts.

In Sao Paulo, free connection to the household, along with promotional activities, was provided. This free connection service includes the installation of internal connections to transport greywater and wastewater to the grid, laying pipes and fittings, building inspection chambers, establishing the connection, and replacing damaged floors for low-income families. However, though the program offered both free connections and conducted promotional activities, it could only connect 19% of the targeted population (35,637 properties out of 192,000 properties). The reported primary reason behind the low uptake of sewer among households was the existing water crisis (Kennedy-Walker et al., 2020).

In Morocco, the sewer connection program, with a combination of both free connection service to the houses and promotional activities, reached 9,036 households (80% of the targeted population) for sanitation services in several cities among 11,300 (targeted) households, benefitted 52,000 people (Beauchêne, 2009).

**Free connection, promotional activities, and community engagement**

A study conducted in Kenya provided free connections to low-income communities, promotional activities for customer awareness, and community engagement to increase community ownership. Due to this amalgamation of interventions, the programme reached 9,843 households among the targeted 13,000 households (76%), providing 37,243 people among 167,000 people (82% of the targeted population) with connection to the sewer (Advani, 2019).

**Free connection, promotional activities, community engagement, and educational interventions**

Three programmes (Melo, 2005; Kennedy-Walker et al., 2020) provided a combination of free connection to the houses, promotional activities, educational interventions (training or workshop, or educational kit distribution), and community engagement for the uptake of sewer connection. In Espirito, Brazil, free connection, door-to-door campaigns, training for private installers, and mass mobilisation were provided to low-income communities. The programme built a free connection of internal plumbing from homes to inspection chambers. This resulted in an increase in the uptake of

sewerage connections from 13,000 households to 33,000 households (54%) (Kennedy-Walker et al., 2020).

In Ecuador, the project provided free connections to low-income communities, promoted programme benefits, trained community leaders, and ensured community participation in the targeted area. The estimated total cost of the connection was US$500 per household. This amount included co-signing and sanitising the existing sanitation solution, building the inspection chambers, directing all the drains of the property to the sewer, and physically connecting to the network. After the interventions, the city's sewer coverage improved by 40%, and its household connection rate reached 85%. This benefitted approximately 10,000 households in economically disadvantaged districts (Kennedy-Walker et al., 2020). In Salvador, Brazil, just 26% of the population had access to sewers in 1995. The project engaged public organisations, schools and community people in the environmental education programme to motivate inhabitants to connect their households to the sewer. Also, the sewer connection was made free for the residents. As a result, the coverage reached 60% by the time the programme officially ended in 2004, with a 34% increase in household connection rate (Melo, 2005).

**Behaviour interventions: Community engagement and education**

In two studies, educational interventions (training, workshops, or distribution of instructional kits) were combined with community engagement to motivate the people to connect their households to the sewer. One is the Connect to the Network programme in Parana, Brazil, which is focused on community engagement activities to promote the benefits of the programme. They also provided training to the plumbers in the project area regarding water, sewer, garbage, and health. As a result, 10 out of 17 projects under this programme succeeded in achieving 80% of household connections to the sewerage network (Sachet, 2020). Similarly, in Bolivia, hygiene education was provided to adopt modern hygiene practices, and training was given to the local people to construct and maintain the condominial sewer. Following that, 4,050 households (81% of the targeted households) in nine neighbourhoods of El Alto were connected to condominial sewerage after the completion of the pilot project (Foster, 2001).

**Behaviour interventions: Community engagement**

The Lodhran Pilot Project (LPP) of Pakistan engaged the community by involving them during the development and maintenance of the sewer and also provided social guidance. The average per-

household cost was about US$72. LPP bore the external cost (construction of the main sewer and disposal station), and the local people had to bear the internal cost (household connection and chamber), which was about 50%. By using this community engagement approach, LPP managed to motivate people to connect to the sewer network, and about 1200 rural households in the study area were connected annually, where the existing sanitation situation was critical (Robinson, 2005).

**Behaviour interventions: Promotion**

In India, promotional activities involving local elected representatives of communities and influencers were implemented to motivate households to connect to the sewer. These helped the connection of 40% of the households (639,104 among 2,613,189 properties) to the sewer in 35 cities (Kennedy-Walker et al., 2020).

**Impact of different interventions:**

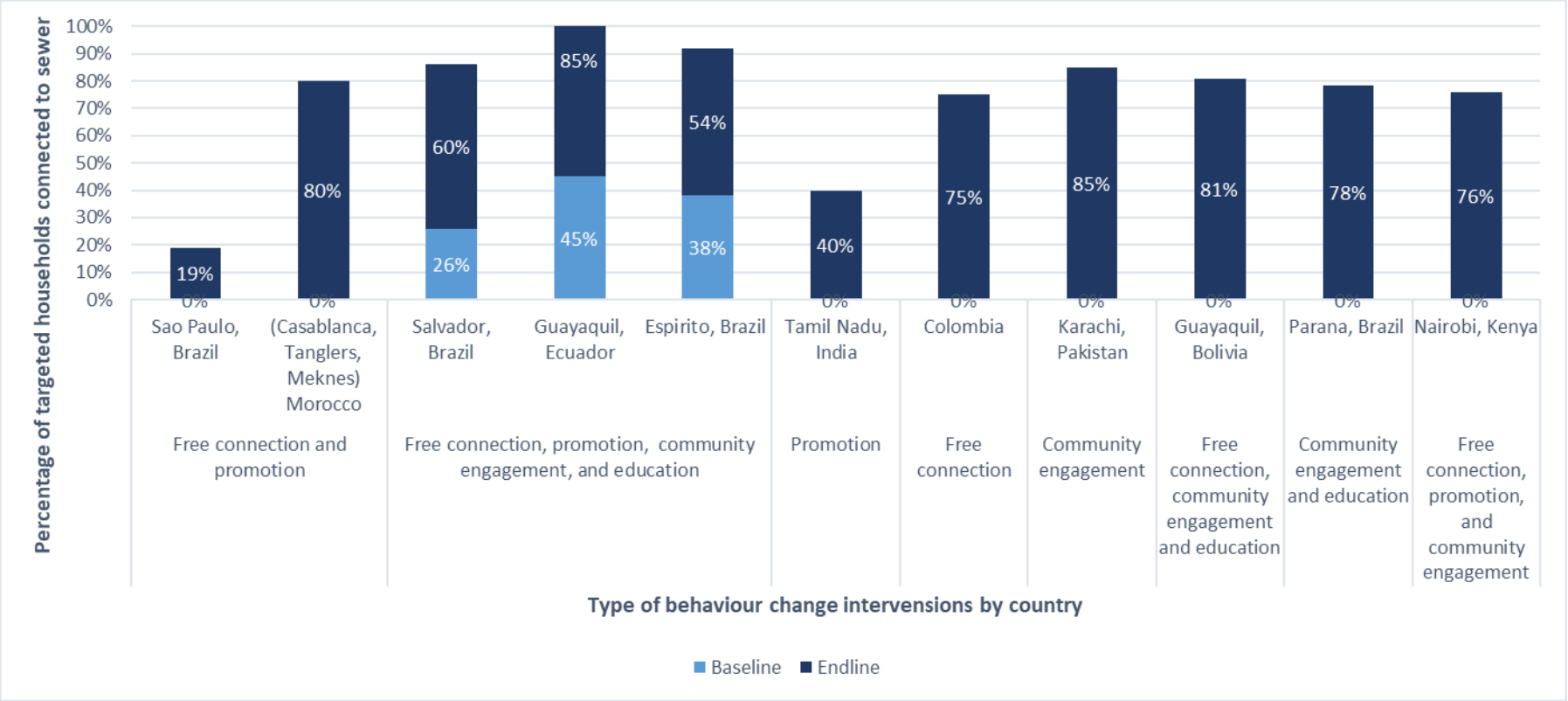


*Figure 8: Percentage of targeted households connected to sewer network at the end of the intervention*

Figure 8 illustrates the effectiveness of different behaviour change interventions in improving sewer connections from baseline to end line in targeted households across different countries. The results demonstrate that the intervention package encouraged people to connect their households to the sewer by offering free connections, promotional efforts, and involving the community. This effectiveness is evident from findings in Colombia (75%) (Kennedy-Walker et al., 2020), Morocco (80%) (Beauchêne, 2009), and Kenya (76%) (Advani, 2019), where sewer connections significantly increased following interventions. A sewer project conducted in Colombia successfully attained a 75% rate of connectivity to the sewer within its intended population. This achievement was facilitated via the implementation of sewer infrastructure and complimentary household connections to the sewer, which were made available to all types of households (Kennedy-Walker et al., 2020). Additionally, Morocco is categorised as a lower-middle-income country (LMIC) that has expanded the number of homes linked to the sewer by implementing a strategy that includes providing free connections to houses and implementing promotional campaigns aimed at households of various income levels. The high success rate of this project in reaching 80% of the intended population can be due to its extensive targeting of all sorts of households and provision of free sewer connection from households to the sewer (Beauchêne, 2009).

The incorporation of free connectivity, along with the execution of targeted promotional activities and community engagement initiatives, showed strong results in terms of connecting households to the sewer. This is especially apparent in low- and middle-income countries (LMICs) such as Kenya. Kenya implemented an intervention package that included providing free sewer connections to specific households, conducting promotional efforts, and community engagement activities. This package notably focused on low-income families and effectively connected the highest proportion of households to the sewer (Advani, 2019). Likewise, the incorporation of educational resources (such as training, educational kits, and workshops) along with free access to sewers, promotional initiatives, and community involvement led to a substantial enhancement in the provision of sewer connections. Salvador, Brazil; Espirito, Brazil, and Guayaquil, Ecuador experienced significant enhancements in terms of connecting targeted houses to the sewer through the implementation of multimodal intervention strategies (Melo, 2005; Kennedy-Walker et al., 2020).

*Table 4: Summary of behaviour change interventions provided to households for connecting to sewer networks*

| **Data source (Author, Year)** | **Country** | **Intervention** | | | | | | **Data source type of the study** | **Size of target population** | **Total cost** | **Outcome (Rates of sewer connection increased)** | **Reasons behind connecting to the Sewer network** | **Recommendations** |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | **Free connection** | **Promotional ctivities** | **Education** | | | **Community engagement** | | | | | | |
| | | | | **Training** | **Educational kit** | **Workshop** | | | | | | | |
| Marlene Alves de Campos Sachet, (2020) (Sachet, 2020) | Brazil (Parana) | _ | _ | Training for plumbers and stonemasons residing in the area of the project to work with the community in servicing home connections | Didactic materials were distributed regarding important issues on environmental sanitation (water, sewerage, garbage, health) | | Social technical work was carried out among the citizens in order to describe 'Connect to the work' programme benefit and their role | Primary | 13,286 households from 17 projects | _ | The overall average of regularised connections was 78.4% | _ | Socio-environmental initiatives carried out within the framework of the "Connect to the Network" program be compared with similar initiatives that are planned and executed with sanitation companies |

| Data source (Author, Year) | Country | Intervention | | | | | | Data source type of the study | Size of target population | Total cost | Outcome (Rates of sewer connection increased) | Reasons behind connecting to the Sewer network | Recommendations |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | Free connection | Promotional ctivities | Education | | | Community engagement | | | | | | |
| | | | | Training | Educational kit | Workshop | | | | | | | |
| Kennedy - Walker, 2020 (Kennedy-Walker et al., 2020) | Brazil (Espirito Santo), | Build free connection of internal plumbing from homes to inspection chambers | Door-to-door campaigns to persuade the population to connect to the network | Training of more than 130 private installers | Community education activities | | Mass mobilisation | Primary | In Brazil (Espirito Santo), 20,000 households | In Espírito santo (es), Brazil, us$8.7 million | The number of household sewerage connections rose from about 13,000 to about 33,000 during that time. | Training operation and maintenance teams to use appropriate techniques for services within these urban blocks. The training covered social aspects and learning to relate to residents | Application of municipal regulations and laws can work even in the absence of subsidies and other economic and financial incentives |

| Data source (Author, Year) | Country | Intervention | | | | | | Data source type of the study | Size of target population | Total cost | Outcome (Rates of sewer connection increased) | Reasons behind connecting to the Sewer network | Recommendations |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | Free connection | Promotional ctivities | Education | | | Community engagement | | | | | | |
| | | | | Training | Educational kit | Workshop | | | | | | | |
| Kennedy - Walker, 2020 (Kennedy-Walker et al., 2020) | Colombia | Governme nt entities received permission to cover the full cost of household access to sewerage connection s. | | | | | | | The initial goal of the program was to connect 90,000 families with water and/or sewerage. | In Colombia, first phase— us$41 million. | In Colombia, sewerage connections were installed in 30,159 homes across 20 municipalities in its first phase of implementation. More than 30,000 connections resulting in 75% connection to sewers | | Working in individual homes has technical and social complications. Each home and each client is different and require individualised responses. |
| Kennedy - Walker, 2020 (Kennedy-Walker et al., 2020) | Ecuador | The household connection was free of cost. The total cost of connection was | Promotion of program benefits | Promoted training courses for community leaders to strengthen local capacity for self- | | | Contractors and inhabitants signed agreements outlining the scope of work, allowing inhabitants to authorise the proposed project, | | | Guayaquil, Ecuador, us$146.5 million | In Ecuador, approximately 40,000 new connections were to be completed. Improving the city's connection rate from 45% to 85%. In Ecuador, 10,000 households | | |

| Data source (Author, Year) | Country | Intervention | | | | | | Data source type of the study | Size of target population | Total cost | Outcome (Rates of sewer connection increased) | Reasons behind connecting to the Sewer network | Recommendations |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | Free connection | Promotional ctivities | Education | | | Community engagement | | | | | | |
| | | | | Training | Educational kit | Workshop | | | | | | | |
| | | estimated at US$500 per household | | management. | | | assess the quality of delivered outputs, and accept or reject the final product in writing. | | | | Benefitting from the sewerage connection | | |
| Kennedy - Walker, 2020 (Kennedy-Walker et al., 2020) | Brazil (Sao Paulo) | Free Connections are key to encouraging low-income households to connect | Carries out social promotion activities in identified neighbourhoods | | | | | Primary | Connecting 192,000 households | São Paulo, Brazil, US$115 million | From 2012 to 2020, the program connected 35,637 properties among 192,000 properties, which is 19% of the targeted population. | Since 2002, it has been mandatory in the city of São Paulo to connect to a sewerage network if it is available. | Connection and tariff subsidies are key to encouraging low-income households to connect, particularly if repair costs of damaged floors are included. |
| Kennedy - Walker, 2020 (Kennedy-Walker et al., 2020) | India (Tamil Nadu) | | Provide efforts to educate people on the need for awareness campaigns; meetings at | | | | | Primary | Connecting 1,551,995 households statewide | 639,104 households completed internal plumbing and connected to the | Sewerage projects have become a reality in 35 cities, work is progressing in 20 cities, and projects are in the preparation stage in five cities | Safely manage human excreta and wastewater through a sewerage network and sewage treatment in | Even after the public deposit contribution, the city is not able to meet its project cost. So, contributions from the ULB or additional grant money from the state |

| Data source (Author, Year) | Country | Intervention | | | | | | Data source type of the study | Size of target population | Total cost | Outcome (Rates of sewer connection increased) | Reasons behind connecting to the Sewer network | Recommendations |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | Free connection | Promotional ctivities | Education | | | Community engagement | | | | | | |
| | | | | Training | Educational kit | Workshop | | | | | | | |
| | | | the ward level with active involvement of elected representatives, ULB staff, and other influencers; issuing pamphlets; engaging nongovernment organisations for facilitation. | | | | | | | sewerage network | | phases in cities and towns. Regulatory provisions in Tamil Nadu (TN) mandate that a house service connection be made when a sewerage line is laid and available within 100 meters from a household. » This provides the legal framework for urban local bodies to push households to connect to sewers | government are needed to fulfil the project. |

| Data source (Author, Year) | Country | Intervention | | | | | | Data source type of the study | Size of target population | Total cost | Outcome (Rates of sewer connection increased) | Reasons behind connecting to the Sewer network | Recommendations |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | Free connection | Promotional ctivities | Education | | | Community engagement | | | | | | |
| | | | | Training | Educational kit | Workshop | | | | | | | |
| Advani, R.K, 2019 (Advani, 2019) | Kenya | Provided free connection to low income communities to connect their households to the sewerage | Customer awareness building _ | _ | _ | _ | Focus group discussions with potential customers, which were carried out before the contractor entered the areas of intervention, helped to increase community ownership | Primary | 137,243 people | In Nairobi, Kenya US$10.55 million | The project reached 137,243 people through the provision of 9,843 household sewerage connections. | | The success of the connection program depended on achieving a balance between expanding services through reducing upfront connection costs. |
| JC Melo, 2005 (Melo, 2005) | Brazil (Salvador) | Households received free connection | Environmental education _ | | | Creation of a utility-embedded social mobilisation unit and extensive community mobilisation efforts | Involving public organisations, schools and communities to get the wider public and inhabitants of the city participating and committed to the | Primary | 2.5 million people | In Salvador Metropolitan Region, Bahia state, northeast Brazil, US $450 million went | The program officially ended in 2004; coverage had increased to 60% | The state government created Law 7307 of 1998 to mandate households to connect to sewerage | |

| Data source (Author, Year) | Country | Intervention | | | | | | Data source type of the study | Size of target population | Total cost | Outcome (Rates of sewer connection increased) | Reasons behind connecting to the Sewer network | Recommendations |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | Free connection | Promotional ctivities | Education | | | Community engagement | | | | | | |
| | | | | Training | Educational kit | Workshop | | | | | | | |
| | | | | | | | goals of the program | | | toward sewerage | | | |
| Foster, V. (2001) (Foster, 2001) | Bolivia | Households received free connection | | | The purpose of the hygiene education component was to provide moral and technical support for households to adopt modern hygiene practices, in particular by helping them to construct their own bathrooms and associated facilities such as kitchens and laundry sinks. Without such investments | | Provided training to the community people for constructing and maintaining the condominial network. Community involvement helps to improve the acceptability of the infrastructure, promotes network connections and provides an entry point for imparting hygiene education. | | | | 4,050 households in nine neighborhoods of El Alto connected to condominial sewerage after the completion of the pilot project | | |

| Data source (Author, Year) | Country | Intervention | | | | | | Data source type of the study | Size of target population | Total cost | Outcome (Rates of sewer connection increased) | Reasons behind connecting to the Sewer network | Recommendations |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | Free connection | Promotional ctivities | Education | | | Community engagement | | | | | | |
| | | | | Training | Educational kit | Workshop | | | | | | | |
| | | | | | within the home, a sewerage connection brings little or no benefit to households and has been shown to have virtually no impact on water consumption. | | | | | | | | |
| Beauchêne, Xavier Chauvot de, 2009 (Beauchêne, 2009) | Morocco | Households located in selected areas were eligible for free connection | Operators also developed new means of reaching potential customers by sending dedicated teams to marketplaces | | | | | | Supply of water to a total of 10,504 households and sanitation services to a total of 9,036 households, benefitting | | The pilots experienced a slow start, with about 2,000 connections (15 percent of the program's three-year objective) in the first year, but connection rates doubled in the second year | Direct benefits to households in terms of time savings, reduced health costs and improved hygiene practices | |

| Data source (Author, Year) | Country | Intervention | | | | | | Data source type of the study | Size of target population | Total cost | Outcome (Rates of sewer connection increased) | Reasons behind connecting to the Sewer network | Recommendations |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | Free connection | Promotional ctivities | Education | | | Community engagement | | | | | | |
| | | | | Training | Educational kit | Workshop | | | | | | | |
| | | | or to the heart of targeted neighbourhoods to record demand from beneficiaries who might not easily travel to one of the operator's agencies | | | | | | more than 52,500 people | | | | |
| Rural, S.U., 2005. Sanitation in South Asia (Robinson, 2005) | Pakistan | | | | | | The responsibility for providing the components is shared: construction of the internal components is financed and managed entirely by the | | In 12 villages Connected 1200 households | | | | |

| Data source (Author, Year) | Country | Intervention | | | | | | Data source type of the study | Size of target population | Total cost | Outcome (Rates of sewer connection increased) | Reasons behind connecting to the Sewer network | Recommendations |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | Free connection | Promotional ctivities | Education | | | Community engagement | | | | | | |
| | | | | Training | Educational kit | Workshop | | | | | | | |
| | | | | | | | community; provision of the external components, technical assistance, hygiene promotion, and social guidance are the responsibility of LPP. | | | | | | |

## Discussion

This review aimed to summarise available evidence for the effectiveness of different behaviour change interventions to promote household connectivity to sewers. The synthesised evidence from this scoping review indicates that providing interventions involving free connections to households along with promotional activities yielded significant outcomes. Additionally, in the context of LMICs, combining community engagement with indirect subsidies encouraged people to connect their households to the sewer, indicating the need for a combined behaviour change intervention package for achieving a greater percentage of sewer uptake.

Eight of our cases (Foster, 2001; Melo, 2005; Beauchêne, 2009; Advani, 2019; Kennedy-Walker et al., 2020) provided a free connection with or without implementing promotional and community engagement activities to increase the uptake of sewerage connections among households. Providing free connections that cover the costs associated with the infrastructure construction, connection, and maintenance fees influenced the community to a greater extent in connecting their households to the sewer. From our review, in Colombia, providing only free connections significantly improved the uptake of sewer connections (Kennedy-Walker et al., 2020). Similarly, most of the other projects that have incorporated free connection in the intervention showed the most significant rise in sewer uptake. Even in Bangladesh, people from low-income communities were willing to connect their toilets to the sewer only if five conditions were met, mostly emphasizing the no installation cost for sewer (Alam et al., 2020).

Along with free connection, providing interventions involving community participation has a larger impact on low-income communities. In Bolivia, engaging the community with a free connection to the households resulted in 80% of the intended households being connected to the sewer. The higher connection rate resulted from the community's training in constructing and maintaining the condominial sewer, which improved the acceptability of the infrastructure and created ownership among them. The households did not bear the cost of infrastructure and provided labour in lieu of money, which improved the connection rate to the sewer (Foster, 2001). Similarly, a study conducted in Ghana explored that sanitation vouchers for toilet construction to stop open defecation were effective. Voucher-eligible households received a voucher covering the total costs of a durable latrine substructure, which included a durable slab and pit lining. Households were responsible for digging the pit and building the superstructure (themselves or with help). This accessible latrine construction voucher and community engagement decreased open defecation, particularly among those who received the interventions (Trimmer et al., 2022). This indicates that

the cost of sanitation and involving the beneficiaries has a more significant outcome and motivates people since it builds ownership among them, starting a chain reaction of more intervention uptake.

While promotional activities can positively influence the uptake of sewer connections, relying solely on promotion without the inclusion of additional behaviour change interventions may yield limited results. In Pakistan and Tamil Nadu, India, people needed to bear the cost of establishing a connection between their households and the sewer and subsequent expenditures of upkeep (Robinson, 2005). Although the organisation provided funding for sewer construction, the exorbitant expenses associated with connecting materials and maintenance posed a significant barrier for low-income residents. As a result, a considerable portion of this population had financial constraints, resulting in a decrease in the number of people in this group who could connect to the sewer (Robinson, 2005). This indicates that only promotion without some level of monetary benefits might not be fruitful. This emphasises the significance of considering not only the initial expenses of a connection to the sewer but also the financial responsibility of households for connection and upkeep when developing sanitation solutions for low-income communities.

In conclusion, the evidence across various countries highlights the critical role of both financial and community engagement strategies in increasing the uptake of sewer connections among low-income households. Programs that provided free connections alongside community engagement activities showed significantly higher connection rates. This indicates that eliminating financial barriers and fostering a sense of ownership through community involvement can enhance the acceptability and sustainability of sanitation infrastructure. Conversely, initiatives that lacked comprehensive financial support struggled to achieve similar success. Therefore, to effectively address sanitation challenges in low-income communities, it is imperative to design comprehensive programs that integrate free connections or financial subsidies, and robust community engagement. This holistic approach might ensure that the infrastructure is not only built but also utilized, leading to sustainable improvements in public health and hygiene.

**Limitations**

Inferences drawn from our review are limited to only eleven cases, with no RCT, and no study has checked the effectiveness of any particular intervention on the uptake of household sewer connectivity. These facts limit the quality of evidence; however, they highlight how this topic is understudied, given its potential policy importance. Therefore, we could not generate granular evidence on the precise BCTs (Behaviour Change Techniques) and their relative effectiveness in

influencing households to connect to the sewer network. Instead, we focused on the comprehensive description and synthesis of overall interventions to increase the uptake of household connection to sewer and their impact in a generalized context.

**Recommendation**

The analysis of our scoping review reveals that applying an intervention that incorporates the two components, free connection or financial aid with community-engagement activities, has better potential to motivate households to connect to the sewer. The evidence also indicates that the effectiveness of the interventions may vary depending on the households' geographical location, cultural context, and socio-economic conditions, which must be dissected for policymakers and intervention delivery partners. Following that, we propose to develop a comprehensive package of behavioural interventions incorporating financial aid and active community participation to have a larger uptake of sewer connections. Additionally, we recommend that prior to developing methods to promote connections to sewer, it is essential to thoroughly comprehend the economic context, including cost issues, financing sources, and appropriate usage of public funds. This method ensured that initiatives are well-informed and strategically formulated, considering the distinctive socio-economic aspects of each community. This also helped to develop the appropriate community engagement methods, incorporating different activities, which would build ownership and ensure the sustainability of the connection. However, there is limited evidence on the long-term quality, functionality, and sustainability of these connections, as few studies monitored households over time or assessed maintenance and service reliability (Wardle and Zakiriaeva, 2018; MachadoOliveira and Matos, 2022). This suggests that while such interventions are sufficient to improve initial uptake, ensuring sustained functionality requires additional measures, including follow-up monitoring, maintenance planning, and institutional support. There should also be more rigorous approaches and studies, such as controlled trials or theory-driven evaluations, to help generate more reliable evidence. Therefore, more high-quality research is required to draw a more evidence-based rigorous inference about the context and resource-specific behaviour change interventions that can influence households to connect to the sewer.

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**Author contributions**

MUA, AR, and SN drafted the research questions and search strategy, conducted the search, analysed the data, synthesised the data, and wrote and interpreted the results. AR and TAU completed the screening and imported full articles for analysis. NN, KFT, AK analysed the data, synthesised the data, and interpreted the results. BE, and PH reviewed and provided critical inputs in drafting the research questions, search strategy, data analysis, data synthesis, and writing and interpretation of the results. All authors reviewed the manuscript and provided inputs, and approved the final version.

**Disclosure statement**

The authors report no conflicts of interest.

**Ethics and consent**

The study involved summarising existing published data from the literature. No ethical issues arose from the execution of this work.

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**Paper context**

- Reviewed the effectiveness of different behaviour change interventions for sewer uptake
- Combining financial support with community engagement significantly improves the sewer connection rates
- Effectiveness of sewer connection intervention varies based on geographical location, cultural context, and socio-economic conditions
- More high-quality research is needed to identify the most effective behaviour change techniques across diverse settings

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# Chapter 5: Barriers to Sewer Connection in Urban Dhaka: Individual and Organizational Challenges

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## Abstract

Access to safe sanitation remains a challenge in urban areas globally, particularly in low-and middle-income countries. In cities like Dhaka, Bangladesh, despite efforts to expand sewer connections, uptake among households remains low. This study investigates both the psychological and administrative barriers to household sewer connections. We conducted a mixed-methods cross-sectional study in five Dhaka zones operated by the Dhaka Water and Sewerage Authority (DWASA). We surveyed 384 households, conducted 5 Key Informant Interviews and 10 In-Depth Interviews. Survey participants included households with toilets connected to the sewer or to stormsewer or drainage. We used the Risks, Attitudes, Norms, Abilities, and Self-regulation (RANAS) framework to examine socio-demographics, and psychological factors determining connection behaviour. Individual-level barriers included the lack of knowledge about connection procedures and perceived low risks of disease transmission among those who had not connected to the sewer. Organizational-level barriers included complex administrative processes, high installation costs, bureaucratic delays, inadequate support from DWASA, and outdated infrastructure. Addressing the global urban sanitation crisis requires interventions that simultaneously tackle administrative barriers (such as streamlining processes and enhancing financial support) and psychological factors (including raising awareness about the benefits and procedures of sewer connection and fostering a sense of ownership).

## Background

Access to sanitation services in urban areas is a critical global challenge, with only 65% of urban households worldwide using safely managed sanitation (JMP, 2024). This issue is particularly dominant in low- and middle-income countries (LMICs); for example, in Sub-Saharan Africa, only one in five people benefit from safely managed services in urban areas (UN-Habitat, 2023). To be categorised as 'safely managed', sanitation systems must hygienically separate excreta from human contact, be exclusive to a single household, and result in proper treatment and disposal of waste (WHO, 2018). Households not connected to a functioning wastewater sewer generate wastewater which often remains untreated at the point of production (Jiao, 2021). These excreta often end up in water bodies through either inefficiently built and improperly managed septic tanks or pit latrines, causing groundwater contamination, or via storm drains, which in turn contaminate open water bodies (Nyenje et al., 2010; Nyenje et al., 2013). A recent report by the UN reveals that only 56% of global household wastewater was adequately treated in 2020 (UN-Habitat and WHO, 2021), with even lower rates in Central and South Asia and Sub-Saharan Africa (UN-Habitat and WHO, 2021). Due to inadequate sanitation, residents in densely populated urban areas face severe health risks (McMichael, 2000), including a higher incidence of infectious diseases like diarrhoea, cholera, and typhoid (UN-Habitat, 2023). Additionally, poor sanitation can be responsible for decreased economic productivity (Hutton, 2013) and compromised security (Lee, 2017). The economic cost of malnutrition from poor sanitation in countries of Africa and Asia, which include impaired school performance and delayed entry into the labour market, is estimated to be equivalent to 9% of the gross domestic product (GDP) (UN-Habitat, 2023).

One of the ways of ensuring safe sanitation is to build sewerage; a system of pipes designed to carry household blackwater (human excreta and toilet flush water) and greywater (water from the kitchen, laundry, and bathing) to a treatment facility prior to discharge to the environment (Tilley et al., 2014). Connecting households with sewers can reduce the burden of managing household-level wastewater and allow authorities to manage the wastewater safely (World Bank, 2020). However, connecting households to sewerage is challenging, and many households do not connect even when the sewer is close to their residence (Kennedy-Walker et al., 2020). Households are often connected to stormwater drainage systems which transport waste away from home, but these are not true sewers and rarely transport waste to treatment (Blackett, 2015; Kennedy-Walker et al., 2020). This somewhat subtle phenomenon of households connected to the "wrong" sewer system, which is

usually drainage of DSCC/DNCC, leads to significant environmental pollution and public health risks and is largely understudied as an issue.

Despite the existence of sewers in much of Dhaka, only 20% of residents are connected (Charlton, 2011), and merely 2% of sewage is treated effectively (Ross et al., 2016; Mansour et al., 2017). Although institutional hurdles such as leaking sewers or dysfunctional pumping stations have been reported (Ross et al., 2016), a more significant issue may be the low uptake of connections by households in areas served by sewers, resulting in under-utilization of sewerage and wastewater treatment facilities. Underutilisation of treatment facilities has detrimental effects on their efficiency, both in terms of operations and finances, and it has a negative influence on the environment and public health (Kennedy-Walker et al., 2020). To address these challenges, the Dhaka Water Supply and Sewerage Authority (DWASA) is implementing a city-wide sewer network with USD 900 million in loans from the World Bank (World Bank, 2019). The project includes construction of sewers in high-income areas as well as provisions for slums and other low-income housing areas (World Bank, 2020) and will also construct wastewater treatment plants in the Pagla catchment and the Dasherkandi catchment. The project aims to connect 65% of households with the network (DWASA, 2016).

Given the substantial investment and the critical need to enhance sewer connection uptake, it is imperative to explore and understand what influences the decision of households to connect to sewers when they are available. This study explores this question by investigating the motivations of households in areas which already have sewers. The study seeks observable differences between households who do and do not connect in these circumstances.

## Methods

### Study Setting and Study Area

We conducted a mixed-method cross-sectional study in urban areas of Dhaka, Bangladesh, where the Dhaka Water and Sewerage Authority (DWASA) has established sewers. DWASA has divided Dhaka city (Dhaka North and Dhaka South city corporation areas) into 10 MODS (Maintenance Operation Distribution and Services) zones to run water and sewer services.

*Table 5: Sewer areas in Dhaka, by operational responsibility of Dhaka Water and Sanitation Authority (DWASA), Dhaka North City Corporation (DNCC) and Dhaka South City Corporation (DSCC) and year of construction*

| **Area Name** | **DWASA – sewer** | **DNCC/DSCC – stormsewer and drainage** |
|---|---|---|
| Basabo | 1985-1990 | 2017-2019 & Drainage |
| Goran | 1985-1990 | 2017-2019 |
| Hazaribagh | 1990-1992 | Drainage |
| Nawabgonj | 1990-1992 | Drainage |
| Mohammadpur Bus stand | 2000-2005 | 2021-2022 |
| Sultangong Sahi Masjid | 1996-2000 | 2017-2018 |
| Nakhalpara | 1990-1992 | 2020-2021 |
| Tanarimor jame masjid | 1996-2000 | 2014-2016 |
| Sahidbag | 1996-2000 | 2018-2020 |
| Modhubag, Moghbazar | 1996-2000 | 2015-2016 |

Among these ten zones, DWASA has installed sewers in 5 zones at different times (Table 5) (MODS Zone 1, 2, 3, 5, & 6). To select the study areas, the data collection team conducted a pre-field visit in September 2023 in five of these zones. We collected the list of service areas and randomly selected three areas from each zone for pre-field visits.

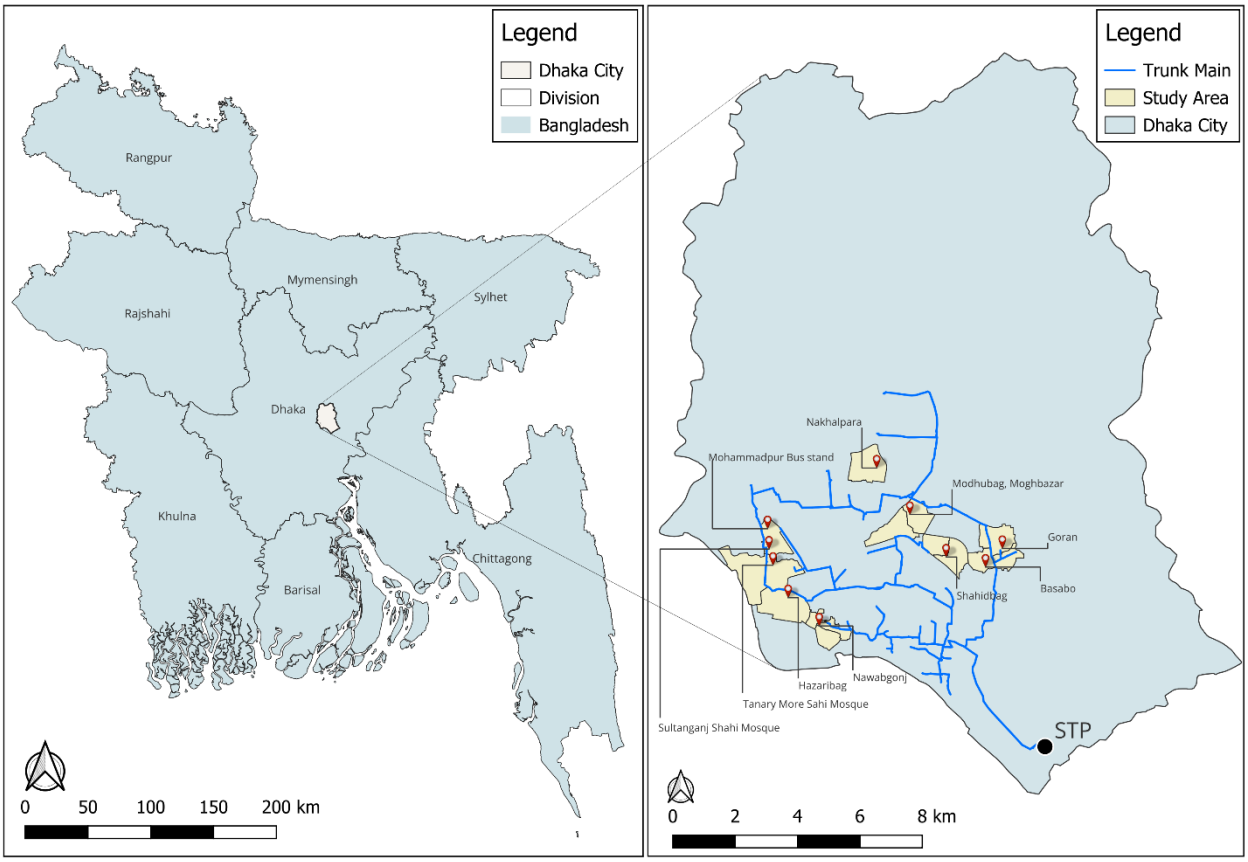


*Figure 9: Data collection site in Dhaka City*

Potential study sites were identified based on their accessibility, the existence of an installed and functioning sewer, the presence of roughly equal numbers of households connected to the DWASA sewer and to the city corporation drainage/open drainage on the same road, and whether landlords were paying bills in those areas. We finally selected two areas from amongst eligible sites, totalling ten areas, as our study sites (Figure 9). Since the context of all the lanes from the same zone was similar, we randomly visited a lane from a selected area to collect data.

**Study population**

Our survey population was the landlords/house owners since they were responsible for connecting their houses to the sewer/drainage system. To enrol households from the selected areas, we followed the DWASA sewer map and selected one lane at random where both sewer and city corporation stormsewer/drainage were available. We selected households sequentially, seeking households where the owner was available until the targeted number of households had been surveyed. We visited each household to determine whether the household was connected to the

DWASA sewer (Figure 10) or whether they were connected to the city corporation drainage/open drainage (Figure 11). Figures 11 and 12 illustrate two distinct scenarios in the study area, showing that resident owners and landlords may be connected to either system. Trained enumerators spot-checked the connection status and confirmed whether the households were connected to the DWASA sewer or city corporation stormsewer/drainage. For each household "connected to sewer", we identified a matching "not connected to sewer" household for inclusion in the study.

We selected pairs of households where:

1. Both connected and not connected to sewer households were located on the same lane or road so that distances from the sewer were similar.
2. Both connected and not connected to sewer households were positioned at the same elevation so that connected households could not claim the benefits of gravity.
3. In all households, the household owner was living in the house and was present during the data collection period.

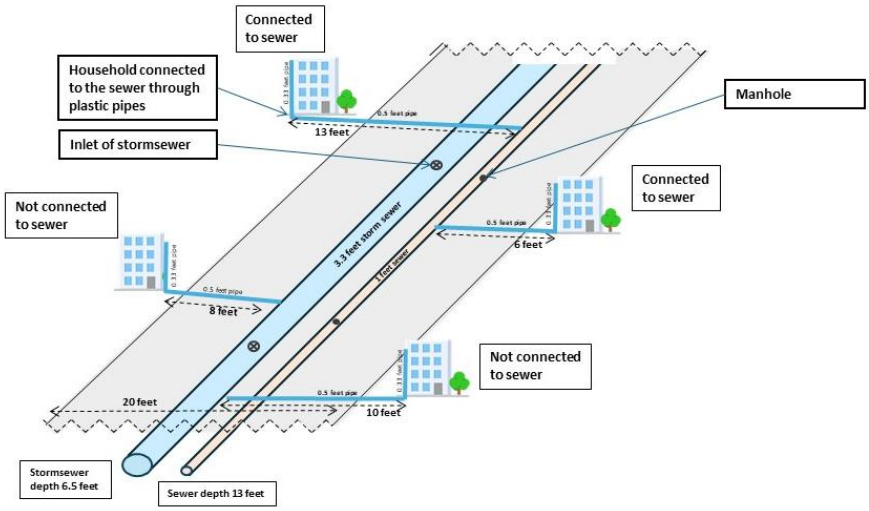


*Figure 10: Typical sewer and stormwater drainage in urban Dhaka*

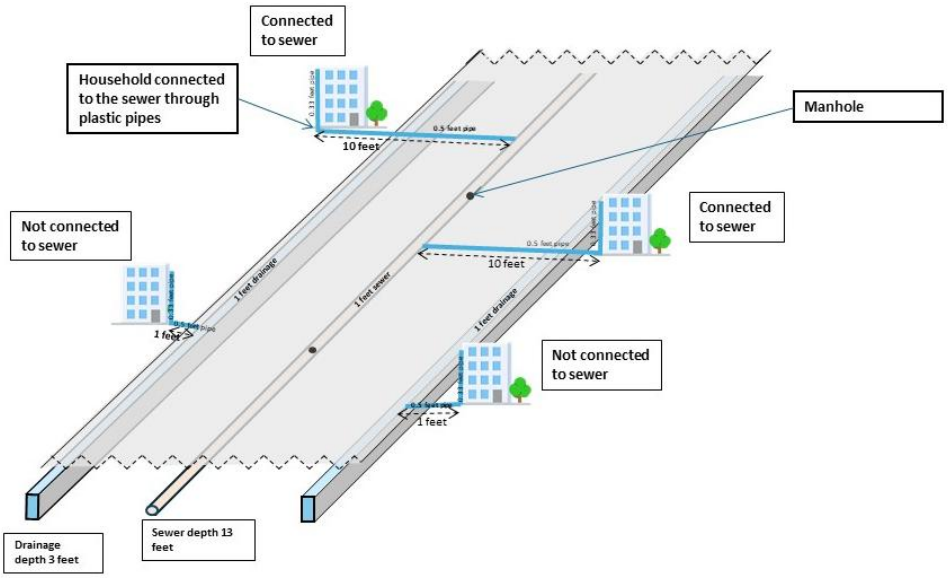


*Figure 11: Typical sewer and drainage in urban Dhaka*

**Sample size calculation**

We considered the following formula for the sample size calculation:

$n = (Z_{\alpha/2}+Z_{\beta})2 * (p1(1-p1)+p2(1-p2)) / (p1-p2)2$, where $Z_{\alpha/2}$ is the critical value of the normal distribution at $\alpha/2$ (for a confidence level of 95%, $\alpha$ is 0.05 and the critical value is 1.96), $Z_{\beta}$ is the critical value of the normal distribution at $\beta$ (for a power of 80%, $\beta$ is 0.2 and the critical value is 0.84,) and p1 and p2 are the expected sample proportions of the two groups (Wang and Chow, 2007a). We considered a maximum uptake among the connected-to-sewer group of 65% (according to the DWASA estimates), and a maximum non-connection among the not-connected group of 80% (according to the current estimates for Dhaka). The estimated sample size was 136 for each group, with 80% power and 95% confidence interval. Adjusting for a 20% non-response rate in this urban area, where accessing households was often challenging, the estimated sample size per group was 164. In total, a sample of 328 (connected to sewer 164 and not connected to sewer 164) was required to detect a minimum 15% difference between these two groups.

**Data Collection**

Data collection was undertaken from the period of 15 October 2023 to 15 January 2024 by the data collection team.

**Qualitative Data Collection**

We collected qualitative data to explore the reason why people did not connect their households to the sewer and explored different individual and organisation-level factors that impede their connection. This involved a series of interviews and discussions to gather comprehensive insights. We conducted five Key Informant Interviews (KIIs) with DWASA officials, to understand the issues surrounding sewer connections. Additionally, 10 In-Depth Interviews (IDIs) with household owners/landlords were conducted to explore their individual experiences and challenges in connecting their households to the sewer. Participants for qualitative exploration were selected purposively, considering different age groups and geographical areas.

**Quantitative Data Collection**

Based on the inclusion criteria, the recruited household owners (connected to sewer and not connected to sewer) were invited to participate in the quantitative survey. We interviewed the enrolled survey participants using a structured survey questionnaire, which included information on individual sociodemographic characteristics, duration of settlement, household characteristics, presence of the sewer system, perception regarding the hygienic status of the existing sewer, and motivating factors that influence people to connect their households with the sewer. The survey also explored an individual's influence of psychological factors through questions linked to each area of the RANAS (Risks, Attitudes, Norms, Abilities, and Self-regulation) tool (Mosler, 2012). The RANAS module was developed considering the scope and context of the study. Potential psychological and behavioural factors were included in the module based on the pre-conducted qualitative interviews and informal discussion during the field test. The questionnaire was translated into Bengali and reviewed by all researchers involved in the study. It was pilot-tested in randomly selected non-study areas. After the finalisation of the questionnaire, enumerators conducted the survey using the mobile/tablet-based platform (Kobo Toolbox). Each day, upon completion of data collection, data was securely transmitted to a cloud-based server, and the quality of data was checked. This meticulous approach ensured robust data collection and analysis for our study on sewer connection behaviours in Dhaka.

**Data Analysis**

Qualitative data were analysed using thematic analysis techniques to identify recurring themes and patterns suggesting reasons why households do or do not connect to the sewer system. Data were coded based on identified themes, such as administrative difficulties, cost barriers, outdated sewer, and knowledge gaps.

Quantitative data analysis was conducted using the statistical software STATA version 14.1. Descriptive statistics, including frequency and percentage, were used to summarise socio-demographic data. The Shapiro-Wilk test was used to assess the normality of continuous variables. T-tests and chi-square tests were conducted to compare various indicators between connected-to-sewer and not-connected-to-sewer households. A violin plot was utilised to examine the relationship between the duration of settlement and sewer connection status. The median difference in settlement duration between connected-to-sewer and not-connected-to-sewer households was assessed using the Mann-Whitney U test. For each RANAS (Risks, Attitudes, Norms, Abilities, and Self-regulation) factor, we calculated the mean difference between the two groups using the ANOVA test and the effect size was estimated using Cohen's d equation.

**Ethical consideration**

Ethical approval for this study was granted by both the University of Leeds and icddr,b in Dhaka, Bangladesh. Before data collection, written informed consent was obtained from each study participant, or thumbprints were taken from those who could not write. Participants were informed about the study's goals and objectives, ensuring they understood the purpose of the study, the benefits, and the risks involved. They were assured of the confidentiality of their data and their right to decline participation or withdraw at any stage without consequence. Participants were also informed about the anonymity of data usage and the platforms on which their information would be shared. These measures were implemented to uphold ethical standards and safeguard the rights and welfare of all involved in the study.

## Results

**Socio-demographic characteristics**

A total of 384 respondents (192 connected to sewer and 192 not connected to sewer) were enrolled in the survey across 10 selected areas who were all landlords. Among them, 57% were male, the mean age of the respondents was 51 years, the majority (41%) completed graduation (16 years of

education), and most (59%) were either homemakers or retired persons. There was minimal difference between these two groups in terms of socio-demographic characteristics. However, the connected to the sewer group lived in the particular settlement longer than not connected to the sewer group, with a median difference of 2.66 years (p=0.008). The monthly family expenditure was higher for connected households (364 USD) than for not-connected households (318 USD). Connected to sewer households paid 3.73 USD more for monthly water and sewer bills (p<0.001) compared to non-connected households (Table 6).

**Factors influencing connection to sewers**

The factors associated with connection and non-connection to sewers can be divided into individual-level and organizational-level factors.

### Individual-level factors influencing sewer connection

**Knowledge about sewer connections**

There was a notable variation in knowledge about the connection process between households connected to sewer and those not connected to sewer. Thirty-one per cent of connected households and 23% of non-connected households possess a complete understanding of the connection process. However, among not-connected households, specifically, 21% reported a complete lack of knowledge regarding the connection process (Table 7). Seventeen per cent of connected households reported having no knowledge due to moving to the area after the process of connection was complete, with a small number of house owners reporting that their parents had been responsible for the connection. During in-depth interviews, two not connected households reported that they didn't have adequate information regarding the DWASA sewer, which prevented them from connecting to the sewer, even if they wanted to. They mentioned that they were unaware of the requirements during the construction of their houses despite obtaining clearance from DWASA for water connectivity. The connected households also perceived that lack of awareness was one of the reasons for not connecting to a sewer (connected households' perception: 12% vs. not connected households' perception: 3.6%) (Table 7). The lack of knowledge about the mandatory sewer connection resulted in their failure to connect to the DWASA network.

*"I did not have appropriate knowledge about the sewer system while constructing the building. I took permission from the commissioner's office and connected to the open drainage system." IDI, Female, House owner, Mohammadpur Bus Stand*

However, landlords were aware of the distinction between sewers and stormsewer or drainage. They could explain that household waste from toilets ('sanitation waste') should be connected to the DWASA sewer, while wastewater from bathing, kitchens, and similar sources should be directed to the drainage.

**Psychological influence of RANAS factors on sewer connection**

We assessed the difference in RANAS factors between households connected to the sewer and those not connected to the sewer to explore the impact of individual psychological factors on connecting to the sewer. Households not connected to the sewer system perceived a lower risk of disease transmission compared to connected households (Difference: 0.24, p-value: 0.003). Additionally, households not connected to the sewer system perceived less possibility of contracting diseases compared to connected households (Difference: 0.18, p-value: 0.026) and believed that, even if they became sick, the severity of the disease would be less (Difference: 0.24, p-value: 0.017) (Table 8).

The not-connected households showed less certainty that connecting to a sewer would increase their social status (Difference: 0.33, p-value: 0.009) and it would increase their respect in the community (Difference: 0.23, p-value: 0.015), subsequently showing lesser importance to connecting to the sewer system (Difference: 0.19, p-value: 0.031) than connected households. They also reported that they perceive the lack of awareness as the contributing factor for them not connecting to the system (p-value: 0.002). However, they were also less confident about connecting the household to the sewer if this is a difficult process (Difference: 0.26, p-value: 0.028) and if the cost of continuing a connection is high (Difference: 0.43, p-value: 0.001) (Table 8).

### Organizational-level factors influencing not connecting to the sewer

**Duration of settlements**

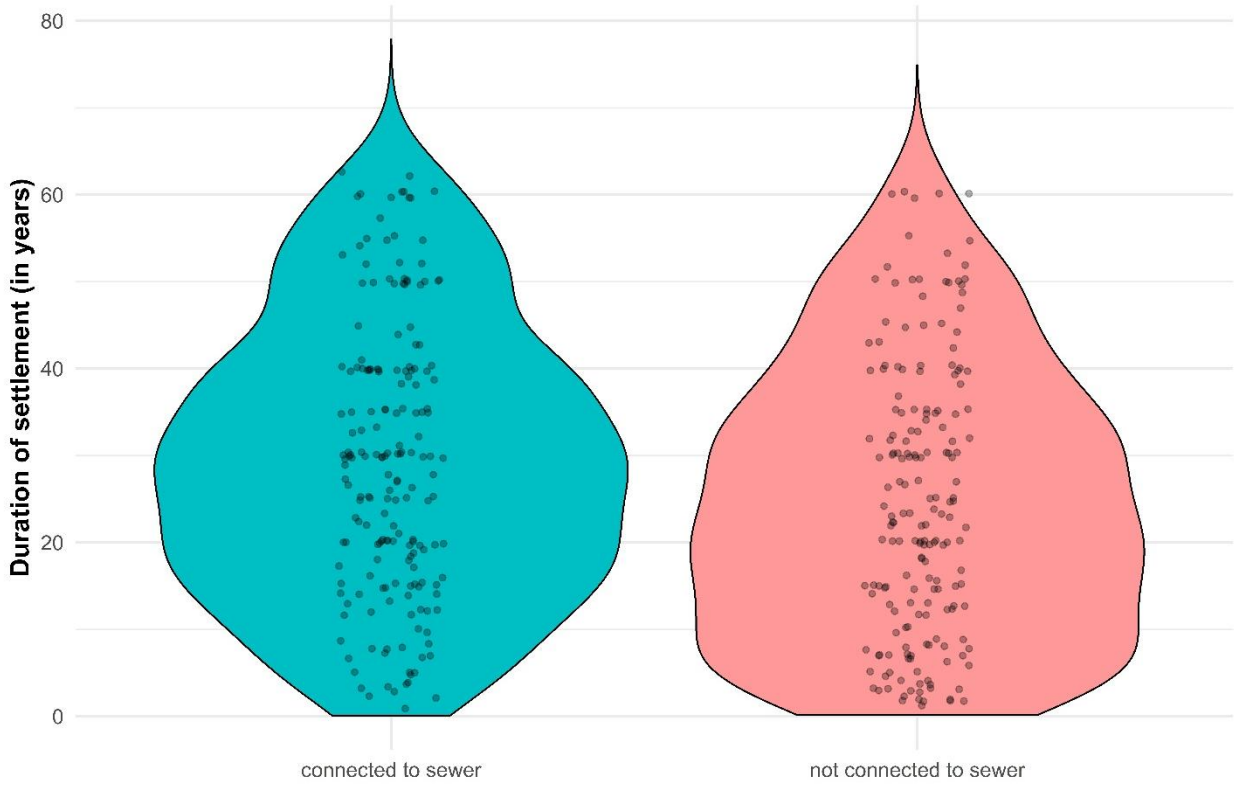


*Figure 12: Duration of household settlement over drainage/sewer connection status*

One of the significant factors associated with sewer connection was the difference in the settlement duration between connected and not-connected households. We considered the settlement duration as the timeframe between the construction of the house and the present time (Figure 12). Both connected and not connected to sewer households have a wide range of settlement durations, spanning from zero to approximately 60 years. However, more not connected households were clustered within the lower duration range (0 to 20 years) (Figure 12: Duration of household settlement over drainage/sewer connection status). Qualitative exploration also identified factors attributing to the higher number of connected households with long-term residence, which was found to be associated with the implementation of sewer by DWASA over a specific period. Between 1990 and 2000, DWASA constructed sewers in these areas and connected all nearby households within a 100-foot radius without imposing extra connection charges or time-consuming administrative processes. The landlords were only responsible for the expenses of installing the

pipeline that connects their houses to the sewer, making the connection process more accessible and convenient for residents.

*"DWASA started construction of the sewer in our area and connected all the households adjacent to the facility. They connected our houses on their own; no documents were required then. We only had to provide the cost of connection pipes from our houses to the sewer." IDI, Male, Sultangong Sahi Masjid.*

By contrast, new households have progressively refrained from connecting to the sewer over time due to inadequate knowledge of sewer connections. According to the not-connected respondents, the buildings that were constructed after the sewer program received no support from the DWASA regarding sewer connection, resulting in a lower sewer connection rate among the new residents.

*"My building is constructed a few years back. During that time, I got permission from the DWASA to make water and sewer connections. DWASA personnel provided a water line to the house, but no sewer connection was made. After a few days, I connected my house to the city corporation drainage." IDI, Male, Goran.*

A DWASA Engineer confirmed that while DWASA would be responsible for building the sewer line along the road, the landlord would be required to cover the cost of connecting the sewer line to their respective residences. Some non-connected households also reported their reluctance to connect to the sewer due to the requirement to obtain authorisation from DWASA. They prefer to establish a connection between their wastewater line and the closest available open drain or the drainage system managed by the city corporation.

*"The house owner is in charge of maintaining the application and making connections; however, DWASA is in charge of building the sewer line on the road." KII, Engineer, DWASA*

**Administrative difficulties with new connections**

Residents who had not connected their households to the sewer mentioned lengthy and complex administrative processes as a significant barrier. During IDIs, participants stated they had applied to DWASA with the required documentation and money. Still, they had to wait a long time, often more than two years, to connect their households to the sewer. Despite being within the required proximity for connection and consistently paying sewage bills, DWASA took no action to make the connection. As a result, frustrated landlords had no choice but to continue disposing of faecal waste in the open drainage instead of properly managing it through the sewage system. Additionally, two

out of ten landlords emphasised the additional time and effort required for administrative tasks involved in connecting a house to the sewer system.

*"My neighbour and I submitted applications to be connected to the sewer two years ago. However, no necessary steps were taken to connect our houses to the sewer. We were compelled to connect to an open drain." IDI, Male, Basabo*

**High cost associated with new sewer connection**

The process of connecting new households to the sewer is impeded by high upfront expenses. Initially, DWASA's sewer program from 1990 to 2000 allowed existing households to connect to the system without any bureaucratic procedures or fees. However, post-program constructions received no such support, requiring landlords to make additional financial investments for sewer connectivity. Additionally, in some areas, the sewer was built on a single side of the road. Consequently, the buildings on the opposite side had to bear extra costs for the installation of connecting pipes, placing additional financial burdens on residents. This issue is further exacerbated as the residents are required to obtain approval to cut roads and make the necessary connections, making the process even more expensive. Consequently, many residents opt to connect to the nearest city corporation's drainage for convenience and to avoid additional costs.

*"I wanted to connect to the sewer, but the line is situated on the opposite side of the road. To connect my house to the sewer, I am required to pay extra money for pipes and labour, which is a burden for me. Consequently, I connected my household sewer connection to the nearest drainage" IDI, Male, Goran*

Due to their dissatisfaction with the additional administrative tasks, cost, and lack of action from the DWASA personnel, the respondents attempted to connect to the sewer independently, which led to legal repercussions. Two out of ten IDI respondents reported being penalised by law enforcement for cutting roads to connect their households to the sewer.

*"I applied to the DWASA to connect my house to their sewer, but they did not come. Eventually, while trying to connect the house on my own, police arrived and fined me for cutting the road, saying I did not have permission. After that, I connect to the drainage." IDI, Male, Mohammadpur Bus Stand*

We found that, currently, the connection fees for DWASA's water and sewerage services range from $84 USD to $342 USD for a 10-meter connection (which is the minimum requirement), depending on the pipe diameter (DWASA, 2020). Landlords have to pay approximately $34 USD per meter, adding

up to $342 USD, just to obtain permission from the DWASA authorities. By contrast, to obtain permission from the city corporation for the connection to the open drainage, the landlords have to pay around $41 USD (Local Government Division, 2022).

**Outdated sewer & lack of maintenance**

All IDI respondents (connected households: 10 out of 10) expressed dissatisfaction with the outdated and dysfunctional sewer lines. They observed that the pipes were of limited diameter and frequently blocked due to inadequate maintenance.

*"The sewer gets clogged frequently, and due to this tenant residing on the ground floor, the toilet overflows and jams, which makes the system unhygienic. I filed a complaint at the local WASA office, and they rarely come to clean." IDI, Male, Tenari more*

Additionally, in certain locations, the deteriorated and narrow sewer infrastructure prevented landlords from connecting their households to the system. The population density has significantly risen due to the construction of new housing developments; however, the sewer has not been improved. Consequently, the newly built houses were unwilling to join the DWASA sewer system and instead sought alternate options.

*"The sewer system connection was constructed long ago, and the pipes were narrow. Due to a lack of proper maintenance, these systems deteriorate and fail to provide appropriate services to the huge community. Consequently, we did not take the sewer connection.*" IDI, Male, Tenari more

Qualitative exploration revealed that some not-connected households were previously connected to the sewer system but later disconnected due to the outdated and poorly maintained infrastructure. They opted for open drainage instead, contributing to the rise in the number of not-connected households. They also found the city corporation's drainage system to be more modern, spacious, and reliable compared to DWASA's sewer system.

"*My house is now connected to the city corporation's drainage. This system is more spacious than the older one (sewer), and the system works properly. Also, the response from the city corporation personnel is more prompt than DWASA's."* IDI, Male, Nawabgong.

Meanwhile, the DWASA billing inspector mentioned that a lack of awareness among the inhabitants led people to dispose of garbage in the toilet, resulting in blockages in the sewerage system. He expressed dissatisfaction with the area residents who improperly disposed of bottles and other

plastic debris into the sewer if the lid was left open or broken. This lack of awareness caused the blockage of the sewer pipes.

*"People throw different types of waste, such as plastics and other waste that causes blockage in the sewer system, and people deliberately accuse the authorities." KII, Billing Inspector, DWASA*

**Key Insights by DWASA officials**

The Executive Engineer from the Dhaka Water Supply and Sewerage Authority (DWASA) mentioned that the city's sewerage lines were facing significant challenges due to their age. These sewers, which form a crucial part of the city infrastructure, have been in place for more than 30 years, serving Dhaka's growing population. Over time, these sewers have become increasingly susceptible to damage and deterioration. The ageing infrastructure in some areas was prone to cracks, leaks, and breakages, leading to issues such as sewage spills and blockages.

In addition, continuous and repeated construction activities by different authorities put an increasing strain on the already vulnerable sewerage lines. The DWASA Executive Engineer expressed grave concern about the lack of cooperation between government institutions, especially with the city corporations. She explained that different government organisations often carry out separate development projects simultaneously on Dhaka streets, including the construction of new roads and improvements to the drainage system. These construction activities, which involve excavation work and heavy machinery can damage sewers.

*"Sewerage networks were very old, and in some areas, pipes were damaged due to construction works. Proper maintenance of the system sometimes hinders as the pipe had undergone significant damage due to the city development projects." KII, Executive Engineer, DWASA*

In many cases where existing sewers were either damaged or disconnected during drainage construction, city corporation officials often redirected these sewer connections into the new drainage system being built by the city corporation. After the drainage work was completed, it became easier for residents to connect their household toilets to these new drains. The city corporation also made it simple for landlords to get road-cutting permissions and directly link their sanitation systems to the new drainage infrastructure, bypassing the DWASA sewer.

*"…… other service organisations constructed new roads, and due to this development, our sewerage pipes get demolished sometimes. They also connect household sewer lines to these newly constructed drainages." KII, Executive Engineer, DWASA*

Moreover, DWASA is currently focusing on ensuring that every household in Dhaka has access to fresh water, aiming for 100% coverage. Once that goal is met, they plan to focus on improving the city sewerage system. DWASA did, however, report that they were developing a small number of infrastructure investments, such as the completion of the Daserkandi Sewage Treatment Plant, to help address problems with the sewerage.

*"The sanitation system improvement is not a priority area for now. Currently, we are focusing on water services in Dhaka city and installing new water pipelines across the city to ensure fresh water for the people. After ensuring the water services, we have a plan to work on the sewer services. For that, we have built the Daserkandi sewer treatment plant, and land acquisition is ongoing." KII, Engineer, DWASA*

## Discussion

Our study revealed various barriers at both individual and organisational levels that impeded household connections to the sewer in urban Dhaka. Key individual-level barriers included a lack of knowledge about connection procedures and psychological factors such as perceived less risk regarding disease transmission, attitude, and ability to connect. Barriers at the organisational level encompassed complex administrative processes, high installation costs, insufficient support from DWASA, outdated infrastructure, DSCC/DNCC enabling connections to drainage, and lack of maintenance.

Those who were not connected to the sewer perceived lower risk of disease transmission and believed that the health repercussions would be less severe. Conversely, those who connected to the sewer had a better understanding of the risks associated with not being connected. While these findings are in line with previous research, they should be treated with caution; those already connected may report placing a higher value on the benefits of connection as a form of ex-post justification for a prior investment. However, in a similar study in Addis Ababa, only 22% of residents knew about the sewer network in their area, and only 7% of them could identify the benefits of sewer connections over onsite sanitation (Ali and Robele, 2023). Thus, the majority didn't perceive the health and environmental risks as severe if not connected to the sewer. Additionally, that study concluded that it was difficult to expect a high number of customers connected to sewers with such a low level of awareness (Ali and Robele, 2023), indicating that the majority didn't perceive the health and environmental risks as severe if not connected to the sewer. This can further be correlated with the present lack of awareness programs by the concerned authority (DWASA),

resulting in lower awareness levels among current residents and influencing a higher number of not connected households. Similarly, a study from the World Bank revealed that, among other factors, a lack of information from service providers about the importance of connecting serves as a barrier, discouraging households from connecting to sewers that often pass right in front of their homes (Gray, 2020). Another study in Brazil revealed that inadequate social awareness and mobilisation strategies and lack of participatory management by water and sewage service providers act as an institutional barrier that discourages individuals from taking sewer connections (Sachet and Bilotta, 2020). These findings underscore the need for deeper exploration to identify the obstacles from the implementor's side that influence the low uptake of sewer connections.

A progressive decline in community awareness over time may explain the association between the duration of settlement and lower uptake of sewer connections. This suggests that efforts to rekindle interest and increase awareness could be effective. For instance, a three-year community awareness intervention program in Espírito Santo, Brazil, significantly increased sewer connections (Kennedy-Walker et al., 2020) due to the extensive support provided to the households in constructing and connecting to the sewer.

Complex administrative processes were another critical factor preventing connections. The World Bank report found that complicated processes and lack of orientation about connecting to the sewer reduced connection rates in Latin American countries, including Bolivia, Brazil, Colombia, Ecuador, Nicaragua, Peru, and Uruguay (Kennedy-Walker et al., 2020), aligning with our findings.

The study also revealed that dissatisfaction with the current sewer system and high costs associated with infrastructural changes to connect, as well as availability of a cheaper, and more reliable option (open drainage by DSCC/DNCC) with no penalty, were major reasons for disconnections. Case studies from Indonesia (Kennedy-Walker et al., 2020) and findings from Morocco (Mangizvo, 2009) also noted user dissatisfaction due to the service provider’s inefficiency regarding operation and maintenance (Mangizvo, 2009). This situation negatively affects the appeal of connecting to the sewer system in addition to posing health risks (Ali and Robele, 2023), which coincides with our findings and emphasises the need for proper maintenance of the sewer.

Our study also revealed that, at present, the landlords require additional financial investments to connect to the network. The connection fees for DWASA's water and sewerage services range from $84 USD to $342 USD (DWASA, 2020) whereas to obtain permission from the city corporation for the

connection to the open drainage, the landlords have to pay around $41 USD, which is substantially lower than the DWASA mandates (Local Government Division, 2022). In a country where the average monthly salary for the population is estimated to be around $270 USD (BBS, 2023), this connection cost places a significant barrier to connecting to the sewer network. Consistent with the present findings, a prior study conducted in Ethiopia reported that the sewer connection fee was a barrier for some households, with approximately 11% of respondents in high-income areas being unable to afford the fee. High connection cost was identified as a barrier to connecting households to the sewer also in Bolivia, Brazil, Colombia, Ecuador, Nicaragua, Peru, and Uruguay (Kennedy-Walker et al., 2020). From the existing evidence and our findings, we can reasonably assume that the percentage of households unable to pay will be higher in low-income areas. In addition, a program implemented in Morocco to improve the sanitation situation reported that when free sewer connection was provided to the households, the program reached 80% of their targeted population. This indicates that free connections influence people to connect their houses to the sewer since they are not required to bear the additional cost of connecting to the sewer. All the discussed factors dissuade households from connecting to the network and make them prefer the newer, more efficient city corporation's drainage. These findings highlight the need for proactive efforts from the DWASA authorities to improve the sanitation system, which will lead to more sewer uptake among the residents of low-income communities.

## Recommendations

To improve sewer connectivity, it is essential to address administrative barriers as well as psychological factors. At the organisational level, improvements to sanitation need to be holistic, addressing both the functionality of the network and connection rates in tandem. DWASA could, for example, focus on upgrading the city's ageing sewer infrastructure and ensuring regular maintenance to handle the increasing demand. However, this would have a more significant effect if paired with streamlined administrative procedures by simplifying the connection process, speeding up approvals, and providing clear guidance to households. To help reduce administrative barriers, DWASA could prioritise providing better organisational support, such as responsive customer service and efficient handling of connection requests. To effectively tackle the financial barriers, financial support, such as flexible payment plans or payment holidays, could make connections more affordable, especially for low-income households. This could also be done by providing direct cash subsidies to targeted households or restructuring tariffs so that the costs of connecting new customers are covered in the general bills of all customers. Importantly, DWASA needs to prioritise

better coordination with other government agencies to prevent damage to sewer lines during construction projects and align sewer improvements with urban development plans.

At the individual level, enhancing knowledge and awareness about the benefits and procedures of sewer connections, enhancing their health risk perceptions and fostering ownership may have a significant effect. This could be achieved through community awareness programs, media campaigns, workshops, and local meetings. Promoting community participation and fostering partnerships between governments, NGOs, and community organisations will further support sewer connectivity initiatives. By tackling these multifaceted issues through a holistic approach, urban planning and public health efforts can ensure safer and more efficient disposal of household sewage, ultimately improving the quality of life in urban settlements.

**Limitations**

We designed this study in a cross-sectional manner, meaning the results do not signify causality. Most of the results shown in this study were self-reported behaviours of participants and, therefore, should be interpreted carefully. The use of a long questionnaire for the interview was another limitation. However, field practice made the interviewers familiar with all questions, and they were able to save time.

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**Conflicts of interest**

The authors declare no conflicts of interest.

*Table 6: Demographic characteristics of the respondents*

| **Indicator** | **Connected to sewer (N= 192)** n (%) | **Not connected to a sewer (N= 192)** n (%) | **Test statistic, p-value** | **Total (N= 384)** n (%) |
|---|---|---|---|---|
| **Sex of respondent** | | | | |
| Male | 105 (55) | 114 (59) | 0.86, p=0.35 | 219 (57) |
| Female | 87 (45) | 78 (41) | | 165 (43) |
| **Age of respondent (in years)** | 52 (±14) | 50 (±14) | 1.26, p=0.21 | 51 (±14) |
| **Household type** | | | | |
| Tin shed | 10 (5) | 13 (7) | 3.99, p=0.26 | 23 (6) |
| One storied building | 24 (12) | 17 (9) | | 41 (11) |
| 2-5 storied building | 145 (76) | 140 (73) | | 285 (74) |
| 6+ storied building | 13 (7) | 22 (11) | | 35 (9) |
| **Education of Respondent** | | | | |
| No education | 4 (2) | 5 (3) | 1.26, p=0.87 | 9 (2) |
| Completed grade 5 | 17 (9) | 21 (11) | | 38 (10) |
| Completed grade 10 | 64 (33) | 69 (36) | | 133 (35) |
| Completed grade 12 | 24 (12) | 23 (12) | | 47 (12) |
| Completed graduation | 83 (43) | 74 (39) | | 157 (41) |
| **Education of household head** | | | | |
| No education | 3 (2) | 7 (4) | 1.99, p=0.73 | 10 (3) |
| Completed grade 5 | 21 (11) | 23 (12) | | 44 (11) |
| Completed grade 10 | 63 (33) | 64 (33) | | 127 (33) |
| Completed grade 12 | 26 (14) | 23 (12) | | 49 (13) |
| Completed graduation | 79 (41) | 75 (39) | | 154 (40) |
| **Occupation of Respondent** | | | | |
| Homemaker | 63 (33) | 55 (29) | 4.51, p=0.61 | 118 (31) |
| Retired | 57 (30) | 51 (27) | | 108 (28) |
| Small/medium business | 40 (21) | 57 (30) | | 97 (25) |
| Private service | 19 (10) | 16 (8) | | 35 (9) |
| Large scale business | 8 (4) | 7 (4) | | 15 (4) |
| Government service | 1 (1) | 2 (1) | | 3 (1) |

| **Indicator** | **Connected to sewer (N= 192)** n (%) | **Not connected to a sewer (N= 192)** n (%) | **Test statistic, p-value** | **Total (N= 384)** n (%) |
|---|---|---|---|---|
| Others | 4 (2) | 4 (2) | | 8 (2) |
| **Number of family members** (mean±sd) | 5 (±2) | 5 (±2) | 0.95, p=0.34 | 5 (±2) |
| | **N=189** | **N=188** | | |
| **Duration of settlement in this household (in years)** (median, IQR) | 30 (17, 40) | 23 (12, 35) | **-2.66, p=0.008** | 26 (15, 40) |
| **Monthly family income (USD)** (median, IQR) | 409 (273, 455) | 364 (227, 455) | 1.66, p=0.09 | 364 (273, 455) |
| **Monthly family expenditure (USD)** (median, IQR) | 364 (272,454) | 318 (227, 454) | **1.99, p=0.05** | 364 (227, 454) |
| **Monthly electricity bill (USD)** | | | | |
| ≤ 15 | 32 (17) | 41 (21) | 1.84, p=0.6 | 73 (19) |
| 15 – 30 | 79 (41) | 69 (36) | | 148 (39) |
| 30 – 45 | 32 (17) | 31 (16) | | 63 (16) |
| > 45 | 49 (26) | 51 (27) | | 100 (26) |
| **Monthly electricity bill (USD)** (median, IQR) | 27 (18, 39) | 27 (18, 45) | 0.12, p=0.90 | 27 (18, 39) |
| **Type of fuel used for cooking** | | | | |
| Natural gas by pipeline | 192 (100) | 191 (99) | 1.003, p=0.32 | 383 (100) |
| Electric heater | 3 (2) | 2 (1) | 0.2, p=0.65 | 5 (1) |
| **Monthly fuel cost (USD)** (median, IQR) | 9.8 (9.8, 9.8) | 9.8 (9.8, 9.8) | 0.46, p= 0.65 | 9.8 (9.8, 9.8) |
| **Monthly water bill of landlord (USD)** | | | | |
| ≤ 5 | 99 (52) | 126 (66) | **9.36, p=0.025** | 225 (59) |
| 5 – 10 | 75 (39) | 57 (30) | | 132 (34) |
| 10 – 15 | 11 (6) | 7 (4) | | 18 (5) |
| > 15 | 7 (4) | 2 (1) | | 9 (2) |
| **Monthly water bill of landlord (USD)** (median, IQR) | 27 (13, 45) | 22 (13, 41)) | **3.73, p=0.0002** | 27 (13, 45) |
| **Monthly sewer bill of the landlord (USD)** | | | | |
| ≤ 5 | 99 (52) | 126 (66) | **9.36, p=0.025** | 225 (59) |
| 5 – 10 | 75 (39) | 57 (30) | | 132 (34) |
| 10 – 15 | 11 (6) | 7 (4) | | 18 (5) |
| > 15 | 7 (4) | 2 (1) | | 9 (2) |
| **Monthly sewer bill of landlord (USD)** (median, IQR) | 27 (13, 45) | 22 (13, 41) | **3.73, p=0.0002** | 27 (13, 45) |
| **Duration of the household connected to the sewer/drainage** | | | | |
| Less than 1 year | 1 (1) | 3 (2) | **55.1, p=<0.001** | 4 (1) |

| **Indicator** | **Connected to sewer (N= 192)** n (%) | **Not connected to a sewer (N= 192)** n (%) | **Test statistic, p-value** | **Total (N= 384)** n (%) |
|---|---|---|---|---|
| 1 to 5 years | 22 (11) | 58 (30) | | 80 (21) |
| 5 to 10 years | 17 (9) | 50 (26) | | 67 (17) |
| More than 10 years | 152 (79) | 81 (42) | | 233 (61) |
| **Type of toilet facilities** | | | | |
| Flush toilet | 133 (69) | 118 (61) | 2.59, p=0.108 | 251 (65) |
| Pour flush toilet | 59 (31) | 74 (39) | 1.0, p=0.317 | 133 (35) |

*Table 7: Factors influencing households not to connect to the sewer*

| Factor | Connected to sewer | Not connected to a sewer | Total | p-value |
|---|---|---|---|---|
| **Who would influenced to take the sewer connection** | | | | |
| Family | 42 (21.9%) | 44 (22.9%) | 86 (22%) | 0.81 |
| Neighbours | 23 (12.0%) | 32 (16.7%) | 55 (14%) | 0.19 |
| NGO | 0 (0.0%) | 1 (0.5%) | 1 (0.26%) | 0.32 |
| Community members | 13 (6.8%) | 16 (8.3%) | 29 (8%) | 0.56 |
| Govt. officials | 24 (12.5%) | 25 (13.0%) | 49 (13%) | 0.88 |
| DWASA | 55 (28.6%) | 40 (20.8%) | 95 (25%) | 0.076 |
| Own | 140 (72.9%) | 152 (79.2%) | 292 (76%) | 0.15 |
| **Knowledge of how to get their household connected to a sewer** | | | | |
| No knowledge at all | 33 (17.2%) | 40 (20.8%) | 73(19%) | 0.26 |
| Some knowledge | 37 (19.3%) | 49 (25.5%) | 86(22%) | |
| Not sure | 28 (14.6%) | 30 (15.6%) | 58(15%) | |
| Moderate knowledge | 34 (17.7%) | 29 (15.1%) | 63(16%) | |
| Complete knowledge | 60 (31.3%) | 44 (22.9%) | 104(27%) | |
| **Barriers to connecting to the sewer system** | | | | |
| Cost | 60 (31.3%) | 67 (34.9%) | 127 (33%) | 0.45 |
| Lack of space | 23 (12.0%) | 31 (16.1%) | 54 (14%) | 0.24 |
| Legal issues | 14 (7.3%) | 17 (8.9%) | 31 (8%) | 0.57 |
| Lack of awareness | 23 (12.0%) | 7 (3.6%) | 30 (8%) | 0.002 |
| Political issues | 4 (2.1%) | 4 (2.1%) | 8 (2%) | 1 |
| No Barriers | 118 (61.5%) | 104 (54.2%) | 222 (58%) | 0.15 |
| **Current system is hygienic** | | | | |
| Not Hygienic | 58 (30.5%) | 97 (50.8%) | 155 (41%) | <0.001 |
| Hygienic | 132 (69.5%) | 94 (49.2%) | 226 (59%) | |
| **Mentioned reasons for the 'current system is not hygienic'** | | | | |
| Poor management | 41 (71) | 66 (68) | 107 (69) | 0.73 |
| Harmful to the environment | 34 (59) | 75 (77) | 109 (70) | 0.014 |
| Spread bad odour | 28 (48) | 70 (72) | 98 (63) | 0.003 |

| Factor | Connected to sewer | Not connected to a sewer | Total | p-value |
|---|---|---|---|---|
| Spread diseases | 20 (34) | 40 (41) | 60 (39) | 0.403 |
| Pollute water bodies | 16 (28) | 21 (22) | 37 (24) | 0.401 |
| Unsafe and unsecured during flood | 16 (28) | 25 (26) | 41 (26) | 0.804 |
| Openly visible faeces | 12 (21) | 46 (47) | 58 (37) | 0.001 |
| Pipes are leaking | 6 (10) | 6 (6) | 12 (8) | 0.348 |
| Blockage of the sewer line | 6 (10) | 1 (1) | 7 (5) | 0.007 |
| Create a financial burden | 1 (2) | 2 (2) | 3 (2) | 0.883 |
| Others | 1 (2) | | 1 (1) | 0.194 |
| **What motivates people to pay for sewer connection** | | | | |
| Awareness-building programs for a better environment | 85 (44) | 84 (44) | 169 (44) | 0.918 |
| Area based subsidy | 57 (30) | 56 (29) | 113 (29) | 0.911 |
| Based on the number of users, like other utility bills | 65 (34) | 62 (32) | 127 (33) | 0.745 |
| Aware of negative impacts of the environment | 55 (29) | 66 (34) | 121 (32) | 0.227 |
| Impose strict laws to pay subsidy | 28 (15) | 20 (10) | 48 (12) | 0.217 |
| Income-based subsidy | 22 (11) | 18 (9) | 40 (10) | 0.504 |
| Unwillingness to pay | 6 (3) | 6 (3) | 12 (3) | 1 |
| Mandatory to include in household rent | 1 (1) | 2 (1) | 3 (1) | 0.562 |
| Don’t know | 17 (9) | 19 (10) | 36 (9) | 0.726 |
| Others | 3 (2) | 3 (2) | 6 (2) | 1 |

*Table 8: Comparison of contextual factors of the study participants regarding sewer connection (Summary of RANAS)*

| **Indicator** | **Mean Difference** | ***p-value*** | **Effect size** |
|---|---|---|---|
| **Risk Factors** | | | |
| Health Knowledge (how high/low the risk of causing disease if the household is not connected to a sewer) | 0.24 | **0.003** | 0.31 |
| Vulnerability (how high/low the possibility of getting you sick (e.g. diarrhoea) if the household is not connected to a sewer) | 0.18 | **0.0265** | 0.23 |
| Severity (imagine that you have a disease (e.g. diarrhoea) from a toilet that is not connected to sewer; how severe would be the impact on your life) | 0.24 | **0.0172** | 0.24 |
| **Attitude Factors** | | | |
| Beliefs about Costs and Benefits: | | | |
| Effort (How difficult do you think it is to connect a household to a sewer) | -0.27 | 0.0942 | -0.17 |
| Space (How difficult do you think it is to find space to build a pipeline to connect with a sewer) | -0.13 | 0.3147 | -0.10 |
| Expensiveness (How expensive do you think it is to construct a connection to the sewer) | -0.02 | 0.9149 | -0.01 |
| Money (How difficult is it to arrange the money to connect to a sewer) | -0.05 | 0.7547 | -0.03 |
| Status (How certain are you that connecting to a sewer would increase your social status) | 0.33 | **0.0098** | 0.26 |
| Health (How certain are you that connecting to a sewer will prevent you from disease) | 0.2 | 0.0811 | 0.18 |
| **Feelings Factors** | | | |
| Behaviour (How much do you like/dislike connecting the household with a sewer) | 0.1 | 0.4070 | 0.08 |
| Proud (How proud would you feel if your household is connected to a sewer) | 0.29 | **0.0116** | 0.26 |
| Respect (How much do you think you would be respected by your community if your household is connected to a sewer? | 0.23 | **0.0155** | 0.25 |
| **Norm Factors** | | | |
| Others' behaviour (Proportion of people perceived the sewer connection as helpful) | 0.23 | 0.0796 | 0.18 |
| Personal Importance (Do you feel a personal obligation to connect to a sewer) | 0.15 | 0.1009 | 0.17 |
| Personal Importance (How important or unimportant is it for you to connect to a sewer) | 0.19 | **0.031** | 0.22 |
| Personal Importance (Others opinions could influence to connect/not connect to the sewer) | 0.13 | 0.4290 | 0.08 |
| **Personal Importance (whose opinions are most influential)** | | | |
| Own | -0.06 | 0.151 | -0.15 |
| DWASA | 0.08 | 0.076 | 0.18 |
| Family | -0.01 | 0.807 | -0.02 |

| **Indicator** | **Mean Difference** | ***p-value*** | **Effect size** |
|---|---|---|---|
| Neighbours | -0.05 | 0.19 | -0.13 |
| Govt. officials | -0.01 | 0.878 | -0.02 |
| Community members | -0.02 | 0.564 | -0.06 |
| NGO | -0.01 | 0.318 | -0.10 |
| **Ability Factors** | | | |
| How to do Knowledge (Do you know how to get your household connected to a sewer) | 0.33 | **0.0310** | 0.22 |
| Confidence in Performance (How confident are you that you can connect to a sewer even if this is a difficult process) | 0.26 | **0.0278** | 0.23 |
| Confidence in Continuation (How confident are you that you would continue sewer even if it costs a lot of money) | 0.43 | **0.0005** | 0.36 |
| Confidence in recovering (How confident are you that you can maintain the sewer on your own if that is blocked/not working) | -0.01 | 0.8799 | -0.02 |
| Confidence in recovering (How confident are you that a govt. dept. (DWASA) will maintain the sewer if that is blocked/not working) | -0.06 | 0.7233 | -0.04 |
| **Self-Regulation Factors** | | | |
| Barrier planning (Do you think any factors could influence connecting/not connecting to a sewer) | 0.21 | 0.1951 | 0.13 |
| **Factors obstructing sewer connection** | | | |
| No Barriers | 0.07 | 0.149 | 0.15 |
| Cost | -0.036 | 0.449 | -0.08 |
| Lack of space | -0.042 | 0.241 | -0.12 |
| Lack of awareness | 0.08 | **0.002** | 0.31 |
| Legal issues | -0.02 | 0.574 | -0.06 |
| Political issues | 0 | 1 | 0 |
| Others | -0.02 | 0.359 | -0.09 |
| Barrier planning (is there a way to overcome that particular barrier) | -0.05 | 0.5693 | -0.06 |
| **Social Factors** | | | |
| Social Dilemma (Feel the community would be working together to connect households to sewer) | -0.19 | 0.2038 | -0.13 |
| Solidarity (If a community project does not directly benefit me but has benefits for many others in the community, I would contribute time or money to the project) | 0.03 | 0.8145 | 0.02 |
| Trust (Most people who live in this community can be trusted) | 0.07 | 0.5868 | 0.06 |
| Empowerment and Political Action (I have the freedom to make important decisions that change my life) | 0.04 | 0.7412 | 0.03 |

| **Indicator** | **Mean Difference** | ***p-value*** | **Effect size** |
|---|---|---|---|
| Collective Action and Cooperation (If there is a sanitation problem in this community, how likely is it that people will cooperate to try to solve the problem? | -0.23 | 0.0802 | -0.18 |
| Social Cohesion and Inclusion (In the last month, how frequently have you met with people in a public place either to talk or to have food or drinks?) | -0.25 | 0.0633 | -0.19 |
| In group Ties (I have a lot in common with other community members) | 0.12 | 0.1561 | 0.15 |
| Centrality (In general, being a member of this community is an important part of my self-image) | -0.07 | 0.3093 | -0.10 |
| In group Effects (In general, I'm glad to be a member of this community) | -0.06 | 0.4434 | -0.08 |
| Social Cohesion (I would be willing to work together with others on something to improve my community) | -0.04 | 0.5656 | -0.06 |
| **Contextual Factors** | | | |
| Age (in years) | 1.94 | 0.174 | 0.14 |
| Education of household head (in years) | 0.66 | 0.191 | 0.13 |
| Duration of household settlements (in years) | 4.41 | **0.007** | 0.28 |
| Household size | 0.11 | 0.609 | 0.05 |
| Monthly income | 4196 | 0.154 | 0.15 |
| Monthly expenditure | 6026 | 0.075 | 0.18 |
| Number of households on the compound | -0.49 | 0.307 | -0.10 |
| Number of toilets on the compound | 0.62 | 0.461 | 0.08 |

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# Chapter 6: Sewer Misconnection: Recommendations for Increasing Sewer Connections in Low-Income Urban Communities in Dhaka, Bangladesh

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Contribution: MUA prepared the first draft of the manuscript together with AR and SN. MA analysed qualitative data together with NN. MA analysed quantitative data together with KFT. AR and SN collected data together with MA. BE and PH provided their technical insights to improve the draft manuscript. BE, PH, NN, and KFT reviewed and edited the draft manuscript.

## Abstract

In Dhaka, Bangladesh, sewer misconnections persist despite sewer infrastructure expansion by the Dhaka Water Supply and Sewerage Authority (DWASA). This mixed-method cross-sectional study aimed to develop targeted, evidence-based interventions to increase sewer connections in urban communities. We surveyed 384 households and conducted 10 in-depth interviews, 3 Key-Informant Interviews, two focus group discussions across five DWASA zones. Using the Risks, Attitudes, Norms, Abilities, and Self-regulation (RANAS) framework, we identified key psychological factors influencing sewer connection behaviours. Building on these insights, we mapped psychological factors to Behaviour Change Techniques (BCTs) to develop tailored interventions. Households that were not-connected to sewer exhibited significantly lower awareness of sanitation-related health risks, less confidence in navigating connection procedures, and weaker perceptions of the social benefits of sewer linkage. Qualitative findings revealed widespread dissatisfaction with dysfunctional sewers, high connection costs, inadequate maintenance support from DWASA, and bureaucratic delays as significant barriers. These results highlight a complex interplay of psychological, financial, and administrative challenges limiting sewer uptake. Based on these insights, we propose a comprehensive intervention package integrating

health education to improve risk awareness, community role models to shift social norms, practical technical guidance to simplify connection processes, and income-adjusted financial incentives to ease economic burdens. These measures aim to boost sewer connection rates and reduce sewer misconnections, an often-overlooked source of environmental contamination and public health risk. The study emphasises the urgent need for integrated, multi-sectoral strategies that address behavioural, structural, and economic barriers simultaneously. Implementing these interventions would advance equitable and sustainable sanitation improvements in rapidly urbanising cities like Dhaka.

## Background

Safely managed sanitation is essential for disease control and public health. Access to such services is still unequal, just 57% of the worldwide population uses safely managed sanitation facilities (JMP, 2024). In urban areas, sewered sanitation is often the first choice, but there are other alternatives. When properly constructed and regulated, non-sewer sanitation systems including septic tanks, pit latrines with effective faecal sludge management, and container-based sanitation can also provide safe services. Due to infrastructure and financial constraints in many low- and middle-income cities, non-sewer solutions are typically more practical and expand faster (Strande et al., 2023). Nonetheless, where sewer networks do exist, challenges often persist in ensuring high connection rates, particularly among low-income households. Therefore, to optimise urban sanitation, systematic strategies are needed to ensure high compliance with sewer network. Without such initiatives, health concerns and environmental damage will persist (Kennedy-Walker et al., 2020; JMP, 2024).

Sanitation in low- and middle-income countries (LMICs) is a critical issue that significantly impacts public health, environmental sustainability, and economic development (Kennedy-Walker et al., 2020). In urban areas of LMICs, increasing sewer coverage faces significant challenges due to infrastructural, administrative, financial, and behavioural factors. The high costs associated with constructing, operating, and maintaining these systems are often prohibitive, especially in households with limited financial resources. Additionally, many LMICs suffer from water scarcity, making it difficult to sustain sewers that rely on large quantities of water for flushing and waste conveyance (Dhawan et al., 2001; Le, 2003; Davis et al., 2010; Robinson, 2011; Yoshino et al., 2019; Kennedy-Walker et al., 2020). Space constraints in densely populated urban areas, particularly in informal settlements, further complicate the installation of sewer lines, as there is often insufficient room to accommodate the necessary infrastructure (Alam et al., 2020). Moreover, many households do not connect to available sewers even when they are nearby (Kennedy-Walker et al., 2020), leading to a higher rate of sewer misconnection.

Misconnection, which is the improper diversion of rainfall into sewers or the discharge of foul wastewater into surface water drainage systems, is a significant but sometimes overlooked problem in urban sanitation. As a result of these connections, untreated sewage is directly released into rivers, streams, and groundwater, posing major threats to the environment and human health (CIWEM, 2025). Such problems are made worse in many low- and middle-income countries (LMICs), including

Bangladesh, by a lack of awareness, poor enforcement of connection requirements, and inadequate infrastructure. In low-income urban contexts, misconnections are often normalised despite their serious effects, particularly due to technical uncertainties, technical inefficiencies, and household-level behavioural factors.

Sewers are designed to convey wastewater, encompassing human waste and greywater, to treatment facilities, whereas surface water drains are purposed to channel rainwater back into the natural ecosystem. When households link to an incorrect system, harmful elements like chlorine, ammonium, and bacteria infiltrate natural water bodies, diminishing oxygen levels and jeopardising aquatic ecosystems and human health (CIWEM, 2025). Institutional challenges such as leaking sewers and dysfunctional pumping stations further exacerbate the problem, contributing to the underutilisation of existing wastewater treatment facilities. Moreover, the overall infrastructure capacity in many countries, including the availability of skilled labour, materials, and technology, is often inadequate, leading to delays, substandard construction, and poor maintenance (Obradović et al., 2023; UN-Habitat, 2023; Karki et al., 2024). These challenges collectively hinder the development and sustainability of effective sewers in LMICs and further exacerbate the occurrence and durability of misconnections.

In Dhaka, Bangladesh, this issue is particularly acute. Only around 20% of the population is connected to the city's official sewer system, which is run by the Dhaka Water Supply and Sewerage Authority (DWASA), and only 2% of sewage is properly treated (Ross et al., 2016; Mansour et al., 2017). With the help of the World Bank, DWASA has started a massive urban sanitation project with the goal of expanding sewer coverage to 65% of homes by building additional sewers, treatment facilities, and inclusive service delivery for low-income communities (DWASA, 2016). This comprehensive approach seeks to improve sanitation coverage, enhance wastewater management, and consequently safeguard public health and the environment. A study by Alam et al. (2020) explored strategies to connect low-income communities to the sewerage network under the Dhaka Sanitation Improvement Project (DSIP), focusing on affordability, legal land tenure, and infrastructure barriers such as narrow lanes and inadequate trunk connections (Alam et al., 2020). While that study provided valuable stakeholder perspectives from low-income settlements, it was limited to communities not yet connected to sewers and did not quantify the sewer connection issues. Our study extends this evidence by including both connected and non-connected to sewer households, incorporating mixed methods, and examining

building types, satisfaction levels, and misconnection risks across diverse urban neighbourhoods. In doing so, it complements and expands on (Alam et al., 2020) by adding quantitative insights from a larger and more diverse sample, allowing comparisons between connected and non-connected households, and highlighting systemic gaps and widespread misconnection issues across Dhaka.

Nonetheless, increasing sewer connections cannot depend exclusively on infrastructural construction. Misconnections are not merely mechanical malfunctions but also manifestations of human behaviour. Our previous study indicates that both connected and not-connected households often possess insufficient awareness regarding connection procedures, with many unaware of the obligatory nature of sewer connection. Psychological and social determinants, such as diminished perceived health risks, limited perceived rewards, low self-efficacy, and prevailing social norms, further impede households from establishing accurate and timely connections. These trends correspond with the RANAS (Risk, Attitude, Norms, Ability, Self-regulation) model, which identifies essential behavioural determinants of sanitation uptake through five core dimensions (Alam et al., 2025).

Beyond the Dhaka context (Alam et al., 2020), most sanitation studies in low- and middle-income countries have either focused narrowly on infrastructure provision, policy analysis, or qualitative assessments of user perspectives, often without quantifying household-level behaviours or misconnection risks. This study addresses these gaps through a comprehensive mixed-method approach that combines a stratified household survey with in-depth interviews and focus group discussions, generating both prevalence data and behavioural insights. By applying the RANAS framework and mapping Behaviour Change Techniques (BCTs) to identified psychological determinants, our analysis goes beyond descriptive findings to offer practical, evidence-based recommendations. This integrated approach allows for a more nuanced understanding of the interplay between behavioural, structural, and institutional barriers to sewer connection, positioning this work as a valuable resource for designing scalable, behaviourally informed sanitation interventions in Dhaka and similar urban settings.

Given the significant environmental and health risks posed by sewer misconnections, this study aims to design and propose evidence-based interventions to increase sewer connections among currently unconnected households in low-income urban areas. By addressing both technical and behavioural

factors, these proposed interventions seek to reduce the prevalence of misconnections, enhance proper sewer usage, and ultimately improve public health and environmental outcomes in rapidly urbanising settings like Dhaka.

## Methods

### Study Setting and Study Area

A cross-sectional mixed-methods study was carried out in ten neighbourhoods in Dhaka, Bangladesh, where the Dhaka Water Supply and Sewerage Authority (DWASA) has established sewer infrastructure in five of its Maintenance, Operation, Distribution, and Services (MODS) zones (Figure 13). The selection of these zones was based on the existence of operational DWASA sewers alongside storm sewers and open drainage systems. The site selection process included pre-field assessments, focusing on locations where households received DWASA sewer billing and where open or city corporation drainage systems were visible on the same road. The specific standards and zoning alignment tactics used are described in detail in earlier research (Alam et al., 2025).

### Study population and sample size

Since landlords and homeowners possessed the majority of the decisions about their sanitary infrastructure, they were the target population. In order to ensure equitable representation of households with DWASA sewer connections and those with city corporations or open drainage, 328 households were enrolled through stratified matching, the details were described in earlier research. During visits, trained enumerators confirmed the type of connection in each household. The sampling strategy expands on methods previously described by (Alam et al., 2025), including power calculation and group stratification thresholds (Alam et al., 2025).

### Data Collection Period

The data collection team collected data between October 2023 and November 2025.

**Quantitative Data Collection**

Participants completed a standardised questionnaire that gathered demographic information, sanitary infrastructure, household conditions, and perceived risks or motivators. The psychological determinants were evaluated utilising the RANAS framework (Risks, Attitudes, Norms, Abilities, and Self-Regulation). The data collection tool was carefully translated into Bengali, pilot-tested in the local context, and then administered electronically through mobile devices to enhance data quality and collection efficiency. Additional methodological specifics are outlined in (Alam et al., 2025).

**Qualitative Data Collection**

We collected qualitative data to explore the barriers that landlords encounter when connecting their houses to the current sewerage system and to gather their recommendations for overcoming these challenges. This includes ten in-depth interviews (IDIs) with landlords and two focus group discussions (FGDs) held at two separate study sites within urban Dhaka. Each FGD included 6-10 male participants, as activities related to sewer connection and decision-making were always performed by male members of the households, even if the landlord is female. Participants were chosen based on age and occupation, to collect community-level perceptions and recommendations for sewer connections. We also conducted three Key-informant interviews (KIIs)- one each with officials from DSCC, DNCC, and RAJUK to get their opinions on sewer connection, and our draft recommendation. The interviews were conducted in the location preferred by the participants. The interviews and discussions were recorded on a voice recorder with informed consent from the participants.

After identifying behavioural determinants to connect with sewer from the quantitative analysis, I conducted the ranking exercise during the FGD, and asked them to rank the statistically significant/most valued (based on analysis from Step 2) determinants from most to least important for them to influence them to connect with sewer. I also asked them to provide reasons why they consider this specific behaviour.

**Data Analysis**

All the quantitative data were analysed using the statistical software STATA version 14.1. Frequency and percentage were reported to demonstrate the categorical variables. For continuous variables, the normality assumption was assessed through the Shapiro-Wilk test (González-Estrada and Cosmes, 2019).

To compare the connected to sewer and not-connected to sewer over the different variables, a chi-square test (Pearson/Fisher's exact test), t-test, and Mann-Whitney test were conducted depending on the nature of the data. Associations between categorical variables were evaluated using Pearson's Chi-square test of independence, following the procedure described by Wuensch (Wuensch, 2011). For an r×c contingency table, expected cell frequencies were obtained as the product of the corresponding row and column totals divided by the grand total. The test statistic was calculated as,

$$\chi^2 = \Sigma_{i=1}^{r} \Sigma_{j=1}^{c} ((O_{ij} - E_{ij})^2 / E_{ij})$$

where Oij and Eij denote the observed and expected counts, respectively. When more than 20% of the cells had an expected frequency less than 5, Fisher's exact test was applied (Upton, 1992).

Comparisons of continuous variables between two independent groups were performed using the independent samples t-test (Ruxton, 2006; Rochon et al., 2012). Under the equal variance assumption, the pooled variance was used to estimate the standard error, and the test statistic was expressed as:

$$t = (\bar{X}_1 - \bar{X}_2) / (s_p * \sqrt{(1/n_1 + 1/n_2)}) \; ; \; s_p^2 = [ (n_1 - 1)s_1^2 + (n_2 - 1)s_2^2 ] / (n_1 + n_2 - 2)$$

where $\bar{X}_1$ and $\bar{X}2$ are the sample means, $s_1^2$ and $s_2^2$ are the variances, and $n_1$ and $n_2$ are the group sizes.

A non-parametric test assumes no specific distribution, whereas a parametric test assumes a specific distribution. Thus, the Mann-Whitney U is conceptually similar to the t-test for determining whether two sampled groups are from a single population. When data do not meet the parametric assumptions of the t-test, the Mann-Whitney U tends to be more appropriate (McKnight and Najab). The Mann-Whitney U test handles any form of ranking. After ranking, the procedure divides the rank scores by group and computes a sum score for each group (Ta and Tb). Equation 1 shows how both the summed ranked score groups (Ta and Tb) and the group sample sizes combine to calculate the U statistic.

If na>nb: U= Ta−(na(na+1))/2

If nb>na: U= Tb−(nb(nb+1))/2 ……. (1)

The U statistic has a discrete or uniform distribution that provides us with the ability to define a critical value, assign a probability to that value, and then test the null hypothesis. A critical value represents a probability level—typically .05—that helps us rule out chance differences. If the U statistic is greater than the critical value, then we reject the null hypothesis.

Cronbach's alpha was measured to test the scale reliability of the RANAS (Risks, Attitudes, Norms, Abilities, and Self-regulation) factors (Tavakol and Dennick, 2011). For each RANAS factor, we computed the mean difference between the two groups using an ANOVA test to identify significant predictors of connecting to the sewerage network. Additionally, we utilised Cohen's d equation to calculate the effect size of each RANAS factor, categorising it as small, medium, or large. The analysis focused on RANAS factors with a significant mean difference and small to medium effect size to inform the design of effective behaviour change interventions.

For the qualitative component, audio recordings of IDIs and FGDs were transcribed and translated into English. Transcriptions were then checked using voice recordings by Bangla-speaking research team members to ensure data accuracy. A combined priori code list was created by team members reviewing existing literature. The data were coded following the codebook and analysed using the thematic analysis approach through NVivo-14 software, with the coded data summarised under relevant themes. After analysis, these summaries were reviewed, and the results for each thematic area were compiled and presented together.

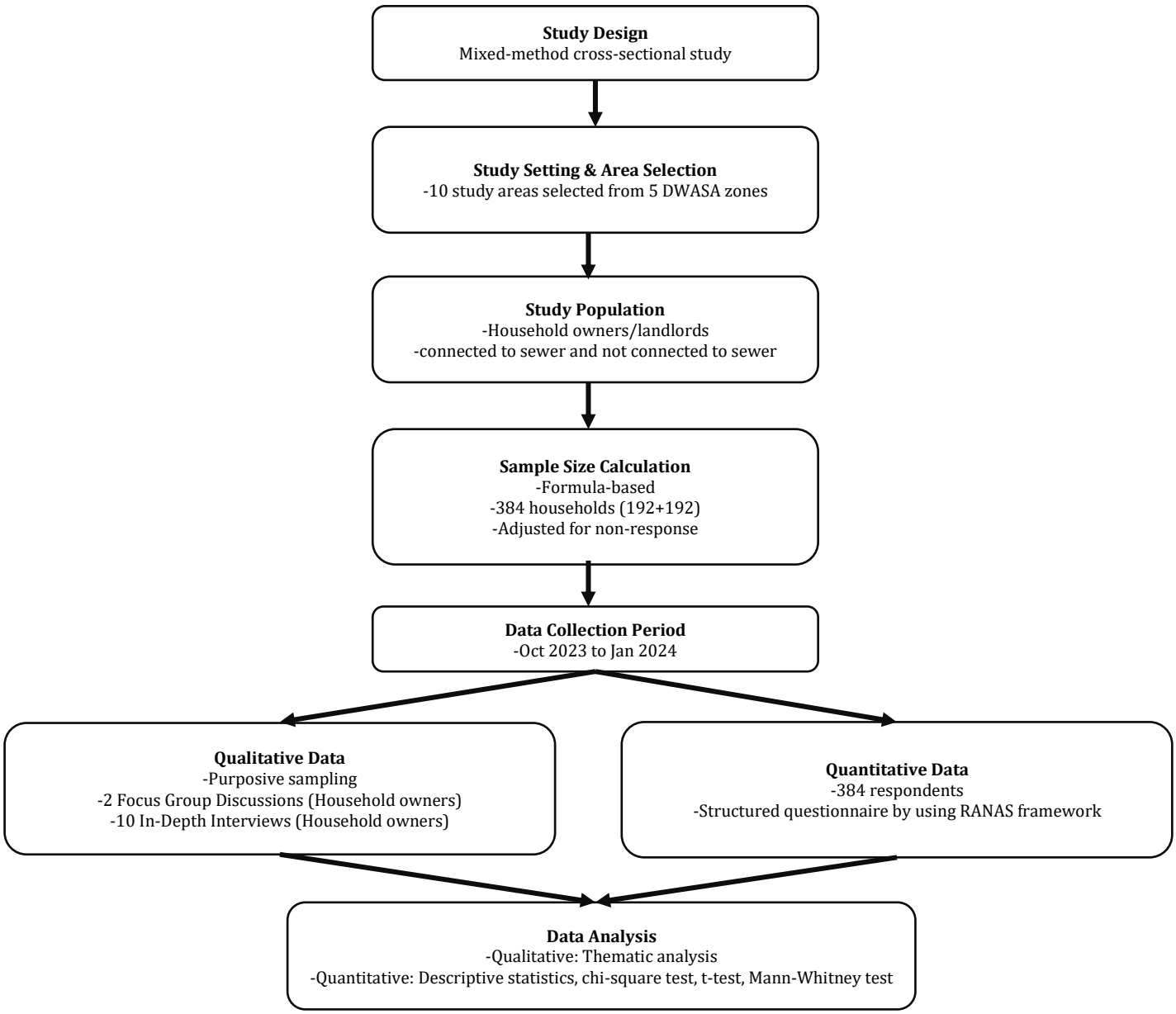


*Figure 13: Research process*

**Application of the RANAS Framework and Behaviour Change Technique (BCT) Mapping for the development of the behaviour change interventions**

The Risk, Attitude, Norm, Ability, and Self-regulation (RANAS) model is a recognised framework for comprehending behaviours and has been extensively utilised in both developmental and emergency settings, especially for interventions aimed at changing WASH-related behaviours (Inauen and Mosler, 2014; Contzen et al., 2015; Tumwebaze and Mosler, 2015). The approach utilises psychological constructs from several theories, categorising them into five groups: risk, attitude, norm, ability, and self-regulation. Risk variables represent individuals' beliefs of their susceptibility to and the severity of an illness (e.g., perceived health risk associated with lack of sewer connectivity). Attitudinal aspects pertain to the perceived costs, benefits, and efforts linked to an activity (e.g., connecting to a sewer). Norm factors refer to social pressures, approval, and perceived accountability. Ability encompasses the information and perceived skills necessary to execute and maintain the behaviour. Self-regulation encompasses action planning, commitment, and behavioural prompts.

In this study, we applied the RANAS framework to structure household survey questions aimed at quantifying key psychosocial determinants of sewer connection behaviour. The resulting data were analysed using descriptive statistics, and mean differences between those connected and not-connected to sewer were examined using ANOVA tests to identify statistically significant predictors of sewerage connection behaviour. A 5% significance level was used to identify factors significantly associated with the likelihood of connecting to the sewerage network. These findings informed the selection of Behaviour Change Techniques (BCTs), which are specific elements of interventions designed to influence the psychological processes underlying behaviour. Following the RANAS methodology, each BCT is mapped to a specific psychosocial factor it is known to influence.

Our analytical approach established a clear connection between the significant psychosocial determinants derived from RANAS and the corresponding behaviour change techniques from the RANAS BCT catalogue (Mosler and Contzen, 2016). This process entailed systematically aligning each identified factor with evidence-based techniques that address it, facilitating the design of targeted interventions. Studies indicate that interventions designed following the RANAS BCT catalogue are generally effective; e.g., interventions in Malawi and Bangladesh using RANAS showed significant improvements in hygiene and sanitation behaviours (Chidziwisano et al., 2020; Harter et al., 2020). This study advances previous

research (Alam et al., 2025) by employing a systematic approach to convert behavioural determinants into practical behaviour change techniques (BCTs). BCTs were proposed for the general population but can be adapted to specific local contexts. Interventions addressing vulnerability (risk), behaviour and status (attitude), personal importance (norms), knowledge and confidence in performance (ability), as well as action and barrier planning were prioritised according to the factor analysis.

### Ethical consideration

Ethical consent was obtained from the University of Leeds, and icddr,b in Dhaka, Bangladesh (Research Protocol number PR-23088). Written consent was sought from all participants, with thumbprints permitted if necessary. Participants were informed of the study's objectives, benefits, and potential risks, and were assured that their data would remain anonymous. They have the liberty to refuse or retract at any moment without consequence. These measures guaranteed that the study adhered to ethical standards and safeguarded participants' rights.

## Results

### Socio-demographic characteristics

The quantitative survey included 384 respondents who were household owners, and the majority lived in 2-5 storied buildings (74%). Respondents were divided equally into connected to sewer (n=192) and not-connected to sewer (n=192). Gender distribution showed no significant difference (p=0.35), with males comprising 57% of the overall sample. Most respondents (41%) had completed graduation, and the most common occupations were homemakers (31%) and retired persons (28%). Monthly median family income and expenditure were significantly (p=0.05) higher for connected to sewer ($409 and $364, respectively) compared to not-connected to sewer ($364 and $318, respectively).

All IDI and FGD participants were male and not-connected to sewer. All KII participants were male. The participants had varied occupations: business owners, social workers and retired individuals. Most participants lived in 2-5 storied buildings, similar to survey participants.

*Table 9: Demographic characteristics of the respondents*

| **Indicators** | **Connected to sewer (N= 192)** n (%) | **Not-connected to sewer (N= 192)** n (%) | **Test statistic, p-value** | **Total (N= 384)** n (%) |
|---|---|---|---|---|
| **Sex of respondent** | | | | |
| Male | 105 (55) | 114 (59) | 0.86, p=0.35 | 219 (57) |
| Female | 87 (45) | 78 (41) | | 165 (43) |
| **Age of respondent (in years)** | 52 (±14) | 50 (±14) | 1.26, p=0.21 | 51 (±14) |
| **Household type** | | | | |
| Tin shed | 10 (5) | 13 (7) | 3.99, p=0.26 | 23 (6) |
| One storied building | 24 (12) | 17 (9) | | 41 (11) |
| 2-5 storied building | 145 (76) | 140 (73) | | 285 (74) |
| 6+ storied building | 13 (7) | 22 (11) | | 35 (9) |
| **Education of Respondent** | | | | |
| No education | 4 (2) | 5 (3) | 1.26, p=0.87 | 9 (2) |
| Completed grade 5 | 17 (9) | 21 (11) | | 38 (10) |
| Completed grade 10 | 64 (33) | 69 (36) | | 133 (35) |
| Completed grade 12 | 24 (12) | 23 (12) | | 47 (12) |
| Completed graduation | 83 (43) | 74 (39) | | 157 (41) |
| **Occupation of Respondent** | | | | |
| Homemaker | 63 (33) | 55 (29) | 4.51, p=0.61 | 118 (31) |
| Retired | 57 (30) | 51 (27) | | 108 (28) |
| Small/medium business | 40 (21) | 57 (30) | | 97 (25) |
| Private service | 19 (10) | 16 (8) | | 35 (9) |
| Large scale business | 8 (4) | 7 (4) | | 15 (4) |
| Government service | 1 (1) | 2 (1) | | 3 (1) |
| Others | 4 (2) | 4 (2) | | 8 (2) |
| **Monthly sewer bill of landlord (USD)** (median, IQR) | 27 (13, 45) | 22 (13, 41) | **3.73, p=0.0002** | 27 (13, 45) |

**Perception about the current wastewater management system**

The perception of the current wastewater management system was explored through in-depth interviews and focus group discussions with house owners, whose residents were not connected to a sewer system. These participants who were using the city corporation's drainage system expressed dissatisfaction regarding their current wastewater management system and cited the inadequate capacity of the drains to carry massive amounts of generated waste, causing frequent blockage and overflowing. Concerns among non-connected to the sewer regarding environmental harm, specifically water pollution, overflowing of the city corporation drains, visible faeces on the roads, and frequent blockage of the drains, were reported through IDIs and FGDs.

*"These lines do not work anymore, the width of the drains is not adequate, and the depth also. This cannot hold the huge amount of wastewater produced. So, the faecal waste overflows the roads, and people come into contact with waste while walking to shop or the mosque. Also, faecal waste from buildings gets mixed with supplied water. All of these pollute the environment" (Focus group discussion_landlords_Basabo)*

During interviews, participants highlighted the importance of regular maintenance, including frequent drainage cleaning and the use of wider pipes during the construction of drainage systems or sewer networks, which was also resonated through FGDs.

*"No system will work properly without regular cleaning. It will get blocked and overflowed. It will keep functioning properly if authorities clean and manage those properly" (IDI_landlord_Basabo)*

While these qualitative narratives highlight strong dissatisfaction among the population not-connected to the sewer, survey findings indicate that 164 of the 384 respondents (43%) reported being satisfied with their current wastewater access (Table 10). However, connected households were more satisfied than not-connected households (55% vs. 30%; p=<0.001). This suggests that although many residents encounter serious issues with the drainage system, a notable proportion perceive their current system as acceptable. Furthermore, perceptions of the current wastewater system were generally similar among both connected and non-connected respondents to the sewer, with only minimal statistically significant differences. This consistency across groups may reflect a broader systemic challenge, affecting residents regardless of sewer connection status.

*Table 10: Perception about the current wastewater management system*

| Indicators | Connected to sewer (N= 192) n (%) | Not-connected to sewer (N= 192) n (%) | Chi-square test statistic, p-value | Total (N= 384) n (%) |
|---|---|---|---|---|
| **What aspects of the existing system should be improved** | | | | |
| Maintenance/repair | 151 (91) | 145 (91) | 0.005, p=0.942 | 296 (91) |
| Install a wider pipe | 97 (58) | 103 (65) | 1.39, p=0.24 | 200 (62) |
| Improved sewer structure | 90 (54) | 99 (62) | 2.16, p=0.142 | 189 (58) |
| Forcibly stop open connection to drain | 17 (10) | 25 (16) | 2.17, p=0.141 | 42 (13) |
| Install septic tank | 1 (1) | 1 (1) | 0.0009, p=0.976 | 2 (1) |
| Don't know | 4 (2) | 3 (2) | 1.11, p=0.746 | 7 (2) |
| Others | 4 (2) | 5 (3) | 0.16, p=0.686 | 9 (3) |
| **What motivates people to pay for sewer connection** | | | | |
| Awareness building programs for better environment | 85 (44) | 84 (44) | 0.01, p=0.918 | 169 (44) |
| Area based subsidy | 57 (30) | 56 (29) | 0.012, p=0.911 | 113 (29) |
| Based on number of users like other utility bills | 65 (34) | 62 (32) | 0.11, p=0.745 | 127 (33) |
| Aware about negative impacts of the environment | 55 (29) | 66 (34) | 1.46, p=0.227 | 121 (32) |
| Impose strict law to pay subsidy | 28 (15) | 20 (10) | 1.52, p=0.217 | 48 (12) |
| Income based subsidy | 22 (11) | 18 (9) | 0.45, p=0.504 | 40 (10) |
| Unwillingness to pay | 6 (3) | 6 (3) | 0, p=1 | 12 (3) |
| Mandatory to include in household rent | 1 (1) | 2 (1) | 0.34, p=0.562 | 3 (1) |
| Don't know | 17 (9) | 19 (10) | 0.12, p=0.726 | 36 (9) |
| Others | 3 (2) | 3 (2) | 1 | 6 (2) |
| **Barriers to connecting to sewer** | | | | |
| Satisfied with the current access | 106 (55) | 58 (30) | **24.52, p=<0.001** | 164 (43) |
| No Barriers | 23 (12) | 41 (21) | **6.08, p=0.014** | 64 (17) |
| Narrow road | 18 (9) | 23 (12) | 0.68, p=0.409 | 41 (11) |
| Cannot afford | 18 (9) | 28 (15) | 2.47, p=0.116 | 46 (12) |
| Lack of space | 16 (8) | 29 (15) | **4.25, p=0.039** | 45 (12) |
| City corporation not approved | 2 (1) | 3 (2) | 0.2, p=0.653 | 5 (1) |
| No sewer in this area | 2 (1) | | 2.01, p=0.156 | 2 (1) |
| Neighbours reluctant | 1 (1) | 1 (1) | 0, p=1 | 2 (1) |
| Inaccessible to connect the pipes | 1 (1) | 1 (1) | 0, p=1 | 2 (1) |
| Don't know | 22 (11) | 27 (14) | 0.59, p=0.444 | 49 (13) |
| Others | 8 (4) | 14 (7) | 1.74, p=0.188 | 22 (6) |

**Motivators and barriers for connecting to the sewer**

Among both connected to sewer and not-connected to sewer, motivators for paying for sewer connections included awareness programs for a better environment (44% for both groups), area-based subsidies (30% connected to sewer vs. 29% not-connected to sewer, p=0.911), and user-based billing (34% connected to sewer vs. 32% not-connected to sewer, p=0.745) (Table 10). Perceived barriers to future sewer connections revealed significant differences between those connected to sewer and not-connected to sewer, with 55% of connected to sewer being satisfied with their current access compared to 30% of not-connected to sewer (p<0.001) (Table 10). A higher proportion of not-connected to sewer (21%) perceived no barriers to their future sewer connection (Table 10).

However, the qualitative investigation identified a number of significant obstacles to sewer connection, such as the DWASA sewer system's dysfunction, the high cost of new connections, the lack of DWASA support for pipeline maintenance, and the complicated administrative processes involved in starting connections. Participants regularly mentioned these obstacles as the main reasons they didn't want to join sewer network. Our previously published results Alam et al. (Alam et al., 2025) offer more insight into these problems, especially the financial burden caused by connection fees, which in certain instances were said to surpass Bangladeshi households' average monthly income.

Qualitative findings from this study also corroborate this, with both IDI and FGD participants identifying the high connection fees as a deterrent. FGD participants emphasised their financial strain, citing that they were already paying bills for sewer services despite the dysfunctional state of the existing system and expressed unwillingness to bear additional financial burdens for repairing or reconstructing to the sewer infrastructure. According to the DWASA policy, households within 100 feet of the sewer network must pay the sewer bills whether they are connected or not connected to the sewer. Therefore, they stressed the need for authorities to bear the repair costs and simplify administrative processes to encourage broader participation in the sewer system.

*“The sewer system does not work at all and we are connected to city corporation drainage. Still, we are paying a monthly bill to Dhaka WASA, which is high. The authorities must replace the dysfunctional sewer or repair the current ones, but we will not pay for that. We are already paying and*

*struggling with it. Additional fees will increase our financial burden. We will do whatever is required to connect our households to the repaired sewer, but authorities need to bear the cost of replacement or repair" (Focus group discussion_landlords_Jafrabad)*

**Development of Interventions According to the Behaviour Change Technique (BCT) Catalogue in RANAS**

Our previous article Alam et al. (2025) applied the RANAS model to identify the key psychological factors that influenced individuals' decision to connect their households to the sewer system in urban Dhaka, Bangladesh (Alam et al., 2025). Building on those findings, this article presents the interventions designed to address each psychological factor, based on insights from our quantitative and qualitative analysis and guided by the Behaviour Change Techniques (BCTs) catalogue outlined in Table 11 according to the RANAS guideline (Mosler and Contzen, 2016). These interventions can be utilised as a package to influence households to connect to the sewer by targeting all the RANAS factors together or by combining more than one factor**.**

The interventions were formulated to target health knowledge (risk factors), social status (attitude factors), respect (feeling factors), individual importance (norm factors), how-to-do knowledge and confidence (ability factors), as well as action planning and barriers (self-regulation factors) (Table 11).

*Table 11: Summary of RANAS (Risks, Attitudes, Norms, Abilities, and Self-regulation)*

| Indicator | Mean Difference | *p-value* | Effect size |
|---|---|---|---|
| **Risk Factors** | | | |
| Health Knowledge (how high/low the risk of causing disease if the household is not connected to a sewer) | 0.24 | **0.003** | 0.31 |
| Vulnerability (how high/low the possibility of getting you sick (e.g. diarrhoea) if the household is not connected to a sewer) | 0.18 | **0.0265** | 0.23 |
| Severity (imagine that you have a disease (e.g. diarrhoea) from a toilet that is not connected to sewer, how severe would be the impact on your life) | 0.24 | **0.0172** | 0.24 |
| **Attitude Factors** | | | |
| Status (How certain are you that connecting to a sewer would increase your social status) | 0.33 | **0.0098** | 0.26 |
| **Feelings Factors** | | | |
| Proud (How proud would you feel if your household is connected to a sewer) | 0.29 | **0.0116** | 0.26 |
| Respect (How much do you think you would be respected by your community if your household is connected to a sewer? | 0.23 | **0.0155** | 0.25 |
| **Norm Factors** | | | |
| Personal Importance (How important or unimportant is it for you to connect to a sewer) | 0.19 | **0.031** | 0.22 |
| **Personal importance (whose opinions are most influential)** | | | |
| Own | -0.06 | 0.151 | -0.15 |
| DWASA | 0.08 | 0.076 | 0.18 |
| Family | -0.01 | 0.807 | -0.02 |
| Neighbours | -0.05 | 0.19 | -0.13 |
| Govt. officials | -0.01 | 0.878 | -0.02 |
| Community members | -0.02 | 0.564 | -0.06 |
| NGO | -0.01 | 0.318 | -0.10 |
| **Ability Factors** | | | |
| How to do Knowledge (Do you know how to get your household connected to a sewer) | 0.33 | **0.0310** | 0.22 |
| Confidence in Performance (How confident are you that you can connect to a sewer even if this is a difficult process) | 0.26 | **0.0278** | 0.23 |
| Confidence in Continuation (How confident are you that you would continue sewer even if it costs a lot of money) | 0.43 | **0.0005** | 0.36 |
| **Self-Regulation Factors** | | | |
| Barrier planning (Do you think any factors could influence connecting/not connecting to a sewer) | 0.21 | 0.1951 | 0.13 |
| **Factors obstructing sewer connection** | | | |
| No Barriers | 0.07 | 0.149 | 0.15 |
| Cost | -0.036 | 0.449 | -0.08 |
| Lack of space | -0.042 | 0.241 | -0.12 |
| Lack of awareness | 0.08 | **0.002** | 0.31 |
| Legal issues | -0.02 | 0.574 | -0.06 |
| Political issues | 0 | 1 | 0 |
| Others | -0.02 | 0.359 | -0.09 |
| Barrier planning (is there a way to overcome that particular barrier) | -0.05 | 0.5693 | -0.06 |

*Table 12: Psychological factors and Behaviour change techniques according to BCT catalogue*

| RANAS block | RANAS Factors | BCT | Interventions | Communication channel |
|---|---|---|---|---|
| **Risk** | Health Knowledge | BCT 2 | Information on benefits of sewer connection on various (diarrheal) disease | Community meeting with video or storytelling |
| | Vulnerability | BCT 3 | Demonstration of risk of getting sick by diarrheal disease if the household is not connected to a sewer | |
| | Severity | BCT 4 | Provide threatening information and severity of disease if not connected to a sewer | |
| **Attitude** | Beliefs about costs and benefits (Status) | BCT 6 | Find people who are already connected to the sewer. Those role models shall talk about their positive experiences with sewer connections, why and how they get connections and why it is good for everyone to be connected. Evoke emotions.<br>Message: I feel proud and other people respect me if there is no faecal matter/sewage beside my house/in front of my drainage | Community meeting with video or storytelling |
| | Feeling | BCT 8 | | |
| **Norms** | Personal importance | BCT 12 | Find people who are already connected to the sewer. Those role models shall talk about their positive experiences with sewer connections, why and how they get connections and why it is good for everyone to be connected. | Community meeting with video or storytelling |
| **Ability** | How-to-do Knowledge | BCT 15 | Information from DWASA how to get connection step by steps and in an easy way | Poster/leaflets |
| | Confidence in Performance | BCT 20 | Train participants on connecting households to a sewer through guided practice and giving feedback | |
| **Self-Regulation** | Action Planning | BCT 26 | Information from DWASA on how to get a connection step by step and in an easy way, and when, where, and how | Poster/leaflets |
| | Barrier Planning | BCT 30 | Increase awareness | |

**Mitigating risks: Educational intervention to increase health knowledge**

The results showed that three key risk factors: inadequate health knowledge, vulnerability, and severity, were significant among not-connected to sewer who had not connected their households to the sewer

(Table 11). Not-connected to sewer perceived lower levels of health knowledge about the increased risk of contracting diseases (e.g. diarrheal disease). Not-connected to sewer also considered themselves less vulnerable to diseases and believed disease severity would be less if they contracted the disease (Table 11). These findings highlighted the urgency of informing and creating community awareness about severe health risks due to not connecting households to the sewer system and the health benefits of connecting.

One of the identified interventions is educating communities about the broader public health benefits of sewer connectivity, particularly reduction of transmission of waterborne diseases through decreased environmental contamination. While connecting an individual household to the sewer may not substantially lower that household's immediate health risks, widespread community-level connectivity is critical for reducing overall public exposure to faecal contamination and associated diseases. Therefore, educational interventions should emphasize how collective action leads to significant health improvements, especially in densely populated urban setting [**BCT 2;** Table 12].

To effectively motivate individual behavioural change, however, the messaging should also highlight perceived personal relevance. This includes providing clear, evidence-based information on how proper sanitation, particularly through sewer connection, reduces disease incidences and helps prevent the spread of waterborne illnesses for risk mitigation **[BCT 2**; Table 12**]**. Additionally, it should encompass the information on the risk associated with poor sanitation, such as increased vulnerability to diarrhoeal and other waterborne diseases, particularly among children and the elderly. These messages should stress the severity and potential health consequences of these illnesses to build concern and drive action at the household level **[BCT 3, 4;** Table 12**]**. An IDI participant also implied that, *"People need to be educated about the risks of diseases due to lack of proper sanitation, otherwise they will never become aware" (IDI_landlord_Shahidbag).* A key informant supported this statement, *"If inhabitants knew how their waste, especially faecal waste and wastewater from drainage, mixed with drinking water due to poor construction, or broken connection, they would never connect their toilet outlet to drainage or storm sewer." (KII, DSCC).*

Community engagement strategies can play a pivotal role in delivering these messages effectively. Local community meetings facilitated by DWASA representatives and trusted local leaders could serve as a platform to disseminate information on health risks and benefits. They can provide evidence-based information about the health risks of exposure to faecal waste through community meetings. These sessions should use participatory approaches, such as group discussions and Q&A sessions that would allow community members to voice their concerns and provide input, ensuring that the messages are context-specific and resonate with local needs. FGD participants also emphasised the need for community engagement activities;

*"Community engagement and awareness meetings with small groups of landlords will also help. These meetings will help DWASA to identify the problems of getting connected with sewer and understand what solutions are proposed by the residents" (Focus Group Discussion_landlords_Basabo)*

**Shifting attitude and norms: Motivations from role models**

Two attitude factors- social status and a sense of respect were significant predictors of sewer connection among connected to sewer (Table 11). Alam et al. found that not-connected to sewer were less confident that connecting to the sewer would enhance their social status or earn them respect within the community (Alam et al., 2025). The potential intervention to address these attitude factors is to share the positive experiences of the individuals who have already connected to the sewer. Thus, those individuals will act as role models in the community and describe why they have connected to the sewer, the process, and why connecting households can benefit at both individual and social levels. This intervention will motivate not-connected to sewer to connect to the sewer by highlighting how it has improved the standing of the population connected to the sewer in the community. Promoting a sense of pride and respect associated with making the connection will further encourage not-connected to sewer households to act. Community meetings with videos or storytelling activities can be the communication channel to implement this intervention and make the content relatable and engaging. However, participants of the qualitative investigation did not indicate the influence of any attitudinal factors that impacted their decision to connect to the sewer.

A single norm factor- personal importance was significant for not-connected to sewer. According to Alam et al. not-connected to sewer respondents, placed less importance on connecting their households

to the sewer due to being uncertain about improving social status (Alam et al., 2025). Sharing positive experiences of role models regarding connecting households to the sewer was again found as an appropriate intervention to enhance the perceived importance of being connected. Identifying and involving respected community members who have successfully connected their households to the sewer can act as role models and influence shifting attitudes and norms **[BCT 12;** Table 12**]**.

Throughout the FGDs, participants highlighted the importance of collective well-being and maintaining clean environments free of sewage overflow. This supports implementing **BCT 6** and **BCT 12** [Table 12], which emphasises leveraging community role models to promote sewer connections to shift beliefs about the value of connecting. These role models can also emphasise how being connected to the sewer system aligns with collective community values, such as maintaining a clean and healthy environment, thus reinforcing positive norms.

A key informant mentioned that, “a role model-based approach works well in Dhaka for other societal problems, and even actors, role models take a minimum honorarium for participating in this type of campaign, so this can be easily done.” (KII, DSCC)

**Strengthening ability and self-regulation: Guidance and technical support to connect**

Three ability factors showed a significant difference between connected to sewer and not-connected to sewer: how-to-do knowledge, confidence in performance and confidence in continuing (Table 11). As reported in Alam et al. a higher proportion of not-connected to sewers lacked knowledge about the process of connecting their households to sewers, and they cited the complicated administrative procedures of securing new connections as a barrier (Alam et al., 2025). Additionally, two self-regulation factors of the RANAS model, barrier and action planning, were identified to develop the interventions. Guided practical sessions with adequate information can function as an intervention targeting these abilities and self-regulation factors.

The qualitative findings of IDI and FGD also emphasised that the participants lacked clear, step-by-step guidance for connecting to the sewer network. Additionally, the lack of cooperation from DWASA when they requested maintenance or improvement of the sewer network discouraged them from continuing their efforts to connect to the sewer.

*"We wrote to them (DWASA). We gave them applications requesting maintenance. We went to their offices for support. However, they just told us it was not solely their responsibility (indicating the involvement of the city corporation). Sometimes, they even neglected us. They never paid attention to our requests, and we did not know what to do after that. Their service should be more supportive to the users" (Focus group discussion_landlords_Basabo)*

Providing adequate information regarding the administrative process of connecting households was identified as a component of intervention to motivate not-connected to sewer to connect their household to the sewer. Furthermore, intervention should include step-by-step guidance from DWASA and training of a few community members through guided practice sessions **[BCT 15, 20]**. Specific guidance on connecting to the sewer will build confidence among not-connected to sewer regarding their attempts to be connected. This was also highlighted by the findings of continuing the sewer connection; however, we did not propose any BCT on that, as the question and responses were hypothetical. In addition to guided practical sessions, instructions from DWASA on the sewer connection procedures through posters and leaflets should be implemented as a form of technical support to not-connected to sewer **[BCT 26]**. Posters and leaflets containing step-by-step instructions and contact details of DWASA representatives can make the information easily accessible and straightforward to follow. Information on technical steps will also raise awareness of barriers and possible solutions to connect to the sewer system **[BCT 30]**.

**Addressing financial barriers: flexible payment plans or payment holiday**

Alam et al. reported that high DWASA monthly water and sewer bills and the fee for new connections affected the households' attitudes and community norms regarding connecting households to the sewer (Alam et al., 2025). High connection fees created a negative attitude by emphasising the economic strain, leading residents to view the expense as unjustifiable relative to perceived benefits. Moreover, dissatisfaction with the existing dysfunctional infrastructure (e.g., leaking sewers) fostered a belief that additional investments would not yield proportional improvements, further lowering motivation. An IDI participant denoted;

*"DWASA bill is already burdening us, but we are not getting any service. I am connected to city corporation's drain. And the cost of connecting new households to the sewer is also higher than connecting to city corporation drain. That fee should be reduced also"* (IDI_landlord_Mohammadpur)

Additionally, when a significant portion of the community perceives sewer connections as financially unattainable, this discourages others from prioritising or normalising the behaviour. Therefore, we also recommend a financial intervention that can positively influence the attitude and norms of the community and motivate households to connect to the sewer. Thus, a reduction of the connection fee for households can directly influence the attitude factor by making sewer connections appear financially feasible. Income-adjusted connection fees could also target norms by fostering collective participation and indicating the community-wide importance of being connected.

Flexible payment plans or payment holidays could make connections more affordable, especially for low-income households. This could also be done through the provision of direct cash subsidies to targeted households or through restructuring tariffs so that the costs of connecting new customers are covered in the monthly bills of all customers.

## Discussion

This study employed the RANAS model to identify the psychological aspects that may affect sewer connections in urban Dhaka, Bangladesh. Based on this analysis, we developed a series of behaviour change interventions grounded in the RANAS approach (Table 12). Core to this process is the application of Behaviour change techniques (BCTs) – which is a systematically developed method to influence the psychological factors that drive human behaviour. Using BCTs as an approach allows for the structured translation of behavioural theory into actionable intervention strategies and policy planning. The formulated BCTs targeting each psychological element were sourced from the BCT catalogue outlined in the RANAS guideline (Mosler and Contzen, 2016), each aligned with a specific psychological factor identified in our analysis. These techniques serve as practical tools for intervention design and can be instrumental for policymakers and implementation partners, such as DWASA, in developing and refining sanitation programs aimed at improving wastewater management across urban Dhaka.

Our study proposed targeted interventions to increase sewer connections by addressing psychological, financial, and administrative barriers. Our study proposes targeted interventions to increase sewer connections by addressing psychological, financial, and administrative barriers, building on emerging

global evidence. MacLeod et al. (2025), in a systematic review of sanitation interventions across urban low- and middle-income settings, found that interventions integrating motivational messaging, norm reinforcement, and practical assistance consistently achieved better adoption rates than those focused solely on infrastructure (MacLeod et al., 2025). This aligns with our recommendation to use role model-based messaging and technical support to strengthen perceived social importance and confidence in sewer connection practices. Educational interventions providing health risk information, emphasising disease severity, and promoting the benefits of sewer connections were identified as effective strategies to address risk and attitudinal barriers. We also recommended role model-based interventions to promote positive attitudes and shift societal norms and enhance the perceived social and individual importance of sewer connections. Additionally, guided practice sessions and technical assistance were found essential for improving confidence and overcoming administrative barriers. To address financial barriers, we proposed incentives, such as reduced fee or free connection, income-adjusted fees, and flexible payment plans. The findings highlight the importance of combining community engagement, targeted education, technical assistance and financial support to achieve sustainable sewer connections and improve urban sanitation outcomes. However, institutional and systemic challenges, such as poor governance, limited user support from utilities, and high costs continue to be significant barriers (Alam et al., 2020; Kennedy-Walker et al., 2020), that need to be addressed.

The dissatisfaction with the current wastewater management among those not-connected to sewer emphasises the urgent need for system improvements. This dissatisfaction provides a critical entry point for behavioural interventions; leveraging negative experiences with current systems could motivate households to transition to sewer. Studies in similar LMIC contexts reveal that inadequate maintenance and environmental harm discourage households from adopting sewer (Kennedy-Walker et al., 2020). Interestingly, more not-connected to sewer perceived no barriers to future connections than connected to sewer, indicating potential openness to change if logistical and psychological hurdles are addressed.

One key recommendation is the implementation of targeted educational campaigns to address the knowledge gap identified among not-connected to sewer. Education has long been known as an effective component of behaviour change interventions in improving urban sanitation (MacLeod et al., 2025). Our previous study found that a significant portion of the population lacks awareness of health risks, benefits and functionalities associated with sewer, which leads to their underutilisation. Evidence

from Brazil emphasises the importance of tailored messaging that resonates with specific community needs and stresses that educational initiatives should focus on practical benefits and environmental impacts (Kennedy-Walker et al., 2020). Furthermore, the environmental education program in Salvador, which involved collaboration between public organisations, educational institutions, and community members, led to a substantial increase in sewer connections. The percentage of households connected to the sewer rose from 26% in 1995 to 60% by the program's conclusion in 2004, demonstrating the effectiveness of such interventions (Melo, 2005). These findings confirm that when educational efforts are practical, locally grounded, and sustained, they can produce meaningful change.

Attitudinal factors, such as perceptions of social status and respect, emerged as significant predictors of behaviour regarding sewer connections. However, during qualitative investigation, we did not find any indication that these influenced their decision to connect to the sewer, which may require further testing of our recommended attitudinal interventions. These attitudinal and normative factors were primarily attributed to insufficient knowledge about the health risks of not being connected and a lack of association between social status and sewer connections. To address this, we recommended involving community role models to share their positive experiences with sewer connections to normalise this behaviour and enhance its social desirability. The positive experience of an individual whose household is already connected to a functional sewer system could highlight tangible benefits such as improved health and hygiene. Promotional activities in India involving local elected representatives and influencers successfully encouraged 40% of targeted households to connect to the sewer (Kennedy-Walker et al., 2020). Similarly, in Paraná, Brazil, trained community leaders and health inspectors provided guidance on sewer connections, demonstrating the effectiveness of role models in driving behaviour change (Sachet et al., 2020).

Financial barriers significantly influenced perceptions of sewer connection costs and benefits, with high fees and suboptimal service quality discouraging adoption. Frustration with paying for incomplete or dysfunctional services exacerbated negative attitudes. Similar trends were observed in Ecuador, Bolivia, Kenya, and Morocco, where free connections, combined with community engagement, successfully motivated households to connect, achieving coverage rates between 75% and 85% (Foster, 2001; Beauchêne, 2009; Advani, 2019; Kennedy-Walker et al., 2020). We proposed offering free or income-adjusted connection fees and a flexible payment plan or payment holidays to address these financial

barriers. This strategy that has successfully increased household connection rates in Espirito Santo, São Paulo, and Salvador, Brazil (Melo, 2005; Kennedy-Walker et al., 2020).

Beyond psychological and attitudinal constraints, households also face administrative and institutional challenges that further hinder sewer connections. Administrative challenges further hindered sewer connections, particularly due to difficulties in navigating bureaucratic procedures. A lack of knowledge about connection processes and low confidence in overcoming administrative barriers highlight the need for technical support and capacity-building initiatives. Research in Thimphu, Bhutan, on faecal sludge management, similarly found that technical knowledge gaps limited access to improved sanitation services, reinforcing the importance of training and support in overcoming administrative barriers (Halcrow et al., 2013). Similarly, Karki et al. (2024) examined wastewater management in South Asia and highlighted deep-rooted institutional challenges, including fragmented governance, weak enforcement of regulations, and inadequate financing mechanisms. These issues mirror participants' frustrations in our study regarding bureaucratic inefficiencies and the limited responsiveness of the Dhaka Water Supply and Sewerage Authority (DWASA) (Alam et al., 2025). To address this, interventions must incorporate hands-on technical support- such as form-filling help, contractor navigation, and procedural walkthroughs, to build user confidence and reduce procedural friction.

Engaging local stakeholders, such as DWASA and DSCC/DNCC officials and community role models, is crucial for implementing these interventions. Community engagement activities including meetings and guided practice sessions have been successfully used in Brazil, Ecuador, Bolivia, Pakistan, and Kenya to raise awareness and increase household sewer connections (Melo, 2005; Advani, 2019; Kennedy-Walker et al., 2020; Sachet et al., 2020). These approaches ensure that solutions are practical and culturally appropriate while fostering trust between the community and service providers. However, sustaining engagement over time requires strong institutional commitment. Beyond behavioural interventions, integrating advanced technologies and improving maintenance practices can enhance the reliability of sewer systems. A comprehensive approach combining infrastructure improvements with community involvement is essential for ensuring the sustainability of sewer connections and the reduction of misconnections.

In addition to BCTs, it is crucial to place these findings and recommendations in the larger framework of Citywide Inclusive Sanitation (CWIS), or other urban sanitation framework, which aims to provide sustainable and equitable sanitation for all urban dwellers, irrespective of their location or income. In places where traditional sewers are not practical, Faecal Sludge Management (FSM) solutions must be used in addition to sewer network expansion, which is still essential for environmental and public health protection (UNICEF, 2025; World Bank, 2025). A dual-track strategy supporting both sewered and non-sewered systems is essential for achieving universal, safely managed sanitation in dense and diverse urban contexts like Dhaka, Bangladesh.

The problem of sewer misconnection, where domestic wastewater or faeces are inappropriately directed into storm drains is one of our study's most significant but little-known findings. These improper connections seriously jeopardise public health, reduce system efficiency, and lead to environmental contamination. Our qualitative findings indicate that misconnection is a serious and underappreciated issue in urban Dhaka, despite the paucity of global statistics on the subject. The scant information we gathered highlights the critical need for additional study to estimate the frequency and causes of misconnection on a local and worldwide scale. By making clear the proper processes, lowering misunderstanding, and helping during the connection process, the interventions suggested in this study, particularly those pertaining to education, technical support, and guided practice can aid in preventing future misconnections.

## Conclusion

In order to address the systemic, financial, and psychological obstacles that prevent household sewer connections in metropolitan Dhaka, this study suggests an extensive, evidence-based intervention package. Role model-based approaches to change social norms, financial tools like free or income-adjusted connection fees, campaigns to increase public awareness of the advantages of sanitation, and technical assistance to streamline the connection procedure are all included in the suggested package. These interventions, based on behavioural science and stakeholder insights, seek to enhance individual confidence, transform community norms, and alleviate the logistical and financial burdens related to sewer connections. They also provide significant secondary advantages, particularly in mitigating the possibility of sewer misconnection, a prevalent yet underreported issue that exacerbates environmental degradation and public health risks in metropolitan areas. Despite the geographical focus of our study,

the results are consistent with the larger goals of Citywide Inclusive Sanitation, which promote equitable, sustainable, and safe sanitation for all. To guarantee thorough coverage in places where sewer development is impractical, increased assistance for Faecal Sludge Management (FSM) is equally essential. Encouraging safe sanitation via FSM and sewer routes contributes to the development of a more robust and inclusive urban sanitation ecosystem. Finally, our identification of misconnection practices highlights a critical gap in the global sanitation evidence base. In order to inform future sanitation planning and infrastructure design, more study is required to evaluate the prevalence and health/environmental effects of misconnection, both in Dhaka and globally. By integrating behaviour change, financial equity, technical support, and system-wide reform, this study offers a roadmap to advance sustainable sanitation in fast-growing urban contexts, contributing to healthier communities and a cleaner environment.

**Limitations**

In our study, we only surveyed landlords who managed their multi-story buildings independently rather than through homeowners' associations or professional management services. This reduces potential bias from collective decision-making structures but limits the generalisability of our findings to contexts where households live in single-family dwellings or rely on externally managed housing. Although the RANAS framework provided a structured approach to identifying behavioural drivers and linking them to targeted Behaviour Change Techniques (BCTs), self-reported data remain subject to recall and social desirability bias. Despite these limitations, the study provides important insights into behavioural, financial, and institutional barriers to sewer connections and offers an evidence base for designing targeted, behaviourally informed interventions to improve urban sanitation outcomes.

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**Authors contribution**

MUA prepared the first draft of the manuscript together with AR and SN. MUA analysed qualitative data together with NN. MUA analysed quantitative data together with KFT. AR and SN collected data together with MUA. BE and PH provided their technical insights to improve the draft manuscript. BE, PH, NN, KFT reviewed and edited the draft manuscript.

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**Conflicts of interest**

The authors declare no conflicts of interest.

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# Chapter 7: Integrated discussion and conclusion

## Introduction

The overarching aim of the study was to identify the behavioural determinants influencing landlords' decisions about sewer connections, in order to inform targeted interventions that can ultimately increase sewer-connection uptake among urban low-income communities. The overall objective of this thesis was to explore the drivers and motivators to sewer connection, identifying enablers and barriers to sewer connection, and develop interventions through empirical research to increase sewer connection in urban areas, particularly in LMIC settings. Data from secondary sources through scoping review and primary data collected from Dhaka, Bangladesh were analysed to explore: the uptake of behaviour change intervention to promote sewer connection in LMICs (Chapter 4), the organisational and individual level barriers to sewer connection in Dhaka (Chapter 5), and the designing of a Behaviour Change Intervention to increase sewer connection (Chapter 6).

Comprehensively, we examined the barriers to household sewer connections in urban Dhaka and proposed targeted interventions to increase uptake. Using a behavioural science perspective, the study provides a holistic understanding of the psychological, economic, and administrative barriers that influence sanitation decisions. The findings highlighted that sewer connection behaviour was shaped by multiple interrelated factors, including low risk perception, financial constraints, complex bureaucratic processes, and dissatisfaction with existing wastewater management systems. Addressing these barriers requires a multi-faceted intervention package that combines community engagement, educational initiatives, financial incentives, and institutional reforms.

This chapter includes an integrated discussion of the previous three chapters, including recommendations for policymakers and implementations, contributions to knowledge, limitations of the work, plans for future research, and a conclusion.

## Summary findings:

**Question 1: What are the drivers and motivators of individuals and household-level to connect with an available sewer in low-income urban countries?**

Chapter 4 presented evidence from a scoping review of relevant peer-reviewed articles and reports that assessed the effectiveness of behaviour change interventions that focused on improving the

sewer uptake in LMICs. Results showed that a dearth of studies focused on the effectiveness of behaviour change interventions in promoting sewer connections. Across the 11 included studies, it was revealed that there are four types of behavioural change interventions: indirect subsidies (free connections), promotional activities, educational interventions, and community engagement that focus on improving the sewer uptake in LMICs.

Among the interventions, those that provided free sewer connections in combination with community engagement initiatives showed the highest impact on uptake. In multiple cases, it was seen that high costs act as a major deterrent, particularly among low-income communities, leading to a lower sewer connection rate. On the other hand, the interventions covering infrastructure costs, connection fees, and maintenance expenses resulted in higher adoption rates. While promotional activities alone can raise awareness, they are often insufficient without complementary financial support, leading to lower uptake of sewer connections. Additionally, integrating community participation in interventions, such as training programs and labour contributions in Bolivia, created a sense of ownership and further encouraged participation. This review highlights the need for combined intervention packages that include both financial support and community-driven approaches to increase sewer connectivity.

**Question 2: What are the individual and organisational level barriers to connecting to the available sewer connections in low-income urban areas**

Chapter 5 explored organisational and individual barriers to sewer connections in Dhaka through fieldwork conducted in selected urban communities in urban Dhaka. We conducted a mixed-methods cross-sectional study, surveyed 384 households, conducted 5 Key Informant Interviews and 10 In-Depth Interviews. As our survey participants, we included landlords of households with toilets connected to the sewer or to stormsewer and drainage.

The findings revealed that at the individual level, lack of knowledge about connection procedures, low-risk perception of disease transmission, and psychological factors such as attitudes and abilities influenced decisions on sewer uptake. It was also found that limited outreach efforts from DWASA have contributed to this lack of awareness, reinforcing the need for targeted communication and mobilisation strategies to improve household connection rates. At the organisational level, complex administrative procedures, high connection costs, and a lack of support from DWASA emerged as significant barriers. Households faced lengthy and unclear application processes, discouraging them

from connecting to the available sewer network. Additionally, user dissatisfaction with DWASA's service quality, including outdated infrastructure and poor maintenance, further reduced willingness to connect.

The financial burden of connection fees was a major constraint, especially for landlords in low-income areas. DWASA's connection costs ranged from $84 to $342 USD, compared to just $41 USD for a drainage permit, making the latter a more attractive option. This study highlighted that without proactive efforts from DWASA to reduce financial and administrative barriers, many households will continue to connect to open drainage, undermining efforts to improve urban sanitation.

**Question 3: What are the behaviour change interventions to promote sewer connection in a low-income urban community**

Following the exploration of the effectiveness of specific behaviour change interventions and barriers to connecting to the sewer network, the study focused on forming key recommendations and developing target-specific behaviour change interventions, based on empirical evidence.

This study provides several key recommendations for increasing sewer connections in low-income urban communities in Dhaka by identifying the psychosocial differences between those who have connected to the sewer system (doers) and those who have not (non-doers). According to the findings, the connected to sewer group had greater awareness of health risks and perceived more substantial social and health benefits of sewer connections than the not-connected to sewer group, highlighting specific areas for behaviour change interventions. To address these gaps, behaviour change techniques (BCTs) such as community engagement, education campaigns, role modelling, and step-by-step guidance were identified as essential for fostering motivation and overcoming barriers. The incorporation of community storytelling, public recognition of connected households, and direct engagement with local leaders can further enhance awareness and drive uptake. Additionally, implementing educational interventions that address knowledge gaps among not-connected to sewer group through community meetings, workshops, and culturally relevant storytelling techniques is recommended. Furthermore, strengthening the relationship between DWASA and local communities through participatory approaches and transparent communication can improve trust, making it easier for residents to navigate administrative and technical challenges.

Finally, addressing economic and infrastructure barriers is essential for sustainable adoption. The study highlights the high financial burden of connection fees as a significant deterrent, particularly for low-income households, reinforcing the need for financial incentives such as subsidies, instalment payment schemes, and targeted financial aid. Additionally, improving the operational capacity and maintenance of sewer systems is critical, as infrastructure failures, such as leaking sewers and unreliable pumping stations - deter potential users. Therefore, a comprehensive approach that integrates financial support, infrastructure improvements, and long-term community engagement is necessary for sustainable sanitation solutions.

## Theoretical contribution/implications

Building on a comprehensive review of sanitation behaviour literature, this study applied established behavioural theories to understand the factors influencing household sewer connections in a low-income urban context. However, this study revealed important distinctions that differ from and challenge the already established assumptions of sanitation behaviour change literature, which predominantly focuses on daily or habitual behaviours such as first-time toilet use, pit-emptying, or handwashing and provides new novel perspectives on the theoretical approach for urban household sewer connections.

In traditional sanitation interventions (e.g., promoting latrine use or handwashing), health-related risk perceptions play a crucial role in developing prevention strategies (McGranahan and Mitlin, 2016; Anthonj et al., 2018). Models like the Health Belief Model (HBM) (Rosenstock, 1974), RANAS (Mosler, 2012), and the Theory of Planned Behaviour (TPB) (Ajzen, 1991), assume that if people understand the health risks of open defecation or the consequences of improper hand washing, they can be motivated to adopt safer alternatives. However, our study reveals that even though risk perception might be a significant component of the intervention design; financial feasibility, institutional trust, and administrative complexity become equally (if not more) significant (Alam et al., 2025). This might be due to the fact that when household sewer connections or misconnections are considered, risk perception becomes secondary when the waste is ‘out of sight’, especially once it leaves the immediate environment of the household properly or improperly. Instead, other practical concerns, such as bad smells, environmental cleanliness, and clogged drains, were more prominent motivators. So, the findings from this study challenge key assumptions of conventional models like the Health Belief Model or RANAS, which emphasise individual risk perception and motivation (Mosler, 2012). Therefore, public health framing alone is insufficient to prompt

behaviour change for sewer connections, especially when people do not perceive direct, personal health risks.

Moreover, the behavioural decision to connect to a sewer is fundamentally different from other sanitation behaviours. Unlike most sanitation behaviour research, which focuses on habitual or daily hygiene practices such as handwashing, sewer connection is a one-time, planned, and large-scale investment-oriented behaviour. This one-off behaviour differs from habitual decisions, for example, it involves high upfront costs, formal applications, and coordination with utility agencies (like DWASA). This is why these behaviours or decisions are more influenced by institutional, structural and economic factors (Satterthwaite et al., 2015) than personal habits or health behaviours - factors that conventional behavioural models do not adequately capture. Even if individuals are motivated, a lack of nearby sewer, poor maintenance of the sewer, complex and unclear application procedures, or high cost can prevent action. These barriers are external and systemic, not behavioural in the individual sense, and can not be addressed solely by following traditional approaches like messaging or awareness campaigns (e.g., CLTS or hygiene promotion campaigns) (Myers, 2016).

Additionally, in low-income urban areas, tenants and landlords have different roles in sanitation decisions. Sewer connection often requires landowner consent and financial investment, which tenants may not control (Tidwell et al., 2019). As risk perception is generally shaped by control and agency, the tenants have limited control over the decision of sewer connection, leading to a diminished perceived personal relevance of risk. On the other hand, landowners may not perceive the same health risks as urgent or personally threatening, especially if they do not reside on the premises. As a result, their risk perception may be low despite being the key decision-makers. That is why behaviour change strategies cannot assume a uniform perception of risk across all residents of a community, since tenants' health-related concerns may not translate into action if landlords do not share or prioritise those risks. This dynamic complicates the application of traditional individual-focused models, which assume that the actor has agency over the behaviour in question (Franco et al., 2021).

In this research, while the RANAS framework proved valuable in identifying psychosocial and behavioural determinants influencing landlords' decisions to connect to the sewer, its individual-level focus inevitably obscures the deeper structural, political economy, and governance constraints that emerged strongly throughout this study. The findings repeatedly showed that landlords'

behaviour cannot be understood, or shifted without recognising the systemic limitations within which they operate: fragmented institutional mandates between DWASA and city corporations, the exclusion of informal settlements from formal planning, inconsistent enforcement of building codes, weak incentives for service providers, and a financing model that places the costs of connection almost entirely on low-power actors. These constraints fundamentally shape the "choice architecture" within which RANAS assumes behaviour takes place. As a result, relying solely on RANAS-informed interventions risks overstating the capacity of information, social norms, or motivational strategies to drive uptake when the enabling environment remains misaligned. In the broader context of DWASA's ambition to scale sewer connections, this analysis highlights that meaningful progress depends not only on influencing individual behaviour but also on addressing institutional bottlenecks, strengthening coordination, and creating incentives for agencies responsible for sewer expansion. The recommendations made in this thesis therefore require realistic consideration of what implementing actors like DWASA, DSCC/DNCC, and development partners can feasibly deliver within current governance structures. Behaviour-change strategies can only be effective if accompanied by systemic reforms that reduce connection costs, clarify responsibilities, and support long-term service functionality. Without this dual approach, efforts to expand sewer connectivity in Dhaka will remain limited in scope and sustainability.

This raises important questions for future research: how should behavioural frameworks account for infrastructure-based sanitation behaviours that are investment-driven and not habit-formed? That is why the conceptual framework of sewer connection intervention that follows a purely behavioural approach is not sufficient for improving the household sewer connection rate; what it needs is a framework that considers the complex interplay of infrastructural availability, financial investment, institutional trust, and social relations by integrating a behavioural informed system approach (Figure 14). For example, the Sanitation Cityscape Framework (Scott and Cotton, 2020) and Faecal Waste Flow Diagrams (Shit Flow Diagrams) (Peal et al., 2014), reflect the ongoing efforts to map the infrastructural and governance systems that enable or constrain household sanitation choices. Similarly, the Citywide Inclusive Sanitation (CWIS) approach advocated by the World Bank and others emphasises the need to account for urban political economy, infrastructure inequities, and institutional arrangements in sanitation planning, especially for marginalised communities. In addition, the Integrated Behavioural Model for WASH (Dreibelbis et al., 2013) have informed elements of this design but often treats behavioural, institutional, and infrastructure factors in isolation. Our framework uniquely positions household decision-making within a multi-layered system that accounts for not only psychological determinants (e.g., perceived risk, trust in utilities,

financial capacity) but also infrastructure availability, community engagement, and policy and regulatory mandates. Drawing examples from these broader approaches, we propose the following integrated framework - one that recognises the structural embeddedness of sanitation behaviours in urban settings. This explains that future research and programming should move beyond individual behaviour change models and incorporate political economy, institutional trust, and distributed agency into their design and evaluation of sanitation interventions involving the sewer.

**Behavioural informed system approach**

The developed conceptual framework presented here illustrates a Behaviourally Informed Systems Approach to understanding and improving household sewer connection uptake in low-income urban settings, specifically drawing on empirical evidence from the study in Dhaka, Bangladesh. At the heart of the framework lies the decision to connect to the sewer system - a complex, one-off, investment-type behaviour that is shaped by different levels of factors like Household Decision Factors, Organisational and Service Factors, and Governance and Power Structures.

**Household Decision Factors:**

Household-level decision factors operate at the micro level but are deeply conditioned by structural realities.

***Tenure dynamics****:* In Dhaka, landlords hold authority over sewer investment decisions. The complex relationship between landlords (who are decision-makers) and tenants (who often bear the health burden but lack agency) can affect the dynamics. This asymmetry distorts traditional assumptions about individual risk perception and power dynamics that influence sewer connection decisions. Whether the household owns or rents the home significantly affects their authority to invest in sewer connections. This unequal risk-exposure and power dynamics challenge traditional behavioural models that assume individuals act in their own health interest.

***Trust in Utilities:*** Households' perceptions of service providers' (e.g. DWASA) reliability and responsiveness play a key role. A lack of trust in service quality can disincentivise connection even when infrastructure is available. Households' willingness to connect is strongly shaped by their confidence in DWASA's ability to provide reliable sewer services. Poor perceptions of responsiveness, unclear responsibilities during blockages, and past experiences of service failure reduce the motivation of landlords and tenants. This distrust pushes households towards other solutions, even when sewer networks exist.

***Financial Capacity:*** The high cost of sewer connections plays a key role in household sewer connections, especially in low-income urban areas. Sewer connection is a significant one-off expenditure involving piping, construction, and utility fees. For many landlords in low-income areas, this cost is more than one month's income. Willingness to connect is therefore constrained by structural affordability rather than individual attitudes.

***Perceived Benefits:*** Households are more motivated by practical benefits (less odour, cleaner environment) than by broader public health implications. Households value immediate and practical improvements like less smell, a cleaner compound, and reduced flooding, more than public-health benefits. However, perceived benefits also depend on expectations of service quality, if households believe blockages or overflow are likely, perceived benefits diminish, regardless of awareness campaigns.

**Organisational and Service Factors:**

These factors capture the role of service providers, operational structures, and supply-side constraints that shape what is feasible for households.

***Infrastructure availability and accessibility****:* The physical availability of a nearby sewer is necessary for a household sewer connection. Connection decisions are impossible without a nearby functional sewer. In informal and low-income areas, network expansion lags behind demand, meaning behavioural interventions alone cannot produce change.

***Maintenance and Support:*** Frequent sewer line blockages and poor maintenance erode public confidence and discourage uptake, even when a sewer is nearby. Frequent sewer line blockages, unclear maintenance responsibilities, and slow response times also reduce public trust. Poor maintenance directly undermines perceived benefits and makes the connection appear risky or futile.

***Administrative process****:* Cumbersome, vague application processes, bureaucratic delays, and a lack of support or clear guidance from utility agencies have a more significant effect on the uptake. Application procedures, unclear documentation requirements, and lack of guidance impose cognitive and procedural burdens. Behaviour-change messaging has limited impact when households face opaque or inconsistent administrative processes.

***Community engagement and awareness:*** Most community mobilisation largely focuses on on-site sanitation or hygiene, not sewer connectivity. It can be beneficial to include trusted local leaders, provide public recognition, and give households access to reliable information. Community mobilisation efforts in Dhaka focus more on hygiene and on-site sanitation (e.g., pit emptying) than on sewer connectivity. As a result, households lack trusted messengers and accurate information about connection processes, costs, or benefits. Inclusion of local leaders, peer examples, and targeted community outreach could help correct this information gap.

**Governance and Power Structures**

This level shapes the enabling environment and determines the boundaries within which both households and service providers operate.

***Political Influence:*** Political priorities, incentives, and historical inequalities affect infrastructure roll-out and service allocation. Political influence can also directly impact Infrastructure availability and accessibility. Low-income and informal settlements often fall outside formal planning priorities. Political influence therefore directly determines (indicated by an arrow in the figure 14) where sewer are constructed and which neighbourhoods are deprioritised.

***Policy, regulation and mandate***: The strength of institutional coordination, regulatory enforcement, and accountability structures is crucial. Fragmented mandates between DWASA and city corporations create institutional ambiguity over responsibilities for network expansion, maintenance, and connection facilitation. Weak regulatory enforcement and limited accountability allow gaps in service provision to persist. These structural deficiencies restrict the effectiveness of behavioural interventions by limiting the availability and reliability of the service itself.

***Financial Mechanisms:*** The absence of subsidies, instalment options, or targeted financial support for low-income households further limits adoption. Financial Mechanisms can also directly impact household sewer connection decisions. Without pro-poor financing instruments at the governance level, the financial burden remains shifted onto households, making connection decisions highly constrained regardless of behavioural motivation. Thus, financial mechanisms can directly influence sewer connection decisions (indicated by an arrow in figure 14).

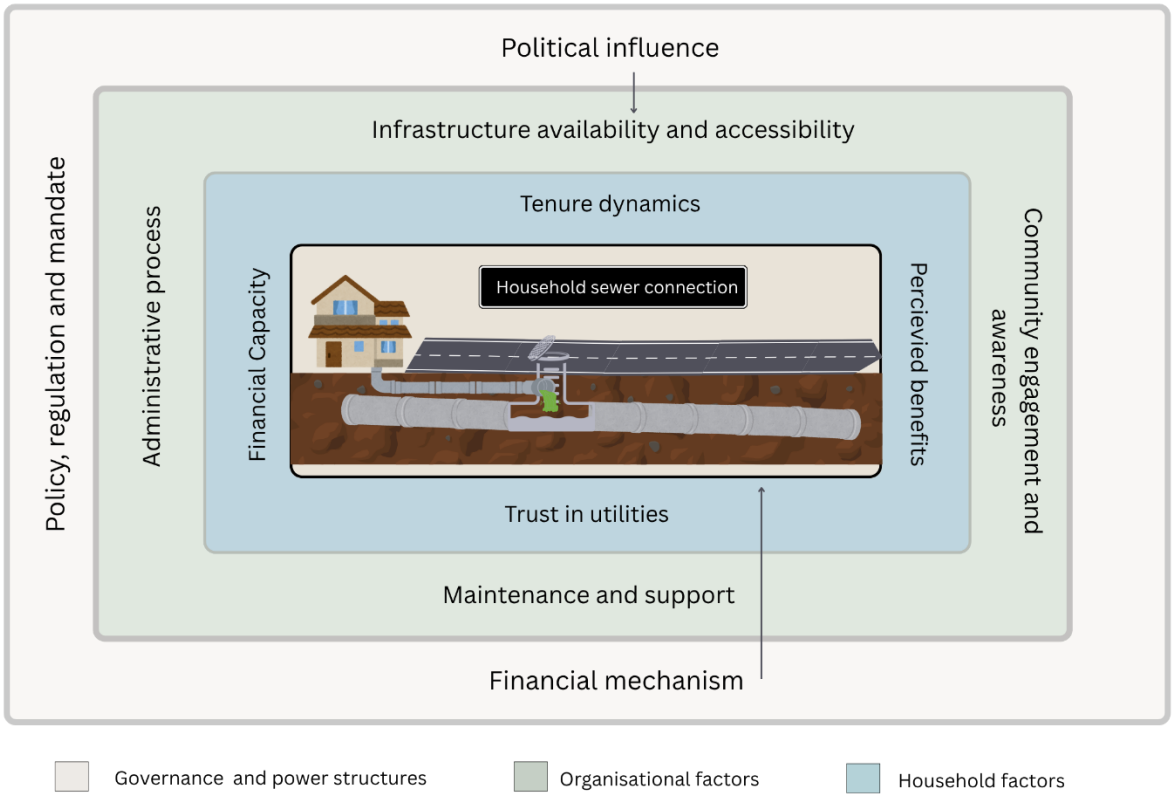


*Figure 14: Behavioural informed system approach*

Across all three levels, the proposed approach highlights that sewer connection uptake is not merely a behavioural choice, but a structurally bounded behaviour. In Dhaka's low-income settlements, where unplanned urban growth, fragmented service responsibilities, and unequal access to basic infrastructure shape everyday life, households' decisions are deeply constrained by broader systemic conditions. Household motivations and perceptions matter, but they operate within a system characterised by infrastructural gaps, institutional fragmentation, and political influence. Thus, any intervention aiming to increase household sewer connections must address not only behavioural determinants but also supply-side, organisational, and governance barriers that shape the decision environment.

**Behavioural Informed System Approach (BISA) and existing theoretical and conceptual models in sanitation**

The Behavioural Informed System Approach (BISA) offers a conceptual advancement over traditional sanitation behaviour models by integrating behavioural insights with infrastructure, governance, and institutional factors. Unlike established frameworks such as the Health Belief Model, Theory of

Planned Behaviour, or RANAS, which emphasize individual health risk perception and motivation, BISA highlights the limitations of these models in addressing one-off, investment-heavy decisions like household sewer connections. It accounts for systemic constraints such as financial feasibility, institutional trust, land tenure dynamics, and administrative complexity, factors often overlooked in daily or habitual behaviour models.

Compared to multi-level frameworks like IBM-WASH or CWIS, BISA uniquely embeds household decision-making within a layered systems perspective that incorporates political economy, service infrastructure, and community agency. It also expands on tools like Shit Flow Diagrams and programmatic approaches like CLTS by offering a more integrated explanation of why infrastructure adoption fails, even when technically available. BISA, therefore, provides a robust foundation for designing and evaluating sanitation interventions in low-income urban contexts where behaviour change is deeply interlinked with structural inequities and institutional barriers.

The table below compares the Behavioural Informed System Approach (BISA) developed in this study with established theoretical and conceptual frameworks commonly applied in sanitation and behaviour change research. It highlights differences in focus, limitations of existing models in relation to infrastructure-based behaviours, and BISA's novel contributions.

*Table 13 Behavioural Informed System Approach (BISA) vs. existing models and frameworks*

| **Framework/Model** | **Key aspects** | **Limitations compared to BISA** | **BISA's novel contribution** |
|---|---|---|---|
| Health Belief Model (HBM) (Rosenstock, 1974) | Risk perception and health motivation | Assumes health risk perception drives behaviour; ignores infrastructure, trust, and systemic barriers. | Reframes risk as insufficient driver; emphasizes infrastructure, financial capacity, and institutional trust. |
| Theory of Planned Behaviour (Ajzen, 1991) | Intention shaped by attitude, norms, and control | Does not address external constraints like tenure, utility reliability, or administrative complexity. | Incorporates distributed agency, especially where tenants lack control over sanitation decisions. |
| RANAS (Mosler, 2012) | WASH behavior via psychological drivers | Strong in behaviour domains but overlooks structural, economic, and institutional constraints in one-off decisions. | Adapts to infrastructure-linked, high-cost decisions such as sewer connection. |
| IBM-WASH (Dreibelbis et al., 2013) | Multi-level WASH behaviour model | Considers multiple domains but treats them in isolation rather than as embedded systems. | Links behavioural drivers to governance, infrastructure, and urban political systems. |

| Framework/Model | Key aspects | Limitations compared to BISA | BISA's novel contribution |
|---|---|---|---|
| CLTS (Kar and Bongartz, 2006) | Collective rural sanitation behaviour change | Not suited for urban infrastructure planning or landlord-tenant decision asymmetries. | Promotes localized, trust-based strategies rather than shame-based community triggers. |
| Sanitation Cityscape Framework (Scott and Cotton, 2020) | Urban sanitation systems and institutions | Strong on infrastructure and governance, lacks behavioural integration. | Integrates behavioural science into systemic urban sanitation frameworks. |
| Shit Flow Diagram (SFD) (Peal et al., 2014) | Excreta flow and system diagnostics | Diagnostic; does not address behaviour or decision-making pathways. | Maps decision-making alongside system diagnostics. |
| Citywide Inclusive Sanitation (CWIS) (CWIS, 2021) | Policy-level inclusive sanitation planning | High-level policy view without behavioural insights. | Bridges policy and micro-level behaviour in system design and uptake. |
| Household-Centred Environmental Sanitation (HCES) (Eawag, 2005) | Participatory sanitation planning, technology selection, and system design from the household to the neighbourhood and city levels; emphasis on ecological sanitation and community involvement. | Limited attention to behavioural determinants of sewer connection (perceived benefits, trust, financial barriers, tenure); does not analyse power asymmetries such as landlord-tenant dynamics. | Understanding household decisions on sewer connection by analysing behavioural determinants, organisational/service-level factors, and governance/power structures together. |

## Methodological implications

This study reflects an important methodological viewpoint on the field of sanitation behaviour research by highlighting the challenges of studying non-routine, investment-type behaviours, such as connecting to a sewer and signals a shift in how such different behaviours should be studied, especially in urban contexts. In low-income urban areas like Dhaka, individual intent to connect to a sewer line is often constrained by factors beyond the household's control, which opens the idea of adopting more systems-oriented lens, accounting not only for individual-level variables (e.g. attitudes, knowledge, intentions), but also for the infrastructural, institutional, and relational contexts in which decisions are made. To investigate such decisions effectively, future studies should focus more on broader system-focused approaches like willingness-to-pay experiments, trust audits,

or procedural knowledge assessments. In summary, methodologically, the study findings point to the importance of multi-actor, multi-layered analysis - including tenants, landlords and utility officials, to understand decision-making in shared urban spaces where control is diffused and infrastructural dependency is high.

## Policy and Practical Implications

This research highlights sewer connectivity as a public health and environmental priority, reinforcing the need for sustained policy commitment in Dhaka and similar urban contexts. The findings offer valuable insights for policymakers, urban planners, and sanitation service providers in Dhaka and other LMICs. Building on our extensive research, we propose implementing holistic intervention strategies combining multiple behavioural change interventions, rather than focusing on a single one. The study has revealed that, combining financial incentives, behavioural nudges, and institutional improvements should be prioritised to improve the sanitation uptake. The behavioural change approaches should further focus on educational campaigns to address knowledge gaps and promote the health and economic benefits of sewer connections, alongside role model-based interventions that leverage community leaders to normalise sewer adoption. Additionally, financial and administrative reforms such as income-adjusted fees, flexible payment plans, connection subsidies and streamlined bureaucratic processes can significantly lower barriers to connection. Strengthening institutional commitment through regular maintenance and infrastructure upgrades is also critical to sustaining public trust and preventing disconnections, ensuring long-term success in urban sanitation initiatives.

## Limitations and Future Research Directions

While this study provides important insights, several limitations should be acknowledged. The cross-sectional design of the study captured the data at a single time point, making it more challenging to establish causal links between intervention and subsequent behaviour change. Additionally, due to the nature of self-reported data collection, respondents may have provided socially desirable answers. Most critically, this study highlights a conceptual limitation in applying the RANAS model to investment-oriented, one-off behaviours like household sewer connection. While RANAS is highly effective for daily or habitual sanitation behaviours, it fails to consider external structural and institutional factors. This misalignment suggests the need for modified or extended theoretical frameworks that integrate systemic, infrastructural, and political-economic dimensions alongside traditional behavioural determinants. Additionally, the study's geographic scope is limited to urban

Dhaka, meaning the findings may not be directly transferable to rural or peri-urban settings, highlighting the need for broader comparative research.

### Future research should explore:

To the best of our knowledge, this is the only study that combines both secondary and primary data to develop an evidence-based, target-specific behaviour change intervention to improve the rate of sewer connection. This research also proposed a new theoretical framework to understand sewer connection by integrating behavioural research into system-based approaches, which can be widely used in urban sanitation research. Building on this research, future studies should explore how policymakers could leverage community networks beyond role models, for example, financial incentives for peer referrals may improve the uptake rate. Further research is needed to assess the feasibility of income-adjusted fees and flexible payment plans within Dhaka's socio-political landscape. Additionally, broader research is needed to explore how emerging technologies, such as digital payment platforms and AI-driven service monitoring, can be integrated to enhance the efficiency and accessibility of sewer connection processes.

## Conclusion

This study provides a comprehensive analysis of the barriers and facilitators of household sewer connections in urban Dhaka. The findings emphasise that financial constraints, psychological factors, and administrative inefficiencies collectively shape sanitation behaviour.

The proposed multifaceted intervention package - combining subsidies, social influence strategies, educational campaigns, and institutional reforms - offers a scalable model for increasing sewer adoption in LMICs. Beyond immediate policy applications, the research contributes to broader public health and environmental sustainability goals by promoting equitable access to sanitation services. Achieving widespread sewer connectivity requires long-term commitment from policymakers, service providers, and communities. By investing in behavioural change strategies, improving financial accessibility, and strengthening governance, urban centres can enhance sanitation infrastructure, ultimately improving public health, environmental quality, and residents' overall quality of life.

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# Appendix A: Supplementary materials

**Supplementary materials for Chapter 4**

Table 1: Literature search strategy and data sources for the scoping review

| | | |
|---|---|---|
| Title | Behaviour change interventions to promote household connectivity to Sewer Networks: A scoping review | |
| Research question | How effective are the behavioural interventions in promoting household connection to available sewer networks? | |
| Search Strategy | Inclusion Criteria | Studies related to sewer |
| | | Studies related to off-site sanitation |
| | | Studies related to septic tanks connected to sewer |
| | | Studies related to behaviour change interventions for off-site sanitation |
| | | Studies related to behaviour change interventions to promote household sewerage connectivity |
| | | Full-text article from a peer-reviewed journal and other grey materials |
| | | Language: Published or unpublished English literature, reports, and commentary |
| | | Off-site sanitation-related reports from different organisations or institutions' websites |
| | Exclusion Criteria | Articles not related to sewer |
| | | Articles related to on-site sanitation system |
| | | Articles not related to behavioural interventions to promote household sewerage connectivity |
| | | Full-text articles not available |
| | | Studies published in languages other than English |
| | | All types of review article |
| | Time Frame | 1 January 1980 to 31 December 2022 |
| Data Sources | Peer-reviewed articles | PubMed, ProQuest, Cochrane, Scopus |
| | Grey literature | Google, Google Scholar, organisations or institutions' websites (e.g. World Bank, WaterAid) |

Table 2: Detail search strategy

| Databases | | Search | Initial search results |
|---|---|---|---|
| **PubMed** | Sewerage related terms (a) | (“Sewerage system” OR Sewage OR “sewer network” OR Uptake OR “Sewerage Uptake” OR “sewer uptake” OR “Wastewater system” OR “Sewer line” OR “Sewage disposal system” OR Sewerage OR "Public Sewer" OR “Urban Sewerage”) AND (“end-user connection” OR Connect* OR Link* OR attach* OR Bridge* OR adhere* OR Approach OR Unconnect*) | 73,320 (1980-2022) |
| | Household related terms (Population) (b) | Domestic OR house OR dwelling OR household OR home OR “Property owner” OR “Home owner” OR “Local people” OR Communit* OR Slum OR Resident* OR “land owner” OR Landlord OR “intra-household” | 1,805,381 (1980-2022) |
| | Effectiveness related terms (c) | Effective* OR benefit OR potential OR efficacy OR advantage OR useful* | 7,812,576 (1980-2022) |
| | Behavioural Intervention related terms (intervention) (d) | "Behavioural Intervention" OR Behavio* OR "behaviour change intervention" OR "behaviour change" OR intervention OR "intervention model" OR "intervention package" OR "economic incentive" OR incentive OR subsid* OR credit OR" willingness to pay" OR payment OR information OR education OR knowledge OR campaign* OR training OR factor* OR alternative OR "cost effective approach" | 16,388,867 (1980-2022) |
| | Promotion related terms (e) | Promote OR improve OR boost OR increase OR encourage OR advance OR assist OR aid | 10,332,167 (1980-2022) |

| | | | |
|---|---|---|---|
| | After combining a AND b AND c AND d AND e | | |
| | | (((((("Sewerage system" OR Sewage OR "sewer network" OR Uptake OR "Sewerage Uptake" OR "sewer uptake" OR "Wastewater system" OR "Sewer line" OR "Sewage disposal system" OR Sewerage OR "Public Sewer" OR "Urban Sewerage") AND ("end-user connection" OR Connect* OR Link* OR attach* OR Bridge* OR adhere* OR Approach OR Unconnect*)) AND (Domestic OR house OR dwelling OR household OR home OR "Property owner" OR "Home owner" OR "Local people" OR Communit* OR Slum OR Resident* OR "land owner" OR Landlord OR "intra-household")) AND (Effective* OR benefit OR potential OR efficacy OR advantage OR useful*)) AND ("Behavioural Intervention" OR Behavio* OR "behaviour change intervention" OR "behaviour change" OR intervention OR "intervention model" OR "intervention package" OR "economic incentive" OR incentive OR subsid* OR credit OR" willingness to pay" OR payment OR information OR education OR knowledge OR campaign* OR training OR factor* OR alternative OR "cost effective approach")) AND (Promote OR improve OR boost OR increase OR encourage OR advance OR assist OR aid) | 2136 |
| | Limits | Full text, Humans, English, Peer-reviewed articles | |

| | | | |
|---|---|---|---|
| | | | |
| **Environmental science collection (ProQuest)** | | (sewerage OR sewer OR “sewer network” OR “Sewerage Uptake” OR “Urban Sewerage”) AND (slum OR household OR community OR house OR "low income communities") AND (connect OR attach OR approach) AND (Effective* OR benefit OR advantage OR useful*) AND (“Behavioural Intervention” OR Behavio* OR “behaviour change intervention” OR “behaviour change” OR intervention OR incentives ) AND (Promote OR improve OR increase OR encourage OR advance OR assist OR aid) | 5404 |
| | Limits | Full text, Humans, English, Peer-reviewed articles | |
| | | | |
| **Cochrane** | | Sewerage AND Urban | 3 |
| | Limits | Full text, Humans, English | |
| | | | |
| **Scopus** | Sewerage related terms (a) | (“Sewerage system” OR Sewage OR “sewer network” OR Uptake OR “Sewerage Uptake” OR “sewer uptake” OR “Wastewater system” OR “Sewer line” OR “Sewage disposal system” OR Sewerage OR "Public Sewer" OR “Urban Sewerage”) AND (“end-user connection” OR Connect*) | 122,269 (1980-2022) |
| | Household related terms (Population) (b) | Domestic OR house OR dwelling OR household OR home OR “Property owner” OR “Home owner” OR “Local people” OR Communit* OR Slum OR | 3,774,152 (1980-2022) |

| | | | |
|---|---|---|---|
| | | Resident* OR “land owner” OR Landlord OR “intra-household” | |
| | Effectiveness related terms (c) | Effective* OR benefit OR potential OR efficacy OR advantage OR useful* | 17,763,943 (1980-2022) |
| | Behavioural Intervention related terms (intervention) (d) | "Behavioural Intervention" OR Behavio* OR "behaviour change intervention" OR "behaviour change" OR intervention OR "intervention model" OR "intervention package" OR "economic incentive" OR incentive OR subsid* OR credit OR" willingness to pay" | 7,476,437 (1980-2022) |
| | Promotion related terms (e) | Promote OR improve OR boost OR increase OR encourage OR advance OR assist OR aid | 11,942,340 (1980-2022) |
| | After combining a AND b AND c AND d AND e | | |
| | | (((((“Sewerage system" OR Sewage OR "sewer network" OR Uptake OR "Sewerage Uptake" OR "sewer uptake" OR "Wastewater system" OR "Sewer line" OR "Sewage disposal system" OR Sewerage OR "Public Sewer" OR "Urban Sewerage") AND ("end-user connection" OR Connect* OR Link* OR attach* OR Bridge* OR adhere* OR Approach OR Unconnect*)) AND (Domestic OR house OR dwelling OR household OR home OR "Property owner" OR "Home owner" OR "Local people" OR Communit* OR Slum OR Resident* OR "land owner" OR Landlord OR "intra-household")) AND (Effective* OR benefit OR potential OR efficacy OR advantage OR useful*)) AND ("Behavioural Intervention" OR Behavio* | 2,174 (1980-2022) |

| | | | |
|---|---|---|---|
| | | OR "behaviour change intervention" OR "behaviour change" OR intervention OR "intervention model" OR "intervention package" OR "economic incentive" OR incentive OR subsid* OR credit OR" willingness to pay" OR payment OR information OR education OR knowledge OR campaign* OR training OR factor* OR alternative OR "cost effective approach")) AND (Promote OR improve OR boost OR increase OR encourage OR advance OR assist OR aid) | |

Table 3: Articles assessed for inclusion and exclusion

| | Title | Author | Year | Objective | Reason behind inclusion | Reason behind exclusion |
|---|---|---|---|---|---|---|
| | **Excluded articles** | | | | | |
| 1 | Risk Factors Associated with Health Care Utilization in Preschool Recurrent Wheezers in a Tropical Environment. | Muñoz C et al. | 2021 | To evaluate the factors associated with health care utilisation in preschool recurrent wheezers in Cartagena, Colombia. | | No mention of sewage connection or incentive or behaviour change intervention |
| 2 | Microbiological and Toxicological Hazards in Sewage Treatment Plant Bioaerosol and Dust | Szulc Justyna et al. | 2021 | To comprehensively evaluate microbiological and toxicological hazards in the air and settled dust in workstations in a sewage treatment plant. | | No mention of a household sewage connection |
| 3 | Water Quality Assessment and Potential Source Contribution Using Multivariate Statistical Techniques in Jinwi River Watershed, South Korea | Choi Hyeonmi et al. | 2021 | To assess the water quality and source contribution using variable statistical techniques in the Jinwi River watershed from 2013 to 2019 | | No mention of a household sewage connection |
| 4 | Compact Sewage Treatment Systems For Rural Sanitation | JT de Sousa et al. | 2020 | To determine the efficiencies of a single family compact (SFC) and a multi-family compact (MFC) station in removing organic matter from domestic sewage, and to investigate the behaviour of aerobic intermittent sand filters (ISFs) regarding nitrification | | No mention of behaviour change intervention or incentives |
| 5 | Evaluation of an Environmental Education Program Using a Cross-Sectoral Approach to Promote the Sustainable Use of Domestic Drains | JJ Martín-Jaime | 2021 | To raise awareness among students of the second and third cycle of primary education about the socio-environmental impacts caused by the dumping of hygienic and sanitary waste in domestic drains on aquatic ecosystems. | | No mention of a household sewage connection |

| | Title | Author | Year | Objective | Reason behind inclusion | Reason behind exclusion |
|---|---|---|---|---|---|---|
| 6 | Wastewater Reflections in Consumer Mind: Evidence from Sewage Services Consumer Behaviour | Petrescu, Dacinia Crina | 2019 | To investigate households' perception and behaviour related to wastewater treatment services. | | Only sewage, no intervention mention |
| 7 | Sustaining Community-Scale Sanitation Services: Co-management by Local Government and Low-Income Communities in Indonesia | Willetts, Juliet | 2020 | To define appropriate roles suitable for local government and communities to jointly manage community-scale systems in the long-term | | No mention of a household sewage connection |
| 8 | Using a theory-driven creative process to design a peri-urban on-site sanitation quality improvement intervention | Tidwell, James B | 2019 | To Assess the state of knowledge about peri-urban sanitation intervention strategies | | No mention of a household sewage connection |
| 9 | A controlled, before-and-after trial of an urban sanitation intervention to reduce enteric infections in children: research protocol for the Maputo Sanitation (MapSan) study, Mozambique | Brown, Joe | 2015 | To examine the relationship between population density, sanitation and health in urban communities where a range of localised population density exists, and to understand whether density is a potential effect modifier for enteric infection risk in this setting. | | No mention of a household sewage connection |
| 10 | Wastewater Project Development Of Tehran | Gholikandi, G Badalians | 2010 | To improve the environmental conditions in greater Tehran with a present population of about 7million | | No mention of a household sewage connection |
| 11 | The Effect of India's Total Sanitation Campaign on Defecation Behaviours and Child Health in Rural Madhya Pradesh: A Cluster Randomized Controlled | Patil et al. | 2014 | To measure the effect of India's Total Sanitation Campaign (TSC) in rural Madhya Pradesh on household availability of improved sanitation facilities as defined by WHO/UNICEF Joint Monitoring Programme (JMP) for water and sanitation, open defecation behaviours of household members, water quality, and child health (diarrheal diseases, highly credible | | No mention of Off-site sanitation |

| | Title | Author | Year | Objective | Reason behind inclusion | Reason behind exclusion |
|---|---|---|---|---|---|---|
| | | | | gastrointestinal illness [HCGI], enteric parasite infections, anaemia, and growth). | | |
| 12 | Cesspits as On-site Sanitation Facilities in the Non-Sewered Palestinian Rural Areas: Users' Satisfaction, Needs and Perception | Rehab A. Thaher | 2020 | To assess the problems of using cesspits in the non-sewered areas in the West Bank of Palestine, knowledge and acceptance of on-site GWTPs as an alternative house on-site wastewater management system in the rural areas, as well as availability and need for irrigation water at household level. | | No mention of Off-site sanitation |
| 13 | Urban Sewer Planning in Developing Countries and "The Neighborhood Deal": A Case Study of Semarang, Indonesia | D Whittington | 1997 | | | Does not meet the inclusion criteria as the intervention was not implemented to increase the uptake of household sewerage connections. |
| 14 | The improvement of the sanitation services in Moshi (Tanzania) | Julien Milanesi | 2006 | | | Does not contain description and outcome of any programme that increased household sewerage connection |
| 15 | "Improving On-site Sanitation and Connections to Sewers in Southeast Asia: Insights from Indonesia and Vietnam." | WSP | 2015 | | | Did not provide any details on the porgramme design and outcome for increasing the uptake of household sewerage connection |

| | Title | Author | Year | Objective | Reason behind inclusion | Reason behind exclusion |
|---|---|---|---|---|---|---|
| 16 | Lusaka Sanitation Project | The World Bank | 2015 | | | Did not provide any details on the porgramme design and outcome for increasing the uptake of household sewerage connection |
| | **Included articles** | | | | | |
| 17 | Connecting The Unconnected (TAMIL NADU, INDIA Connecting 1,551,995 households statewide) | Kennedy -Walker | 2020 | Efforts to provide urban sanitation services should develop from a range of technical solutions to help ensure that everyone can access safely managed sanitation encompassing both on-site sanitation and management of fecal sludge, sewerage systems, and wastewater | Mention of providing sewerage connection to the households and behaviour change interventions | |
| 18 | Connecting The Unconnected (ESPÍRITO SANTO, BRAZIL Connecting 20,000 properties to sewerage) | Kennedy -Walker | 2020 | Efforts to provide urban sanitation services should develop from a range of technical solutions to help ensure that everyone can access safely managed sanitation encompassing both on-site sanitation and management of fecal sludge, sewerage systems, and wastewater | Mention of providing sewerage connection to the households and behaviour change interventions | |
| 19 | Connecting The Unconnected (COLOMBIA More than 30,000 connections resulting in 75 percent connection to sewers) | Kennedy -Walker | 2020 | Efforts to provide urban sanitation services should develop from a range of technical solutions to help ensure that everyone can access safely managed sanitation encompassing both on-site sanitation and management of fecal sludge, sewerage systems, and wastewater | Mention of providing sewerage connection to the households and behaviour change interventions | |

| | Title | Author | Year | Objective | Reason behind inclusion | Reason behind exclusion |
|---|---|---|---|---|---|---|
| 20 | Connecting The Unconnected (GUAYAQUIL, ECUADOR Improving the city's connection rate from 45 percent to 85 percent) | Kennedy -Walker | 2020 | Efforts to provide urban sanitation services should develop from a range of technical solutions to help ensure that everyone can access safely managed sanitation encompassing both on-site sanitation and management of fecal sludge, sewerage systems, and wastewater | Mention of providing sewerage connection to the households and behaviour change interventions | |
| 21 | Connecting The Unconnected (SÃO PAULO, BRAZIL Connecting 192,000 properties to sewerage) | Kennedy -Walker | 2020 | Efforts to provide urban sanitation services should develop from a range of technical solutions to help ensure that everyone can access safely managed sanitation encompassing both on-site sanitation and management of fecal sludge, sewerage systems, and wastewater | Mention of providing sewerage connection to the households and behaviour change interventions | |
| 22 | Sustainability analysis of new household connections to the municipal sewage collection network in Paraná | Marlene Alves de Campos Sachet1 ; Patrícia Bilotta2* | 2020 | The aim of this study was to understand why many households do not respond promptly to the "Connect to the Network" program in the state of Parana and how much the further efforts cost the sanitation company to regularise this problem | Mention of sewage connection | |
| 23 | Implementation completion and results report https://documents.worldbank.org/en/publication/documents reports/documentdetail/538801548820464282/implementation-completion-and-results-report-icr-document-nairobi-sanitation-project-p131512 | Advani, R.K | 2019 | | Mention of providing sewerage connection to the households and behaviour change interventions | |

| | Title | Author | Year | Objective | Reason behind inclusion | Reason behind exclusion |
|---|---|---|---|---|---|---|
| 24 | The experience of condominial water and sewerage systems in Brazil. Case studies from Brasılia, Salvador and Parauapebas. Lima: Water and Sanitation Program Latin America | JC Melo | 2005 | | Mention of providing sewerage connection to the households and behaviour change interventions | |
| 25 | Output-Based Aid in Morocco (Part 1): Extending Water Services to the Poor in Urban Areas | XC Beauchêne | 2009 | | Mention of providing sewerage connection to the households and behaviour change interventions | |
| 26 | Sanitation in South Asia | SU-Rural | 2005 | | Mention of providing sewerage connection to the households and behaviour change interventions | |
| 27 | Condominial water and sewerage systems - costs of implementation of the model : an economic and financial evaluation of El Alto Pilot Project in Bolivia. | Foster, V., | 2001 | | Mention of providing sewerage connection to the households and behaviour change interventions | |

Table 4: Critical appraisal data

| | Were populations demographic characteristics clearly described? | Were the sewerage condition of those areas history clearly described and presented as a timeline? | Was the current condition of the household connection clearly described? | Were methods and the results clearly described? | Was the intervention(s) clearly described? | Was the post-intervention condition clearly described? | Were adverse events (harms) or limitations identified and described? | Does the case report provide takeaway lessons (Recommendations)? | Total score |
|---|---|---|---|---|---|---|---|---|---|
| Marlene Alves de Campos Sachet, (2020) [30] | 0 | 0 | 0 | 0 | 1 | 1 | .5 | 1 | 3.5 |
| Kennedy -Walker, 2020 [9] | 1 | .5 | 0 | 1 | 1 | 1 | .5 | 1 | 6 |
| Kennedy -Walker, 2020 [9] | 1 | 1 | 1 | 1 | 1 | 1 | .5 | 1 | 7.5 |
| Kennedy -Walker, 2020 [9] | 1 | 1 | .5 | 1 | 1 | 1 | .5 | 1 | 7 |
| Kennedy -Walker, 2020 [9] | .5 | 1 | .5 | 1 | 1 | 1 | 1 | 1 | 7 |
| Kennedy -Walker, 2020 [9] | .5 | 1 | .5 | 1 | 1 | 1 | .5 | 1 | 6.5 |
| Advani, R.K, 2019 [37] | 1 | 0 | .5 | 1 | 1 | 1 | .5 | 1 | 6 |
| JC Melo, 2005 [20] | 1 | 0 | .5 | 1 | 1 | 1 | .5 | 0 | 5 |
| Foster, V. (2001) [28] | 1 | 0 | .5 | 1 | 1 | 1 | .5 | 0 | 5 |
| Beauchêne, Xavier Chauvot de, 2009 [31] | 1 | 0 | 1 | 1 | 1 | 1 | .5 | 1 | 6.5 |
| Rural, S.U., 2005. Sanitation in South Asia [29] | 1 | 0 | 1 | 1 | 1 | 1 | .5 | 1 | 6.5 |

**Preferred Reporting Items for Systematic reviews and Meta-Analyses extension for Scoping Reviews (PRISMA-ScR) Checklist**

| SECTION | ITEM | PRISMA-ScR CHECKLIST ITEM | REPORTED ON PAGE # |
|---|---|---|---|
| **TITLE** | | | |
| Title | 1 | Identify the report as a scoping review. | 01 |
| **ABSTRACT** | | | |
| Structured summary | 2 | Provide a structured summary that includes (as applicable): background, objectives, eligibility criteria, sources of evidence, charting methods, results, and conclusions that relate to the review questions and objectives. | 01 |
| **INTRODUCTION** | | | |
| Rationale | 3 | Describe the rationale for the review in the context of what is already known. Explain why the review questions/objectives lend themselves to a scoping review approach. | 02-03 |
| Objectives | 4 | Provide an explicit statement of the questions and objectives being addressed with reference to their key elements (e.g., population or participants, concepts, and context) or other relevant key elements used to conceptualize the review questions and/or objectives. | 03 |
| **METHODS** | | | |
| Protocol and registration | 5 | Indicate whether a review protocol exists; state if and where it can be accessed (e.g., a Web address); and if available, provide registration information, including the registration number. | NA |
| Eligibility criteria | 6 | Specify characteristics of the sources of evidence used as eligibility criteria (e.g., years considered, language, and publication status), and provide a rationale. | 05 |
| Information sources* | 7 | Describe all information sources in the search (e.g., databases with dates of coverage and contact with authors to identify additional sources), as well as the date the most recent search was executed. | 05 |
| Search | 8 | Present the full electronic search strategy for at least 1 database, including any limits used, such that it could be repeated. | 28-30 |
| Selection of sources of evidence† | 9 | State the process for selecting sources of evidence (i.e., screening and eligibility) included in the scoping review. | 05-06 |
| Data charting process‡ | 10 | Describe the methods of charting data from the included sources of evidence (e.g., calibrated forms or forms that have been tested by the team before their use, and whether data charting was done independently or in duplicate) and any processes for obtaining and confirming data from investigators. | 05-06 |
| Data items | 11 | List and define all variables for which data were sought and any assumptions and simplifications made. | 04 |
| Critical appraisal of individual sources of evidence§ | 12 | If done, provide a rationale for conducting a critical appraisal of included sources of evidence; describe the methods used and how this information was used in any data synthesis (if appropriate). | 06 |
| Synthesis of results | 13 | Describe the methods of handling and summarizing the data that were charted. | 06-07 |
| **RESULTS** | | | |

| SECTION | ITEM | PRISMA-ScR CHECKLIST ITEM | REPORTED ON PAGE # |
|---|---|---|---|
| Selection of sources of evidence | 14 | Give numbers of sources of evidence screened, assessed for eligibility, and included in the review, with reasons for exclusions at each stage, ideally using a flow diagram. | 08 |
| Characteristics of sources of evidence | 15 | For each source of evidence, present characteristics for which data were charted and provide the citations. | 17-22 |
| Critical appraisal within sources of evidence | 16 | If done, present data on critical appraisal of included sources of evidence (see item 12). | 09, 36 |
| Results of individual sources of evidence | 17 | For each included source of evidence, present the relevant data that relate to the review questions and objectives. | 10-14 |
| Synthesis of results | 18 | Summarize and/or present the charting results as they relate to the review questions and objectives. | 15-16 |
| **DISCUSSION** | | | |
| Summary of evidence | 19 | Summarize the main results (including an overview of concepts, themes, and types of evidence available), link to the review questions and objectives, and consider the relevance to key groups. | 23-24 |
| Limitations | 20 | Discuss the limitations of the scoping review process. | 24 |
| Conclusions | 21 | Provide a general interpretation of the results with respect to the review questions and objectives, as well as potential implications and/or next steps. | 24 |
| **FUNDING** | | | |
| Funding | 22 | Describe sources of funding for the included sources of evidence, as well as sources of funding for the scoping review. Describe the role of the funders of the scoping review. | 26 |

JBI = Joanna Briggs Institute; PRISMA-ScR = Preferred Reporting Items for Systematic reviews and Meta-Analyses extension for Scoping Reviews.
* Where *sources of evidence* (see second footnote) are compiled from, such as bibliographic databases, social media platforms, and Web sites.
† A more inclusive/heterogeneous term used to account for the different types of evidence or data sources (e.g., quantitative and/or qualitative research, expert opinion, and policy documents) that may be eligible in a scoping review as opposed to only studies. This is not to be confused with *information sources* (see first footnote).
‡ The frameworks by Arksey and O'Malley (6) and Levac and colleagues (7) and the JBI guidance (4, 5) refer to the process of data extraction in a scoping review as data charting.
§ The process of systematically examining research evidence to assess its validity, results, and relevance before using it to inform a decision. This term is used for items 12 and 19 instead of "risk of bias" (which is more applicable to systematic reviews of interventions) to include and acknowledge the various sources of evidence that may be used in a scoping review (e.g., quantitative and/or qualitative research, expert opinion, and policy document).

*From:* Tricco AC, Lillie E, Zarin W, O'Brien KK, Colquhoun H, Levac D, et al. PRISMA Extension for Scoping Reviews (PRISMAScR): Checklist and Explanation. Ann Intern Med. 2018;169:467–473. doi: 10.7326/M18-0850.

**Supplementary table for Chapter 6**

*Table 1: Descriptive statistics of RANAS factors and scale reliability by measuring Cronbach's alpha*

| Factors | Variables | N | Range | Mean ± SD | α | Items |
|---|---|---|---|---|---|---|
| Risk factors | **Risk factors** | 384 | [0, 4] | 3.0 ± 0.77 | 0.837 | 3 |
| | Health Knowledge (how high/low the risk of causing disease if the household is not connected to a sewer) | 384 | [0, 4] | 3.63 ± 0.79 | 0.697 | |
| | Vulnerability (how high/low the possibility of getting you sick (e.g. diarrhoea) if the household is not connected to a sewer) | 384 | [0, 4] | 3.62 ± 0.81 | 0.720 | |
| | Severity (imagine that you have a disease (e.g. diarrhoea) from a toilet that is not connected to sewer, how severe would be the impact on your life) | 384 | [0, 4] | 3.42 ± 1.01 | 0.916 | |
| Attitude factors | **Perceived belief:** | 384 | [0, 4] | 3.5 ± 3.30 | 0.768 | 6 |
| | Effort (How difficult do you think it is to connect a household to a sewer) | 384 | [0, 4] | 1.56 ± 1.59 | 0.699 | |
| | Space (How difficult do you think it is to find space to build a pipeline to connect with a sewer) | 384 | [0, 4] | 0.93 ± 1.27 | 0.746 | |
| | Expensiveness (How expensive do you think it is to construct a connection to the sewer) | 384 | [0, 4] | 1.91 ± 1.43 | 0.675 | |
| | Money (How difficult is it to arrange the money to connect to a sewer) | 384 | [0, 4] | 1.89 ± 1.47 | 0.669 | |
| | Status (How certain are you that connecting to a sewer would increase your social status) | 384 | [0, 4] | 2.97 ± 1.23 | 0.792 | |
| | Health (How certain are you that connecting to a sewer will prevent you from disease) | 384 | [0, 4] | 3.29 ± 1.08 | 0.782 | |
| | **Perceived feelings:** | 384 | [0, 4] | 3.0 ± 1.05 | 0.826 | 3 |
| | Behaviour (How much do you like/dislike connecting the household with a sewer) | 384 | [0, 4] | 3.36 ± 1.17 | 0.794 | |
| | Proud (How proud would you feel if your household is connected to a sewer) | 384 | [0, 4] | 2.82 ± 1.13 | 0.674 | |
| | Respect (How much do you think you would be respected by your community if your household is connected to a sewer? | 384 | [0, 4] | 2.83 ± 0.93 | 0.798 | |
| Norm factors | Others' behaviour (proportion of people perceived the sewer connection helpful) | 384 | [0, 4] | 2.88 ± 1.31 | - | |
| | **Personal Importance** | 384 | [0, 4] | 3.0 ± 1.59 | 0.479 | 3 |
| | Personal Importance (Do you feel a personal obligation to connect to a sewer) | 384 | [0, 4] | 3.39 ±0.90 | 0.139 | |
| | Personal Importance (How important or unimportant is it for you to connect to a sewer) | 384 | [0, 4] | 3.43 ±0.88 | 0.111 | |
| | Personal Importance (Others opinions could influence to connect/not connect to the sewer) | 384 | [0, 4] | 1.46 ± 1.54 | 0.952 | |
| | How to do Knowledge (Do you know how to get your household connected to a sewer) | 384 | [0, 4] | 2.10 ± 1.49 | - | |

| Factors | Variables | N | Range | Mean ± SD | α | Items |
|---|---|---|---|---|---|---|
| Ability factors | **Overall confidence** | 384 | [0, 4] | 3.0±0.49 | 0.907 | 2 |
| | Confidence in Performance (How confident are you that you can connect to a sewer even if this is a difficult process) | 384 | [0, 4] | 3.15 ± 1.14 | - | |
| | Confidence in Continuation (How confident are you that you would continue sewer even if it costs a lot of money) | 384 | [0, 4] | 3.10 ± 1.22 | - | |
| | **Confidence in recovering** | 384 | [0, 4] | 2.0 ± 1.86 | 0.164 | 2 |
| | Confidence in recovering (How confident are you that you can maintain the sewer on your own if that is blocked/not working) | 384 | [0, 4] | 3.63 ±0.67 | | |
| | Confidence in recovering (How confident are you that a govt. dept. (DWASA) will maintain the sewer if that is blocked/not working) | 384 | [0, 4] | 1.71 ± 1.58 | | |
| Self-Regulation Factors | **Barrier planning** | 384 | [0, 4] | 2.0 ± 1.49 | 0.298 | 2 |
| | Barrier planning (Do you think any factors could influence connecting/not connecting to a sewer) | 384 | [0, 4] | 1.65 ±1.61 | - | |
| | Barrier planning (is there a way to overcome that particular barrier) | 384 | [0, 4] | 0.36±0.89 | - | |

The variable dropped from bi-variate analysis if variable's Cronbach alpha was less than 0.7.

# Appendix B: Ethics approval

icddr,b

**Ethical Review Committee**
**Approval letter**

21 October 2023

To
Mr Mahbub-Ul Alam
Principal Investigator of research protocol # PR-23088
Health Systems and Population Studies Divisions (HSPSD)

Sub: **Approval of research protocol # PR-23088**

| | |
|---|---|
| Approval Date: | 21 October 2023 |
| Expiration Date: | 20 October 2024 |
| Review Type: | Full Committee Review |
| Risk Level: | No more than minimal |
| Project type: | New Project |

Dear Mr Alam,

Thank you for your memo dated 08 October 2023 attaching the modified version of your research protocol PR-23088 titled, "Behavioural determinants of household wastewater management in urban Dhaka, Bangladesh;" version No. 1.02 date 13 August 2023; addressing the issues raised by the in its September ERC meeting held on 26 September 2023. I am pleased to inform you that your protocol is approved. You will be required to observe the following terms and conditions in implementing the research protocol:

1. The research protocol is approved for 12-month period from the date of approval of the protocol by the Ethical Review Committee. The Federal regulations require review of an approved study not less than once per 12-month period. To comply with federal regulations, a continuing review application must be submitted to the IRB Secretariat for this study to continue beyond 20 October 2024.

   All necessary materials for continuing review must be reviewed with sufficient time for review and issuing continued approval before the expiration date. Failure to initiate a continuing review application in a timely fashion may result in discontinuation of study activities until approval can be renewed. Performing study activities, including data analysis, beyond the expiration date results in noncompliance of federal regulations.

2. The ERC approval shall automatically be revoked after one year if the protocol is not started. After one year, you shall have to seek approval for revalidation of the protocol by the ERC before starting.

3. You should notify the IRB Secretariat of the start date of the protocol for updating in the integrated Navision system. The protocol start date will not be updated in the Navision system until receiving information from you. Therefore, you will not be able to operate budget code and continue spending funds under the research protocol.

4. As Principal Investigator, the ultimate responsibility for scientific and ethical conduct including the protection of the rights and welfare of study participants vest upon you.

Ethical Review Committee, IRB Secretariat, Research Administration, CMS
International Centre for Diarrhoeal Disease Research, Bangladesh
68, Shaheed Tajuddin Ahmed Sarani, Mohakhali, Dhaka 1212, Bangladesh
Mail: icddr,b, GPO Box 128, Dhaka 1000, Bangladesh
Phone: 880-2-9827084, Web: http://www.icddrb.org

You shall also be responsible for ensuring competence, integrity and ethical conduct of other investigators and staff directly involved in this research protocol.

5. You shall conduct the study in accordance with the ERC-approved protocol and shall fully comply with any subsequent determinations by the ERC.

6. You shall obtain prior approval from the Research Review Committee and the ERC for any modification in the approved research protocol and/or approved consent form(s), except in case of emergency to safeguard/ eliminate apparent immediate hazards to study participants. Such changes must immediately be reported to the ERC Chairman.

7. You shall recruit/enrol participants for this study strictly adhering to the criteria mentioned in the research protocol.

8. You shall obtain legally effective informed consent (i.e. consent should be free from coercion or undue influence) from the selected study participants or their legally responsible representative, as approved in the protocol, using the approved consent form prior to their enrolment in this study. Before obtaining consent, all prospective study participants must be adequately informed about the purpose(s) of the study, its methods and procedures, and also what would be done if they agree and also if they do not agree to participate in the study.

9. They must be informed that their participation in the study is voluntary and that they can withdraw their participation any time without any prejudice. Signed consent forms should be preserved for a period of at least five years following official termination of the study.

10. You shall promptly report the occurrence of any Serious Adverse Event or unanticipated problems of potential risk to study participants or others to the ERC in writing within 24 hours of such occurrences.

11. Any significant new findings, developing during the course of this study that might affect the risks and benefits and thus influence either participation in the study or continuation of participation should be reported in writing to the participants and the ERC.

12. You shall report progress of research to the ERC for continuing review of the implementation of the research protocol as stipulated in the ERC Guidelines. Relevant excerpt of ERC Guidelines and `*Annual/Completion* Report for Research Protocol involving Human Subjects' are attached for your information and guidance.

13. Data and/or samples should be collected and interviews should be conducted, as specified in the ERC-approved protocol, and confidentiality must be maintained. Data/samples must be protected by reasonable security, safeguarding against risks such as their loss or unauthorized access, destructions, used by others, and modification or disclosure of data. Data/samples should not be disclosed, made available to or use for purposes other than those specified in the protocol, and shall be preserved for a period, as specified under Centre's policies/practices.

14. You shall promptly and fully comply with the decision of the ERC to suspend or withdraw its approval for the research protocol.

15. The ERC should be immediately notified if the protocol is discontinued before the expected date of completion.

**Approved documents:**

a. Protocol version No. 1.02; version date 13 August 2023
b. Information sheet for KII with stakeholders; version No. 1.01; version date 24 August 2023
c. Consent form for KII with stakeholders; version No. 1.01; version date 24 August 2023
d. Information sheet for FGD with Male/Female; version No. 1.01; version date 24 August 2023
e. Consent form for FGD with Male/Female; version No. 1.01; version date 24 August 2023
f. Information sheet for Household Survey; version No. 1.01; version date 24 August 2023
g. Consent form for Household Survey; version No. 1.01; version date 24 August 2023

The IRB of icddr,b shall take into account the regulations of the Bangladesh Medical Research Council (BMRC), WHO, international guidelines for biomedical research as laid down by the Council of International Organization of Medical Sciences (CIOMS), the Declaration of Helsinki in relation to biomedical research involving human participants, ICH Guidelines on Good Clinical Practice (GCP), National Institutes of Health (NIH), National Institute of Allergy and Infectious Diseases (NIAID), and Division of Microbiology and Infectious Diseases (DMID). If there is any new declaration involving human participants, contents of such declaration should be appropriately adhered to and the applicable laws and policies of the local government.

I wish you success in running the above-mentioned study.

Professor Ahmed Abu Saleh
Chairperson
Ethical Review Committee (ERC)
Phone: +8801718378953
Email: aasaleh@gmail.com

Cc: Senior Director (Acting)
Senior Manager, Budget & Planning, Finance

icddr,b

**Research Review Committee**
**Approval letter**

24 August 2023

To
Mr Mahbub-Ul Alam
Principal Investigator of research protocol # PR-23088
Health Systems and Population Studies Division (HSPSD)

Subject: **Approval of research protocol # PR-23088**

Dear Mr Alam,

Thank you for your memo dated 18 July 2023 requesting for expedited review and approval of your research protocol # PR-23088 titled, "Behavioural determinants of household wastewater management in urban Dhaka, Bangladesh"; version No. 1.01; version date 13 August 2023 and subsequent memo dated 13 August 2023, addressing the issues raised by the reviewer to the satisfaction of the committee. I am pleased to inform you that your protocol is approved through expedited review mechanism to proceed subject to the approval of the Ethical Review Committee (ERC).

## Terms of approval

1. The research protocol is approved for 12-month period from the date of approval of the protocol by the Ethical Review Committee. Approval for further continuation of the research work, if needed, shall be obtained before expiration of the initial approval.

2. You should notify the IRB Secretariat of the start date of the protocol for updating in the integrated navision system. The protocol start date will not be updated in the navision system until receiving information from you. Therefore, you will not be able to operate budget code and continue spending funds under the research protocol.

3. The RRC approval shall automatically be revoked after one year if the protocol is not started. After one year, you shall have to seek approval for revalidation of the protocol by the RRC & ERC before starting the protocol.

4. This approval is only valid whilst you hold a position at icddr,b; and in the event of your departure from the Centre, a new Principal Investigator will be designated for the research protocol.

5. Any changes to the research protocol require the submission (in prescribed form) and approval of an amendment/addendum. Substantial variations may require a new protocol.

6. Continued approval of this protocol is dependent on your periodically updating the Centre's database for the protocol to show the progress; and a final report/completion report should be submitted at the conclusion of the protocol.

Research Review Committee, IRB Secretariat, Research Administration, CMS
International Centre for Diarrhoeal Disease Research, Bangladesh
68, Shaheed Tajuddin Ahmed Sarani, Mohakhali, Dhaka 1212, Bangladesh
Mail: icddr,b, GPO Box 128, Dhaka 1000, Bangladesh
Phone: 880-2-9827084, Web: http://www.icddrb.org

7. You shall submit a report for time extension of the protocol (in prescribed form) if you are unable to complete the protocol activities within the time mentioned in the protocol.

8. You are responsible for systematic storage and retention of the original data pertaining to the research protocol; and the ownership of data after certain period shall be determined as per Centre's rules and regulations.

9. The RRC should be notified if the protocol is discontinued before the expected date of completion.

I wish you all the success in conducting the research protocol.

Thank you.

Dr Md Shafiqul Alam Sarker
Chairperson
Research Review Committee of icddr,b
Phone: +8801713039813
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Cc: Senior Director (Acting), HSPSD
Senior Manager, Budget & Planning, Finance

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UNIVERSITY OF LEEDS

**Faculty of Engineering and Physical Sciences Faculty Research Ethics Committee (EPS)**

7th June 2023

Dear Mahbub

**MEEC 22-022 - Behavioural determinants of household wastewater management in urban Dhaka, Bangladesh**

***NB: All approvals/comments are subject to compliance with current University of Leeds and UK Government advice regarding the Covid-19 pandemic.***

I am pleased to inform you that the above research ethics application has been reviewed by Faculty of Engineering and Physical Sciences Faculty Research Ethics Committee and I can confirm a favourable ethical opinion based on the documentation received at date of this email.

The reviewers had some comments for your consideration which are below, these do not impact your approval. If you decide to update any documents in response to these comments please submit these to this email address for storage.

- ***Questionnaire Form – Add version control and some form of heading on the form would make this look more professional but not essential (suggestion)***

***Please retain this letter as evidence of approval in your study file.***

Please notify the committee if you intend to make any amendments to the original research as submitted and approved to date. This includes recruitment methodology; all changes must receive ethical approval prior to implementation. Please see http://ris.leeds.ac.uk/downloads/download/179/amendment_form or contact the Research Ethics & Governance Administrator for further information (epsresearchethics@leeds.ac.uk) if required.

Ethics approval does not infer you have the right of access to any member of staff or student or documents and the premises of the University of Leeds. Nor does it imply any right of access to the premises of any other organisation, including clinical areas. The committee takes no responsibility for you gaining access to staff, students and/or premises prior to, during or following your research activities.

***Please note:*** You are expected to keep a record of all your approved documentation, as well as documents such as sample consent forms, risk assessments and other documents relating to the study. This should be kept in your study file, which should be readily available for audit purposes. You will be given a two-week notice period if your project is to be audited.

If you require this confirmation in letter form, for example to show to external funders, then please do email me. I am happy to provide this if required.

It is our policy to remind everyone that it is your responsibility to comply with Health and Safety, Data Protection and any other legal and/or professional guidelines there may be.

I hope the study goes well.

Very best wishes,

Rachel Prinn
***On behalf of Virginia Pensabene CHAIR, EPS FREC***

# Appendix C: Data Collection Tools (Survey)

**Behavioural determinants of household wastewater management in urban Dhaka, Bangladesh**

**Household Survey**

**Section 1: Questionnaire identification**

| Q no. | Questions | Answer Options | Ans code | Skip note |
|---|---|---|---|---|
| 1. | Household ID | □□ | 2digit | |
| 2. | Data collectors name & code: | Select | | |
| 3. | Name of the area | Basabo | 10 | |
| | | Goran | 11 | |
| | | Hazaribagh | 12 | |
| | | Nawabgonj | 13 | |
| | | Mohammadpur Bus stand | 14 | |
| | | Sultanganj Shahi Mosque | 15 | |
| | | Nakhalpara | 16 | |
| | | Tanary More Sahi Mosque | 17 | |
| | | Shahidbag | 18 | |
| | | Modhubag, Moghbazar | 19 | |
| 4. | Ward number | | 2digit | |
| 5. | Road number | Text | | |
| 6. | Holding Number | Text | | |
| 7. | Household type | Tin shade | 1 | |
| | | One storied building | 2 | |
| | | 2-5 storied building | 3 | |
| | | 6+ storied building | 4 | |
| 8. | Date of data collection (DD/MM/YYYY): | □□/□□/□□□□ | | |
| 9. | Do you want to participate in this study? | No | 0 | End of survey |
| | | Yes | 1 | |

**Section 2: Respondent information**

| Q no. | Questions | Answer Options | Ans code | Skip note |
|---|---|---|---|---|
| 10. | Respondent selection/types | Household owner | 1 | |
| | | Manager/Caretaker | 2 | |
| 11. | Name of respondent | | | |
| 11 a. | Contact Number | □□□□□□□□□□□ | | |
| 12. | Age of respondent: (in completed years) | _____ (year) | | |
| 13. | Sex of respondent | Male | 1 | |
| | | Female | 2 | |

| | | | | |
|---|---|---|---|---|
| | | Transgender | 3 | |
| | | Nonbinary person | 4 | |
| 14. | Completed years of education of the respondent | Continious | | |
| 15. | Name of the landlord (if different than the respondent) | Text | | |
| 16. | Age of the landlord (if different than the respondent) | _____ (year) | | |
| 17. | The main occupation of the landlord | Govt. service | 1 | |
| | | Private service | 2 | |
| | | Small and medium scale Business | 3 | |
| | | Large scale Business (Export-import) | 4 | |
| | | Industrialist | 5 | |
| | | Retired | 6 | |
| | | Homemaker | 7 | |
| | | Others: Specify | 8 | |
| 18. | Name of Household head | Text | | |
| 19. | Education of the household head (in completed years) | Continious | | |
| 20. | What is the relation of the household head to the respondent? | Household head himself/herself | 1 | |
| | | Spouse of household head | 2 | |
| | | Son of household head | 3 | |
| | | Daughter of household head | 4 | |
| | | Mother of household head | 5 | |
| | | Father of the household head | 6 | |
| | | Brother of the household head | 7 | |
| | | Sister of household head | 8 | |
| | | Other male relative of the household head | 9 | |
| | | Other female relative of the household head | 10 | |
| 21. | How many people in total live in your household at present? (including all children) | □□□□ (4 digit) | | |
| 22. | Duration of settlement in this household? (in year) | □□□□ (4 digit) | | |
| 23. | What is the current monthly income of the household from all sources? | □□□□□□ | | |
| 24. | What is your average monthly expenditure? | □□□□□□ | | |
| 25. | What is the status of the house you are living in? | Self-owned | 1 | |
| | | Rental land | 2 | |
| | | Government land | 3 | |
| | | On lease | 4 | |
| | | Others: Specify | 77 | |

**Section 3: Current sanitation scenario**

| Q. no | Questions | Answers Options | Ans Code | Skip Note |
|---|---|---|---|---|
| 26. | Number of households on this building/plot/compound | Continious | | |
| 27. | How many people live in this building/plot/compound? | Continious | | |
| 28. | How many toilets (cubicle) do you have in this building/plot/compound? | Continious | | |
| 29. | Where does the fecal matter finally go from the toilet? | The DWASA sewer | 1 | (31-36) |
| | | DNCC/DSCC stormsewer | 2 | (31-36) |
| | | Septic tank/pit | 3 | |
| | | Drainage | 4 | (31-36) |
| | | Open water body nearby such as canals, lakes, rivers | 5 | (31-36) |
| | | Others: Specify | 77 | (31-36) |
| | | Don't know | 99 | (31-37) |
| 30. | Did you know where fecal matter was going at the end during the time of connection? | Yes | 1 | |
| | | No | 0 | |
| 31. | If final disposal is in septic tank or pit, when was the last time it was emptied/de-sludged? | Less than 6 months | 1 | |
| | | 6-12 months | 2 | |
| | | In the past 1-3 years | 3 | |
| | | Not yet filled | 4 | |
| | | Never | 5 | |
| | | Don't know | 99 | |
| 32. | If emptied/ de-sludged, who was responsible for it? | Private | 1 | |
| | | City corporation | 2 | |
| | | NGO | 3 | |
| | | Others: Specify | 77 | |
| 33. | How frequently does your toilet overflow/get clogged? | More than once in a year | 1 | |
| | | Once in a year | 2 | |
| | | In more than 1 year | 3 | |
| | | Never/not applicable | 4 | |
| | | Others: Specify | 77 | |
| | | Don't know | 99 | |
| 34. | How do you empty the toilets after it overflows/gets clogged? | Manually | 1 | |
| | | Vacuum | 2 | |
| | | Do not empty | 3 | |
| | | Others: Specify | 77 | |
| 35. | How do you manage the money required for emptying? | Individual | 1 | |
| | | Shared | 2 | |
| | | Landlord only | 3 | |
| | | NGO/Govt. | 4 | |
| | | Others: Specify | 77 | |
| 36. | How much do you spend on emptying? | BDT □□□□□□ | | |
| | | Don't know | 99 | |
| 37. | | Less than 1 year | 1 | |

| | | | | |
|---|---|---|---|---|
| | How long has your household been connected to this system? | 1 to 5 years | 2 | |
| | | 5 to 10 years | 3 | |
| | | Greater Than 10 years | 4 | |
| 38. | What type of toilet facilities do you use? | Flush toilet to septic tank/pit | 1 | |
| | | Pour flush toilet to septic tank/pit | 2 | |
| | | Flush toilet to sewer/drainage/open | 3 | |
| | | Pour flush toilet to sewer/drainage/open | 4 | |
| | | Others | 77 | |
| 39. | What are the available cleaning agents at the toilet for handwashing? | Bar Soap | 1 | |
| | | Powder detergents | 2 | |
| | | Sanitizer | 3 | |
| | | Liquid soap | 4 | |
| | | Ash/Mud/ sand | 5 | |
| | | Soapy water | 6 | |
| | | None were available | 7 | |
| | | Other (please specify) | 77 | |

**Section 4: RANAS**

| | Behavioural factor | Definition | Question | Response scale |
|---|---|---|---|---|
| | **RANAS Psychosocial Factors**<br>Risk factors: Represent a Person's Understanding and Awareness of the Health Risk | | | |
| 40. | Health knowledge | A person's knowledge about the causes of a disease, (personal) its consequences, and preventive measures. | How high do you think the risk is that you will cause other people disease if your toilet is not connected to a sewer network? | 0 = Not at all risky<br>1 = Slightly risky<br>2 = Risky<br>3 = Moderately risky<br>4 = Very Risky |
| 41. | Vulnerability | A person's estimate of the general probability of contracting a disease and the subjective awareness of the personal risk of contraction. | How high do you think the possibility is of you contracting a disease if the toilet is not connected to a sewer network? | 0 = Not at all risky<br>1 = Slightly risky<br>2 = Risky<br>3 = Moderately risky<br>4 = Very Risky |
| 42. | Severity | A person's assessment of the seriousness of the infection and of the significance of the disease's consequences. | How severe do you think the disease would be from a toilet that is not connected to a sewer network? | 0 = Not severe<br>1 = Slightly severe<br>2 = Severe<br>3 = Moderately severe<br>4 = Very severe |
| | **Attitude Factors: Represent a Person's Positive or Negative Stance towards a Behaviour** | | | |
| | Beliefs about Costs and Benefits | A person's beliefs about monetary and non-monetary costs (time, effort etc.) and benefits (lower medical costs, improved health) of a behaviour, including social benefits (higher status, appreciation by others). | | |
| 43. | Beliefs about Costs and Benefits (Effort) | | How difficult do you think it is to connect a household to a sewer? | 0 = Not at all difficult<br>1 = Slightly difficult<br>2 = Neutral<br>3 = Moderately difficult<br>4 = Very difficult |
| 44. | Beliefs about Costs and Benefits (Space) | | How difficult do you think it is to find the appropriate space to build a pipe line to connect with sewer? | 0 = Not at all difficult<br>1 = Slightly difficult<br>2 = Neutral<br>3 = Moderately difficult<br>4 = Very difficult |
| 45. | | | | 0 = Not at all expensive |

| | | | | |
|---|---|---|---|---|
| | Beliefs about Costs and Benefits (Expensiveness) | | How expensive do you think it is for constructing a connection to the sewer? | 1 = Slightly expensive<br>2 = Neutral<br>3 = Moderately expensive<br>4 = Very expensive |
| 46. | Beliefs about Costs and Benefits (Money) | | How difficult is it to arrange the money to connect to a sewer? | 0 = Not at all difficult<br>1 = Slightly difficult<br>2 = Neutral<br>3 = Moderately difficult<br>4 = Very difficult |
| 47. | Beliefs about Costs and Benefits (status) | | How certain are you that connecting to a sewer will increase your social status? | 0 = Not certain<br>1 = Slightly certain<br>2 =Certain<br>3 = Moderately certain<br>4 = Very certain |
| 48. | Beliefs about Costs and Benefits (health) | | How certain are you that connecting to a sewer will improve your health? | 0 = Not certain<br>1 = Slightly certain<br>2 =Certain<br>3 = Moderately certain<br>4 = Very certain |
| | Feelings | A person's emotions (joy, pride, disgust etc.) which arise when thinking of a behaviour or its consequences or when practicing the behaviour. | | |
| 49. | Feelings (Behavior) | | How much do you like or dislike the sewer system connecting to the household? | 0 = Strongly dislike it<br>1 = Dislike it<br>2 = Neither like or dislike it<br>3 = like it<br>4 = Strongly like it |
| 50. | Feelings (Proud) | | How proud would you be if your household is connected to a sewer? | 0 = Not proud at all<br>1 = Slightly proud<br>2 = Neutral<br>3 = Moderately Proud<br>4 = Very proud |
| 51. | Feelings (Respect) | | How much do you think you would be respected by your community if your household is connected to a sewer? | 0 = Not respected at all<br>1 = Slightly respected<br>2 =Not sure<br>3 = Moderately respected<br>4 = Very respected |
| **Norm Factors: Represent the Perceived Social Pressure towards a Behavior** | | | | |
| 52. | Others' behaviour (Descriptive norm) | A person's observation and awareness of others' behaviour, his or her perceptions as to which behaviours are typically practised by others | According to your perception, what proportion of people in your area find the sewer network to be helpful? | 0 = (Almost) nobody<br>1 = Some of them<br>2 = Half of them<br>3 = Most of them<br>4 = (Almost) all of them |
| 53. | | | | 0 = Strongly dislike it |

| | | | | |
|---|---|---|---|---|
| | Injunctive Norm (Others' (Dis)Approval) | A person's perceptions as to which behaviours are typically approved or disapproved by relatives, friends, or neighbors. This includes the awareness of institutional norms, i.e. the dos and don'ts expressed by recognized authorities such as village, tribe, or religious leaders, and other institutions. | How much do you think people who are important to you would approve or disapprove if you wanted to connect to the sewer network? | 1 = Dislike it<br>2 = Neither like or dislike it<br>3 = like it<br>4 = Strongly like it |
| 54. | | | How much do you think, people who are important to you would approve or disapprove if you do not want to connect to the existing sewer network**?** | 0 = Strongly dislike it<br>1 = Dislike it<br>2 = Neither like or dislike it<br>3 = Like it<br>4 = Strongly like it |
| | Personal Importance | A person's beliefs about what she or he should do or should not do | | |
| 55. | | | Do you feel a personal obligation to connect to a sewer? | 0 = Not obliged;<br>1 = Slightly obliged;<br>2 = Obliged;<br>3 = Moderately obliged;<br>4 = Very obliged |
| 56. | | | How much personal obligation do you feel to connect your household to a sewer? | 0 = Not obliged;<br>1 = Slightly obliged;<br>2 = Obliged;<br>3 = Moderately obliged;<br>4 = Very obliged |
| 57. | | | How much do you think that other's opinions could influence you to connect or not connect to the existing network? | 0= Strongly agree<br>1= Agree<br>2= Neutral<br>3= Disagree<br>4 = Strongly disagree |
| 58. | | | Whose opinions do you think can influence you the most regarding taking sewer connection? | 0= Family<br>1= Neighbors<br>2= NGO<br>3= Community members<br>4= Govt. officials<br>5 =DWASA<br>6 = Own |

| | | | | |
|---|---|---|---|---|
| **Ability Factors: Represent a Person's Confidence in Her or His Ability to Practice a Behaviour** | | | | |
| 59. | How-to-do Knowledge | A person's knowledge of how to execute the behaviour | Do you know how to get your household connected to a sewer? | 0 = No knowledge at all<br>1 = Some knowledge<br>2= not sure<br>3 = Moderate knowledge<br>4 = Complete knowledge |
| 60. | Confidence in performance | A person's perceived ability to organize and execute the courses of action required to practice a behaviour. | How confident are you that you can connect to a sewer even if this is a difficult process (e.g. because of limited money/ space)? | 0 = Not Strongly Confident<br>1 = Not Confident<br>2 = Neutral<br>3 = Confident<br>4 = Strongly Confident |
| 61. | Confidence in Continuation | A person's perceived ability to continue to practice a behavior, which includes the person's confidence in being able to deal with barriers that arise. | How confident are you that you would connect your household to the sewer even if it costs a lot of money? | 0 = Not Strongly Confident<br>1 = Not Confident<br>2 = Neutral<br>3 = Confident<br>4 = Strongly Confident |
| 62. | Confidence in recovering | A person's perceived ability to recover from setbacks, to continue the behavior after disruptions. | How confident are you that you can maintain the sewer on your own? | 0 = Not Strongly Confident<br>1 = Not Confident<br>2 = Neutral<br>3 = Confident<br>4 = Strongly Confident |
| 63. | | | How confident are you that a govt dept will maintain the sewer? | 0 = Not Strongly Confident<br>1 = Not Confident<br>2 = Neutral<br>3 = Confident<br>4 = Strongly Confident |
| **Self-Regulation Factors: Represent a Person's Attempts to Plan and Self-Monitor a Behaviour and to Manage Conflicting Goals and Distracting Cues** | | | | |
| 64. | Action planning | The extent of a person's attempts to plan a behavior's execution, including the | Do you have a plan to connect your household to the sewerage network? | 0= No detailed plan<br>1= A little planned<br>2= Planned<br>3= Moderately planned<br>4= Very detailed plan |

| | | | | |
|---|---|---|---|---|
| | | when, where, and how of the behavior. | | |
| 65. | Action control | The extent of a person's attempts to self-monitor a behavior by continuously evaluating and correcting the ongoing behavior toward a behavioral goal. | How much attention do you pay to check the sewer condition? | 0 = Pay no attention<br>1 = Pay a little attention<br>2 = Pay attention<br>3 = Moderatly pay attention<br>4 = Pay much attention |
| 66. | Barrier planning | The extent of a person's attempts to plan to overcome barriers that would impede the behavior. | Do you think any factors could influence you to connect /not connect to the existing network? | 0= Strongly agree<br>1= Agree<br>2= Neutral<br>3= Disagree<br>4 = Strongly disagree |
| 67. | | | Which factors do you think acted as a barrier while connecting to a sewer network? | 0= Cost<br>1= Lack of space<br>2= Legal issues<br>3= Lack of awareness<br>4= Political issues<br>5= No Barriers<br>77= Others |
| 68. | | | Do you have plans to overcome barriers to connecting to the sewerage network (e.g. costs, space)? | 0= No detailed plan<br>1= A little planned<br>2= Planned<br>3= Moderately planned<br>4= Very detailed plan |
| 69. | | The obligation a person feels to practice a behavior. | How committed do you feel for getting your household connected to a sewer system? | 0 = Not committed at all<br>1 = Slightly committed<br>2 = Neutral<br>3 = Moderately committed<br>4 = Very committed |

| **Social Factors** | | **Questions** | **Response scale** |
|---|---|---|---|
| **70.** | Social Dilemma | How much do you feel your community would be working together for connecting their households to the sewer line? | 0 = Not at all<br>1 = Slightly<br>2 = Neutral<br>3 = Moderately |

| | | | |
|---|---|---|---|
| | | | 4= Very much |
| **71.** | Social Capital: Solidarity | If a community project does not directly benefit me but has benefits for many others in the community, I would contribute time or money to the project. | 0= Strongly agree |
| | | | 1= Agree |
| | | | 2= Neutral |
| | | | 3= Disagree |
| | | | 4 = Strongly disagree |
| **72.** | Social Capital: Trust | Most people who live in this community can be trusted. | 0= Strongly agree |
| | | | 1= Agree |
| | | | 2= Neutral |
| | | | 3= Disagree |
| | | | 4 = Strongly disagree |
| **73.** | Social Capital: Empowerment and Political Action | I have the freedom to make important decisions that change my life. | 0= Strongly agree |
| | | | 1= Agree |
| | | | 2= Neutral |
| | | | 3= Disagree |
| | | | 4 =Strongly disagree |
| **74.** | Social Capital: Collective Action and Cooperation | If there is a sanitation problem in this community, how likely is it that people will cooperate to try to solve the problem? | 1= Very Unlikely |
| | | | 2= Unlikely |
| | | | 3= Neutral |
| | | | 4= Likely |
| | | | 5= Very Likely |
| **75.** | Social Capital: Social Cohesion and Inclusion | In the last month, how frequently have you met with people in a public place either to talk or to have food or drinks? | 1= Never |
| | | | 2=Rarely |
| | | | 3=Sometimes |
| | | | 4= Often |
| | | | 5= Always |
| **76.** | Social Identity: In-group Ties | I have a lot in common with other community members. | 0= Strongly agree |
| | | | 1= Agree |
| | | | 2= Neutral |
| | | | 3= Disagree |
| | | | 4 = Strongly disagree |
| **77.** | Social Identity: Centrality | In general, being a member of this community is an important part of my self-image. | 0= Strongly agree |
| | | | 1= Agree |
| | | | 2= Neutral |
| | | | 3= Disagree |
| | | | 4 = Strongly disagree |
| **78.** | Social Identity: In-group Affects | In general, I'm glad to be a member of this community. | 0= Strongly agree |
| | | | 1= Agree |
| | | | 2= Neutral |
| | | | 3= Disagree |
| | | | 4 = Strongly disagree |
| **79.** | Social Cohesion: Neighborhood Cohesion | I would be willing to work together with others on something to improve my community. | 0= Strongly agree |
| | | | 1= Agree |
| | | | 2= Neutral |
| | | | 3= Disagree |
| | | | 4 = Strongly disagree |

**Section 5: Strategies to increase demand**

| Q. no | Questions | Answer Options | Ans. Code | Skip Note |
|---|---|---|---|---|
| 80. | Do you think your existing fecal exit route is hygienic to you? | No | 0 | 81 |
| | | Yes | 1 | 82 |
| | | Don't know | 99 | |
| 81. | If yes, why do you think this is sufficient/ hygienic? (multiple) | Does not harm the environment | 1 | |
| | | Does not spread the bad odor | 2 | |
| | | Does not spread diseases | 3 | |
| | | Reduced financial burden | 4 | |
| | | Water bodies would remain unpolluted | 5 | |
| | | Feces not openly visible | 6 | |
| | | Better than previous one | 7 | |
| | | Optimum as per financial ability | 8 | |
| | | Safe and secure during flood | 9 | |
| | | Don't know | 99 | |
| | | Others: Specify | 77 | |
| 82. | If not, why do you think this is not sufficient/ hygienic? | Harmful for the environment | 1 | |
| | | Spread bad odor | 2 | |
| | | Spread diseases | 3 | |
| | | Create a financial burden | 4 | |
| | | Pollute water bodies | 5 | |
| | | Poor management | 6 | |
| | | Pipes are leaking | 7 | |
| | | Openly visible feces | 8 | |
| | | Unsafe and unsecured during flood | 9 | |
| | | Blockage of the sewere line | 10 | |
| | | Others: Specify | 77 | |
| 83. | How satisfied are you with the current system of your household? | Very satisfied | 1 | |
| | | Satisfied | 2 | |
| | | Neutral | 3 | |
| | | Dissatisfied | 4 | |
| | | Very dissatisfied | 5 | |
| 84. | Do you think it is really necessary to have a proper sewerage connection for your entire community? | No | 0 | 85 |
| | | Yes | 1 | |
| 85. | How can we improve the existing sewerage system? | Improved sewerage structure | 1 | |
| | | Maintenance/repair | 2 | |
| | | Install a wider pipe | 3 | |
| | | Install a septic tank | 4 | |
| | | Forcibly stop open connection to the drain | 5 | |
| | | Don't know | 99 | |
| | | Others: Specify_____ | 77 | |
| 86. | What might be the motivating factor for paying to connect to the sewerage network? | Impose a strict law to pay a subsidy | 1 | |
| | | Area-based subsidy | 2 | |
| | | Income-based subsidy | 3 | |
| | | Mandatory to include in household rent | 4 | |

| | | | | |
|---|---|---|---|---|
| | | Based on the number of users like other utility bills | 5 | |
| | | Aware of the negative impacts of the environment | 6 | |
| | | Awareness-building programs for a better environment | 7 | |
| | | Unwillingness to pay | 8 | |
| | | Don't know | 99 | |
| | | Others: Specify | 77 | |
| 87. | What barriers do you think you may face if we connect you to a sewerage network in the future? | Narrow road | 1 | |
| | | Lack of space | 2 | |
| | | Neighbors reluctant | 3 | |
| | | Informal settlement | 4 | |
| | | Cannot afford | 5 | |
| | | City corporation has not approved | 6 | |
| | | No sewerage line in this area | 7 | |
| | | Inaccessible to connect the pipes | 8 | |
| | | Satisfied with the current access | 9 | |
| | | No Barrier | 10 | |
| | | Don't know | 99 | |
| | | Others: Specify_ __ | 77 | |

**Section 6: Water Source and Waste Management**

| Q. no | Question | Answer Options | Ans. Code | Skip note |
|---|---|---|---|---|
| 88. | What is the main source of water (for drinking, cooking, handwashing and using for toilet) for members of your household? | Wasa Water into dwelling | 1 | |
| | | Wasa water to yard/plot | 2 | |
| | | Collected wasa water from neighbor | 3 | |
| | | Public tap/standpipe | 4 | |
| | | Self-deep Tube well or borehole water | 5 | |
| | | Supply water via wasa tanker truck | 6 | |
| | | Bottled water | 7 | |
| | | Surface water (River/dam/lake/pond/stream/canal/ irrigation channel) | 8 | |
| | | Water ATM | 9 | |
| | | Reverse osmosis filter | 10 | |
| | | Chlorine filter | 11 | |
| | | Ceramic filter | 12 | |
| | | Bottled water | 13 | |
| | | Other: Specify_____ | 77 | |
| 89. | How long does it take to go there, get drinking water, and come back? (in minutes) | □□□□ | | |
| 90. | Where is that cooking water source located? | In own dwelling | 1 | 91 |
| | | In own yard/plot | 2 | |
| | | Elsewhere | 3 | |

| | | | | |
|---|---|---|---|---|
| 91. | How long does it take to go there, get water, and come back (in minutes) ? | □□□□ | | |
| 92. | Where is that handwashing water source located? | In own dwelling | 1 | 93 |
| | | In own yard/plot | 2 | |
| | | Elsewhere | 3 | |
| 93. | How long does it take to go there, get water, and come back (in minutes)? | □□□□ | | |
| 94. | Is there rain or greywater drain outside the plot? | Yes | 1 | |
| | | No | 0 | |
| 95. | What types of solid waste disposal system does your household have? | Stored at household and collected by a company/govt | 1 | |
| | | Stored at a public place and collected by a company | 2 | |
| | | Taken outside the compound to a disposal site by household members | 3 | |
| | | Buried/ Burned | 4 | |

**Section 7: Water and Electric Bills**

| Q. no | Questions | Answer Options | Ans. Code | Skip Note |
|---|---|---|---|---|
| 96. | Monthly electricity bill/cost | □□□□ | | |
| 97. | What type of fuel do you use? | Gas | 1 | |
| | | Electric Heater | 2 | |
| | | Kerosene stove | 3 | |
| | | Wood | 4 | |
| 98. | Monthly gas/other fuel bill/cost | Integer | | |
| 99. | Monthly water bill | Integer | | |
| 100. | Monthly sewer bill (don't know the amount/ not paid, then put '0') | Integer | | |
| 101. | Is this the house within 100ft from the sewer line? | Yes | 1 | |
| | | No | 0 | |
| 102. | Is there a risk of flooding during the rainy season | Yes | 1 | |
| | | No | 0 | |
| 103. | GPS coordinates of household | | | |

End of the survey

**Thank You!**