

Why Food Stays Contaminated: A COM-B Framework Analysis of Child Feeding Practices in Dhaka's Informal Settlements

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Abstract

Background: Foodborne diseases are the major public health concerns in low- and middle-income countries, particularly during the complementary feeding period. Children become increasingly exposed to environmental pathogens at this age. Food hygiene during this period is critical to prevent such diseases. This formative qualitative study examined behavioral determinants of complementary food hygiene practices in an informal settlement in Dhaka, Bangladesh, using the Capability–Opportunity–Motivation Behavior (COM-B) framework to inform intervention design.

Methods: The study was conducted in the Korail slum, Dhaka, between August 2023 and March 2024. Multiple qualitative methods were employed, including semi-structured household observations (8 hours per household, n=32), semi-structured interviews (n=16), and focus group discussions (3 groups, n=24). Participant selection varied by method, such as observation; households were purposively selected to ensure contextual diversity; interview participants were selected based on observed hygiene practices to explore behavioral drivers; and FGD participants were recruited to capture variation by caregiving experience. Data were analyzed iteratively using thematic analysis guided by the COM-B framework, with triangulation across methods to enhance credibility.

Results: Findings reveal that five key behaviors—food reheating, food and water storage, utensil cleaning, surface cleaning, and hand hygiene are central to reducing microbial contamination and protecting children from enteric infections. Caregivers demonstrated strong psychological capability and reflective motivation, expressing awareness of recommended practices and concern for child health. However, physical opportunity constraints, including irregular fuel access, overcrowded shared kitchens, inadequate storage, distant communal washing areas, and the absence of designated handwashing facilities, consistently limited safe practice. Automatic motivation further shaped behavior, with reliance on visual cleanliness and sensory cues rather than microbial risk influencing routine decisions.

Conclusions: Food hygiene behaviors in low-resource urban settings are constrained by inadequate technical knowledge, structural barriers, and habitual practices. Interventions should address these limitations by combining enabling environments with behaviorally informed strategies that target routine practices. Integrated approaches are essential to improve complementary food hygiene and reduce child exposure to contamination in informal settlements.

Background

Foodborne illness is a foremost public health concern in low- and middle-income countries where unsafe food hygiene practices contribute to widespread microbial contamination [1]. The most recent assessment by the WHO Foodborne Disease Burden Epidemiology Reference Group (FERG) further highlights that foodborne diseases remain persistent globally, accounting for millions of disability-adjusted life years (DALYs) and continuing to pose a considerable strain on public health systems [2]. In these settings, the ingestion of contaminated food is a leading cause of diarrheal disease, particularly among children during the complementary feeding period [3]. From the age of six months, children start

transitioning from exclusive breastfeeding to semisolid and solid foods, as part of complementary feeding [4]. This period coincides with a decline in passive immunity and increasing exposure to environmental pathogens, amplifying vulnerability to enteric infections [5].

During complementary feeding, food hygiene practices within the domestic environment play a critical role in shaping child health outcomes [6, 7]. Unsafe behaviors such as inadequate reheating of food, prolonged ambient storage, improper cleaning of feeding utensils, and inconsistent hand hygiene create multiple exposure pathways to enteric pathogens [8]. These exposures contribute to repeated diarrheal infections that impair nutrient absorption, increase the risk of stunting and wasting, and reduce physical and cognitive development [3]. Subclinical conditions such as environmental enteric dysfunction caused by chronic ingestion of fecal pathogens further compromise intestinal health even in the absence of overt symptoms [9].

In densely populated urban settlements, food preparation and feeding typically occur in single-room households shared by multiple family members [10]. Food is commonly cooked once a day and stored unrefrigerated and often left uncovered on the floor or in broken storage units [11, 12]. The use of untreated tap water to rinse food or utensils, limited access to soap, and the absence of dedicated handwashing areas compound contamination risks. Shared sanitation and water facilities further increase the likelihood of cross-contamination, while pests such as cockroaches and rodents frequently enter food storage spaces [13]. Despite widespread awareness of illness associated with spoiled food, practical constraints prevent caregivers from consistently following safe food hygiene practices [14].

Existing interventions have often targeted individual behaviors such as handwashing without addressing the interconnected and structural nature of food hygiene risks, limiting their effectiveness [15,17]. Some programs have provided enabling tools like safe storage containers and soap, while others have used visual cues, education campaigns, and community engagement to shift social norms around food hygiene [8, 18, 19]. However, many interventions have shown limited or temporary improvements, especially when environmental constraints such as lack of infrastructure and shared sanitation remain unaddressed [16, 17, 20]. There is a need to understand how food hygiene behaviors are shaped not only by knowledge and motivation but also by the availability of resources and physical infrastructure, which are often limited in low-resource urban environments [14, 17]. Caregivers frequently recognize the importance of food safety yet face barriers to acting on this knowledge due to a lack of opportunity and support, such as inadequate access to clean water, soap, and safe storage facilities [8, 12]. Structural constraints, including fuel scarcity, overcrowding, and insufficient storage options, restrict the feasibility of safe food hygiene practices in these settings [11, 14]. Behavioral change in such contexts requires integrated approaches that combine infrastructural improvements with behaviorally informed strategies tailored to the local environment and cultural context [13, 18].

This formative research examines food hygiene practices among caregivers of children aged 6 to 24 months in an informal urban settlement in Dhaka, Bangladesh. Using a behavioral framework, the study explores the factors that enable or inhibit safe feeding behaviors, including how knowledge, physical

conditions, and social expectations interact within the caregiving routine. The objective was to identify specific barriers and facilitators across five critical behaviors related to complementary feeding and to generate actionable insights for the design of an integrated intervention that can reduce food contamination risks and improve child health outcomes in low-resource urban environments.

Methods

Study Design

This was a formative qualitative study guided by the Capability, Opportunity, Motivation–Behavior (COM-B) framework to examine the determinants of food hygiene practices among caregivers. The COM-B model posits that behavior emerges through the interaction of capability, opportunity, and motivation rather than through isolated influences [21]. In this study, capability referred mainly to psychological capability, meaning caregivers’ knowledge and understanding of safe food hygiene practices. Opportunity captured external factors that enabled or constrained behavior, including both physical conditions, such as the availability of soap, fuel, storage, and infrastructure, and social influences, such as norms, expectations, and household support. Motivation encompassed reflective drivers such as beliefs and intentions as well as automatic processes, including habits and emotional responses shaped by cultural expectations and caregiving norms. Together, these elements provided a structured lens to interpret how food hygiene behaviors were enacted, constrained, or sustained in daily practice.

Study Site and Population

The study was conducted in Korail slum, the largest low-resource settlement in the capital city of Dhaka, where the International Centre for Diarrhoeal Disease Research, Bangladesh operates an urban Health and Demographic Surveillance System (HDSS) site. Korail is home to about 60,000 residents, many living below the poverty line and working in low-income jobs. The population is densely packed and shares water and sanitation infrastructure with many households [22]. We accessed the HDSS database and purposively selected participants, guided by the objective of capturing a range of household contexts that influence food hygiene practices. Eligibility was restricted to children aged 6–24 months to correspond with the complementary feeding period. We selected a mix of households with both housewives and working mothers, first-time and experienced parents, as well as senior caregivers, including grandmothers. The HDSS divides the settlement into eight zones, and caregivers were selected from each zone to ensure geographic and contextual diversity. This approach followed the principles of maximum variation sampling, allowing for a comprehensive understanding of behavioral patterns and contextual influences across diverse household settings. In total, 32 caregiver–child dyads were observed, 16 caregivers participated in semi-structured interviews, and three focus group discussions

(n=8 per group, total n=24) were conducted. The demographic and household characteristics of participating caregivers and households are presented in Table 1.

Data collection method

Two separate teams, each comprising two qualitative researchers, were formed for data collection. Before fieldwork, the teams received structured training led by the study's co-investigators and senior qualitative experts to ensure consistency and high-quality data collection. Data were collected in two sequential phases. From August to November 2023, we conducted semi-structured observations and collected environmental samples. In the second phase, conducted between January and March 2024, we carried out semi-structured interviews and focus group discussions (FGDs) to gather comprehensive insights into caregivers' routines, motivations, and contextual barriers.

Semi- structured observation

Semi-structured observations were conducted in alignment with each household's routines for eight hours per household, from 8:00 AM to 4:00 PM, to document daily food hygiene practices within the home environment. Observers recorded structured observations of behavior and storage with a predefined checklist, and wrote unanticipated events related to food hygiene in unstructured field notes. Data were entered in real time on digital forms using the Kobo Toolbox platform, which allowed observers to enter observational notes and coded behaviors simultaneously. Findings from observation guided the design and focus of interviews and focus group discussions. A summary of key household environmental conditions and hygiene practices observed during observation is presented in Table 2.

The English version of the observation checklist is provided as supplementary file 1.

Semi-Structured Interviews (SSIs) and Focus Group Discussions (FGDs)

We conducted semi-structured interviews with caregivers to explore behavioral determinants of food hygiene practices within the COM-B framework. Five priority hygiene behavior themes were identified based on observed practices and laboratory-confirmed contamination patterns. For the interview phase, we identified households with the highest contamination levels and purposively selected them for an interview to better understand behavioral drivers associated with contamination. Interview continued until thematic saturation was reached. In total, 16 interviews were conducted. Following the individual interviews, we conducted three FGDs with caregivers to further explore shared experiences and group dynamics that might not emerge in one-to-one settings. The FGDs were designed to validate and expand on themes identified in the interviews, and to capture collective norms, peer influences, and differences across caregiver roles. Participants of FGDs were purposefully recruited from the same community but were not limited to the 32 observed households in order to broaden perspectives and increase group

diversity. Recruitment was conducted through community networks and household visits. Each session was facilitated by two female moderators using a standardized guide and held in neutral, private community spaces familiar to participants to ensure comfort and openness. To capture diverse perspectives, participants were purposively categorized into three groups (group size, n=8) based on caregiving experience: (1) first-time mothers, (2) mothers or caregivers of more than one child, and (3) older family members, including grandmothers. The English version of the semi-structured interview and FGD is provided as supplementary files 2 and 3.

Data Analysis

We analyzed and integrated household observations, semi-structured interviews, and FGDs using an iterative thematic approach. Observations provided direct evidence of everyday hygiene behaviors. Semi-structured interviews added individual explanations and motivations, and because saturation was reached relatively quickly in interviews, FGDs were used to extend variation and examine group dynamics and shared norms, particularly among the caregivers of different age and parity of children. Data collection and analysis proceeded concurrently. The field team held daily debriefs to document emerging findings, and detailed notes were shared with the research team. All interviews and FGDs were conducted in Bengali (Bangla), audio recorded, and transcribed verbatim before being translated into English for coding. All transcripts and field notes were systematically coded by the qualitative researchers using Atlas.ti 25.0.2. Deductive codes aligning with specific behaviors and determinants were developed a priori using the COM-B framework and refined through weekly coder meetings to ensure consistency. Observation checklists were summarized descriptively using Stata 18, and observation notes underwent thematic analysis. A triangulation matrix was used to compare findings across data sources, identifying convergences that strengthened credibility and divergences that revealed contextual variation.

Results

Preliminary contamination data from food, drinking water, and domestic surface samples, presented in Table 3, showed that food contained the highest pathogen concentrations, followed by domestic surfaces, identifying food as the primary reservoir of microbial contamination, while drinking water contamination was minimal. These observational and laboratory findings informed the selection of five priority food hygiene behaviors for COM-B analysis: reheating food, safe food and water storage, utensil cleaning, surface cleaning, and hand hygiene, as summarized in Table 4. Across these behaviors, unsafe habitual practices and limited physical opportunities—including inadequate storage, fuel scarcity, and lack of dedicated handwashing areas—consistently constrained caregivers' ability to translate knowledge and motivation into practice. Although caregivers expressed strong concern for child health, resource and environmental limitations prevented consistent adoption of safe food hygiene behaviors.

Reheating Food

Children were commonly fed meals prepared for adult family members, with foods such as rice and lentils mashed into semisolid form. Some caregivers prepared separate meals for children, such as semolina and instant noodles, which were quick to prepare and softer in consistency.

During observation, we found that food for children was typically prepared once per day and then fed throughout the day. Caregivers reported rinsing cooked adult foods, such as fish or meat, with tap water to remove spices before feeding them to children. They often relied on family traditions and guidance from elders to prepare meals that children could easily eat. As one caregiver explained:

We usually cook once in the morning and feed the same food throughout the day. If the cooked fish or meat tastes too spicy for my child, I rinse it with water to remove the spices. We've always done it this way.

When asked about reheating practices, caregivers acknowledged their importance for preventing illness and avoiding spoilage, especially during the summer. However, we did not observe any instances of adequate reheating during our eight-hour observation periods. A small number of households reheated food, and of those, the majority just warmed the food, without it reaching a safe temperature. Resource constraints such as limited access to a proper kitchen and inadequate fuel reflect restricted physical opportunity and make it difficult for caregivers to maintain safe hygiene practices.

As two caregivers described the challenges:

We can't always reheat food before feeding the baby—there's no gas. We are using the wood stove, which fills the house with smoke while cooking. The kitchen only has a roof, no walls, so when it rains, the person cooking gets soaked. It's just not possible to keep heating food every time.

And,

Cooking is really difficult. Six of us (family) have to share two gas stoves. The kitchen is so small that we're forced to cook in cramped conditions. Most of the utensils are kept in the bedroom, and the kitchen has only a single burner.

Food and Water Storage

The majority of caregivers reported storing cooked meals for more than four hours, with many keeping leftovers for the next day. Caregivers said they typically covered food to protect it from flies and domestic animals; however, observations revealed that covering was often delayed or inconsistent. Some caregivers believed that covering hot food could lead to spoilage, leading them to use perforated lids or leave food uncovered until it cooled.

Caregivers demonstrated awareness of ideal storage practices, such as keeping raw and cooked foods separate, and storing food in refrigerators or an enclosed meatsafe. However, observations revealed a gap between knowledge and practice: food and utensils were often stored under beds, on the floor, or inside a damaged meatsafe. Meatsafes were rarely used due to pest intrusion or physical damage, limiting their effective use. Some households repurposed meatsafe for non-food items. Caregivers commonly store drinking water in plastic bottles or jars, emphasizing the importance of keeping it separate from other household water. Some who treated water for their children preferred aluminum pots for water storage. However, observations revealed that these pots were often left uncovered, with visible dirt inside. We found that around one-third of food containers were either half-covered or not covered at all during observation. While a few caregivers acknowledged the importance of treating water due to the risk of pathogens, many reported not experiencing any negative health effects from consuming untreated water. Most caregivers mentioned that irregular cooking gas supply was a barrier to boiling water, and others said that water filters were unaffordable. When water became available, caregivers quickly filled any available containers and sorted it into separate jars designated for cooking, handwashing, and drinking.

In nearly every household, we observed insects, especially cockroaches and rats, in rooms where food was stored. Even in households with shelves or a fridge, pests made keeping food safe challenging. One caregiver described the problem:

I have a meatsafe, fridge, and lids for everything, but there are rats. So, if I do not cover the food or put something heavy on top of the lid, the rats get into the food. That is the problem.

All varieties of food were stored inside the bedroom due to a lack of space in the cooking area or because it was deemed riskier to store food in a partially open kitchen.

Utensil Cleaning

In Korail, most households consist of a single multipurpose room used for sleeping, cooking, and food storage, with limited ventilation and no separate kitchen or washing area. Toilets are typically shared among several families, and dishwashing areas are located in communal spaces near toilets rather than near food preparation areas. Water is obtained from shared taps, which are often crowded and subject to interruptions in supply.

Within this setting, mothers were responsible for cleaning utensils in most households. Caregivers said they washed cooking and feeding utensils daily. Many showed awareness of the importance of washing with soap, especially for feeding pots, and recognized visible dirt as a sign of contamination.

Cleaning practices varied based on perceived effectiveness and financial constraints. While most caregivers washed with soap and a scouring pad, some caregivers, particularly grandmothers, preferred

washing with ash, which they believed provided better results. Effectiveness was often judged by visible cleanliness and shine after washing. As one caregiver explained:

I scrub and clean my utensils with a soap bar using a scouring pad. Here, when I cook with a wood stove, I clean the pots and pans with ash. When the bar runs out, I clean with detergent powder. When both bar and powder soap run out, I clean with ash. Cleaning with ash results in the best cleanliness. After cleaning with ash and then rinsing with water, the pots and pans shine.

Although mothers were aware of hygienic practices, constraints in opportunity shaped behavior. All caregivers washed dishes at a communal water tap, which was closest to bathrooms and toilets. There was no place designated for cleaning utensils near the kitchen. Caregivers faced challenges such as inconsistent water supply, the need to store water, and crowding at taps, which made thorough cleaning difficult.

Most mothers knew about boiling bottles for feeding children from healthcare workers. Despite this knowledge, some caregivers said that it was not always possible to boil child utensils and containers such as milk bottles, and they opted to wash them with water instead. As one caregiver shared:

When my baby falls sick, I make sure to use boiled water for everything, including drinking and cleaning bottles. But on regular days, I usually just use tap water because boiling every time takes too much time and cooking fuel.

Some caregivers knew about the health risks of feeding children with dirty utensils. However, reflective motivation varied across routines. Many caregivers stacked dirty utensils in a single bucket, citing lack of motivation, limited time, and competing household chores as contributing factors. This stacking behavior was observed in the majority of households. As one caregiver explained:

With so many tasks to manage throughout the day, I usually stack the utensils and wash them all at once when I have time.

Caregivers reported washing water containers weekly or biweekly. Visible dirt, such as black or reddish discoloration, often triggers decisions to clean. Common cleaning materials included soap, water, and occasionally brick pieces that caregivers believed helped remove buildup.

Some caregivers said they cleaned serving dishes before use, to prevent contamination by insects. In practice, cleaning generally meant a quick rinse of bowls and spoons with water immediately before serving food, without subsequent drying. No caregivers explicitly mentioned drying utensils before storage. Instead, caregivers typically carried dirty utensils in a bowl to the communal washing area and returned the cleaned utensils to the room in the same container. Only 3% of households placed utensils in an inverted position to allow natural air drying.

Domestic Surface Cleaning

Caregivers perceived the use of floor cleaner or detergent powder as the most effective method for cleaning household surfaces. This practice was often learned through employment in other households where they worked as domestic helpers. Participants emphasized daily mopping, with some saying they needed to clean two or three times a day because children frequently played on the floor.

Observations showed that resource constraints affect hygiene practices. Many caregivers had only a single mopping cloth, which was repurposed for multiple tasks, including cleaning floors, wiping children's hands, managing urine spills, covering bedding with plastic, and even serving as a diaper. In most cases, mopping was performed once daily using only water. Floors in Korail slum were mostly compacted earth or wooden planks, with some upgraded homes having uneven concrete slabs. These rudimentary floors were often dusty and covered with dirt.

Children played on floors inside the room or in nearby alleyways that animals could access. When children urinated on the floor, caregivers typically wiped the area with the same cloth, often without using water, and allowed children to resume play. Caregivers said they cleaned utensil storage shelves once every month or two; however, observations showed that these shelves were often dirty and damp, with visible dust and dirt accumulation. Caregivers said that mopping was physically demanding and difficult to perform daily. Some caregivers said they needed insect spray but could not afford it.

Despite these limitations, caregivers were highly motivated to keep living spaces clean, especially where children played, because they believed in the importance of hygiene to prevent illness. This motivation was reflected in daily cleaning routines using floor mopping with water and basic tools. One caregiver said:

I know using floor cleaner is better, I learned that from the house where I work. But at home, I use just water and one cloth for everything. It's hard to mop every day because I don't have enough energy or time. Still, I try to keep the floor clean because my baby plays there, and I don't want him to get sick.

Handwashing

During interviews, caregivers demonstrated knowledge of when and how to wash hands. Half of them learned about handwashing in school, and some mentioned COVID-19 awareness messages. One caregiver explained her understanding this way:

It is necessary to wash hands as they contain germs. If we have to feed children all of a sudden, then our children get ill if we feed them with unhygienic hands.

Caregivers mentioned key moments for washing hands with soap: after toileting, before feeding, after feeding, and after the child defecates. Because many use their left hands for anal cleansing, they tend to wash only that hand with soap after defecation, which may limit the effectiveness of hand hygiene practices.

Although mothers and grandmothers reported knowing how to wash hands, this was not reflected in observations. Caregivers were only seen washing hands with soap after toileting in a small number of observed events, and even then, not all steps of handwashing were followed. Older caregivers emphasized washing hands with soap or ash after toileting and after handling raw fish. Outside the washroom, communal soap was available in some places for hand cleaning after toilet use, while in other places, individuals kept soap in their rooms. After using the toilet, individuals often returned to their rooms to use soap. The soap used was usually the same bar of soap used for bathing and other purposes. Because there were no designated handwashing areas, participants sometimes skipped washing their hands. One caregiver explained:

It is not feasible to keep the (bar of) soap near the toilet because it is often crowded and the chance of getting lost is frequent. As a result, there are times when I do not wash my hands at all, or I only rinse mine and my child's hands with water.

Observations showed that when a child defecated once in a day, caregivers usually cleaned the child and washed their hands with soap. However, when a child defecated multiple times in the same day, caregivers were more likely to rinse hands with water only, skipping soap use.

Reflective motivation facilitated handwashing after toileting because caregivers understood that fecal pathogens can enter the body and cause diarrheal diseases. However, automatic motivation shaped hand hygiene at other key moments. Some caregivers believed that if hands did not have visible dirt, water was enough before feeding. As one caregiver said:

It isn't necessary to wash my child's hands with soap because they spend most of their time in bed. I only use soap to wash their hands during bath time.

Caregivers also used soap to eliminate bad odors after chopping fish or meat or after using the toilet. As a result, soap use was limited mainly to situations with bad odors, reducing the overall frequency of washing hands with soap for both caregivers and children.

Discussion

The study aimed to explore the behavioral determinants of food hygiene practices in urban slum Bangladesh. Based on the COM-B framework, our study unpacked these hygiene practices in urban Dhaka slums and extended earlier work [23], highlighting intergenerational dynamics. A key insight was the resistance of older family members to adopting new practices, which shaped the feasibility and sustainability of behavior change. This underscores the importance of considering household power structures when designing interventions. While we are not yet in a position to present definite evidence for each of these elements of a comprehensive package of interventions to reduce food contamination, we propose the following elements: 1) Cooking and systematic reheating, 2) Safe food storage, 3) Cleaning of utensils for child feeding, 4) Cleaning of domestic surfaces, and 5) Hand hygiene.

Our findings are interpreted using the COM-B framework and contextualized through comparison with

existing studies to identify and propose priority areas for the development of targeted food hygiene interventions.

Evidence strength varies across these five proposed elements. Strong RCT evidence supports hand hygiene with enabling hardware (fixed stations plus soapy water), which increased handwashing and reduced cholera/diarrhea among household contacts in urban Bangladesh and in Malawi. They found that hand washing with soap significantly reduced diarrheal disease among children under 5. [18, 24] Robust trial evidence also supports complementary-food hygiene packages (safe storage, reheating, hygienic feeding) that improved behaviors and reduced child diarrhea in Gambia [25]. Evidence is promising but more limited for kitchen/feeding bundles targeting utensil cleanliness, storage, and reheating. A cluster RCT in Nepal showed sustained behavior change for such a package [15], while a Nairobi proof-of-concept RCT found mixed effects for utensil cleaning/storage despite gains in other food-hygiene actions [26]. Evidence gaps remain for domestic surface/floor cleaning and utensil air-drying racks as standalone strategies with health outcomes; high biological plausibility and observational links exist, but rigorous RCTs demonstrating morbidity impact are few or inconclusive [27].

1) Cooking and systematic reheating: The study found caregivers have typically cooked once daily and reheated food inadequately, often diluting leftovers with untreated water. By “systematic reheating”, we indicate reheating to a temperature adequate to effectively reduce microbial contamination, at every time that a child is fed stored food. Although reheating was perceived as protective, in practice it rarely reached safe temperatures ($\geq 60^{\circ}\text{C}$), [28, 29]. Barriers to systematic reheating consisted of irregular fuel access, smoky shared stoves, and cramped kitchens. Facilitators were caregivers’ belief in reheating’s benefits. Effective interventions should pair simple guidance (e.g., “reheat until steaming hot”) with structural support such as reliable energy access, introduction of low-energy technologies such as solar kettles to reheat small portions of food (instead of waiting in line to access the stove in the shared kitchen), and portioning strategies to reduce prolonged storage [23].

2) Safe food storage: Cooked food was frequently stored uncovered for >4 hours, placed on floors, or left exposed to pests, contrary to WHO guidelines [2]. Even near refrigerators, cockroach and rodent activity created recontamination risks. Misconceptions about covering hot food and reliance on damaged containers undermined protective intentions. These practices mirror earlier findings of microbial contamination, such as coliform and yeast, in children’s food in the Dhaka slum [10]. Evidence shows that behavior change programs improved coverage and separation with partial sustained adoption where emotional drivers persisted, though infrastructure gaps limited broader maintenance [20]. A feasible package might combine behavior counselling with pest-proof containers, immediate covering, elevated racks, and integrated pest management [2]. Our recent randomized controlled trial in Korail found that a low-cost ventilated food-storage cabinet (called Meatsafe) improved food covering and storage practices but did not reduce *E. coli* contamination or caregiver-reported diarrhoea (Rahman 2025).

3) Cleaning of utensils for child feeding: Utensils were washed daily with soap or ash, but bottles were only intermittently boiled, and “clean” was judged by shine rather than safety [30]. Sponges and multipurpose cloths widely reused are known pathogen reservoirs [18]. Reviews of WASH interventions also point out that behavior change efforts frequently neglect detailed hygiene behaviors like safe cloth

use or utensil drying methods [20]. Bundled interventions combining fixed washing niches, soapy-water supplies, separate brushes, and drying racks have proven effective [15] and could fill this critical gap.

4) Cleaning of domestic surface: Floors were frequently mopped with a single multipurpose cloth and water only, leaving uneven surfaces soiled by animals. Infants' frequent hand-to-mouth contact makes floors a high-risk exposure pathway [31]. While WASH trials prioritized water and hand hygiene, surface hygiene has been overlooked [32]. Attention also must be paid to the cleaning of the area where infants are fed: highchairs, mats or tables. Practical solutions include task-specific cloths, regular detergent use, raised racks/shelves to keep items dry, and simple barriers to limit animal access.

5) Hand hygiene: caregivers recognized key handwashing moments, but low soap use and water-only rinsing align well with observations from studies showing that handwashing with soap remains infrequent despite awareness, as reported in behavior change interventions. Evidence supporting soapy-water systems, fixed handwashing stations, and visual cues increasing sustained handwashing is supported by systematic reviews highlighting the importance of infrastructure and environmental cues for improving hand hygiene [33, 34]. The challenge of sustainability without resupply and maintenance plans is also documented, emphasizing that durable hardware and ongoing support are critical for lasting behavior change [33]. Programs should prioritize durable stations at kitchen/toilet thresholds, secured soap containers, resupply systems, and visual cues, while reinforcing washing both hands with soap at key times [35].

Interpretation of Findings Using the COM-B Framework

Applying the COM-B model shows that gaps in food hygiene practice were driven primarily by constraints in physical opportunity and automatic motivation, rather than lack of knowledge or intent. Caregivers demonstrated strong psychological capability, accurately describing recommended practices (e.g., reheating food, handwashing with soap, utensil cleaning) and associated contamination risks. Reflective motivation was also evident, with clear intentions to prevent child illness. In contrast, physical opportunity was consistently constrained by fuel scarcity, shared and overcrowded kitchens, inadequate storage, irregular water supply, distant dishwashing areas, and lack of accessible handwashing stations. Automatic motivation further limited practice, as caregivers relied on habits and sensory cues (e.g., visual cleanliness, absence of flies) rather than microbial risk, leading to inconsistent handwashing, incomplete cleaning, and unsafe storage. Together, these findings indicate that knowledge alone is insufficient to change behavior in low-resource urban settings. Consistent with prior evidence from informal settlements, structural barriers and habitual decision-making undermine safe food handling despite awareness. Effective food hygiene interventions should therefore prioritize enabling environments (energy, water, infrastructure) and target habitual behaviors alongside education.

Strengths and Limitations

This study has several strengths. The use of multi method combined with extensive household observations, semi-structured interviews, FGDs, and microbiological sample analysis. This combination provided both behavioral insights and objective contamination evidence. The systematic application of the COM-B framework offered a structured approach to understanding determinants of hygiene practices and directly informed intervention design. The study achieved data saturation in interviews and complemented that with FGDs to capture diverse caregiver perspectives, including first-time mothers and grandmothers.

However, there are limitations. The study was conducted in a single informal settlement in Dhaka which limits the generalizability of findings to other urban informal settlements or rural contexts. The qualitative nature and relatively small sample size limit statistical power for broader quantitative conclusions about contamination patterns. The timing of data collection across specific months may not capture seasonal variations in food hygiene practices or resource availability. Representation of male caregivers and their roles in child feeding and hygiene could have been explored more comprehensively. Observational data may have been influenced by participants modifying behavior due to observer presence, although extended observation periods and triangulation with interviews likely reduced this effect.

Conclusion

This study reveals that caregivers in a low-resource urban settlement in Dhaka possess knowledge about safe food hygiene for child feeding but face significant physical opportunity constraints and habitual patterns that undermine safe practice. Applying the COM-B framework showed that capability and motivation alone were insufficient to produce consistent food hygiene behaviors without enabling physical opportunity. Structural interventions that improve physical opportunity, such as access to fuel, safe storage, dishwashing systems, and handwashing facilities, must precede and enable sustainable hygiene improvements. Integrated intervention designs that combine infrastructure support with culturally tailored behavioral strategies are needed to reduce food contamination risks and improve child health outcomes in urban low-resource environments.

Abbreviations

LMICs - Low and Middle-Income Countries

WHO- World Health Organization

COM-B - Capability – Opportunity – Motivation - Behavior

WASH - Water, Sanitation, and Hygiene

FERG- Foodborne disease burden Epidemiology Reference Group

DALYs - Disability Adjusted Life Years

HDSS- Health and Demographic Surveillance System

FGD- Focus Group Discussion

SSI - Semi-Structured Interview

Declarations

Ethics approval and consent to participate

The study adhered to the Declaration of Helsinki and received approval from the Ethical Review Committee and Institutional Review Board at icddr, b in Bangladesh (Protocol PR 23079). Written informed consent was obtained from all participating caregivers prior to enrollment.

Consent to Publication

Not applicable

Availability of data and materials

Data are available upon reasonable request. This study was based on the primary data. The data are available from the corresponding author on reasonable request.

Competing interests

All other authors declare that they have no competing interests. AI tools are applied for language editing, complemented by manual language editing by the co-authors.

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Authors' contributions

RH and PW conceptualized the manuscript. RH and RD designed the study. RH, SN, and NA conducted the qualitative and quantitative analyses. RH and SN drafted the manuscript. PJW, RD, MR, MJR, and TMNH critically revised the manuscript for important intellectual content. All authors read and approved the final version of the manuscript.

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Tables

Table 1: Socio-demographic characteristics of the primary caregivers

Variable	Category	In-depth interview (IDI) participants n = 32 (%)	Focus group discussion (FGD) participants n = 21 (%)
<i>Child Age</i>	0-6 months	2 (6.3)	2 (9.5)
	7-12 months	17 (53.1)	11 (52.4)
	13-24 months	13 (40.6)	8 (38.1)
<i>Child Gender</i>	Male	10 (31.2)	7 (33.3)
	Female	22 (68.8)	14 (66.7)
<i>Caregiver Relationship</i>	Mother	28 (87.5)	14 (66.7)
	Other women (grandmother/aunt etc.)	4 (12.5)	7 (33.3)
<i>Caregiver Age</i>	≥18 years	30 (93.7)	18 (85.7)
	<18 years	2 (6.3)	3 (14.3)
<i>Mother's Education</i>	No education	0 (0.0)	8 (38.1)
	Primary	6 (18.8)	6 (28.6)
	Secondary and above	26 (81.2)	7 (33.3)
<i>Household Income (BDT)</i>	<15,000 (<125 USD)	9 (28.1)	6 (28.6)
	≥15,000 (>125 USD)	23 (71.9)	15 (71.4)
<i>Total Family Members</i>	<5	17 (53.1)	5 (23.8)
	≥5	15 (46.9)	6 (28.6)
<i>Fuel Used</i>	Natural gas	21 (65.6)	21 (100.0)
	Liquid Petroleum Gas	4 (12.5)	3 (14.3)
	Traditional cook stoves	5 (15.6)	8 (38.1)
<i>Water Source</i>	Municipal water authority (WASA) line	32 (100.0)	21 (100.0)
<i>Treat Drinking Water</i>	Yes	10 (31.3)	3 (14.3)
<i>Water Treatment Process</i>	Boiling	10 (31.3)	2 (9.5)
	Filter	0 (0.0)	1 (4.8)

Table 2 : Observed household environmental conditions and hygiene practices (n=32)

Variable	Category	(n)	Percentage
<i>Flies or insects observed in the living area</i>	Mosquito	21	65.6
	Fly	30	93.7
	Cockroach	10	31.2
<i>Animals observed in the living area</i>	Cat	2	6.2
	Chicken	1	3.1
<i>Place of chopping during food preparation</i>	Inside the bedroom	16	50.0
	Common space/ yard	2	6.25
	Cooking area	1	3.1
<i>Washed chopping equipment before chopping</i>	No	19	100
<i>Location of cooking place</i>	Inside bedroom	4	12.5
	Common space/yard	4	12.5
	Shared kitchen	24	75.0
<i>Presence of flies or insects in the cooking area</i>	Mosquito	21	65.6
	Fly	30	93.7
	Cockroach	10	31.2
<i>Presence of animals in the cooking area</i>	Cat	2	6.2
	Chicken	1	3.1
<i>Presence of animal feces in the cooking area</i>	Yes	13	40.6
<i>Presence of waste bin in the cooking area</i>	Yes	20	62.5
<i>Type of waste bin in the cooking area</i>	Waste bin with lid	5	25.0
	Waste bin without lid	15	75.0
<i>Cleanliness of food serving utensils</i>	Clean	8	25.0
	Watery	18	56.2
	Dirty	6	18.7
<i>Type of feeding</i>	By hand	24	75.0
	By spoon	11	34.3
	Child feeds itself	5	15.6
	Bottle feeding	6	18.7

<i>Presence of flies or insects in the feeding area</i>	Mosquito	16	50.0
	Fly	28	87.5
	Cockroach	4	12.5
<i>Presence of animal feces in the feeding area</i>	Yes	19	59.3
<i>Utensils used to feed formula milk</i>	Plastic	7	100
<i>Material for cleaning utensils</i>	Water and Soap	12	48.0
	Water and ash	1	4.0
	Water	12	48.0
<i>Keep dirt dishes stacked to once one single time of a day</i>	Yes	27	84.3
<i>Do they dry utensils</i>	Yes	1	3.1
<i>Cleanliness of Utensils storage place</i>	Clean and dry	1	3.1
	Watery	18	56.2
	Dust	13	40.6
<i>Do they reheat food</i>	Yes	8	25.0
<i>Type of reheating</i>	Correctly reheat food	3	37.5
	Just warm the food	5	62.5
<i>Do they add ingredients while reheating</i>	Water	1	12.50
<i>Drinking water storage</i>	Plastic	21	65.63
	Aluminum	4	12.5
	Melamine	4	12.5
	Still	3	9.38
<i>Cooked food storage place</i>	Meatsafe	21	65.6
	Freeze	1	3.1
	Floor in living room	8	25.0
	In Kitchen	1	3.1
<i>Storing type</i>	Fully covered	20	62.5
	Half covered	4	12.5
	Not covered	13	40.6
	Not stored food	2	6.2

<i>Type of sample</i>	Store food	24	24.74
	Cooked food	47	48.45
	Reheated food	15	15.46
	Local food	11	11.34
<i>Household has a handwashing area</i>	Yes	28	87.5
<i>Resources available in handwashing area</i>	Only water	21	75.0
	Water and soap	7	25.0
<i>How far the toilet (number of steps) from the kitchen</i>	<5	8	25.0
	>5	24	75.0
<i>Resources available in the toilet</i>	Water	17	53.1
	Soap	1	3.1
	Water and soap	7	21.8
<i>Type of waste bin in this household</i>	No bin	7	21.8
	With lid	12	37.5
	Without lid	18	56.2
	Only polythene bag	2	6.2

Table 3:Prevalence of different pathogens identified in food, drinking water and domestic surface samples (n=193)

Pathogen types	Any food N=97	Cooked (N=47)	Stored (N=24)	Reheated (N=15)	Snacks (N=11)	Domestic swabs (N=64)	Drinking water (N=32)
Any pathogen							
V. cholerae		5 (11%)	4 (17%)	1 (7%)	2 (17%)	37 (58%)	--
B. cereus		2 (4%)	5 (22%)	3 (20%)	1 (8%)	35 (55)	--
S. aureus		--	4 (17%)	2 (13%)	2 (17%)	32 (50%)	--
C. perfringens		--	2 (9%)	--	--	18 (28%)	--
V. parahaemolyticus		--	--	1 (7%)	1 (8%)	2 (3%)	--
Rotavirus		1 (2%)	1 (4%)	--	--	6 (9%)	11 (34%)
Norovirus (GI)		1 (2%)	2 (9%)	1 (7%)	--	5 (8%)	2 (6%)
Norovirus (GII)		--	--	--	--	--	1 (3%)
E. coli O157		--	--	--	--	--	--
Salmonella		--	--	--	--	--	--
Shigella		--	--	--	--	1 (2%)	--

Note: *(--) pathogen was not detected

Table 4: Justification for selection of major hygiene behavior themes based on observational and laboratory findings

Hygiene Behavior Theme	Key Observational Findings	Related Laboratory Findings	Justification
1. Cooking and Reheating	<ul style="list-style-type: none"> -25% of food was reheated -Of those, 62.5% only warmed the food -12.5% added water during reheating 	Food samples showed microbial load despite cooking	Inadequate reheating fails to eliminate bacteria that may have grown during storage. Reheating food to $\geq 70^{\circ}\text{C}$ is vital to reduce foodborne pathogens (FSA, 2023; PMC, 2024).
2. Food and Water Storage	<ul style="list-style-type: none"> -40.6% stored food uncovered or partially covered -48% used plastic containers for water storage -56.2% stored utensils in wet areas 	-41% of food and -33% of water samples were contaminated at least with one pathogen	Improper storage creates favorable conditions for microbial growth and cross-contamination. WHO links poor storage to diarrheal pathogens like <i>E. coli</i> and <i>Salmonella</i> .
3. Utensil Cleaning	<ul style="list-style-type: none"> - 97% did not dry utensils - 84.3% stacked dirty dishes once daily - 48% used only water to clean utensils 	Indirectly linked via contaminated food/water samples	Wet or inadequately cleaned utensils can harbor bacteria. Studies show strong links between utensil hygiene and diarrheal illness (Islam et al., 2013; Luby et al., 2007).
4. Domestic Surface Cleaning	<ul style="list-style-type: none"> -93.7% had flies in cooking areas -31.2% had cockroaches present -65.6% had mosquitoes in living/cooking areas - Up to 87.5% had fly presence in feeding areas 	80% of environmental swab samples were contaminated with any pathogen	Dirty surfaces and pests facilitate microbial spread. Environmental hygiene is essential for safe food prep (Boone & Gerba, 2007; Ejemot-Nwadiaro et al., 2015).

5. Hand Hygiene of the primary caregiver	- 75% fed children by hand - 18.7% used unclean utensils	Implied in food and environmental contamination	Hand-to-mouth feeding and unclean utensils raise the risk of pathogen transfer. Hand hygiene is a critical control point (CDC, 2020).
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Supplementary Files

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- [Supplementaryfile1Observationchecklist.docx](#)
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