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Research Paper

Barriers to sewer connection in urban Dhaka: Individual and organisational 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 five Key Informant Interviews, and 10 In-Depth Interviews. Survey participants included households with toilets connected to the foul-water sewer or to open 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. Organisational-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complex administrative processes, high installation costs, bureaucratic delays, inadequate support from DWASA, and outdated infrastructure.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).

Key words: barriers, LMIC, organisational challenges, RANAS, sanitation, sewer

HIGHLIGHTS

- Identified individual and organisational barriers to sewer connectivity in urban areas of Dhaka.
- Highlighted psychological factors that impacted household decisions on sewer connections.
- High installation costs and complex administrative procedures hinder sewer connection uptake.
- Proposed holistic interventions to increase connection, including financial aid, community awareness, and simplified administrative processes.

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; 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, 2013). A recent report by the UN reveals that only 56% of global household wastewater was adequately treated in 2020 (UN-Habitat

& WHO 2021), with even lower rates in Central and South Asia and Sub-Saharan Africa (UN-Habitat & 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 (UN-Habitat 2023).

One of the ways of ensuring safe sanitation is to build 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). 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 that transport waste away from home, but these are not true foul-water 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 leads to significant environmental pollution and public health risks and is largely understudied as an issue.

Despite the existence of foul-water 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 (2019). The project includes the 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 foul-water sewers when they are available. This study explores this question by investigating the motivations of households in areas that already have sewers. The study seeks observable differences between households that 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 foul-water sewers. DWASA has divided Dhaka city (Dhaka North and Dhaka South city corporation areas) into 10 Maintenance Operation Distribution and Services (MODS) zones to run water and sewer services.

Among these 10 zones, DWASA has installed sewers in five zones at different times (Table 1) (MODS Zone 1, 2, 3, 5, and 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.

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 10 areas, as our study sites (Figure 1). 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 foul-water sewer map and selected

Table 1 | 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 – foul water sewer	DNCC/DSCC – stormwater sewer and drainage systems
Basabo	1985–1990	2017–2019 and Open Drainage
Goran	1985–1990	2017–2019
Hazaribagh	1990–1992	Open Drainage
Nawabgonj	1990–1992	Open 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

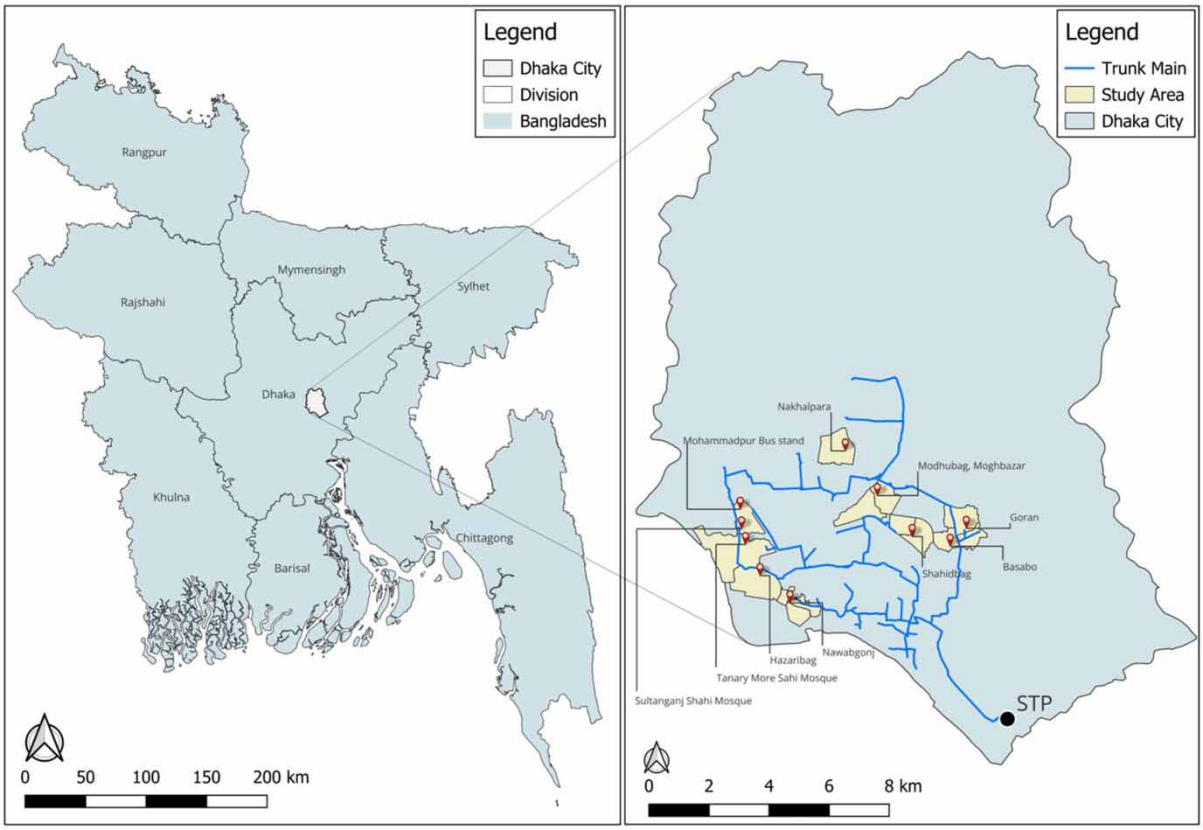

Figure 1 | Data collection site in Dhaka City.

one lane at random where both foul-water sewer and city corporation drainage/open 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 foul-water sewer (Figure 2) or whether they were connected to the city corporation drainage/open drainage (Figure 3). Figures 2 and 3 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

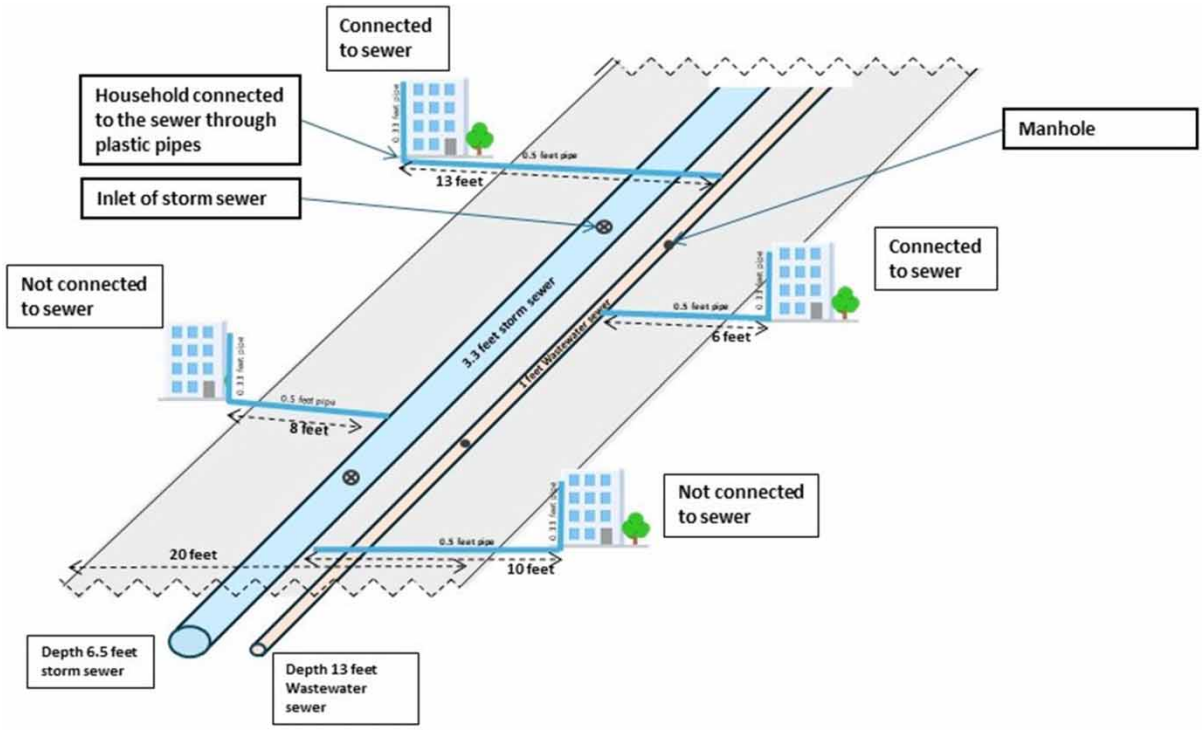

Figure 2 | Typical foul-water sewer and storm sewer in urban Dhaka.

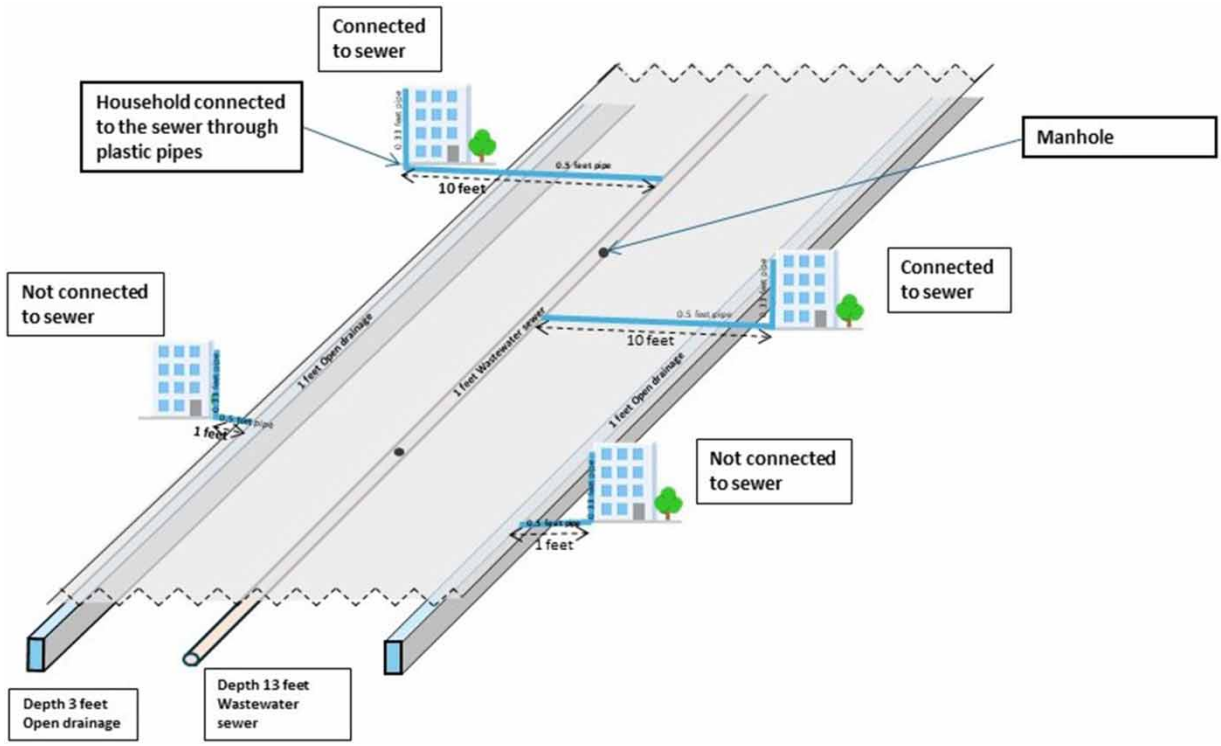

Figure 3 | Typical foul-water sewer and open drainage in urban Dhaka.

the DWASA foul-water sewer or city corporation drainage/open 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:

(i) Both connected and not connected to sewer households were located on the same lane or road so distances from the sewer were similar.
(ii) 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.
(iii) In all households, the household owner was living in the house and was present during the data collection period.

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%, α is 0.05 and the critical value is 1.96), Z_{β} is the critical value of the normal distribution at β (for a power of 80%, β is 0.2 and the critical value is 0.84,) and $p1$ and $p2$ are the expected sample proportions of the two groups (Wang & Chow 2007). 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 2023–15 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 with DWASA officials, to understand the issues surrounding sewer connections. Additionally, 10 In-Depth Interviews (IDIs) with household owners 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 socio-demographic 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 risks, attitudes, norms, abilities, and self-regulation (RANAS) 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 sewers, 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 factor, we calculated the mean difference between the two groups using the Analysis of Variance (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. Among them, 57% were male, the mean age of the respondents was 51 years, the majority (41%) completed graduation, 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 those 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 2).

Factors influencing connection to foul-water 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 connected households, specifically, 21% reported a complete lack of knowledge regarding the connection process (Table 3). 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 IDIs, two not-connected households reported that they did not 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

Table 2 | Demographic characteristics of the respondents

Indicator	Connected to sewer ($N = 192$) *n* (%)	Not-connected to a sewer ($N = 192$) *n* (%)	The 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 ($\pm$ 14)	50 ($\pm$ 14)	1.26, $p = 0.21$	51 ($\pm$ 14)
Respondent types				
Household owner (landlord)	192 (100)	192 (100)		384 (100)
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)
Others	4 (2)	4 (2)		8 (2)
Number of family members (mean $\pm$ sd)	5 ($\pm$ 2)	5 ($\pm$ 2)	0.95, $p = 0.34$	5 ($\pm$ 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)				
$\leq$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)

(*Continued*.)

Table 2 | Continued

Indicator	Connected to sewer ($N = 192$) *n* (%)	Not-connected to a sewer ($N = 192$) *n* (%)	The test statistic, *p*-value	Total ($N = 384$) *n* (%)
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)
1–5 years	22 (11)	58 (30)		80 (21)
5–10 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	192 (100)	191 (99)	1.0, $p = 0.317$	383 (100)

Bold values indicate statistical significance level at 5%.

households' perception: 12% vs. not connected households' perception: 3.6%) (Table 3). 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 foul-water sewers and storm drains or open drains. They could explain that household waste from toilets ('sanitation waste') should be connected to the DWASA foul-water sewer, while wastewater from bathing, kitchens, and similar sources should be directed to the open 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 4).

Table 3 | Factors influencing households not to connect to the sewer

Factor	Connected to sewer	Not-connected to a sewer	Total	*p*-value
Who 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
Sewer system hygienic system				
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
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 programmes 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 the 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

(*Continued.*)

Table 3 | Continued

Factor	Connected to sewer	Not-connected to a sewer	Total	*p*-value
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
Do not know	17 (9)	19 (10)	36 (9)	0.726
Others	3 (2)	3 (2)	6 (2)	1

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 is high (Difference: 0.43, *p*-value: 0.001) (Table 4).

Organisational-level factors influencing not connecting to the sewer

Duration of settlements

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 4). Both connected and not-connected to sewer households have a wide range of settlement durations, spanning from zero to approximately 60 years. However, more non-connected households were clustered within the lower duration range (0–20 years) (Figure 4). 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 foul-water sewer systems 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 foul sewer over time due to inadequate knowledge of sewer connections. According to the not-connected respondents, the buildings that were constructed after the sewer programme 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 foul-water sewer due to the requirement to obtain authorization 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.

Table 4 | 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 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 a 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
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

(*Continued.*)

Table 4 | Continued

Indicator	Mean difference	*p*-value	Effect size
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
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 rffects (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	4,196	0.154	0.15
Monthly expenditure	6,026	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

Bold values indicate statistical significance level at 5%.

'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

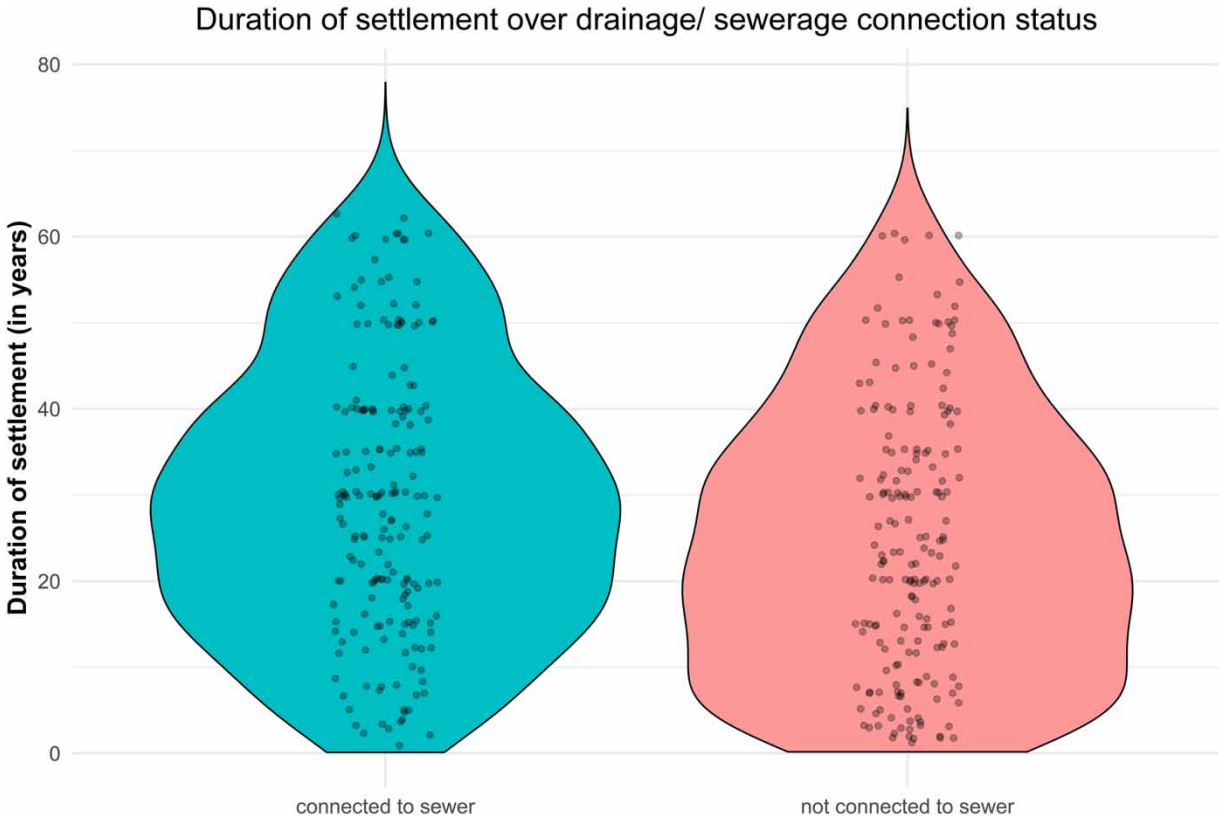

Figure 4 | Duration of household settlement over drainage/sewer connection status.

money. Still, they had to wait a long time, often more than two years, to connect their households to the foul-water 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 10 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 programme from 1990 to 2000 allowed existing households to connect to the system without any bureaucratic procedures or fees. However, post-programme 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 10 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 (33 feet) 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 (Ministry of Local Government, Rural Development and Co-operatives (2022)).

Outdated sewer and 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 foul-water sewer system 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 foul-water 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 aging 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 foul-water sewer system.

> '…… *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 foul-water 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, and lack of maintenance.

Those who were not connected to the sewer perceived a 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 & Robele 2023). Thus, the majority did not 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 & Robele 2023), indicating that the majority did not 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 programmes by the concerned authority (DWASA), resulting in lower awareness levels among current residents and influencing a higher number of non-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 & 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 3-year community awareness intervention programme 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 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 & 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 (Ministry of Local Government, Rural Development and Co-operatives (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 programme implemented in Morocco to improve the sanitation situation reported that when free sewer connection was provided to the households, the programme 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 aging 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 programmes, media campaigns, workshops, and local meetings. Promoting community participation and fostering partnerships between governments, non-governmental organisations (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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DATA AVAILABILITY STATEMENT

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

CONFLICT OF INTEREST

The authors declare there is no conflict.

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