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Research Paper

Behavioral influences on risk of exposure to fecal contamination in low-resource neighborhoods in Accra, Ghana

J. Hurd, M. Hennink, K. Robb, C. Null, D. Peprah, N. Wellington, H. Yakubu and C. L. Moe

ABSTRACT

Rapid urbanization in low-resource countries has led to a growing sanitation crisis, with widespread fecal contamination and risk of adverse health outcomes. Understanding how to change sanitation behaviors and reduce exposure to fecal contamination is central to Sustainable Development Goal 6. This study examines behavioral influences on fecal contamination in six low-resource neighborhoods of Accra, Ghana. Qualitative data comprised 12 key informant interviews with community leaders and 16 focus group discussions with residents. Results identify behaviors that increase the presence of feces in urban neighborhoods and risk of exposure to fecal contamination. Significant barriers to access and use of public and private latrines led to a range of defecation and excreta management practices. These methods of fecal disposal, together with poor sanitation services (i.e. refuse collection, public drainage, public latrines), environmental conditions (i.e. wind, rain), and employment activities (i.e. fishing, hawking), exacerbate the spread of feces and risk of exposure to fecal contamination. The transfer of fecal contamination between public and private domains creates repeated risk of exposure to fecal contamination for residents during daily activities. This pervasiveness of fecal contamination in the environment, suggests the need for multi-sectoral approaches to reduce fecal contamination that go beyond provision of public or private latrines.

Key words | Accra, behavior, fecal contamination, Ghana, qualitative research

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INTRODUCTION

The Sustainable Development Goals (SDG) have highlighted the need for interventions to improve the health of populations in developing countries, including improvements in water, sanitation, and hygiene (UN 2016). Specific SDGs focus on providing access to safe sanitation facilities and eliminating open defecation by 2030 (SDG 6.2), involving local communities to improve sanitation management (SDG 6), reducing epidemics, deaths, and illness due to waterborne contamination (SDG 3.3 and 3.9), and reducing under-five mortality to at least 25 per 1,000 live births, a goal that would necessitate reducing diarrheal disease and other sanitation-related health effects (SDG 3.2) (UN 2016). To change sanitation behaviors and meet the SDGs, there needs to be a better understanding of the context and pathways of fecal contamination for residents of low-resource urban neighborhoods.

The population in sub-Saharan Africa is expected to continue to increase at a rapid rate, from 414 million in 2012 to

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1.2 billion in 2050 (UN 2012), placing further pressure on limited sanitation access (AMCOW 2012). As the urban population increases in sub-Saharan Africa, so too has the number of people practicing open defecation as their primary sanitation behavior, increased from 16 to 25 million (AMCOW 2012). In urban areas of Ghana, an estimated 73% of the population relies on shared sanitation facilities, higher than any other country (WHO/UNICEF JMP 2015). Furthermore, open defecation and use of plastic bags for defecation are still common practices in low-resource urban neighborhoods because of the low use of pay-per-use latrines, especially among children (Peprah *et al.* 2015). Therefore, improved management of public latrines, including improved management of fecal sludge, especially in low-resource communities in Accra, Ghana, is needed in order to eliminate open defecation. In homes or neighborhoods, there are private latrines and public latrines. A private latrine is a facility within a private household or shop. It may contain a fecal sludge tank (septic tank) that needs to be emptied regularly. Types of private latrines include bucket/pan latrines, pit latrine with slab, ventilated improved pit latrine, and pour flush toilets and may be single-family latrines within the household or shared latrines that are used by 1–3 families. Public latrines are defined as a facility that is pay-per-use and are available at a cost per use to everyone in the neighborhood (Awoke & Muche 2013). In the public domain, which includes beaches, markets, schools, and religious places of worship, there are few free latrines (Boot & Scott 2009), and the population must rely on public latrines (WHO/UNICEF JMP 2015).

In order to develop strategies and programs to decrease health risks associated with poor sanitation and exposure to enteric pathogens, the areas of fecal contamination must be accurately identified. The risk of exposure to fecal contamination varies based on people's daily activities and behaviors (Jenkins & Curtis 2005). Populations who come in contact with human feces are at risk of disease (Schriewer *et al.* 2015). By identifying residents' exposure to fecal contamination in their daily activities; we can develop focused approaches to risk reduction (Jenkins *et al.* 2009). This study uses key informant interviews, focus group discussions, and observational transect walks to examine household and community behaviors that place residents at risk of exposure to fecal contamination in low income areas of Accra.

METHODS

Study design

This study is part of the larger SaniPath Study, which aims to characterize the pathways of exposure to fecal contamination in low-resource, urban settings. The rationale and design of the SaniPath Study is described in detail elsewhere (Robb *et al.* in press). This parent study utilized a mixed-methods approach to collect quantitative environmental microbiological data and survey data on the exposure behaviors that bring people, especially children, in contact with fecal contamination. Qualitative data were used to identify the context of fecal exposure pathways that may not be captured using quantitative methods, and inform the design of the survey and structured observation protocols. This paper focuses on the analysis of the qualitative data from the SaniPath study.

Study sites

This study was conducted in Accra, the capital of Ghana, with a population of approximately 2.3 million people (GSS 2014). Accra comprises densely populated urban slums (the term 'slum' is defined as a neighborhood that lacks access to improved water or sanitation, security, durability of housing, and/or sufficient-living area (United Nations 2015), and in a locality characterized by poor road conditions, open drainage systems, and lack of improved sanitation facilities or adequate drinking water). One-third of the population of Accra does not have access to a private latrine and rely on other forms of fecal disposal (GSS 2014). Six low-resource neighborhoods in Accra (Alajo, Nima, Shiabu, Old Fadama, Bukom, and Madina) were selected for this study, and reflect diversity in population characteristics, such as culture (ethnicity and religion), employment, geographic location (coastal vs. inland neighborhoods), and infrastructure (proximity to refuse dumping sites, coverage of private and public latrines, and squatter settlements). These characteristics were deemed important for this study as potential influences on sanitation behaviors. In addition, many residents in the study neighborhoods rely largely on communal latrines and open defecation.

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Data collection

Data were collected through key informant interviews and transect walks with community leaders and focus group discussions with community residents, as described below. Data from key informant interviews were used to refine the instrument for focus group discussions. Data were collected in both English and local languages by a trained field team with experience in qualitative research and knowledge about the sanitation issues in the study sites. The field team completed CITI ethics training and the study received ethical approval from Emory Institutional Review Board and the Noguchi Memorial Institute Review Board. Data were collected from October 2011 to May 2012.

Key informant interviews and transect walks

A total of 12 key informant interviews and six transect walks, a type of walking interview through the neighborhood of interest, were conducted with community leaders from each study neighborhood (De Leon & Cohen 2005; Evans & Jones 2011). Community leaders were comprised of chiefs and local representatives familiar with neighborhood issues. They were identified in collaboration with local government officials in the Accra Metropolitan Area (AMA) and TREND research consultants. Key informant interviews were used to understand sanitation issues, practices, and facilities in each neighborhood. A semi-structured interview guide was used that included the following topics: role of the community leader, neighborhood facilities (clinics, hospitals, schools, etc.), and local sanitation conditions and issues. Following the interview, a transect walk with each community leader was conducted at key locations in the neighborhood, such as the markets, schools, beaches, and residential areas, to observe sanitation conditions and behaviors (e.g. public latrines, defecation sites, refuse dumping). During the transect walk interviewers discussed the facilities, conditions, improvements, and challenges at each location. Transect walks are a valuable tool to capture both interview and observational data of physical conditions within each neighborhood and are used to triangulate data from interviews and focus group discussions (Brown & Durrheim 2009; Carpiano 2009; Holton & Riley 2014). Data from key informants were captured via a digital recorder and note-taker.

Focus group discussions

Sixteen focus group discussions were conducted with mothers (14 groups) and fathers (two groups) of children under 12 years of age. This study population was selected due to the increased risk of enteric disease amongst young children. Focus group discussions were used to identify community norms surrounding daily sanitation practices and residents' perceptions of fecal contamination risk through routine daily activities. Each focus group was comprised of six to eight participants who were recruited purposively with the assistance of community leaders to provide diversity in the number and age of their children, employment activities (e.g. hawkers, market sellers), and their location of residence in the neighborhood. A discussion guide was developed and refined using issues raised in the earlier key informant interviews, and covered the following topics: daily routines of adults and children, sanitation practices (i.e. latrine use, defecation, and refuse disposal), water sources and storage, and perceptions of risk of being exposed to fecal contamination. Sixteen focus groups were deemed sufficient to reach data saturation for the concepts in this study, the point at which no more new concepts emerged from the discussion groups (Morse 1991). All focus group discussions were digitally recorded and a note-taker was present.

Data analysis

All interviews and group discussions were translated into English and transcribed verbatim. All data were de-identified and entered into MaxQDA10 software (Marburg Germany 2010) for analysis. The grounded theory approach (Glaser & Strauss 1967) guided data analysis, and was selected to enable core themes to be identified and linked into a broader conceptual process to understand the complex pathways of exposure to fecal contamination. Data analysis included the following tasks. First, data were thoroughly read and memos developed to distinguish core themes. A codebook of themes was developed, including both deductive codes from topics in the interview guides and concepts from the literature, and inductive codes from data itself (e.g. feces dumping practices, refuse collection practices, risk perceptions, etc.). Inter-coder agreement was conducted between two qualitative researchers using tools in MaxQDA10 to

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assess and improve consistency in coding data. All data were coded with themes from the codebook and codes were used to search for key themes in data. A detailed description of each theme was developed, and patterns identified through comparisons by population characteristics (e.g. geographic location, culture, gender, socioeconomic status, etc.). Connections between themes were identified and related themes grouped into broader categories (e.g. latrines, open drains, refuse disposal, etc.). A conceptual framework (Figure 1) was then developed to summarize core themes by categories and display their interconnections to depict behavioral influences on the risk of exposure to fecal contamination reported in the study neighborhoods. These findings were validated at each stage of analysis by using an iterative process to develop themes, categories, and connections and to ensure all were well supported by data. Additionally, the concept-indicator model (Strauss 1987) was used to confirm all components of the conceptual framework, which were validated with the data.

RESULTS

Figure 1 displays the study results in a conceptual model that highlights behaviors that increase fecal contamination in the environment and behaviors that increase residents' risk of exposure to the fecal contamination, which could contribute to morbidity in the study communities. The results section is structured to summarize each component of the model and the interconnections between components. First, the use of public and private latrines is described, highlighting problems that lead to alternative methods of fecal disposal. Next, alternative methods of fecal disposal are identified and the ways in which environmental conditions, neighborhood infrastructure, and refuse disposal practices exacerbate the spread of feces and risk of fecal contamination throughout low-income neighborhoods are explored. Overall, this conceptual model identifies how residents of low-resource neighborhoods are at *continued* risk of exposure to fecal contamination during their daily activities. Furthermore, it shows how fecal contamination in one domain (e.g. market, public latrine, or recreation areas) could be transferred to other domains (e.g. school or household) thus contributing to pervasive fecal contamination and continual re-contamination.

Latrine use

Participants distinguished two types of latrines in the study sites, public and private, each of which have different influences on their use (shown in the upper section of Figure 1). Participants reported that private latrine ownership was low and there were significant barriers to using public latrines, as described below.

Private latrines

Private latrines were uncommon in the study communities, but were available in some households and commercial shops for staff use. Those with a private household latrine described the high costs of maintaining their latrine. They reported that water was scarce and costly in the dry season, and residents had to walk long distances to find water. During the dry season, water use was prioritized for food preparation, not for sanitary purposes such as flushing latrines, hand washing, or cleaning latrines. In addition, private latrines required constant cleaning, repair and fecal sludge removal, which owners found an incessant task that deterred their use of the latrine; therefore, many private latrines were not used regularly or were in disrepair.

In the study communities, fecal sludge removal and spillover were also disincentives for private latrine ownership. Fecal sludge tanks were emptied routinely via large trucks, which were costly and often arrived later than requested by residents (often several days later), leading to non-use of the latrine at this time. One female participant described how fecal sludge tanks often overflowed in her neighborhood:

> '… *there are some [fecal sludge tanks] there, you will see that they are never emptied. So those ones, when it starts raining … they open them … so you will see that [fecal sludge] is flowing. It is disturbing us in the area, and we are always complaining, but we can't get anybody to say that he will correct [this problem].*'

The cost of building a private household latrine was also a significant barrier. Participants mentioned that competing

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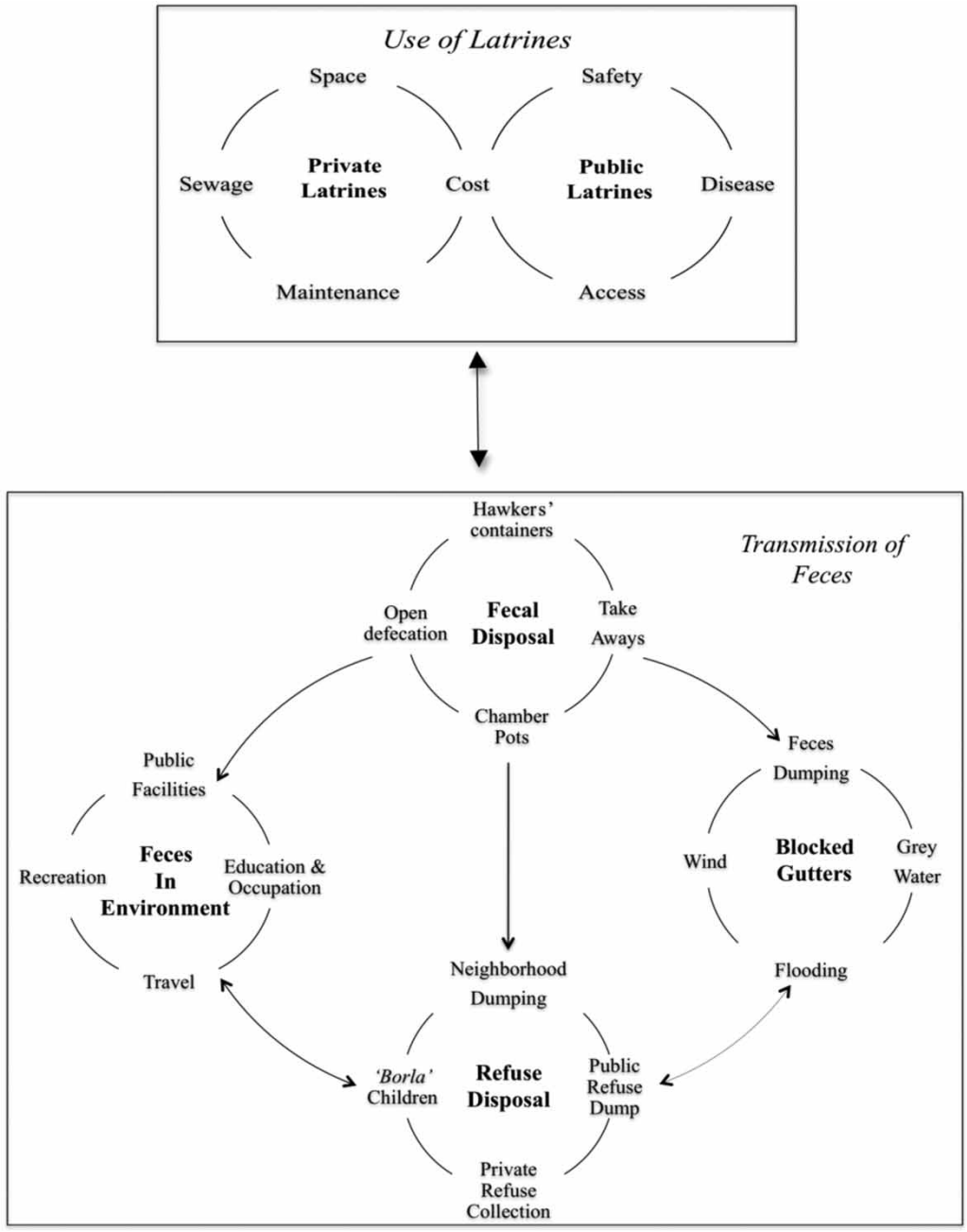

Figure 1 | Behavioral influences on fecal contamination in study neighborhoods.

household demands, such as food and school fees, meant they could not afford to build a private latrine in their home. In the densely populated study neighborhoods, there was little space to construct a private latrine or install a fecal sludge tank. If a household latrine was desired, it meant losing valuable living space in already cramped living conditions.

Public latrines

Although public latrines were available in the study neighborhoods, their use was limited. Residents were deterred from using public latrines because of the recurring costs associated with their use. A public latrine costs 15–50

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pesewas (US$0.06–0.18) per use depending on the type of latrine: flush latrines were the most expensive, followed by different open pit latrines (e.g. block and cement). Public latrine use became particularly costly when a family member had diarrhea, or among large families (>4 children) because of the high number of latrine visits per day. One woman described how public latrine use was unaffordable for her family:

> '*I have five children, and if all of them have to use the latrine every morning at 20 pesewas [$0.07] each, including me, then we will be spending close to 2 cedis [$0.75] while we have not eaten […].*'

The lack of regular cleaning of public latrines was also a barrier for their use. Many participants, especially women, believed that using unclean public latrines had a high-risk for disease, such as vaginal yeast infection, from touching a 'dirty' latrine seat. Additionally, participants generally perceived the foul smell of public latrines to be a health risk. They reported the need to change their clothes or bathe after using a public latrine, and therefore preferred not to use one. Parents not only feared disease, but also for the safety of their children when using a public latrine, particularly for small children who could fall into the latrine.

Participants also expressed concerns about difficulties with access to the public latrine in their neighborhood. Many complained of long lines at the public latrines in the morning when they urgently needed to use the facilities; this issue was particularly problematic for children. Due to their inability to wait their turn for a public latrine, participants often used other forms of fecal disposal. One woman described how long lines at the latrine led to alternative fecal disposal for her child.

> '*There is a public latrine for the children. But sometimes when you take them there, there may be too many kids waiting to use the place, so you will have to return home and look for a bag for the child to defecate into it, and combine it with your rubbish.*'

In other locations, public latrines were far away so participants used more convenient forms of fecal disposal such as 'take aways' (which involved defecating in a plastic bag that was tied and discarded), open defecation, chamber pots, and hawker's/vendor containers (discussed below).

Transmission of feces

Due to the problems with public and private latrines described above, four alternative methods of fecal disposal were commonly used by residents in the study neighborhoods, including: 'take aways', open defecation, chamber pots, and hawker's/vendor containers (shown in the lower section of Figure 1). These alternative methods of fecal disposal led to an increase of fecal contamination in neighborhoods, and its spread through refuse disposal systems and public drains, thus increasing residents' risk of exposure to fecal contamination. Participants described the circumstances that led to alternative methods of fecal disposal and how these methods contributed to the distribution of fecal contamination in their neighborhoods.

Alternative fecal disposal methods

The most common alternative method of fecal disposal was a 'take away'. Participants bought plastic bags for 'take aways' for 5–10 pesewa each [US$0.02–0.04] from public latrine attendants, or in bulk at the market. 'Take aways' were typically used to dispose feces when in public places (e.g. beach, market, streets, etc.), but were also used for fecal disposal in private households. Participants used 'take aways' at home because they were convenient when they had diarrhea, safer than walking to a public latrine at night, cheaper than using a public latrine, and when private latrines were in disrepair. When used at home, 'take-aways' were often disposed of in private latrines, but when used in public areas they were disposed of in the public domain, such as open drains, streets, or garbage containers of other residents.

A second method of fecal disposal was open defecation, typically in open areas in the neighborhood, such as streets, open drains, behind buildings, in the sand or water at the beach, and on railway tracks. Participants stated that open defecation was convenient and inexpensive compared to walking long distances to latrines or paying for public latrines or the bags for 'take aways'. Men, women, and children practiced open defecation in private and public

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settings; however, open defecation was most commonly mentioned among adult men in public settings, as described by a male participant:

> '*Yes there are many places [to defecate] as you can see. Behind us is the beach. Some go to the beach, while others use the rocky area at the beach and under the bridge area at the beach. It is because we have little money to go pay for the public latrine. Also the fresh air at the beach make[s] you feel free.*'

Open defecation on the beach was most common amongst residents living adjacent to the beach, particularly among men and children at night. One woman described:

> '*Reaching the beach, you will see feces all over. Unknowingly (you) step in the feces; sometimes people dig holes and shit inside it, and unknowingly (you) step on it and it splashes on (your) sandals so (you) will need to use the seawater to wash the toilet away.*'

Men, women, and children practiced open defecation. Participants described how young children who were not trained or able to use a latrine often defecated in streets, drains in the market, in the rocky areas, or under a bridge at the beach, or within their household compound. One woman described why children defecated on the ground in a household:

> '*Someone may not have trained her child in using the chamber pot, so when the mother is not around or even at times when she is at home, when the child says 'Mum, I will go to toilet', she will say 'go and spread a paper on the ground and shit', and after that, she will ask the child to pick the feces to dispose it. So in this area, when you see a child with 'take away', the child is on his way to throw the toilet away.*'

Chamber pots were another method of fecal disposal used by both adults and children. Small children who were unable to use latrines also used chamber pots that were then dumped into a latrine. Adults also used chamber pots, as they were quick and convenient especially in evening or early morning when they were afraid to use the public latrine. Elderly adults used chamber pots due to difficulties in walking to a public latrine or when joint discomfort did not enable them to squat for open defecation.

Women working at the market frequently used another method of fecal disposal. Although market women practiced open defecation, they preferred using containers for fecal disposal. Market workers described keeping a small container, under their market stall in which they would defecate during the day and keep covered until the end of the day when they dumped the contents into market refuse bins, in public drains, or in the streets. This strategy meant that they would not lose customers while going to defecate during the day. This form of fecal disposal was not as common as other methods mentioned above, but was a typical practice for market workers and street vendors.

Fecal contamination in the environment

Participants described how the alternative methods of fecal disposal described above led to increased fecal contamination in the environment, which was then spread throughout the neighborhood via four mechanisms of daily living (see Figure 1): recreation, occupation, traveling between neighborhoods, and while using public facilities (e.g. latrines and bathhouses).

Recreation activities often happened in the same areas as open defecation and thus contributed to the spread of feces, particularly at the beach or open areas in residential neighborhoods. Participants often complained that it was difficult to avoid contact with feces on the beach and while swimming, particularly for children. They described that both children and adults defecate into the water while swimming, and come into contact with feces while playing on the sand. Therefore, the beach was described as a particularly high-risk area for fecal contamination. In residential areas, children often play in the streets and on vacant land where open defecation is practiced, thereby coming into contact with feces and bringing it into their homes on shoes and hands.

Occupational activities (e.g. fishing and truck driving) also transmitted fecal contamination in the environment. Fisherman often dragged fishing nets over the beach sand to repair nets or sell fish, thus spreading feces from open defecation in beach sand to the fishing nets and onto the

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fish, fisherman, and customers, placing all at risk of exposure to fecal contamination. This situation is described below:

> '*… the fishermen are also to blame … because when they go to sea and return, when the net is in the canoe it's difficult to pull the canoe ashore … and you see them dragging the net on the ground through the feces to take the fish [up] the hill*'.

Occupational spread of feces is not limited to fishermen. Fecal contamination was also spread in residential neighborhoods when trucks drove over 'take aways' discarded in the streets or in overflowing garbage bins, resulting in feces splashing over streets, walkways, and pedestrians. Participants were very concerned about getting splashed with feces, which would then be transferred to their homes, increasing their risk of disease. Feces were also spread in the environment during hawking (e.g. selling goods) by the roadside or in the market. When residents went hawking, they had to pass through contaminated rail tracks, and step through overflowing drains containing 'take aways' around the market as they were wandering to solicit customers, thereby continually coming into contact with and spreading fecal contamination in the neighborhood.

A further method of fecal transmission throughout neighborhoods was simply attributed to people walking through contaminated streets during their daily activities. Participants noted that there was often garbage in the streets that contained 'take aways' which blocked the streets and walking paths. Therefore, residents spread fecal contamination throughout the neighborhood and into their homes and workplaces during their daily routines. This situation was exacerbated during the rainy season when drains overflowed and washed refuse and feces into surrounding streets where residents passed. Furthermore, during rainstorms, fecal sludge tanks overflowed washing additional fecal matter into surrounding streets. Therefore, it was nearly impossible for residents to avoid contact with feces, and they continually transmitted fecal contamination through their neighborhood.

Finally, feces were also spread in the environment when residents used public bathhouses. Participants stated that people often defecated in the shower stalls of the bathhouse because they did not want to pay to use the latrine in addition to using the shower. In addition, participants also described using 'take-aways' while bathing and disposing these into a bucket inside the bathhouse. This behavior clearly exposes bathhouse users to fecal contamination.

Refuse disposal

Public and private methods of refuse disposal also contributed to fecal contamination (see Figure 1). As described above, household refuse often contained feces from 'take aways', diapers, chamber pots, and market centers; therefore, wherever refuse was present, feces were also likely present. In addition, not all residents could afford to pay for refuse collection, so instead dumped their refuse in public drains. Thus methods of refuse disposal have the potential to further spread fecal contamination in neighborhoods.

Although some residents used private refuse collection services, these services contributed to the spread of feces in neighborhoods due to their unreliable schedule. Private refuse collection companies in Accra, collect garbage from private refuse bins that are provided to customers for a fee. However, some residents could not afford to pay for services from these companies and discretely disposed of their garbage in neighbor's refuse bins, causing these bins to overflow onto the streets. Participants complained that the collection schedules of these companies were unreliable, and they often arrived three or four days late, leading to overflowing refuse bins on the street. Also, the waste collection companies only collected garbage that was inside the bin leaving any overflow on the streets, and hence contributing to a buildup of refuse in the streets. One woman described her frustration with this situation:

> '*Now the dustbins that are being provided, that is, the [waste collection company]; not everybody has money. As for me, in my house, I have the big and small one, but it is not everybody who has [a bin] … For me, before I wake up some people would put rubbish behind my store, and I have to add it to [my bin]. Also these [waste collection company] people, if dustbins are full and they came today, say Wednesday, it may happen that they will not come the following Wednesday*

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but Saturday … so we have put the excess rubbish boxes beside our main bin, they will collect the main bin and leave the others.'

Other private methods of refuse collection involved paying *borla* (garbage) children a small amount (e.g. 20–70 pesewas or US$0.07–$0.25) to take household refuse to the public refuse dump. However, *borla* children often kept the money for themselves and would not collect the garbage or dump it in the neighborhood. One participant described these *borla* children:

'*… there are some children who move about requesting to dispose of the rubbish for a fee. Such children take the money and collect the rubbish, and when they get to an alley and there is nobody watching them, they drop it there and run away.*'

Blocked drains

Participants also became exposed to fecal matter that was dumped in public drains via takeaways, grey water, or from the wind or rain (see Figure 1). Participants felt their constant contact with public drains put them at high risk of exposure to fecal contamination.

Participants described how they were often in contact with refuse, and therefore feces, in public drains during their daily activities. Children walked through uncovered public drains while playing in the neighborhood or when walking to and from school. One woman described how children are exposed to feces when defecating into open drains:

'*Yes, they squat by the big gutter [open drains] and ease themselves into it. Sometimes some of the children even fall into the gutter.*'

Although children were unaware of the heightened risk from walking in drains, adults were hyperaware of the risk, particularly if they had an open wound (e.g. cut). Participants also mentioned dumping 'grey water' (household wastewater) into public drains, which would become mixed with fecal waste in the gutter. When the drains became blocked and overflowed the now contaminated grey water would overflow onto surrounding roads, thereby spreading fecal contamination onto the roads and walkways. Participants also increased their risk of exposure to fecal contamination by moving 'take aways' with their hands so that the drain did not flood their house. One woman described how her neighbor poured grey water into a blocked drain, and it overflowed onto the surrounding roads.

'*Please, you will see toilet [in the open drain] … so the person who lives close the gutter has [been] blocked [on] both sides. This prevents the water from flowing directly through the gutter, so it flows through another direction, and if you have to pass by [the open drain], then you will pass through the mud [from the open drain] to wherever you are going to.*'

Furthermore, environmental conditions, such as heavy wind or rain, moved fecal contamination in the neighborhood in two ways. First, the wind blew contaminated refuse out of the drains into surrounding streets and into households. Women then swept this refuse from their homes and collected it, often by hand, to dump it back in the drain or into their private refuse bin, thus directly contacting refuse contaminated with feces. Secondly, wind blew refuse from private bins into the drains, thus transferring contaminated waste to drains. During heavy rain, when the drains were filled with refuse, the waste spilled into the doorsteps of residents. Overall, each component of fecal transmission identified in Figure 1 contributed to pervasive fecal contamination throughout low-resource neighborhoods.

DISCUSSION

This study provides an important understanding of the behavioral influences on fecal contamination and exposure to this contamination in low-resource urban neighborhoods. The use of qualitative research methods provided access to study participants' own experiences, perceptions, and reasoning that influence behaviors reported. This enabled a more detailed understanding of methods of fecal disposal, modes of fecal contamination, and residents' perceptions of risk, than has been reported elsewhere. Viewing these issues from the lens of study participants' daily lives also provided a contextual understanding of the social complexities and

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multi-faceted contributors of fecal contamination in the study setting. Furthermore, the grounded theory approach to analyze these qualitative data not only enabled a delineation of different types of behaviors (i.e. fecal disposal strategies), domains in which they occur (i.e. residential, commercial, recreational), and contributing systems (i.e. refuse collection, drainage) that influence fecal contamination; but also how the interconnections between these components exacerbate fecal contamination in low-resource neighborhoods. Our explanatory framework of fecal contamination, based on participants' own experiences, differs from much previous research, which typically focuses on a single behavior (i.e. hand washing) or a single domain (i.e. public latrine or household) without attention to the influence of broader contextual components on fecal contamination

This study provides important information on behavioral influences on fecal contamination in low-resource urban neighborhoods, which contributes directly to SDG 6. Our results identify both the behavioral and service-related contributors to fecal contamination in the study communities, and how these are interrelated. We identify specific behaviors that increase fecal contamination in urban neighborhoods and other behaviors that increase exposure to contamination from fecal sludge. Our study shows significant barriers to using both public and private latrines in low-resource neighborhoods, which lead to a wide range of alternative methods of fecal disposal beyond simple open defection (e.g. 'take-ways', hawkers'/vendors' containers, chamber pots, public bathhouses). These behaviors increase fecal contamination in communities, and we detail not only *why* these behaviors occur in specific domains but also *how* each behavior contributes to fecal contamination and exposure. In addition, we identify how services designed to manage fecal sludge can also contribute to increased contamination in communities and an elevated risk of exposure to feces. Thus an important finding of our study is the intersection of behavioral and service-related influences that multiply the risk of exposure to fecal contamination and put residents at elevated risk for disease. For example, we show how methods of fecal disposal intersect with sanitation services (i.e. refuse collection, public drainage, public latrines/bathhouses) and environmental conditions (i.e. wind, rain) and highlight how employment activities (i.e. fishing, hawking, market work) exacerbate the spread of fecal contamination throughout low-resource neighborhoods. Furthermore, the focus group discussions clearly demonstrate the participants' awareness about how feces can spread from private households to public refuse in residential neighborhoods, and conversely from public drains back into private households. The interconnections between public and private domains are critical in the widespread fecal contamination throughout low-resource neighborhoods. This demonstrates that although fecal contamination may be low in one setting (e.g. a household or school), sanitation behaviors and services contribute to continual transfer of feces between public and private domains, thus increasing residents' exposure to feces during their normal daily activities. Previous studies have described sanitation behavior and the risk of exposure to fecal contamination in daily lives (Pickering 2011; Jenkins *et al.* 2014); however, they have compartmentalized fecal contamination to household level excreta disposal behavior and not examined drivers of sanitation behavior from all domains.

Overall, this study highlights the multifaceted nature of fecal contamination and how human behavior, urban systems and environmental conditions become mechanisms for the spread of feces in settings where alternative methods of fecal disposal are used. The implications of our findings indicate that reducing exposure to fecal contamination requires a multi-sectoral approach that focuses not only on facilitating latrine use, but also on improving aspects of refuse collection, drainage, flooding, and other mechanisms that exacerbate the spread of feces in communities. For example, increasing private latrine use requires addressing the space, cost, maintenance, and water supply issues that pose significant barriers to their use; while increasing public latrine use requires managing the cost and hygiene of these facilities, improving their perceived safety risks and increasing their availability in low-resource neighborhoods. Thus, programs that emphasize only latrine *provision* may not improve sanitation practices unless they also address the considerable financial, physical, practical, and health deterrents to latrine access or use in urban settings of developing countries. Improvements to latrines alone are unlikely to mitigate fecal contamination in communities without also improving the management of both

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public and private refuse collection services to avoid refuse buildup and dumping throughout low-resource neighborhoods. Additional interventions are needed to curb behavioral practices that contribute to fecal contamination, such as open defecation, disposing feces in public bathhouses, public drains, and household refuse. Interventions also need to consider the social context of poverty that drives some human behaviors and sanitation practices that contribute to fecal contamination.

CONCLUSIONS

This study identifies the multifaceted context of fecal contamination in low-resource urban neighborhoods. It highlights the barriers to latrine use, alternative methods of fecal disposal, and how poor sanitation services, such as refuse collection and disposal, sludge removal, and public drainage, contribute to increased fecal contamination in these urban settings. An important finding of this study is the continual transfer of feces between public and private domains, which exposes residents to fecal contamination throughout their daily activities. This study underscores the pervasive risk of exposure to fecal contamination throughout low-resource urban neighborhoods and suggests the need for a multi-sectoral approach to interventions aimed at reducing fecal contamination and associated health risks.

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