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Exploratory investigation of water, sanitation, hygiene, and health of migrant labourers in the Mumbai Metropolitan Region (MMR), India

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Abstract

Background/objectives Adequate access to water, sanitation, hygiene, and health services remains challenging in urban areas. This study aims to assess the current water, sanitation, and hygiene services and the health conditions of informal migrant workers in the Mumbai Metropolitan Region (MMR).

Methods This structured questionnaire-based study consisted of 31 items divided into three sections addressing water access, sanitation facilities, hygiene practices and health services among informal migrant labourers. The primary data was collected through interviews with the participants who have migrated to the region, primarily in search of a livelihood. Logit regression was used to identify the variables that influenced the water, sanitation and health status of the migrant workers.

Results The local municipality supplied the primary source of drinking water yet only 64% of participants reported access to improved drinking water sources meeting the criteria for availability and accessibility. More than half (50%) reported experiencing intermittent water shortages. 57% of the participants relied on limited sanitation services which they shared with members of other households. All participants (100%) reported access to basic hygiene facilities with the availability of soap and water. Greater number of respondents (63%) reported children frequently missing school due to illnesses that they thought were related to water or sanitation issues. The results of the logistic regression revealed that the location of the washroom significantly affected the sickness and hospitalization of the family members ($p < 0.05$).

Conclusions Our findings provide the empirical baseline evidence of WASH disparities impacting migrant communities in Mumbai Metropolitan Region (MMR). Analyzing key trends and challenges in urban settlements will help policymakers improve living conditions for the urban poor.

Highlights

- The primary drinking source was Municipal water for the majority of participants.
- More than half reported irregularities in water supply.
- More than half of the participants used shared sanitation facilities with other members of the community.

- Health issues related to poor WASH conditions, such as skin-related issues and stomach issues, were reported.
- More than 60% of children missed school due to illnesses related to water or sanitation issues.

Keywords Water, Sanitation, Hygiene, Health, Mumbai, Informal migrant workers

1 Introduction

Access to clean drinking water, proper sanitation, and hygiene services is a fundamental human right, vital for safeguarding public health and advancing sustainable development. Water, sanitation and hygiene (WASH), and health serve as the foundational pillars of public health efforts, playing a critical role in preventing waterborne diseases such as diarrhea, cholera, dysentery, hepatitis A, and typhoid while strengthening community resilience [1, 2]. Since 2015, global progress has expanded access to safely managed drinking water services for over 687 million people. By 2022, approximately 5.82 billion people used safely managed drinking water services. Despite these gains, significant gaps remain: 2.2 billion people still lack access to safely managed water. Among them, 1.5 billion depend on basic services, 292 million have limited access, 296 million use unimproved sources, and 115 million continue to collect drinking water directly from rivers, lakes, and other surface water sources [3]. For India, the coverage of safely managed drinking water for households is around 50% due to issues like intermittent supply and contamination (fluoride, arsenic, nitrates) [4, 5]. These disparities disproportionately affect the poorest populations and rural communities, amplifying the inequalities. Globally around 4.2 billion use safely managed sanitation, with 3.5 billion lacking safe sanitation, 1.5 billion deprived of basic sanitation services, including private toilets and latrines [1] and 419 million practicing open defecation in gutters, behind bushes, or near open water bodies. With regard to hygiene services, 4.8 billion have access to basic hand-washing facilities (soap and water at home) with 2.3 billion lacking basic facilities, 670 million having no hand-washing infrastructure at all. According to NFHS-5, in India, ~ 80% of households have soap and water but consistent practice of handwashing remains lower (~ 60%) [6].

Access to clean water and sanitation constitutes not only a fundamental human right but also a key factor in achieving multiple United Nations Sustainable Development Goals (SDGs) targeted for 2030 [7]. While SDG 6 mandates "clean water and sanitation for all", it also has cross-cutting impacts on other SDGs. The interdependence between WASH infrastructure and SDGs manifests in poverty alleviation (SDG 1) where households without piped water spend disproportionately on informal vendors, diverting income from nutrition and livelihoods [8]. Similarly, SDG 3's targets of good health and well-being are inseparable from WASH as contaminated water accounts for nearly 10% of the global disease burden, including diarrheal deaths and chronic malnutrition [9]. Quality education (SDG 4) and gender equity (SDG 5) are equally dependent on WASH accessibility. The responsibility of water collection remains heavily gendered, with women and girls bearing the primary burden in most countries [10] and them losing an estimated 200 million collective hours daily fetching water [5, 11], reducing school attendance. Similarly inadequate sanitation facilities force menstruating students into skipping school [12]. These disparities increase existing inequalities (SDG 10), as marginalized communities, rural populations and informal urban settlers face systemic

exclusion from water and sanitation infrastructure, worsening spatial and socioeconomic divides [13].

Mumbai is the financial hub of the world's largest democracy, and its economic growth and infrastructure development have attracted migrants from within Maharashtra and various states across India, seeking new opportunities similar to the "American Dream." According to the 2011 Population Census, total population of the Mumbai Urban Agglomeration was approximately 23.5 million with around 10.1 million migrants constituting 43.02% of the population [14]. Despite being India's financial capital, Mumbai has a high cost of living [15], and many workers earn only half of the state-mandated monthly minimum wage of ₹7,000–₹8,000 [16]. Due to their transient status and low incomes, migrant workers are compelled to reside in peripheral, under-developed settlements and densely populated slum clusters [17]. Most of these slums and informal settlements lack proper WASH infrastructure, including access to clean water and toilets [18], posing serious health risks and making them vulnerable to disease outbreaks such as cholera, typhoid, and diarrhea [19–21]. Enhancing the water, sanitation and hygiene services in Mumbai's slums to marginalized communities such as informal migrant workers is not just a public health necessity but also vital for economic development and reducing disparities [22, 23]. Improving water sanitation and hygiene infrastructure in these areas will ensure more sustainable urban development thereby aligning with the objectives of SDG 3 (Good Health and Well-being) and SDG 6 (Clean Water and Sanitation). The One Health approach, advocated by the World Health Organisation (WHO), which underlines the interconnectedness of human, animal, and environmental health, can serve as a framework or a practical tool for safeguarding the health and well-being of migrant workers [24].

Several previous researchers have examined WASH infrastructure and their interconnections with health conditions from different parts of India [25, 26] as well as Mumbai [18, 23, 27–29], yet there remains a significant research gap regarding the informal migrant worker communities of Mumbai. The majority of these works are focussed on slum residents [27, 30, 31], general population [32] and the urban poor [33]. However, none of these studies have addressed the informal migrant workers that constitute a bulk of the resident population in the urban slums of Mumbai [15]. Further, all of these mentioned studies either did not have a health focus [30, 33] or had only specific health focus [27, 31]. Our study attempted to address this research gap by focussing on the informal migrant workers with multiple health areas focus. The current study makes three exploratory contributions to the existing literature. First, it specifically focuses on migrant laborers in informal economic sectors, a vulnerable subgroup that remains understudied despite constituting a substantial portion of Mumbai's urban poor. The primary objective was to assess on-the-ground challenges faced with respect to water access and availability, sanitation and hygiene infrastructure using Joint Monitoring Programme (JMP) framework for households [34] and collect information regarding their health condition. Second, this study assessed WASH conditions and health outcomes simultaneously, revealing important interconnections which are often overlooked in studies that focus on a specific sector. Third, this questionnaire-based cross-sectional study aims to fill the research gap using empirical methods and to establish methodological frameworks for studying the migrant workers of Mumbai that can inform larger-scale research and contribute towards improved healthcare and public health outcomes.

2 Method

2.1 Study approach

A questionnaire-based cross-sectional study was conducted in the Mumbai Metropolitan Region (MMR) to assess the service availability of water, sanitation and hygiene, and health conditions of 100 informal migrant workers. The sample size of 100 respondents was determined based on methodological considerations. Given the exploratory nature of this baseline study, and considering research timeline, 100 sample size was logistically feasible which would modestly capture meaningful responses. We employed cluster sampling design intended to capture the heterogeneity of Mumbai's informal settlements (Fig. 1). The study was conducted in accordance with the ethical guidelines of our university. No experiments were performed during this study and the research design allowed collection of data through human responses. We obtained ethical clearance from the Research and Ethics Review Board (RERB) of our University (RERB/2024/134). The study was conducted in three suburban localities of Mumbai, viz. Vikhroli, Parksite, and Powai that included few clusters from each locality (Fig. 1). This ensured our sample included the diversity of the informal settlements of Mumbai. The participants were reached out during normal working hours, i.e., 9:00 A.M. to 05:00 P.M. Participation in the study was voluntary. Before conducting the interview, the participants were briefed about the aim of the study, and the confidentiality of the data obtained from them was guaranteed. Also, they were assured they could withdraw from the study at any given time if they felt uncomfortable during the process of answering questions. Informed consent was sought following the Principles of Helsinki for human studies [35]. Unique identification codes maintained the confidentiality and anonymity of the participants. The questionnaire was prepared in three different languages, English, Hindi, and Marathi as the migrants to the city come from different parts of the country. The interviews were conducted face-to-face. Out of the total, 7% of the subjects completed the questionnaire by themselves. For the remaining, the interviewer verbally explained the questions and filled out their responses. 25% of the interviews were conducted in Marathi, and the rest were in Hindi. The questionnaire consisted of 31 structured questions on the

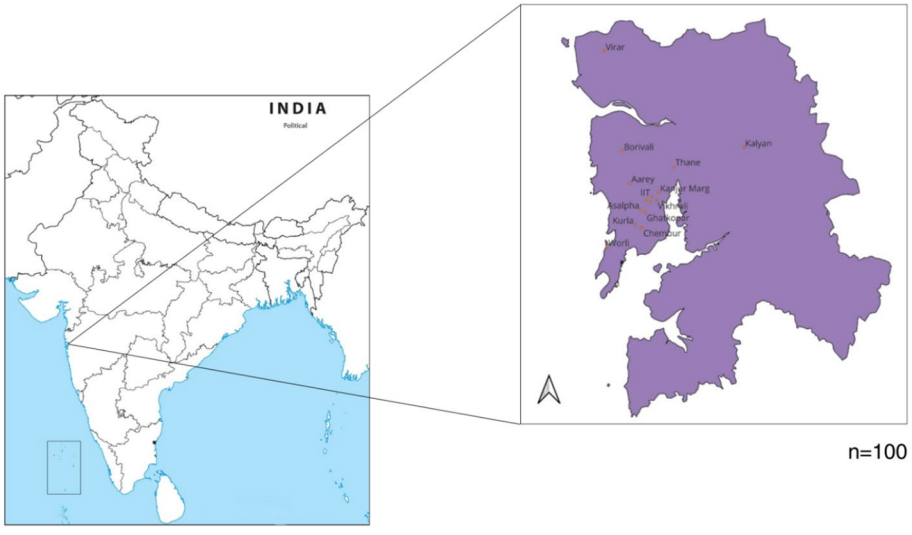

Fig. 1 The figure depicts the locations where the participants of the study are currently residing in the Mumbai Metropolitan Region (MMR)

availability of water, sanitation, and hygiene services of these participants, along with their health conditions, access to health care, and health education or information on the importance of hygiene and sanitation. The questions were both closed-ended and open-ended. The questionnaire prepared was based on the WHO/UNICEF Joint Monitoring Programme (JMP) core questionnaire for households [34]. In total, 11 questions were related to water availability, 9 questions on sanitation and hygiene, and 11 questions were regarding health conditions, access to health care, and health education.

2.2 Socio-demographic and general information

The questionnaire recorded the socio-demographic information of the participants. Information regarding their gender, age, marital status, occupation, current residence, duration of stay at their present residence, and place of birth were recorded (Supplementary Information 1).

2.3 Water availability and accessibility

The participants were asked about the primary source of drinking water for the members of their households and the source of water for other purposes, such as cooking and washing. The response included Municipal water supply, borewells, and hand-pumps. Questions were asked about the location of the water source and whether they were inside or outside the house. We asked the respondents how long it would take them to fetch water and return to their houses if the water sources were not inside their household's premises. Questions regarding the storage of water, duration of water supply, and issues faced regarding the non-availability or insufficient water supply during the last week or month were also asked. Participants were asked whether they shared the water facility with individuals outside their household. Finally, they were asked about the disposal of used water, whether it drained into a formal drainage system or open gutters. Based on their responses, the service level received by the respondents was assessed using WHO/UNICEF Joint Monitoring framework [34]. Improved services meant drinking water received was from an improved water source such as piped water, boreholes or tube wells, protected dug wells, protected springs, rainwater, and packaged or delivered water and the collection time of >30 min for a round-trip including queuing. Unprotected dug well, unprotected spring, river, dam, lake, pond, stream, canal, and irrigation canal where collection time was <30 min accounted for unimproved service level.

2.4 Sanitation and hygiene services

The second part of the questionnaire assessed the study participants' sanitation and hygiene services and practices. The respondents were asked to indicate the location of their toilet facilities. The ones reporting in-house toilet facility were subsequently asked to indicate the total number of toilets present. The next set of questions was targeted at the participants who used a common toilet facility. The participants were asked if the toilet facility was accessible at all times of the day and night and if they faced any risks while using the toilets. Participants were asked about their household waste disposal methods. To assess the hygiene service level, the participants were asked if there was a bar of soap and water available at their house for washing their hands and where did they wash their hands. Based on the responses, the service level received by the respondents was assessed using WHO/UNICEF Joint Monitoring framework [34]. Limited sanitation

services implied improved sanitation systems shared with two or more households. On the other hand, basic sanitation referred to improved sanitation facilities that are not shared by households. Basic hygiene service included availability of a hand-washing facility on premises with soap and water whereas limited service meant a hand-washing facility without soap and water.

2.5 Health conditions

In the last section of the questionnaire, the participants were asked about their health parameter status in the past month or year. Hospitalization in the past month or year of any family members and sickness for which they might have been hospitalized were asked. All responses were optional and were subject to participant comfort levels. Participants were asked whether they suffered from health problems probably related to poor sanitation and hygiene and unclean drinking water, like skin rashes, stomach issues, diarrhoea, jaundice, typhoid, and tuberculosis. They were also enquired about their ease of access to medical care. The participants were asked to report if their children had frequently missed school due to issues related to water and sanitation.

2.6 Statistics

The present study utilized descriptive statistical analysis, which involved summarizing and describing the main features of a dataset. The raw data collected through questionnaires were recorded, compiled, and entered into the MS Office Excel sheet. The data obtained were tabulated and analyzed to obtain the results in terms of percentages. We also used logistic regression to identify the various factors that influenced the water, sanitation and health status of the migrant workers. We selected variables to determine the factors influencing the health outcomes of migrant workers based on the WHO Commission on Social Determinants of Health framework (Solar & Irwin, 2010). In particular, we used both the structural factors (e.g., household size, duration of residency, occupation type), material factors (water source location, washroom location, water storage availability) and intermediary factors (hygiene education, medical care access) in the questionnaire and included them as independent factors while doing logistic regression. This framework enabled us to explore the different factors that might affect the health outcomes of the informal migrant workers in the Mumbai slums. We divided the responses received in the questionnaire into 2 sets of variables, i.e. dependent and independent. Dependent variables related to the responses related to the water, sanitation and health parameters while independent variables related to the responses related to the variables that determined the water, sanitation and health parameters (Table S2). In total, 6 dependent variables and 22 independent variables were identified (Table S2). Each dependent and independent variables were coded prior to use in logistic regression (Table S2). For the variables with only two choices, they were coded as 0 or 1 (Table S2). Variables with more than two categories were converted to factors and subsequently treated as dummy variables in the logistic regression model. This step created (n-1) binary variables automatically, with the first factor level serving as reference. For each dependent variable, separate logistic regressions were performed with the 25 independent variables using the binomial distribution and logit link functions. We only considered independent variables to have a significant effect on the dependent variables if their p values were less than 0.05 ($p < 0.05$). The significant variables (with $p < 0.05$) were

further evaluated individually (univariable logistic regression) to assess their impact on the outcome. The fit of the univariable logistic regression models was determined using log likelihood, deviance and Chi-square goodness-of-fit measures ($p < 0.05$). All regression analyses were performed using R 4.2.2 software.

3 Results

3.1 Socio-demographics

The study population consisted predominantly of male participants (68%), with female participants accounting to 32% of respondents. The majority of the participants fell in the age bracket of 20–40 years. The sample consisted of 86% married individuals and 14% unmarried individuals. Most of them have been staying in the region for the past 11–20 years. The sample population was predominantly middle-aged, married male, with diverse socioeconomic backgrounds and moderate regional residency duration (see Table 1). The occupations of the migrants workers was highly diverse, dominated by house helpers (17%), followed by laundrymen and security guards (6% each). Other significant roles included porters (5%), shopkeepers, sweepers, taxi drivers, and technicians (4% each). Minor occupations (1–2%) included beauticians, drivers, plumbers, and street vendors, showing that the migrants were in employment spanning service-oriented and skilled labor sectors but mostly informal sector (see Table S1).

3.2 Availability and accessibility of water

Municipal water constituted the principal drinking water source, with all the respondents identifying it as their primary supply. For non-potable usage, 95% relied on

Table 1 Socio-demographic information of the informal migrant workers in the Mumbai Metropolitan Region

Variables			
Gender		Male	Female
		68 (68%)	32 (32%)
Age	Below 20	1 (1%)	0
	20–30	21 (21%)	4 (4%)
	31–40	21 (21%)	13 (13%)
	41–50	17 (17%)	6 (6%)
	51–60	8 (8%)	8 (8%)
	60 and above	0	0
Marital Status	Married	58 (58%)	28 (58%)
	Unmarried	3 (3%)	11 (11%)
Social Category	General	4 (4%)	3 (3%)
	OBC	16 (16%)	10 (10%)
	SC	25 (25%)	14 (14%)
	ST	7 (7%)	1 (1%)
	N.A.	9 (9%)	0
	Not Sharing	7 (7%)	4 (4%)
How long have you been staying in Mumbai?	Less than a year	1 (1%)	0
	1–10 years	24 (24%)	10 (10%)
	11–20 years	23 (23%)	12 (12%)
	21–30 years	16 (16%)	9 (9%)
	31–40 years	2 (2%)	1 (1%)
	41–50 years	1 (1%)	0
	51–60 years	1 (1%)	0
	More than 60 years	0	0

municipal water, while 3% utilized bore-well water. A small proportion of participants (3%) depended on alternative sources for drinking water, whereas 97% of the total sample population exclusively depended on municipal water. The respondents predominantly accessed water from the taps located indoors (64%), with 36% having taps outside their residences (23%). Among the 36% of households who did not have water sources inside their premises and were dependent on external water taps, the water collection time (including travel, filling, and return) was completed within 1–3 min by 64% of respondents. Water storage was a common practice among participants, with 79% utilizing large storage tanks. Despite this, 57% reported intermittent water shortages. The duration of daily water supply varied across the study population, with 25% receiving it for less than an hour, 35% having it for 2–5 h, 17% for 6–10 h, and 21% enjoying more than 10 h of water supply. Wastewater disposal was uniformly managed by municipal drainage systems (see Table 2). Figure 2a, b (top panel) shows water conditions of the informal migrant workers in the Mumbai Metropolitan Region (MMR). According to the drinking water service level, 64% of participants reported access to improved drinking water services, meeting criteria for availability and accessibility. In contrast, 36% of participants depended on basic drinking water services.

Table 2 Table illustrating informal migrant workers' response to water service availability and accessibility in Mumbai Metropolitan Region

Questions	Choices	Percentage
What is the main source of drinking water for members of your household?	Municipal Water	100%
What is the main source of water used by members of your household for other purposes, such as cooking and hand washing?	Municipal Water	97%
	Borewell	3%
Do members of your household regularly use any other drinking water sources?	Yes	3%
	No	97%
Where is the water that is used collected from?	Tap inside the house	64%
	Tap outside the house	36%
How long does it take to go there, get water, and come back? (In minutes)	Less than 1 min	0%
	1–3 min	23%
	4–6 min	6%
	7–10 min	4%
	More than 10 min	4%
	N.A.	63%
Does your household have a large storage tank for water?	Yes	79%
	No	22%
Has there been any time in the last week/month when you have not been able to store sufficient water to meet your needs?	Yes	43%
	No	57%
Do you share this facility with others who are not members of your household?	Yes	33%
	No	67%
How many hours per day is water supplied on average?	Less than 30 min	2%
	30 min–1 h	25%
	2–5 h	35%
	6–10 h	17%
	More than 10 h	21%
What is your main source of drinking water in the wet season and the dry season?	Municipal Water	99%
	Municipal Water/Borewell	1%
How do you dispose of household water used for cooking, laundry and bathing?	Municipal Drainage	100%

Fig. 2 Water (top panel), sanitation (middle panel) and hygiene (down panel) conditions of the informal migrant workers in the Mumbai Metropolitan Region (MMR). **a**: A small common water tank that is operated using a generator set up by the Municipality located near a shop in Vikhroli, **b**: a water storage tank/drum present in one of the participant's house in Powai, **c**: a mobile toilet set up for a people living in kaccha houses (not constructed using bricks or cement) that have been evicted due to illegal encroachment in Powai, **d**: a common municipal toilet for the people in the vicinity located in Parksite, **e**: a dirty toilet seat in Vikhroli, **f**: a common municipal bin which is overflowing due to uncollected garbage in Powai

3.3 Sanitation & hygiene services

Over half (57%) of the study's migrant workers used shared sanitation facilities provided by municipal authorities with only 43% respondents reported having private household toilets. Among those with in-house sanitation, 26% possessed a single toilet, while 17% had two toilets per household. Among households with private toilets, 57% reported sharing it with multiple members, including members outside their households. This

reflected the shared nature of accommodation wherein more than one household lived in a building or a "chawl" but shared common resources such as water and sanitation. The study found high toilet accessibility with 94% of participants indicating unrestricted access. However, 6% of respondents experienced occasional disruptions, which were primarily due to nocturnal facility closures or inadequate lighting near toilet premises. Safety concerns were minimal, with only 5% of participants reporting higher risk during night-time access. Around 43% relied on municipal bins for solid waste disposal while 46% utilized door-to-door waste collection services by municipal sweepers. All participants confirmed access to functional hand-washing facilities, including soap. Members of the household washed their hands at various locations, with only 29% having a dedicated wash basin. Rest had hand-washing facilities at the taps inside the house (17%), taps outside the house (13%), and inside washrooms located within the house (21%) or outside the house (16%; see Table 3). Figure 2c, d (middle panel) depicts sanitation conditions and Fig. 2e, f shows the hygiene situation of the informal migrant workers in the Mumbai Metropolitan Region (MMR). According to the JMP sanitation service level criteria, 44% of participants had access to improved sanitation services, which included adequate toilet facilities and proper waste disposal. The remaining 55% depended on limited sanitation services, using communal toilets provided and maintained by the

Table 3 Table illustrating informal migrant workers' response to sanitation and hygiene services in Mumbai Metropolitan Region

Question	Choices	Percentage
Where is the toilet facility located?	Inside the house	43%
	Outside the house	57%
How many toilets do you have?	One	26%
	Two	17%
	Zero (Common toilet used)	57%
Do you share this facility with others who are not members of your household?	Yes	56%
	No	44%
How many people including family members, use the toilet?	Multiple	57%
	One - three	7%
	Four - Six	27%
	Seven - Ten	8%
	More than 10	1%
Is everyone in the household able to access and use the toilet at all times of the day and night?	Yes	94%
	No	6%
Do you or other household members face any risks when using the toilet?	Yes	5%
	No	95%
How does your household usually dispose of garbage?	Common municipal garbage bin outisde house	47%
	Collected by municipal sweeper	48%
	Collected by municipal garbage truck	1%
	Open disposal	4%
Where do members of your household most often wash their hands?	Tap inside house	17%
	Tap outside the house	13%
	Wash basin	29%
	Washroom inside house	21%
	Washroom outside the house	16%
	Washing area	2%
	Kitchen Sink	2%
Do you have soap or detergent in your household for washing hands?	Yes	100%
	No	0%

municipal corporation. All participants (100%) reporting access to basic hygiene facilities with the availability of soap and water.

3.4 Health conditions

The data presented in Table 4 summarizes key health indicators and healthcare access patterns among participants. Only 11% of participants reported family members falling sick and being hospitalized in the past year, with 9% of respondents reporting no hospitalization of their sick family members. 17% of them had family members being sick in the past month. The participants indicated relatively high accessibility to medical care, with 88% reporting ease of access. 32% of respondents reported that they or their family members experienced health problems, such as skin rashes or infections, which were likely caused by inadequate sanitation. 35% reported stomach issues or diarrhea, and

Table 4 Table illustrating informal migrant workers' response to health-related questions in Mumbai Metropolitan Region

Question	Choices	Percentage
Has any member of your family fallen sick and hospitalized in the past year?	Yes	11%
	No	80%
	Yes, but not hospitalized	9%
Has any family member fallen sick and hospitalized in the past month?	Yes	17%
	No	81%
	Yes, but not hospitalized	2%
Can you share with us the reason/disease name if you are comfortable?	Accident	2%
	Alcoholism	1%
	High B.P.	1%
	Tumor in the Stomach	1%
	Cold and Cough	2%
	Diabetes & Thyroid	2%
	Iron Deficiency - Anemia	1%
	Blood deficiency	1%
	Asthma	1%
	Joint pain	1%
	Stomach Infection	1%
	Diarrhea	1%
	Not Sharing	14%
	N.A.	66%
Do you have access to easy medical care when you or your family member is sick?	Yes	88%
	No	12%
Do you or your family members suffer from any health issues like skin rashes or infections (that might be due to poor sanitation facilities)?	Yes	32%
	No	68%
Have you experienced any health problems like stomach issues or diarrhoea in the last month/last year?	Yes	35%
	No	65%
Have you experienced any health problems like jaundice in the last month/last year?	Yes	13%
	No	87%
Have you received any health education or information on the importance of hygiene and sanitation?	Yes	63%
	No	37%
Do your children frequently miss school due to illnesses that you think are related to water or sanitation issues?	Yes	63%
	No	26%
	N.A.	11%
Do anyone in your family suffer from chronic or acute illness?	Yes	7%
	No	93%

Table 5 Results of the logistic regression analysis

Variable	Estimate	Log-likelihood	Deviance	Chi square GOF[+]	*P* value
Dependent: Has any family member fallen sick and hospitalized in the past month?					
Independent:					
Washroom inside the house	−2.2485	−4.020326	8.040651	4.1655	0.04126 (< 0.05)
Dependent: Do you or your family members suffer from any health issues like skin rashes or infections (that might be due to poor sanitation facilities)?					
Independent:					
Are you on medication?	−1.6094	−6.393419	12.78684	4.2345	0.03961 (< 0.05)
How many people are at your home	−2.996	−4.020326	8.040651	4.3778	0.03641 (< 0.05)
Does your household have a large storage tank for water?	1.7607	−52.45126	104.9025	5.1135	0.02374 (< 0.05)
Do you have access to easy medical care when you or your family member is sick?	−1.2607	−52.51626	105.0325	3.9863	0.04587 (< 0.05)
Dependent: Have you experienced any health problems like stomach issues or diarrhoea in the last month/ last year?					
Independent:					
Tap inside the house	−1.7272	−6.157579	12.31516	4.1871	0.04073 (< 0.05)
Tap outside the house	−2.1972	−3.525462	7.050924	3.9277	0.0475 (< 0.05)
Dependent: Do your children frequently miss school due to illnesses that you think are related to water or sanitation issues?					
Independent:					
Have you received any health education or information on the importance of hygiene and sanitation?	−1.4877	−40.7581	81.5162	6.3211	0.01193 (< 0.05)

[+] Chi square GOF represents Chi-square Goodness-of-fit test

13% reported jaundice in the last month or last year. Furthermore, exposure to sanitation and hygiene education was reported by 63% of participants. Also, a higher percentage of respondents (63%) reported that their children frequently missed school due to illnesses that they think are related to water or sanitation issues. Unlike the service framework applied in prior sections, the JMP Questionnaire for households does not incorporate a comparable service level for health services. Consequently, no further analysis was conducted on this metric.

3.5 Logistic regression analysis result

The results of the logistic regression revealed that the location of the washroom had a significant association with the sickness and hospitalization of the family members ($p < 0.05$; Table 5). If the washroom was located inside the house, a smaller number of

family members got sick and were hospitalized (Table 5). The likelihood of family members suffering from health issues like skin rashes or infections was significantly associated with parameters like medication, number of people at home, availability of a large storage tank for water, and access to easy medical care ($p < 0.05$; Table 5). Among all of these factors, if the number of people was more than 5, the likelihood of getting skin rashes or infection was higher (Table 5). The likelihood of people experiencing stomach issues or diarrhea in the last month/year was significantly dependent on the location of the tap inside or outside the house ($p < 0.05$; Table 1). If the tap was located outside the house, there are more chances of people suffering from stomach issues or diarrhea (Table 5). The results also showed that the likelihood of children missing school due to illness related to water or sanitation issues was higher when the family had received less education or information on the importance of hygiene and sanitation ($p < 0.05$; Table 5).

4 Discussions

Our study shows that Municipal water in the Mumbai Metropolitan Region constitutes the principal drinking water source for migrant workers. This highlights a greater dependence on centralized water supply systems. Although centralized systems generally meet safety standards since it is treated and reduces waterborne diseases [36], it risks exclusion of the marginalized groups (like migrant workers) due to informal settlements lacking legal connections and forcing the marginalized communities and groups to depend on external, unreliable water supply such as tankers and groundwater [37, 38]. A small segment of the respondents faced accessibility challenges. Most respondents accessed water through indoor tap connections, while the others relied on water sources from outside. This disparity possibly arose from demographic and socioeconomic factors with a proportion of participants residing in informal settlements and unauthorized slum clusters, where piped water infrastructure is absent. These participants depended on communal water sources for their daily needs. These findings are consistent with prior studies that document systemic inequality in water access across urban and rural regions of India [2]. Water storage is a common practice, yet over 50% of respondents reported experiencing intermittent water shortages. The duration of the water supply by the civic body was unequal, with respondents reporting water supply for varying durations, exhibiting variability and highlighting inequities in water distribution. These disparities affect daily water access and storage practices among the respondents. Shortages in water supply during summers intensify water access and availability and storing water becomes an adaptive measure. In our study, more than two-thirds of participants reported utilizing large storage tanks while others lacked water storage infrastructure. Such behavioural practices and patterns align with several challenges, such as seasonal scarcity and urban-rural disparities in water access, consistent with other studies [2, 32, 39] that documented spatial clustering of water availability in Indian cities and metropolitan areas. Wastewater disposal was uniformly handled by municipal drainage systems. According to the JMP drinking water service level, 64% of migrant respondents had access to improved drinking water services, meeting the criteria for availability and accessibility whereas 36% met the basic services due to inconsistent supply. The reliance of a third of study population on basic drinking water services rather than improved sources suggests systemic gaps in water supply regularity and quality assurance, inadequacies in drinking

water infrastructure and management, pointing to the need for targeted interventions to mitigate associated public health risks.

Access to clean sanitation remains a critical issue for Mumbai's migrant populations. The JMP sanitation service level showed that more than half of the respondents relied on limited services and primarily shared communal or public toilets managed by Municipal corporations. These public facilities are overcrowded, unhygienic, unsanitary and poorly maintained which increases the health risks of users such as waterborne diseases and infections. Our finding aligns with other existing literature [21, 40–42], showing a correlation between inadequate sanitation infrastructure and adverse health outcomes, particularly affecting low-income and marginalized communities. Previous qualitative and ethnographic studies from slums have highlighted recurring concerns about safety (particularly for women and children), lack of privacy, and limited water availability, worsening the daily challenges of vulnerable populations [28, 29]. The migrant populations are often excluded from long-term municipal planning which broadens urban inequities in these rapidly growing metropolitan centres where informal settlement expands faster than infrastructure development. Waste disposal methods further show the population's dependence on Municipal services. Nearly half of the participants utilize door-to-door waste collection, while others rely on communal garbage bins, which are frequently overflowing and unsanitary, posing significant health hazards. Open disposal was a common issue in these areas highlighting poor waste management infrastructure. These observations are consistent with studies [43, 44] that emphasize the need for enhanced waste management systems in slums and other marginalized communities. Additionally, during rainy season, floodwater contamination due to inadequate waste management poses public health risks concern as documented in previous studies [45, 46].

Hand-washing behaviour among the study participants varied. Some utilized washbasins inside their homes, others used bathroom taps or household taps, taps in communal toilets, and public taps. This reflects a lack of standardized and dedicated hygiene facilities in many households indicating transient nature of the migrant settlements. Despite a lack of a proper hand-washing area, all participants reported access to soap when they wash their hands, reflecting strong hygiene awareness. The reliance on shared facilities suggests inadequate housing and water infrastructure impacting hygiene of migrant populations. This corroborates with other findings [47] stressing the importance of policy and behavioural interventions for better hygiene initiatives.

The study findings reveal that a significant majority of participants reported no incidence of typhoid or tuberculosis. However, a notable proportion experienced gastrointestinal ailments, like diarrhea, and dermatological conditions, such as skin rashes. Additionally, some participants reported a history of jaundice. These health conditions are frequently associated with poor water quality and inadequate sanitation facilities [48]. Although the prevalence of serious diseases such as typhoid and tuberculosis remains relatively low, the data underscores the need for targeted interventions to mitigate waterborne diseases and enhance sanitary conditions. Logistic regression analysis showed that washroom location had a significant association with the sickness and hospitalization of the family members and health outcomes like skin rashes or infections was significantly associated with medication, household population availability of a large capacity water storage tank and access to primary healthcare services. Our results align with previous studies [49, 50] on inadequate WASH infrastructure and health outcomes.

Education and awareness regarding hygiene and sanitation play a critical role in improving public health outcomes. Nearly two-thirds (63%) of participants reported receiving education on proper hygiene and sanitation practices, whereas the remaining one-third (37%) lacked such knowledge, similar to reports from other Indian cities [51, 52]. This indicates persistent gaps in awareness, particularly among marginalized populations. Also, children were more likely to miss school due to water- and sanitation-related illnesses when their families had limited access to education or information regarding hygiene and sanitation practices. Addressing this challenge through educational initiatives in schools, particularly in primary schools, is imperative. Accessibility to healthcare services was reported by many participants since it is a metropolitan area. However, the healthcare infrastructure needs a boost for the large populations that these cities accommodate. Prior research document financial challenges encountered by low-income populations in accessing healthcare [53], which is further compounded by the low number of medical staff and overcrowding in government hospitals. Addressing these systemic inequities is essential for improving health outcomes in these communities.

5 Limitations and challenges

This study should be treated as a baseline exploratory investigation of water, sanitation, hygiene (WASH), and health conditions among informal migrant workers in Mumbai. The study has several limitations that we would like to address in the future. The sample of 100 participants falls below the minimum required ($n = 384$ for 95% confidence level and 5% margin of error as per sample size estimation [54]), limiting statistical power and generalizability. This sample size ($n = 100$) limits our discussion of a causal-effect relationship between the different health determinants and the outcomes of the logistic regression. The exploratory study provides preliminary evidence suggesting disparities in access to water, sanitation, hygiene, and healthcare services among migrant workers engaged in the informal sector of Mumbai's economy. Our descriptive findings indicate potential inequities in water distribution, reliance on shared sanitation facilities, and sub-standard infrastructure that may affect health outcomes. However, these findings require validation in future studies with larger sample sizes. Women were underrepresented despite them being disproportionately affected by lack of WASH infrastructure. Cultural norms and social restraints probably diminished female engagement. The study also has temporal limitation missing seasonal variations in WASH access (e.g., monsoon-related water contamination). Other factors such as duration of residency, occupation-specific risks, or any pre-existing health conditions were not systematically assessed but may have influenced outcomes. Also, neither reported WASH access was verified with physical audits nor any biomarker tests (e.g., water quality tests, health diagnostics) were conducted during this study. A primary challenge was participant's reluctance to engage due to skepticism and mistrust regarding the study's objectives and utility. Respondents frequently questioned the purpose of the inquiry, such as, "Why are you asking such questions?" or "How do you think these questions will benefit you?" Also, interactions revealed hesitancy among certain individuals to openly discuss their water, sanitation, hygiene, and health conditions. This might have led to under-reporting of sensitive issues (e.g., infectious diseases and hygiene challenges). Environmental conditions negatively affected data collection, particularly during the monsoon phase of fieldwork with heavy rainfall and waterlogging disrupting survey administration. The regression findings

should be interpreted within the broader framework of social determinants of health, which recognizes that health outcomes are influenced not only by biological factors but also by living conditions, access to basic services, socioeconomic status, education, and healthcare accessibility [55], Migrant workers often experience multiple vulnerabilities simultaneously, including insecure housing, overcrowding, inadequate sanitation infrastructure, and limited access to social protection, creating interconnected pathways through which WASH conditions may influence health outcomes [56, 57]. Therefore, to achieve SDG 11 (making cities inclusive, safe, resilient, and sustainable) future research should prioritize: (a) representative surveys with larger sample size; (b) mixed-methods designs incorporating qualitative inquiry; (c) longitudinal follow-up to assess causal relationships; and (d) inclusion of objective measures such as water quality testing, health records, etc. to enable a more rigorous assessment of the WASH infrastructure accessibility among Mumbai's migrant populations.

6 Conclusion

Our study documents disparities in access to water, sanitation, and hygiene (WASH), and healthcare services among the migrant workers engaged in the informal sector of the economy. Inequitable water distribution, overcrowded and shared sanitation facilities, and sub-standard infrastructure were identified as key factors affecting health outcomes. Our findings align with current literature, reinforcing the need for infrastructure development and policy interventions to address the problems of urban migrants. Assured access and availability of clean drinking water, safe sanitation and effective hygiene is fundamental to achieving the United Nations Sustainable Development Goals (SDGs) and is critical for promoting good health, reducing poverty, improving education and ensuring gender equity among the vulnerable and marginalized populations such as the migrant communities. To achieve SDG 11 which focuses on making cities and settlements inclusive, safe, resilient, and sustainable, it is important to build community centric resilient urban environments. Migrants should be included in policymakers' focus groups. Their lived experience should influence urban planning. Following these steps will ensure equitable access to safe water, dignified sanitation, effective hygiene, and healthcare services in growing urban centers.

Supplementary Information

The online version contains supplementary material available at https://doi.org/10.1186/s12982-026-02678-4.

Supplementary Material 1.

Author contributions

Conceptualization: NAJ and AC; data curation: AM; formal analysis: AM and NAJ; investigation: AM; methodology and data collection: AM, NAJ and AC; supervision: NAJ and AC; visualization and writing: AM, and NAJ; original draft: AM; reviewing and editing drafts: AM, NAJ and AC; final version: AM, NAJ and AC. All authors have read and agreed to the published version of the manuscript.

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Data availability

All data supporting the findings of this study are contained within the article. Additional information or clarifications can be obtained from the authors upon reasonable request.

Declarations

Ethics approval and consent to participate

Ethical approval was obtained from the Research and Ethics Review Board (RERB) of O.P. Jindal Global University in June 2024 (Letter No: RERB/2024/134) after review of study protocol and data collection instrument. The study was conducted in accordance with the ethical principles outlined in Declaration of Helsinki. Informed consent was obtained from all individual participants included in the study. Given that all participants were adults, no guardian consent was required. For participants who required assistance, the questionnaire was read aloud by the interviewer to facilitate their understanding and consent process. All participants were informed about the aim of the study, confidentiality of data and right to withdrawal from the study at any given time in case of experiencing discomfort. A record of this verbal consent process was maintained.

Consent for publication

Not applicable.

Competing interests

The authors declare no competing interests.

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