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Research Paper

Exploring waste and sanitation-borne hazards in Rohingya refugee camps in Bangladesh

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ABSTRACT

Improper sanitation and waste management is the number one cause for ill health, disease and death throughout the world, particularly under extremely dense living conditions in refugee camps in the global South. This paper discusses the results of a mixed-method study conducted in Rohingya refugee camps, located in Chittagong, Bangladesh, currently hosting the world's largest concentration of refugees. Our structured questionnaire, group discussion and interviews were centered on waste-borne hazards. The research has evidenced severe challenges associated with overall precarious sanitation and waste situations in the camps. Garbage littering and open defecation are widely practiced. Congested drainage systems contribute to flooding, bringing waste and contaminants into people's homes. Improvements can be made by involving camp inhabitants in decision-making processes and giving them greater ownership in everyday infrastructure maintenance. Our research suggests that community participation is the key tool to maintain proper cleanliness of drains and toilets. Creating a stronger sense of community in the camps and practicing transparency and inclusion in planning and decision-making can contribute to addressing the key threats identified in this research and also apply to other refugee camps worldwide, with similar hazardous living conditions.

Key words: refugee camps, Royingha, sanitation, WASH, waste management

HIGHLIGHTS

- Precarious sanitation infrastructure, dense living and improper waste management pose serious challenges in refugee camps.
- Lack of planning, inappropriate design and the absence of participation in camp decisions are root causes for environmental contamination in refugee camps.
- Community engagement and grassroots participation of refugees are vital to finding appropriate solutions to WASH issues and environmental health.

1. INTRODUCTION

Worldwide, inadequate sanitation and waste management have been found to be two of the world's most significant causes of poor health conditions and anthropogenic environmental degradation. As of 2017, globally, only four out of 10 people have access to safely managed sanitation services, which means that more than half of the world's population live under improper sanitation (UNICEF 2019). Worldwide, over 673 million people are forced to practice open defecation (WHO 2019b). Poor sanitation may lead to diarrheal deaths, spread of tropical diseases and malnutrition, among many other health impacts. Sanitation-related diarrheal symptoms globally produce a high death toll of 432,000 annually; including the death of 297,000 children aged under 5 years (WHO 2019b). In a broader perspective, poor sanitation can also be connected to other socio-economic crisis, e.g., sexual assault, illiteracy and lack of access to formal education, domestic violence, anxiety or psychological trauma (Pommells *et al.* 2018; Biswas & Joshi 2021). Adding to these sanitation-related issues, improper waste management strategies make the situation even worse, expanding the scope of human contact with improperly managed waste (WHO 2019a). The per capita waste generation worldwide ranges between 0.11 and 4.53 kilograms a day; and at

least 33% of all waste produced does not undergo any sort of adequate treatment or management (World Bank 2016). The scenario is complex in the case of vulnerable populations found in poor neighborhoods in low-income countries (Mageswari & Gowtham 2020) and specifically in refugee camps (Jobbin *et al.* 2018).

Poorly managed sanitation systems are among the most serious everyday problems in refugee camps (Cronin *et al.* 2008) and improved sanitation is critical particularly during and after emergency periods, when people are most susceptible (specifically children, elderly, pregnant and lactating mothers). It has been reported that managing solid waste in refugee camps is a challenging task for the authorities in host regions (Saidan *et al.* 2017).

Rohingya Muslims, one of the stateless populations in the world, is an ethnic minority from Myanmar. Rendered stateless, the Rohingya fled to Bangladesh and other neighboring countries to take refuge (Parnini *et al.* 2013; Milton *et al.* 2017). Over 1 million Rohingya Muslims displaced by Myanmar are currently sheltered in different camps in Cox's Bazar, Chittagong Division, in Bangladesh. These camps are lacking basic services including safe drinking water, sanitation and waste management (Hsan *et al.* 2019). The recent influx of over 600,000 Rohingya refugees has increased even more the uncertainty in planning for these kinds of basic service provisions to improve access to water, sanitation, hygiene (WASH) – and to reduce waste-borne risks and hazards (Uddin *et al.* 2014; ISCG 2019).

Although grey literature and news articles are available on the waste and sanitary situation in refugee camps in Bangladesh, there are limited systematic studies and scientific literature on WASH issues in Rohingya refugee camps. There is a significant lack in understanding waste flows (packaging waste, bottled drinks, sachets, as well as fecal sludge and other solid and liquid waste) and recycling practices in these refugee camps (Bashar 2021; Halim *et al.* 2021). Our study aims to fill this void by addressing the surfacing socio-environmental challenges related to improper sanitation and waste management in refugee camps. We begin by describing the methods and then present and discuss the results and conclude with some recommendations to government agents, to practitioners and non-governmental organizations to improve WASH in refugee camps.

2. METHODS

A mixed-method research approach was carried out for the purpose of this study to have a dynamic perspective on the sanitation and waste-borne hazards in the selected camps. The Rapid Participatory Appraisal method was used to collect data (see, Ong *et al.* 1991; Mclntyre 2008; Kemmis *et al.* 2014; Richie *et al.* 2014), designed for an integrative perspective and a community-engaged approach (Amauchi *et al.* 2021). This allowed the researchers to gain insights into the community's needs for proper sanitation and waste management, leading to the discussion of appropriate recommendations. The tools applied are structured questionnaire, a group discussion, key informant interviews and direct observations. The data collection commenced in October 2019 and final data entry was concluded in May 2020.

Six research assistants (RAs), with knowledge of the Rohingya language, were recruited to conduct the interviews and apply the questionnaire, accompanied by volunteer camp participants, non-government organization (NGO) workers and field officers. The RAs recorded all relevant observations in a diary. The qualitative data helped validate the quantitative responses recorded in the questionnaire.

Through purposive sampling, a total of 227 individuals were chosen from the two camps (Camp 2 and Camp 4) to participate in the questionnaire application. Both female and male respondents could participate but had to be over 18 years of age and only one person per household could answer the questionnaire. Illiteracy was not a hindrance in participating in this study, since interviews and questionnaire were applied orally. There were more female (79%) than male (21%) participants, given that men were often not at home during the questionnaire application. A higher number of individuals were chosen from Camp 2 due to its larger population. Out of the 227, a total of 170 participants were chosen from Camp 2 and 57 from Camp 4.

This study received approval from the Ethics Review Committee (ERC) of the Asian University for Women (AUW) and the Human Research Ethics Board (HREB) of the University of Victoria (UVic) (Protocol # 19-0107). Proper permission from government camp authorities was also given (RRRC/NGO/RESEARCH WORK/1-96/2018/1827, 30.09.2019). Participation was based on informed oral consent. Each participant was informed about the purpose and details of the study, possible risks and benefits, as well as the use of the data by the researchers. The respondent's anonymity and privacy were assured, maintaining maximum ethical standards. Throughout the process, research data were kept secure and confidential. Data were entered in Excel spreadsheets with an identification number that links to an identification name, given by the research participant. The original data set is stored encrypted and password-protected. The data will remain available for other and future

researchers to use the same data upon request to the authors. No other organization except for the authors have ownership to the data.

2.1. Study site

The present study was conducted in two sites within the Kutupalong refugee camp in Bangladesh, currently the world's largest refugee camp, located in Ukhia Upazila, the coastal area of Cox's Bazar, district of Chittagong (see Figure 1). Kutupalong is one of the two government-run refugee camps in Cox's Bazar, inhabited predominantly by Rohingyas, the Muslim minority, who are denied citizenship in Myanmar. Around 800,000 refugees have fled Myanmar in 2017, after escalating ethnic and religious persecution in their country.

It is not only the largest refugee camp worldwide but with a total of over 1 million people also the most densely populated, exceeding its original planned capacity. For the purpose of this study, Camp 2 East and Camp 2 West (herein referred to as Camp 2) and Camp 4 Extension (herein referred to as Camp 4) were chosen as study sites (see Figure 1). Camp 2 is older and lacks planning while Camp 4 has been built recently with better design of shelter and facilities. Camp 2 covers an area of 782,714 m^2 (56,216 inhabitants) and Camp 4 an area of 497,476 m^2 (6,172 inhabitants) (UNHCR 2020). Particular blocks were chosen from these camps, to ease the process of recruiting research participants. Camp 2 is subdivided in several blocks (Camp 2 East: blocks A–E and Camp 2 West: Blocks A–D), which is not the case in Camp 4.

2.2. Data collection

The questionnaire focused on the identification of common sanitation issues and waste-borne hazards in the camps. It consisted of 11 questions, broadly based on the research objectives with most of them having multiple responses and a few being open-ended. Data on some general issues and concerns such as the types of waste produced, daily waste production estimates, waste dumping locations, the composition of recyclable waste materials, common types of diseases experienced, accessibility of toilet facilities per household and issues related to insufficient and deficient camp toilets were collected through the questionnaire. The RAs were accompanied by 12 local Rohingya volunteers, fluent in the native Rohingya language and in Bengali enabling the communication between the RAs and interviewees. The questions were read out by the RAs and translated by the volunteers into the native language, facilitating understanding between researchers and research participants.

Key informant interviews were conducted with government officials from the Refugee Relief and Repatriation Commissioner (RRRC), Camp-in-Charges (CiCs), the Department of Public Health Engineering (DPHE) and other WASH actors from national and international organizations. We talked about the strengths, needs and gaps in sanitation, waste disposal, management and recycling options, as well as recommendations for improvements. The interviews were facilitated by the researchers and RAs helped with note-taking and recording. Audio recordings were transcribed for thematic analysis.

A group discussion was conducted at the camp with camp inhabitants, management personnel, waste collectors, block leaders, desludging operators and volunteers. The discussion helped identify the sanitation practices, details about sanitation behavior of camp residents and waste disposal/accumulation/recycling and related health issues. Notes were taken and were later used in the thematic analysis.

Throughout several visits to the camps, we observed various waste dumping locations, camp toilet sites, water sources and households in order to witness waste handling and recycling practices. Community members and NGO field staff supported the researchers during the field visit and shared their views. Photographs were taken during the field visits and observations were noted into a diary.

2.3. Data analysis

Qualitative data werre transcribed, organized in spreadsheets, reviewed and manually sorted for theme coding, followed by data interpretation. Responses were coded and general themes were established, ensuring consistency between the themes and the factors related to sanitation and waste management in the camps. In order to identify and understand factors related to sanitation and waste management in the camps, the implicit meanings of the narrative responses were interpreted manually. Quantitative data from the questionnaire were tabulated and analyzed using the Statistical Package for Social Sciences (SPSS), version 20.0 and Microsoft Excel. The data set was checked by the researchers for consistency. All incomplete data or missed values were statistically handled prior to analysis. Frequency distributions were generated for the descriptive analysis. The χ^2 tests using SPSS 20.0 were applied to identify associations between dependent and independent variables.

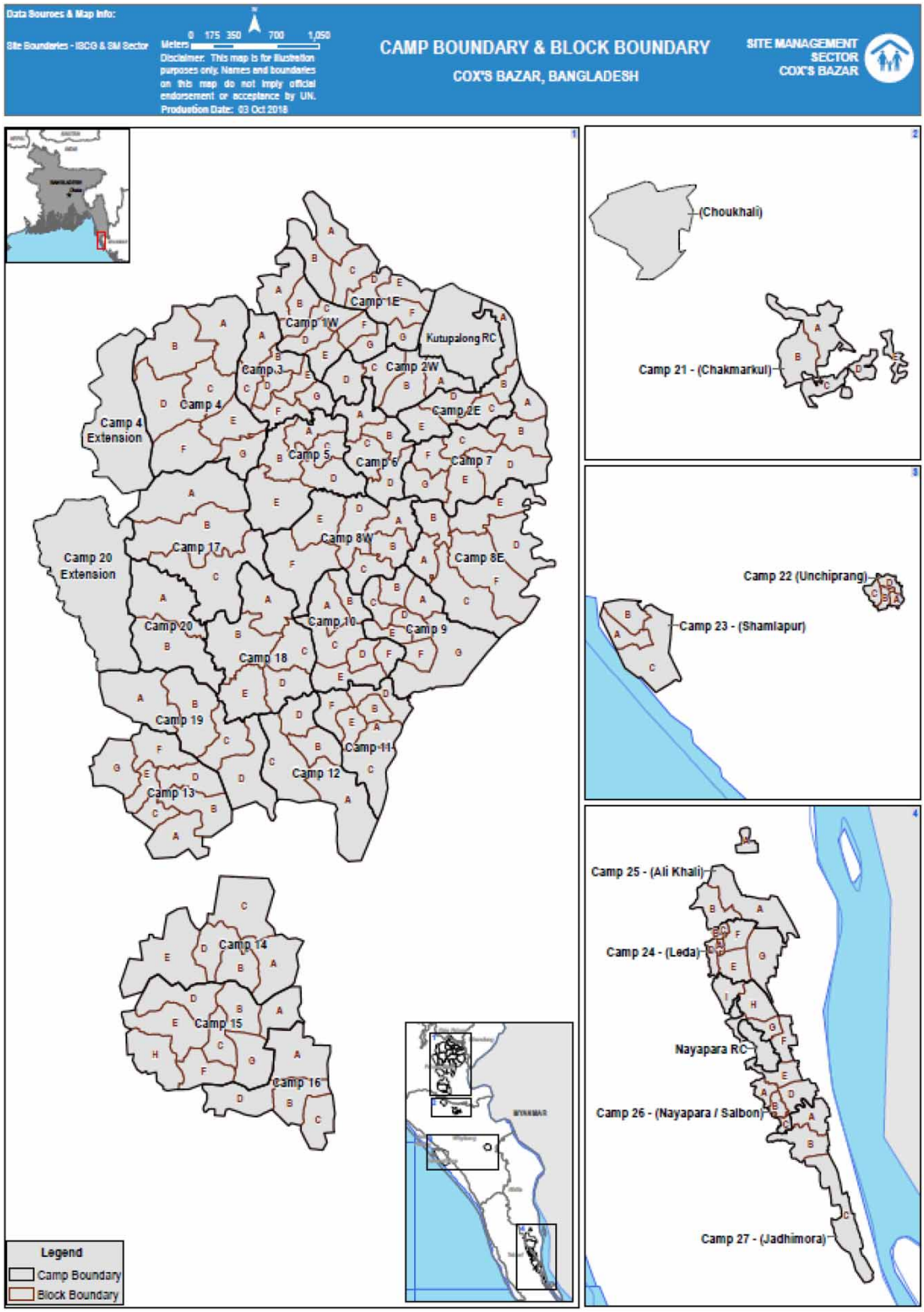

Figure 1 | Map of Rohingya Refugee camps. *Source:* ISCG and SM Sector (2019).

3. RESULTS AND DISCUSSION

3.1. Solid waste generation in the camps

The United Nations Development Program (UNDP) estimates that the 700,000 refugees in the Rohingya camps in Bangladesh generate around 10,000 tons of waste every month, which amounts to 460 g of waste per person, every day (ADRA 2019). This number includes waste generated at the household level and the residues generated by all other sources.

In our study, households were asked to estimate the quantity of waste they generate on a daily basis. 75% of the participants responded that the amount of waste produced every day in their households would usually exceed 500 g, while 25% responded that on average they would generate less than 500 g/day. Overall, more participants from Camp 4 (40%) compared to Camp 2 (20%) confirmed that smaller amounts of waste were being generated. This denotes that on average, household waste generation and corresponding risks might be higher in Camp 2 compared to Camp 4. Our observations during the field visits confirmed cleaner household environments and less littering in Camp 4, compared to Camp 2.

Most waste is generated by the households themselves, confirmed by most participants. Some shops were also identified as additional sources of waste generation and 29% of the participants affirmed that the waste produced by these shops had a significant impact on the total volume of waste. About 6% of the participants mentioned other sources for waste such as few schools, hospitals and littered spaces, such as drains and roads.

The major types of waste produced at the household level included organic food waste, plastics, paper, cardboard and glass. This sequence from most to least dominant type of waste identified by the research participants, was similar in both camps. Almost all participants in both camps (98%) confirmed that organic waste was the most dominant category of everyday waste. The second category was plastic, as per the responses of 88% of the participants. 61% of the responses also mentioned paper and cardboard and 27% highlighted bottles and glass as equally important components generated at the household. Apart from these categories, some participants also referred to dust, house dirt or leaves and other types of waste materials adding to the household generation of waste. Human waste was regarded as another major waste category, particularly from children defecating in open space, in or around the household.

3.2. Solid waste disposal and impacts in the camps

In the Rohingya camps, solid waste is usually collected by community volunteers and dumped in open sites nearby the camps. Due to the general absence of proper treatment methods burning of waste is quite common, in and around the camps. As the camps are dense in population, waste regularly tends to accumulate fast and waste bins tend to overflow. The open disposal practice in the camps creates severe health-related drawbacks, including odor pollution as well as ground and surface water pollution (ADB & DPHE 2019). Table 1 presents the data for both camps on primary destination of solid waste generated at the household level, according to the residents (Table 1).

Figure 2 highlights key impacts perceived by the respondents, related to waste accumulation. In both camps, waste overflows trash bins and accumulates in the open. However, Camp 2 has an insufficient number of trash bins given its population density; and, thus accumulates even more waste. It is common that households throw their trash into adjacent drains or open spaces nearby. The majority of the participants responded that the bad smell emitted from accumulated waste is one of the biggest issues affecting them. Temperatures in Chittagong are high during most of the year and rainfall is dominant throughout half of the year, favoring the development of smells from putrefying waste, but also the spread of

Table 1 | Frequency distribution of waste dumping locations

Waste dumping locations by family	Absolute number	%
Dustbin	104	48.1
Drain	59	27.3
Open space	22	10.2
Waste is buried	3	1.4
Dustbin and drain	22	10.2
Drain and open space	2	0.9
Dustbin and open space	4	1.9

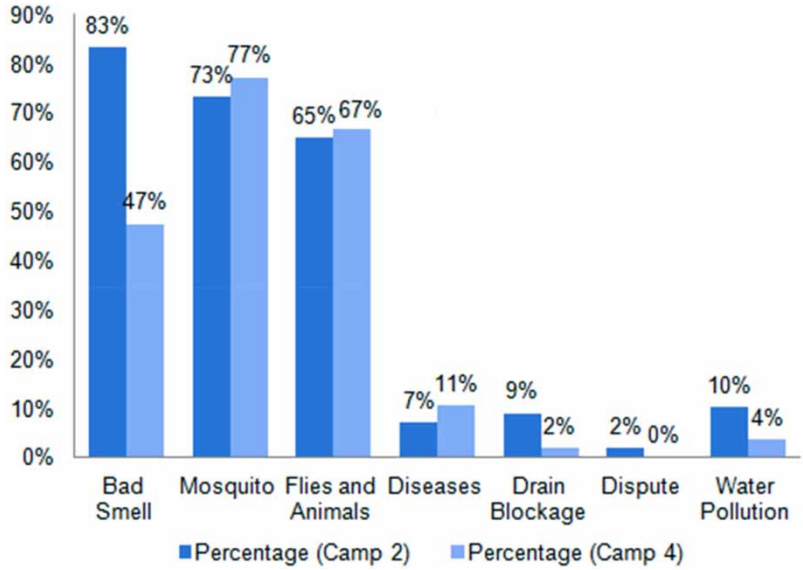

Figure 2 | Consequences of waste accumulation.

infectious diseases associated to waste. Biological vector-borne diseases (urban zoonosis) are closely associated with solid waste in human agglomerations, where discarded waste over time creates burrowing sites and food reservoirs for animals who can transmit disease such as scrub typhus or leptospirosis (Krystosik *et al.* 2020).

Another issue participants mentioned is the increase in mosquito populations. As a result of inadequate water and sanitation infrastructure and the already high level of vulnerability of the refugee population due to inadequate shelter, food and health care, the spread of malaria, dengue and chikungunya infections by mosquitos add other health threads to the region (Rahman & Islam 2019).

A large number of the participants responded that they also have been suffering from rat infestations in the camps, associated with waste disposal. Rats are known to carry different pathogenic serovars (Boey *et al.* 2019), specifically leptospirosis, an infectious disease that affects humans and animals and is considered one of the world's most widespread re-emerging zoonotic disease (Samsudin *et al.* 2020). This scenario seems to be similar in both camp sites.

There seems to not be an awareness linking waste to environmental and human health risks. Few respondents related the health implications they were suffering from, such as rashes and allergies to the direct or indirect contact with waste accumulated in their vicinity. In Camp 2, residents suffer more from water pollution and drain blockage as many of the residents have dumped their waste, over the past years, near to water sources and in drains.

Also, disputes over trash bins and the build-up of waste in specific areas is a common occurrence in the camps and creates disagreements and quarrels among neighbors. Residents of Camp 4 usually suffered less from these issues as they have a better cleaning system and lower occupation density. The specific waste-water nexus and related health impacts will be discussed in the following section (Section 3.4).

A sanitation facility is defined as upgraded or improved when there is a hygienic separation between human waste and human contact. A few examples of these improved facilities include pit latrines with proper ventilation, septic tanks, flush containing sewer systems, composting toilets and pit latrines containing slabs. According to UNICEF and the World Health Organization (WHO), access to a shared sanitation facility among households does not necessarily refer to an improved sanitation situation (UNICEF & WHO 2015). The handbook indicates that the minimum sanitation standard set for populations in camp situations is below 25 people sharing a single toilet and the distance between household and toilet should not exceed fifty meters. Table 2 shows the residents' perspectives on sanitation linked to toilet access.

In order to quickly accommodate an overcrowded refugee population, it is extremely difficult to maintain the required sanitation and health standards. REACH and UNICEF report approximately 100 people in the Rohingya refugee camps with access to a toilet, independent of gender and age (REACH & UNICEF 2018). The low number of toilets to people creates long queues, often dominated by men, preventing women from using the public toilets. Rohingya women are bound to certain cultural and social norms that do not allow them to leave the house without dressing appropriately and covering themselves

Table 2 | Number of families per toilet and consequences of insufficient toilet access

Variable	Issues reported due to insufficient toilets (absolute numbers and %)		*P*-value	χ^2
	None	At least one or more issues		
Families using one toilet				
Less than 50	35 (100.0)	99 (53.5)	<0.001	26.712
50–100	0 (0.0)	47 (25.4)		
More than 100	0 (0.0)	39 (21.1)		

(Banerjee 2019). Waiting in long queues serves as an additional inconvenience or obstacle for them and they prefer urinating or washing in privacy inside the house. At worse, they also choose open defecation which has its own safety and health hazards. In our study, when the participants were asked about issues due to lack of toilet facilities, the majority of them, equivalent to 64.4%, complained about the long queues and 9.3% stated that urinating inside the house impacted the household (see Table 3). Damaged or inaccessible toilets, toilets without proper doors or locks and non-functional security lights in some

Table 3 | Frequency distribution of WASH-borne issues and hazards

Variables	Frequency	Percentage (%)
Number of families using one toilet		
Less than 50	135	61.1
50–100	47	21.3
More than 100	39	17.6
Issues due to insufficient toilets		
None	35	15.6
Long queue	145	64.4
Far-distance	24	10.7
Open defecation by children	30	13.3
Urination/defecation in household space by elderly or women	21	9.3
Security concern	34	15.1
No inclusive programming	12	5.3
Distant bathing space	8	3.5
Poor latrines/bathing facilities	25	11.1
Fighting/dispute	26	11.6
Convenient in using drain	9	4.0
Diseases experienced by the camp residents		
None	15	6.7
Diarrhea	126	56.0
Dysentery	34	15.1
Skin infection	105	46.7
Jaundice	39	17.3
Eye irritation	15	6.7
Respiratory disease	18	8.0
Cholera	4	1.8
Malaria/dengue	13	5.8
Common cold/fever	86	38.2
Others	27	12.0

places, were mentioned in a study conducted by Oxfam (Oxfam 2018). In our research, 11.1% claimed to have poor latrines/bathing facilities and 15.1% mentioned security concerns for females. To address these limitations, women improvise toilets and bathing arrangements at home by using tarps, which obviously creates opportunities for infectious disease to spread.

Our study found a significant association between the number of families accessing a toilet and the specific issues created due to insufficient toilets. Overall, the sanitation situation is better in Camp 4 where on average only 3–4 households share a toilet, compared to up to 60 families sharing one toilet.

3.3. Waste–water nexus and related disease occurrences

Table 4 presents the principal diseases experienced by camp residents with respect to two variables (families using one toilet and location of the waste dumping). We observed a high incidence of disease among respondents that share one toilet with less than 50 families (59.7%) based on the large sample size of research participants in this category. Almost half of the participants in Camp 2 (47.6%) were able to share one toilet with less than 50 families, whereas all residents of Camp 4 (100%) claimed that less than 50 families were accessing one toilet. This result was found to be statistically significant (p-value <0.05). Our study found no strong correlation between WASH-related diseases and the response to waste dumping location.

In 2016, adequate WASH facilities would have prevented worldwide, 1.9 million deaths as well as uncountable life years of suffering by sick people (expressed in 123 million disability adjusted life years) as consequence of WASH-related diseases (WHO *et al.* 2020). The same source also asserts that shockingly 13% of deaths in children under the age of 5 years were related to the same causes. Despite several improvements that have been done over the years, inadequate access to clean WASH remains a major global concern in refugee camps putting refugees at high risk of communicable diseases. It has been reported that only 30% of WASH services have been reaching the Rohingya population. Only a fraction of the 9 million liters of clean water the refugee and drought affected population worldwide would need every day, is being made available (Islam & Nuzhath 2018). Due to the currently inadequate WASH facilities and growing population density in these sites, the risk of pathogen dissemination and the spread of various communicable diseases continues to increase also among Rohingya refugees.

Our findings report a high incidence of WASH-related diseases (Table 3). Interviews with WASH-related organizations confirmed several WASH attributable infections among the refugee population, such as bloody diarrhea, cholera, skin infection, unexplained fever, acute respiratory infection (ARI), other respiratory issues, and had identified 224,145 confirmed cases of acute water diarrhea. While conducting the group discussion and key informant interviews with NGOs and health organizations in the field in Camp 2, a few participants reported child deaths due to diarrheal infection. This may be a result of children in the camps practicing open defecation. Latrines and handwashing points are often constructed at an elevated platform which are ideally equipped for adults but are difficult to access by children and people with disabilities, as a result often

Table 4 | Association between diseases experienced by the camp residents and availability of toilets

	Disease experienced			
Variables	**WASH-related (%)**	**WASH-unrelated (%)**	***P*-value**	χ^2
Families using one toilet				
Less than 50	108 (59.7)	27 (71.1)	0.035	6.702
50–100	37 (20.4)	10 (26.3)		
More than 100	36 (19.9)	1 (2.6)		
Waste dumping site				
Dustbin	80 (45.5)	24 (63.2)	0.105	10.491
Drain	48 (27.3)	11 (28.9)		
Open	19 (10.8)	2 (5.3)		
Buried	3 (1.7)	0 (0.0)		
Dustbin and drain	22 (12.5)	0 (0.0)		
Drain and open	1 (0.6)	1 (2.6)		
Dustbin and open	3 (1.7)	0 (0.0)		

elderly people and children lack practice of regular hand washing and latrine use. Consequently, the health status of children is alarmingly poor, further amplified by malnutrition. Cases of respiratory infections (ARIs) and unexplained fever accounted for almost one-third and slightly over one-fourth of children taking consultations followed by acute watery diarrhea, skin diseases, burns, eye infections and malaria (EWARS 2018). Based on our rapid assessment, an in-depth study on hand washing practices and personal hygiene behaviors of the population needed to be conducted in order to be able to make affirmations on the water and waste related nexus to diarrhea incidences.

When comparing the two camps (see Table 5), the majority of the participants in both camps experienced WASH-related health impacts in contrast to other non-WASH-related illnesses (Camp 2, 85.1% and Camp 4, 75.4%). In Camp 2, only one-third of the respondents (31.88%) were taking their waste to the dustbin, compared to 94.6% in Camp 4. Dumping waste into drains was the largest response (36.25%) in Camp 2, a practice adopted by only few residents in Camp 4 (1.79%). It seems that Camp 2 struggles with severe challenges related to waste dumping, overcrowding and lack of proper waste management.

3.4. Initiatives to address key problems identified in the study

So far, few initiatives have helped to improve waste management in the camps. Though there are good practices of waste segregation among some of the residents, other waste treatment initiatives are lacking. In addition, fecal sludge management is still a significant concern in both camps. Generally, fecal sludge is collected from the toilets at certain intervals, but this process itself causes critical exposure to harmful agents.

Figure 3 summarizes the major sanitation and waste-borne issues we identified in the Rohingya camps. We organized the information into three broad categories: (a) improper maintenance of existing facilities, (b) lack of toilets and (c) lack of waste management facilities.

Almost all national and local organizations in the camps perform manual desludging. Recently, however, there has been the introduction of technologies such as ABRs (Anaerobic Baffled Reactors) and biogas latrines to better address the issues that come with desludging. Nevertheless, none of these technologies meet the required effluent standard (OXFAM *et al.* 2020). So far, only traditional methods have been used in both camps, such as burying the fecal sludge. In a pilot project, Oxfam has started to operate a fecal sludge management plant in Camp 4, treating fecal sludge from different Rohingya camps.

Table 5 | Waste and sanitation-related issues

	Camp location (absolute numbers and %)			
Variables	**Camp 2**	**Camp 4**	***P*-value**	**χ^2 value**
Families using one toilet				
Less than 50	78 (47.6)	57 (100.0)	0.000	48.931
50–100	47 (28.7)	0 (0.0)		
More than 100	39 (23.8)	0 (0.0)		
Issues due to insufficient toilets				
No issues	3 (1.8)	32 (56.1)	0.000	95.723
At least one or more	165 (98.2)	25 (43.9)		
Disease experienced				
WASH-related	143 (85.1)	43 (75.4)	0.095	2.783
Others	25 (14.9)	14 (24.6)		
Waste dumping site				
Dustbin	51 (31.9)	53 (94.6)	0.000	66.078
Drain	58 (36.2)	1 (1.8)		
Open	22 (13.8)	0 (0.0)		
Buried	3 (1.9)	0 (0.0)		
Dustbin and drain	20 (12.5)	2 (3.6)		
Drain and open	2 (1.2)	0 (0.0)		
Dustbin and in the open	4 (2.5)	0 (0.0)		

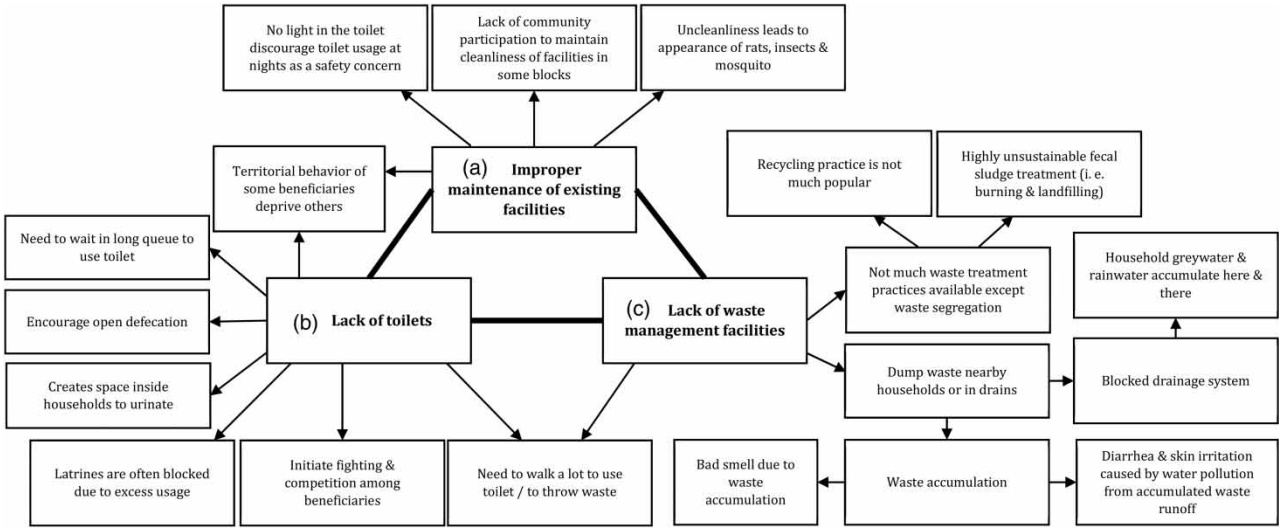

Figure 3 | Major sanitation and waste-borne issues in the Rohingya camps.

There is no formal system for waste diversion and recycling in the camps (ADB & DPHE 2019) and most participants are unaware of the concept of source separation (Figure 4).

Current waste management involves communal waste collection and the practice of open disposal. Camps lack standard operating procedures for proper recycling (OXFAM *et al.* 2020). The few families that recycle and reuse usually recover plastic bottles, food packaging and paper to make different handicrafts. Some also collect plastic bottles for sale.

Only in Camp 4 colored bins were created to differentiate and separate organic from inorganic waste. These bins are regularly cleaned by NGO workers. The source separated collection and classification of recyclable materials for reuse, transformation and recycling constitutes an opportunity not yet harnessed. Involving camp members in recycling (e.g., 'cash for work') can create positive outcomes.

4. CONCLUSION AND PROSPECTS: SOME RECOMMENDATIONS

The present research has evidenced several key challenges associated with the overall precarious sanitary conditions and waste situations in the Rohingya camps. Participants voiced a severe lack of toilets and an absence of designated waste dumping sites in their blocks as a major health risk and identified these factors as strongly impacting their quality of life. Either a large number of families shared toilet utilities or the individuals had to walk long distances to use a toilet or to dump their waste at a proper waste disposal site.

The findings underline that deprivation often encourages people to defecate in open spaces or to dump household waste in improper spaces. Such activities regularly lead to conflicts among families residing close to these spaces, besides generating

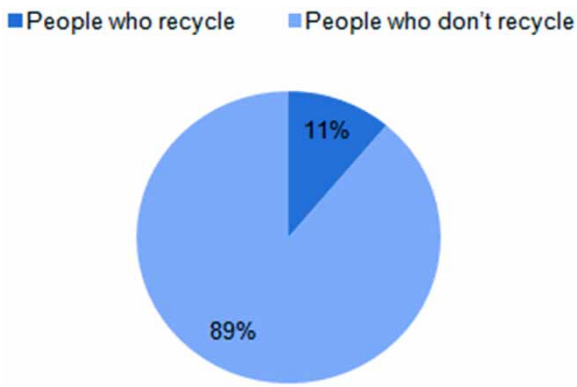

Figure 4 | Camp residents practicing recycling.

overall environmental and health implications. As a consequence, community members often initiate the construction of self-made pit latrines or they allocate a dedicated household space to urinate. These practices are highly questionable in terms of individual and public health as well as overall sustainability. Runoff from such human waste can be hazardous in both the short and long term. Children are the worst victims of these troubles caused by insufficient toilet facilities. Quite often children are found to defecate in open spaces. Though there is evidence that community members install small toilet facilities for children, such initiatives are scarcely noticed. Women, children and youth are more affected by insufficient lighting of public toilets and, despite the existence of toilets, the lack of illumination discourages their use at night, specifically by those who are already affected by safety concerns.

The absence of proper drainage systems affects the disposal of household greywater and consequently increases the risk of contamination. Especially during the rainy season, the situation becomes even worse with the rainwater runoff moving waste sometimes even inside the houses. Garbage-congested drainage systems also increase the risk of flooding, which also brings waste and other contaminants into people's homes. Regular clean-ups could be organized to help educate the locals and to put more pressure on camp administrators and local authorities, to address the lacking infrastructure in the camp.

Apart from these challenges, many participants mentioned that inadequate and irregular maintenance of the local infrastructure facilities also generates public health hazards and environmental contamination. Lack of maintenance of drains, dustbins and toilets creates bad smells and frequently causes drains and toilets to overflow due to blockage. Desludging is still a significant challenge for the Rohingya camps. The frequency of cleaning drains and toilets can vary significantly. As a consequence, the appearance of insects is quite common in places with insufficient cleaning and maintenance. For example, in some places, toilets and drains are cleaned once a month, whereas in other places users participate by rotation in the cleaning of the toilets and drains almost every day.

There are certainly improvements that can be made, by organizing infrastructure maintenance in a transparent and participatory form, involving the camp inhabitants in decision-making processes and giving them greater ownership and co-responsibility in the maintenance of the infrastructure they use on a daily basis. Community participation is the key tool that can largely help maintain proper cleanliness of drains and toilets. Creating a stronger sense of community in the camps, practicing transparency and inclusion in camp decision-making could also reflect beneficially on some of the existing conflicts that have been noted during the research over the use of toilet facilities. Existing innovative forms of dealing with waste and sludge need to expand from the current pilot stage, building on the experiences accomplished so far.

Finally, our results clearly show that more engagement of camp inhabitants is needed in waste management. Very few individuals are currently involved in recycling local waste. Here is an opportunity to build community with better waste sorting for reuse, material transformation and recycling. Additional research is needed to determine how refugee camps could participate in the circular economy and how community members could best be involved in these actions. The specific findings and proposed interventions for the Rohingya camps certainly are also applicable to other refugee camps, whose populations might be similarly deprived and where environmental impacts could also be reduced with proper interventions.

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DATA AVAILABILITY STATEMENT

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

CONFLICT OF INTEREST

The authors declare there is no conflict.

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