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2020

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This article was originally published at:
https://doi.org/10.3390/su12187325

Citation for this paper:

Akhter, M., Uddin, S. M. N., Rafa, N., Hridi, S. M., Staddon, C., & Powell, W. (2020). "Drinking water security challenges in Rohingya refugee camps of Cox's Bazar, Bangladesh." *Sustainability*, *12*(18), 7325. https://doi.org/10.3390/su12187325

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Drinking Water Security Challenges in Rohingya Refugee Camps of Cox's Bazar, Bangladesh

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Received: 3 August 2020; Accepted: 4 September 2020; Published: 7 September 2020

Abstract: About a million Rohingyas have fled due to the ethnic cleansing in Myanmar and sought refuge in Bangladesh. The refugees are located in temporary settlements on hilly areas of Cox's Bazar with inadequate water and sanitation facilities, giving rise to diseases such as cholera, typhoid, and diarrhea. This exploratory study reports drinking water security challenges in two Rohingya refugee camps within the larger camp network—Camp 2 and the recently-built Camp 4 Extension (Camp 4Ext)—to discover the key everyday issues refugees are facing related to drinking water. Both qualitative and quantitative methods have been applied to determining whether contamination is occurring during the collection, transportation, and storage of drinking water by comparing the water quality at the source with that in storage. The results show that Camp 4Ext is more suited for living in several respects compared with the other camps, attributable to significantly better planning during its construction: there is a lower prevalence of diseases, lower water collection times, higher standards of sanitation, and better access to water sources. This study's outcomes will help camp authorities and the various agencies working there to provide sustainable water and sanitation interventions to improve the wellness of the Rohingya refugees in Cox's Bazar. The outcomes will also provide useful information and strategic direction to the global scientific and development communities who are working in refugee camps in other parts of the world, to tackle water security challenges.

Keywords: drinking water; inequalities and insecurity; marginalization; Rohingya; refugee; water security; sanitation; social exclusion

1. Introduction

Globally, 79.5 million people live outside their country of nationality [1]. They are mostly migrants, people who leave their homelands in search of better opportunities. However, over one-third of them are refugees, escaping political violence, and other threats in their own country [1]. The majority of refugees flee to bordering countries, but often with the hope of returning home should situations change. Refugees face a plethora of health problems arising from factors related to their living conditions, which are often overcrowded, with insufficient public utilities or non-existent basic services and social infrastructure [2]. More than 60% of United Nation-registered refugees live in countries with less than half the global average of freshwater per capita [3]. Such huge influxes of refugees can accelerate the depletion of the water resources of the host country. A number of studies have shown how refugee influxes have put pressure on the water supply in host countries [4–7]. For example, prior to the influx of Syrian refugees that began in 2011, groundwater extraction had already reached maximum sustainable levels in many parts of Jordan [8]. As the number of Syrian refugees living in Jordanian camps ballooned to nearly 2 million, the accelerated groundwater extraction required to meet the needs of one of the densely populated refugee camps led to an overall reduction in groundwater levels throughout the country [7,9,10]. The government of Jordan had not anticipated the long-term effects on water supply, and as a temporary solution, water was trucked in to meet the needs of the refugees. A similar situation exists at the Dadaab camp in northeastern Kenya, home to approximately half a million, mostly Somalian, refugees [11]. The sudden rise in demand for water and shelter by refugees can lead to localized water insecurity that must be assessed in order that effective resilient measures are taken for both the refugees and the local communities.

Water security refers to a condition where water of sufficient quantity and acceptable quality is available at affordable prices for sustaining human health, social and economic growth, and ecosystems [12]. The drinking water security of a community is therefore measured by the quality and availability of an improved drinking water source, and the access to it. It is also, as recent studies by the Household Water Insecurity Experience Consortium (HWISE) have shown, a matter of *experience* rather than mere top-down planning or investment—experienced water insecurity can coexist with active water and sanitation programmes emanating from government or the humanitarian sector [13]. The Rohingya refugees face a multitude of challenges, including those related to water and sanitation. This is why the issue of water security in the camps is an important area of research. To mitigate drinking water insecurity, it is necessary to identify gaps in the site planning and infrastructure as well as to highlight behavioral practices carried out at the community level. In the context of crowded refugee camps, the link between inadequate sanitation and clean water supply is particularly clear. This study was carried out in two Rohingya refugee camps—Camp 2 and Camp 4Ext—of Ukhia Upazila in Cox's Bazar, in order to find key everyday issues refugees are facing with drinking water. Our research supports conclusions by others regarding how inadequate sanitation can compromise the quality of water supply as discovered directly through testing and indirectly through resident self-reporting (via surveys and focus groups). Our research also identifies key vectors of bacterial transmission from source to end-use, including types of containers used, and disinfection processes (if any). This study may contribute to improving—in terms of quality and access—water sources, and increase awareness among refugees regarding their water handling and general hygiene practices which is ultimately affecting their health.

1.1. Status and Conditions of Rohingya Refugees

Rohingyas in Myanmar are an ethnic group but are not regarded by the State as citizens despite their centuries of existence in the country. The Rohingyas' position in Myanmar has been repeatedly questioned and they have been mistreated often in the past [14]. The influx of refugees to Bangladesh is not unprecedented. In 1978, the (then) Burmese military undertook Operation Nagamin, to discontinue the Rohingya ethnic insurgency in (what is now) Rakhine state. The operation led to the execution of thousands of Rohingyas and over 200,000 Rohingyas escaped to Bangladesh, a country that has received multiple refugee influxes in recent decades [15]. Since August 2017, around 671,500 Rohingyas have fled a new wave of ethnic cleansing in Myanmar to seek refuge in Bangladesh. Despite already being overpopulated and resource-restricted, Bangladesh has accepted displaced people from the cultural, linguistic, and religious minorities of the Northern Rakhine State (NRS) of Myanmar [15]. At present, more than 855,000 destitute Rohingya refugees are living in the Ukhiya and Teknaf Upazilas (subdistricts) of Cox's Bazar, with a great majority of them staying in 34 densely populated camps [16]. Of the 855,000, approximately 30,000 Rohingya refugees who have been resettled and accepted by Bangladesh to live in government and United Nations High Commissioner for Refugees (UNHCR) registered camps, and nearly 200,000 Rohingyas live without any official identity, legal status, or foreign assistance in various unregistered camps and local areas [17].

The refugees are exposed to significant public health risks due to overcrowded living conditions and poor water, sanitation, and hygiene (WASH) practices at the camps, especially at the Kutupalong expansion sites. Local organizations and the government have struggled to provide basic services such as food, water, access to healthcare, shelter, and sanitation to meet the needs of such a huge population of refugees. Rapidly upscaled efforts and collaborative responses from United Nations Children's Fund (UNICEF), UNHCR, Action against Hunger, and other international Non-Governmental Organizations (NGOs), have greatly helped to stabilize the situation [18]. Figure 1 shows the location map of Cox's Bazar with the study area highlighted in red.

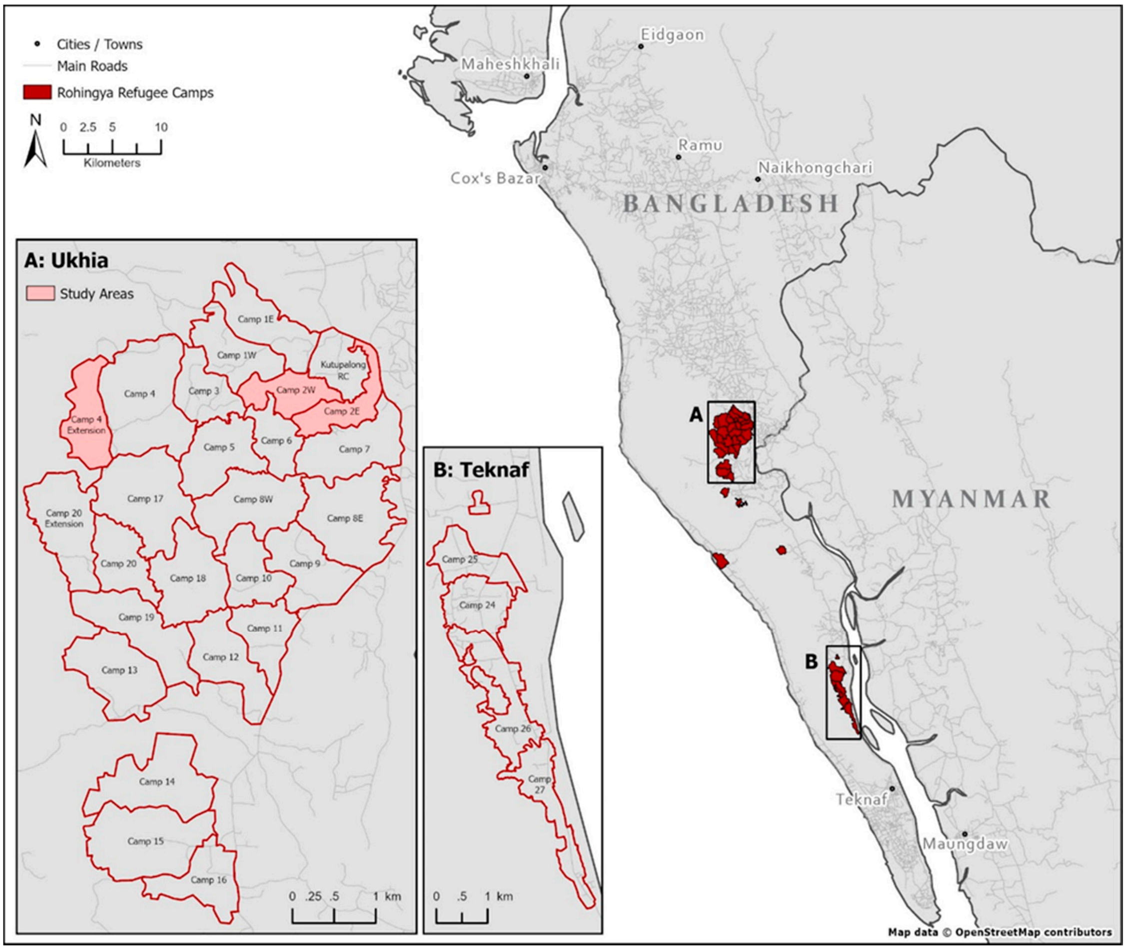

Figure 1. Location map of Cox's Bazaar with the Rohingya refugee camps, including the study areas (Map credit: Chad Staddon).

However, despite this progress, the refugees continue to live in very fragile conditions. The refugee camps have an average population density of less than 15 m^2/person, well below the international guideline of 30–45 m^2/person for refugee camps, implying that the camps are already overcrowded [19]. Studies have shown that even 20 m^2/person does not leave enough space for the necessary infrastructure, such as water and waste treatment facilities [19]. There are problems with the quality and highly uneven distribution of water, with many people walking long distances through densely inhabited camps to the water sources. All of this was outlined in a report on the challenges facing Rohingya refugees due to inadequate sanitation facilities and the lack of safe and adequate water supplies [20]. The report stated that the number of tube wells failed to meet the projected needs for the population size, and there is a sanitation-related decline in quality during the monsoon season. In addition, many private tanks that were supplied by humanitarian organizations are built in inaccessible locations. The long lines and unpredictable hours of availability often created safety hazards for women and exposes them to assault. The latrines have shallow pits and lie in the vicinity of water points, which leads to further contamination of groundwater sources [20]. Moreover, water shortages leave the latrines almost always unclean following usage. Due to the unsafe and insecure sanitation, and of lighting at night, many refugees, especially young children, often opt for open defecation which gives rise to additional health issues [21]. The shortage of water results in unhygienic conditions responsible for various waterborne diseases such as cholera, typhoid, and diarrhea, particularly Acute Watery Diarrhea (AWD), which is very common among the refugees. Over 64,000 cases of AWD were reported in April 2019 alone, among which over 40% involved children below the age of five [19,22].

1.2. Water Quality and Access

1.2.1. Water Source and Collection

During the genocide in central Africa in 1994, more than a million Rwandans fled to the Democratic Republic of the Congo (DRC), where as many as 60,000 people died from a prolonged cycle of water scarcity and cholera [23]. The emergency mitigation measures taken were eventually successful and emphasized low technology approaches: bucket chlorination at unimproved water sources, allocated defecation zones, and active illness case reporting through community interaction. These interventions contributed to a significant decrease in mortality levels by the second month of the crisis [24].

In most cases, refugees have to rely on limited water sources or distribution points, far from their settlements, so collecting water takes up a good portion of their day. The journey to and from the source may even expose them to certain risks. Women and children in most rural areas of developing countries collect water from a communal source, usually located far from their homes. The source itself may be unimproved (streams, springs, rivers) with seasonal flows, or improved (public tap, hand pump, protected wells, springs, or harvested rainwater). In the refugee camps of eastern Chad, water collection took as long as six hours per day, prompting many households to turn to unsafe water sources, and thus, causing malnourishment and diarrheal diseases [23]. The situation was worse in northern Uganda, with people waiting three hours a day for an average availability of 3 L per person, often from contaminated sources [23]. Furthermore, they could not go looking for water beyond camp boundaries because of the risks of being attacked by the Lord's Resistance Army, then engaged in a guerrilla war with the Ugandan government.

In the Rohingya refugee camps, 56% of households have trouble accessing water supply points, due to distance and the number of hours waiting in queues [18]. Table 1 shows the primary water source types available in the Rohingya refugee camps and % of households reporting usage.

Table 1. Primary sources of water in the camps and % of households reporting usage [25].

Primary Water Sources	Drinking Water
Improved Water Sources	**>99%**
Tubewells/boreholes/handpumps	73%
Tap stand/piped water	20%
Water tank	5%
Protected dug well	<1%
Cart with small tank	<1%
Unimproved Water Sources	**<1%**
Unprotected dug well	<1%

With nearly 15 million liters of groundwater being drawn each day, the Rohingya refugee camps are already under threat of critical water scarcity in the future. To provide water to the refugees, approximately 5731 tube wells were installed between August–December 2017, 21% of which had already broken down by the end of January 2018 [26]. The excessive reliance on groundwater drastically reduced the water levels in this region. It was reported that the water levels throughout the camp areas lowered between 5–9 m [27]. In Ukhia and Teknaf, 70% of the shallow tube wells were running dry. Teknaf (Cox's Bazar) and Naikhongchhari, in particular, have very limited sources of freshwater because the 25–30 m deep water table makes tube wells an expensive option. Irrigation wells are gradually drying up as the water level falls due to the degradation of the reservoir and a substantial decline in groundwater recharge, threatening not just water security but food security as well. Increased pressure on the aquifer may lead to saltwater intrusion, further compromising water quality. A recent United Nations Development Program (UNDP) survey revealed that 209 out of 300 shallow tube wells were out of supply [27]. Fifty of these had mechanical flaws, but the remaining wells simply had no water to draw. A field study of the refugee camp showed a number of non-functional hand pumps [19]. The piping needed to be repeatedly adjusted and reinstalled at increased depths in the same area to find sufficient water in aquifers. Water at shallow levels was easily drained due to significant groundwater extraction, which could have some serious long-term consequences [28].

From 2017–2019, UNHCR and its partners built WASH facilities to address the initial crisis. Through chlorinated water networks, an upgraded water supply was achieved by 2019, along with latrines with larger pits. This provided more secure water sources to both refugees and the local population. Fifty-five networks have now been installed, with others under construction. In order to ensure its efficient and secure use, UNHCR continues to closely track groundwater supplies. The refugees were provided with water purifying tablets and containers for safer water collection and storage [16]. 29% of refugees now use piped distribution systems to access chlorinated water, while the rest get their water from tube wells. Nonetheless, recent water quality analysis shows that 52% of tube wells still contain traces of *E. coli* contamination. Rohingya refugee camps in Teknaf Upazila still face water shortages, especially during the dry season, and require water trucking to meet their needs [16].

1.2.2. Source to Storage Contamination

Water, both at source and storage in Rohingya refugee camps, has been found to have high levels of contamination. One study analyzed 12,650 drinking water samples from the camps and found fecal contamination in 28% of the source samples and in 73.96% of the storage samples [29]. This suggests that the high-density population in the camps, along with inadequate hygienic practices, is possibly resulting in the secondary contamination of drinking water during collection, transportation, and storage [29]. Similar results regarding fecal contamination in the Rohingya refugee camps were obtained from a government study [18]. With several studies indicating that water contamination is occurring between source and point of use, policies must address the risks of post-collection contamination [30–33]. Secondary contamination can happen due to the absence of proper knowledge and understanding of hygiene. For example, surveys show that many people in the Rohingya refugee camps did not wash their hands after defecation [22]. If defecation is then followed by handling the water sources or storage containers, fecal coliform pathogens can be introduced [31]. In addition, many households did not cover the containers during transportation and storage [22], which could allow for easy entry of pathogens that degrade the quality of drinking water and endanger the health of the refugees. Household storage of drinking water was also frequently cited as a possible cause of contamination [30,34,35]. These are critical factors for modeling transmission dynamics to identify the pathogen flow routes and to make necessary interventions [29]. Several humanitarian agencies and government-led awareness campaigns have been conducted to improve the water handling and hygiene practices of Rohingya refugees in the camps [16,18,26].

1.2.3. Groundwater Contamination by Latrine

When fecal contamination affects the water supply, severe deterioration of water quality occurs, leading to a high prevalence of waterborne diseases. Pit latrines normally do not have a physical barrier, such as concrete, between deposited fecal matter and the soil and groundwater [36]. The enteric pathogens *Salmonella* spp., *Shigella* spp., *Vibrio cholerae*, and *E. coli.*, and viruses like *Adenoviridae*, Rotavirus, and Norovirus present in the pit latrine excreta could potentially reach the groundwater source through overflowing, leaching, or due to a lack of sewage treatment facilities [37]. The separation distance between water source points and sanitation facilities is critically important. Rahman et al. (2009) found an inverse relationship between total coliform count in tube well water and its distance from pit latrines [38]. Several other studies have exhibited how pit latrines affected groundwater quality microbiologically and chemically [17,37,39–43].

Effective sewer systems provide an estimated 69% reduction in diarrheal diseases [44], but the shortage of space in the Rohingya refugee camps impedes efficient human waste management. Too often the latrines have only shallow pits and are located too near to water sources, leading to potential contamination of the water points. Water sources, along with 86% of drinking water wells, have in many cases been polluted by human waste [27]. The conditions in the vicinity of the Balukhali—Kutupalong mega-camp is especially concerning because of fecal contamination in surface sources as well as groundwater aquifers [26]. More than 30% of latrines were found to be situated less than 10m from tube wells in January 2018 [26]. There are incidents of leakage, runoff, and overflow of the latrines causing pollution of groundwater [27]. The problem intensifies when fecal contaminants are spread by rainwater flow, causing waterborne diseases such as cholera, bloody diarrhea, and hepatitis E among refugees and local populations [45].

1.2.4. Storage Container Material

Water collected from fecally contaminated, unimproved sources may also be stored in containers that are not properly handled, which causes increased growth of bacterial pathogens and thus further degrades the stored water quality. This is especially significant in cases where drinking water is stored over a long period of time as contamination can occur even in clean containers [46]. The material of the storage container itself has an effect on water quality. It is, therefore, necessary from a safety standpoint to take into consideration the type of storage vessels in order to maintain drinking water quality during storage. Duru et al., (2013) compared the physiological parameters in water stored in different material containers and found biological load in decreasing order as follows: calabash > clay pot > metal vessel > plastic vessel > glass vessel [46]. However, in another study, water stored in metal containers still recorded higher color, turbidity, and relative iron content than permissible under the World Health Organization (WHO) portability guidelines [47]. Other studies have shown that the microbiological quality of water stored in clay pots, brass, copper, and silver is better than in other container types [48,49]. The aforementioned studies show that some materials can encourage the growth of microorganisms [46], while others can exhibit antimicrobial properties [49]. Therefore, even if the pathogens enter the containers, whether or not they persist depends on the containers' materials.

1.3. Sanitation

Improved sanitation is essential for reaping the benefits of having access to an improved drinking water source because improper and inadequate sanitation can significantly affect the quality of drinking water by the transfer of exposed fecal matter into water resources, helping to spread serious diseases such as cholera, dysentery, and typhoid. For example, during the crisis of Kurdish refugees from Iraq in 1991, 70% of the deaths caused by diarrhea and cholera were attributed to poor sanitation access or use, along with unsafe water, lack of adequate amounts of water, scarcity of soap and hand washing, and contaminated foods [50].

The emergency nature of the situation with the Rohingya refugees meant that no appropriate planning had gone into the placement or structure of latrines, and the continuous arrival of Rohingyas exerted considerable pressure on the existing facilities. Hundreds of latrines were rapidly built along hillsides near the settlements without adequate soak pits and were simply too close to water points. 53% of households have difficulty accessing the latrines, for reasons including "distance, overcrowding, location, and overflowing. 49% of girls and 40% of women reported feeling unsafe using latrine facilities, 40%, and 34% respectively for bathing facilities" [18] (p. 43). The existing unplanned shelters have reduced available space and the hilly topography limits the scope of construction, resulting in a restricted number of wells, waste disposal bins, and collection points. Around one-third of the residents of all the camps indiscriminately dump solid waste that ends up in drains, eventually leading to blockages [18]. Multiple reports mention the unavailability of soap [16,18,26,51], which means good hand washing hygiene is not possible and therefore represents a gap in WASH practices of refugees that urgently requires addressing.

2. Materials and Methods

2.1. Study Area

The study areas are located in the Kutupalong camp of Ukhia Upazila of Cox's Bazar district in Chittagong, Bangladesh, highlighted in Figure 1 (Section 1.1). Kutupalong is one of the mega-camps, consisting of 22 camps and over 600,000 individuals [52]. After consultation with the Additional Refugee Relief and Repatriation Commissioner (RRRC), refugee Camp 2 East (2E), 2 West (2W), and Camp 4 Extension (4Ext) were chosen for this study. Camp 4Ext, which was recently built with better planning and space efficiency, had improved facilities and living conditions compared with the other camps. For the purpose of conducting a comparative study, adjacent Camps 2E and 2W are considered as a single Camp 2. Camp visits were approved and permitted by the RRRC authority. Ethical approval for the study was sought and received from the Asian University for Women (AUW), located in Chittagong, Bangladesh, on 30 May 2019. Additionally, a high ethical standard was maintained by taking oral informed consent from the participants.

As of August 2019, the total area of Camp 2 is 782,714 m^2, sheltering a total of 13,278 households and 56,216 individuals, making a population density of 21 m^2/person. The total area of Camp 4Ext is 497,476 m^2, sheltering a total of 1492 households and 6172 individuals, making a population density of 80 m^2/person [53].

2.2. Primary Data Collection

An exploratory approach was used combining synoptic attention to sociological and natural environmental conditions to quickly assess a complex situation. Both quantitative and qualitative data were collected during the period between October 2019 and May 2020 for this study. Quantitative data were collected through a structured questionnaire survey and water sampling from both camps. Additionally, qualitative data were collected through key informant interviews, focus group discussions, and direct observations that helped the researchers gain familiarity with the community particularly with respect to water services. Through observation and conversation with various NGO workers and volunteers, an insight into the refugees' general sanitation practices and drinking water security was obtained. Qualitative data were used to supplement the analysis of the results collected through quantitative research methods.

2.2.1. Quantitative Data: Questionnaire

The questionnaire was prepared based on the key objectives of the study and on recent online literature and resources highlighting the scarcity of drinking water in some camps due to a high population [25–27,51]. The questionnaire consisted of 15 questions that covered drinking water quality and availability, transportation, cleaning and storage methods, and the future perception of water security (Supplementary Materials). One hundred households—70 from Camp 2 and 30 from Camp 4Ext—were selected for this study using a simple random sampling method [54]. The sample included a higher number of participants from Camp 2 since it has a larger size and population than Camp 4Ext. Both male and female members of the households, depending on availability, were included in the survey. The nature of the questionnaire was explained to each of the participants, who were asked whether they consented to be included in the survey. When consent was not given, the household was replaced with a different household in the same block. Table 2 below shows the basic socio-demographic characteristics of the participants interviewed.

Table 2. Camp-wise socio-demographic characteristics of participants.

	Camp 2 (N = 70)		Camp 4 (N = 30)	
Variable	**n (%)**	**Mean ± SD**	**n (%)**	**Mean ± SD**
Sex				
Male	21 (30)		8 (26.7)	
Female	49 (70)		22 (73.3)	
Age (years)		31.03 ± 11.69		31.18 ± 12.43
Education (years)				
Never Attended School	8 (11.4)		4 (13.3)	
Primary School	42 (60)		17 (56.7)	
Secondary School	20 (28.6)		9 (30)	
Employment Status				
Employed	5 (7.1)		3 (10)	
Unemployed	65 (92.9)		27 (90)	

For translation purposes, Research Assistants who received prior training in speaking the Rohingya language were hired. The RAs read out the questions to participants in the Rohingya dialect of "Chittagonian Bengali" and communicated their responses back to the interviewer in the English language, which was then recorded in the survey questionnaire. Moreover, we received assistance from volunteers of NGOs (RRRC, Action Contre la Faim) and refugees who could speak both Bengali and Chittagonian Bengali to facilitate communication between interviewer and interviewee.

2.2.2. Quantitative Data: Water Sample Collection and Analysis

From each camp, two samples from deep tube wells and two samples from storage containers—a total of four water samples—were collected from sites selected at random. The water samples were collected in 125 mL sterilized bottles. While sampling from storage containers (typically pitchers or buckets), the bottles were fully immersed into the water and inverted to remove the air inside the bottles. When sampling from tube wells, the bottles were rinsed with the water from the tube wells before allowing them to be filled completely. The samples were stored in cool bags, due to ice not being available in the field, and refrigerated at 4 ± 2 °C within four hours of collection. Water storage conditions inside the house were assessed through house visits and observation. Water quality analysis—both physical and biological parameters—was undertaken by the CWASA Mohora Water Treatment Plant Laboratory in Chittagong.

Water Quality Analysis: Physical Parameters

pH was recorded using Hanna HI 8424 pH Meter, and turbidity using HF Scientific DRT 100B Turbidity Meter. Residual chlorine was tested with the DPD Colorimetric Method using HACH DR-2000. A sample vial was filled with 10mL of the water sample, placed in the test unit, and covered. The sample was analyzed to set the standard for water clear of reagent. The sample was then removed, DPD was added and the vial was shaken after the lid was replaced. It was then placed back on the meter and analyzed. Dissolved oxygen (DO) was measured using BOYN 820 DO Meter.

Water Quality Analysis: Biological Parameters

The water samples were analyzed for total coliform (TCs) and fecal coliform by membrane filtration. Samples were added in small volumes to ensure proper dispersion across the filter membrane. For total coliform detection, the filter was incubated at 35 °C for 24 h in the mEndo-LES agar medium. For fecal coliform detection, the filter was incubated at 44 °C for 24 ± 2 h in the mFC agar medium. The media was prepared to minimize interference of background or non-coliform bacteria. To assess the quality of drinking water, the parameters were compared with standards as indicated by PCRWR on WHO guidelines.

2.2.3. Qualitative Data: Focus Group Discussions (FGD)

Three focus group discussions (FGDs) were conducted to identify the concerns of camp refugees on key issues and to generate suggestions and ideas [55]. The FGDs consisted of homemakers, volunteers, community people, and block leaders (also called Majhi). The age of the participants ranged from 15 to 60 years old. Two FGDs were held on the spot, where people were found in gatherings. The third FGD, mediated by an ACF volunteer, comprised of local leaders in a common meeting spot central to the camps. FGDs were no longer than 30 min in duration. Key points of the discussion were space issues in the camp, problems with tube wells, the lack of sanitation, waste disposal, common diseases, what facilities should be provided to meet their needs, and what improvements they could make to their own practices. KIIs were recorded and transcribed for ease of descriptive analysis.

2.2.4. Qualitative Data: Key Informant Interviews (KII)

Key informant interviews (KIIs) were undertaken [56] with individuals who had in-depth knowledge about water and sanitation issues in the camps. Several key informant interviews were held with RRRC officials, Camp-in-Charges (CiCs), and local and international NGOs. Selected questions from the questionnaire were asked. The interviews revealed useful information on the water, sanitation, and overall situation of the refugee camps, as well as the gaps in water programs and plans. KIIs were recorded and transcribed for ease of descriptive analysis.

2.3. Secondary Data Collection

Secondary data were collected through an online literature survey. Available water quality data obtained from field agencies like International Organization for Migration (IOM), UNHCR, and UNICEF, which are working in the Rohingya refugee camps in Cox's Bazar, have also been used to understand the broader situation across the camps. Particularly, their data collected during the periods of February–December 2019, and January–June 2020 were used. UNHCR predominantly works in our study area and took about 150 to 400 samples from water sources at Camp 2 and about 20 to 60 samples from water sources at Camp 4Ext within the two periods. Moreover, water availability mapping was conducted using the Thornthwaite Monthly Water Balance Model [57,58]. The average monthly temperature and rainfall data around Cox's Bazar from 1981–2010, collected from the Bangladesh Meteorological Department, was used.

2.4. Data Analysis

Data analysis was done using Statistical Package for Social Sciences (SPSS), version 22.0.

2.5. Limitation

Limited resources and the rapidly evolving situation at Cox's Bazar led the authors to the adoption of an "exploratory" approach to this research [59]. The sample size was subject to time and resource constraints. Certain responses may have been under-reported or over-reported due to perception bias. People have a tendency to give a socially agreeable response or choose the "right answer" which they think the interviewer wants. The possibility of such biases was taken into account when respondents showed lower confidence and changed their answer under the influence of onlookers.

3. Results and Discussion

3.1. Water

3.1.1. Water Quality Assessment

According to WHO guidelines, water intended for human consumption should contain no microbial agents. None of the water samples collected tested positive for either total coliform or fecal coliform, which would have otherwise indicated fecal contamination. Even though the Bangladesh Department of Public Health Engineering (DPHE) and WHO recommends a value of minimum 0.2 mg/L of free chlorine, residual chlorine in all of the water samples was nil. This is consistent with the REACH, UNICEF WASH Assessment Report (2018), where 87% of storage water in Rohingya refugee camps returned no trace of residual chlorine. Solar-powered water systems installed by UNHCR in the refugee camps draw water from chlorinated tanks [60]. These tanks are situated away from the camps, as observed in the case of Camp 4Ext, and are accessed and monitored by authorities. One possibility for the decreasing residual chlorine content in the water could be due to the long distance between the tanks where the water is chlorinated and the point of collection (tap stands) [61].

Table 3 shows the results of the water quality analysis of the two camps. The suitable range of pH for drinking water as per WHO guidelines are 6.5–8.5. The water samples from Camp 4Ext storage and source had pH 7.12 and 7.06 respectively. The samples from Camp 2 storage and source had pH 5.38 and 5.43 respectively, which is relatively acidic and below the regulatory level. The turbidity of all water samples was below the WHO safe limit of 5 NTU. Drinking water should ideally have DO concentrations above 6.5–8 mg/L. Camp 2 had DO values of 5.71 mg/L and 5.84 mg/L, while the values for Camp 4Ext were 6.12 mg/L and 6.07 mg/L for source and storage samples respectively.

Table 3. Physiological and microbiological parameters of source (tubewell) and storage water samples.

Sl. no	Parameter	Unit	Method/Instrument Used	Result				WHO Limit
				Storage 2	Tubewell 2	Storage 4Ext	Tubewell 4Ext	
1	pH	–	Hanna HI 8424 pH Meter	5.38	5.43	7.12	7.06	6.5–8.5
2	Turbidity	NTU	HF Scientific DRT-100B Turbidity Meter	0.2	0.7	1.0	4.0	Max. 5
3	Residual Chlorine	mg/L	DPD Colorimetric Method using HACH DR-2000	Nil	Nil	Nil	Nil	Min 0.2
4	Dissolved Oxygen	mg/L	BOYN 820 DO Meter	5.84	5.71	6.07	6.12	–
5	Total Coliform	cfu/100 mL	Membrane Filter Technique	Nil	Nil	Nil	Nil	Nil
6	Fecal Coliform	cfu/100 mL	Membrane Filter Technique	Nil	Nil	Nil	Nil	Nil

The results obtained from this study are mostly consistent with the findings of different field agencies who assessed the water quality during a similar time period (February-December 2019), information of which was obtained from IOM, UNHCR, and UNICEF. For samples from Camp 2, more than half of the water samples assessed by the field agents had a pH below 6.5 [62]. In addition, 8.31% of household samples and 91.69% of source samples from Camp 2, and 66.07% of the household samples and 33.93% source samples from Camp 4Ext had turbidity above the WHO ideal limit of 1 NTU, but the information is unavailable for whether samples exceed 5 NTU [62].

Alarmingly, more recent water assessments (conducted between January–June 2020) reveal that water quality is deteriorating. Over half of the water samples obtained from households of Camp 2 had *E. coli*, with 20% of them having 11–100 CFU/100 mL [63]. About 90% of the recent samples collected from water sources at Camp 2 were free of *E. coli*, denoting contamination during collection, transport, or storage. For Camp 4Ext, about 23% of household samples and about 22% of source samples showed the presence of *E. coli*. Turbidity exceeded ideal limits for all of the household and source water samples in the recent water quality assessment [63].

3.1.2. Water Source

Camps 2E and Camp 2W have 352 and 299 functional water points respectively, with 65 and 63 people per water point respectively [64]. Camp 4Ext has 47 functional water points, with 126 people using per point [64]. The ratio of people to functional water points abides by the standard level. Overall, the most common source of drinking water was tube wells, as reported by 77% of the households combined. This is the main source in Camp 2, with 97% collecting water from tube wells and only 3% from both tube wells and tap stands. The source in Camp 4Ext is a combination of tube wells (30%), tap stand (46.6%), and both tube wells and tap stand (23.3%). Figure 2 shows a water supply tank in Camp 4Ext.

Figure 2. Water supply tank in Camp 4Ext, October 2019, Credit: SMN Uddin.

The difference in pH level can be explained by different sources of water collected. The number of solar-powered water systems and the size of the population are important factors. Camp 4Ext has a solar-powered water supply network, widely distributed around the camp so that each household has access to safe drinking water. The quality and availability of water, which are not yet of concern, seems to reflect the balance between the number of residents and the number of drinking water sources. On the other hand, Camp 2 is densely populated with many people relying on a few tube wells. Solar panels were more frequently observed in the east wing of Camp 2, but less frequently in the rest of Camp 2, suggesting that the number of solar panels that have been installed is not sufficient to provide power to pump drinking water for all the refugee households. Freshwater options are very limited in the area and the FGDs revealed that in one block, there were 25 families, with an average of four persons per family, sharing four tube wells. This imposes a great deal of stress on the groundwater levels. The recommended depth of boring a deep tube well is 150 ft because water available at less than 100ft is contaminated with a high amount of iron concentration. The low pH of water from Camp 2 may be due to iron residues that are building up due to the over-extraction of groundwater. Therefore, the acidity found in the samples implies that the water level might be receding around Camp 2.

The iron residue could also be present either naturally in the aquifer or due to hand pump corrosion. Standards for hand pumps recommend that galvanized iron pump components are not to be used in groundwater due to the possibility of corrosion, but that standard is not usually implemented [65]. High concentrations of iron give rise to growth conditions for iron-oxidizing bacteria, which could lead to the water having an unpleasant taste, odor, and appearance. Corrosive effects can lead to deterioration of pumping materials and make the tube well dysfunctional [65]. While observing refugees collecting water, it was noted that few of the tube wells in Camp 2 needed much pressure to be applied for water to be drawn. Provided that the iron concentration is not due to the decline in the groundwater table, it is possible that galvanized iron plumbing was used for the tube wells because reddish stains were noticed on the fixtures. In comparison, since most respondents in Camp 4Ext (70%) collect water from tap stands, this prevents the possibility of iron contamination from pump corrosion. Whatever the reason may be, according to the data obtained from field agencies, the concentration of iron was found to be above the recommended levels of 0.3 mg/L in both source and household water samples in both camps, which is another source of concern. 75% of the household samples and 57.84% of the source samples from Camp 2, and 60% of the household samples and 28.57% of the source samples from Camp 4Ext had unsafe concentrations of iron [62]. While iron is required by the human body in small amounts, excess iron causes toxicological problems in terms of accidental acute exposures and chronic iron overload. Ingestion of iron in excess amount causes severe toxicity in human physiological systems leading to heart, liver, and lung diseases as well as diabetes mellitus, hormonal abnormalities, and dysfunctional immune system [66].

3.1.3. Water Source Availability

Climate trends heavily influence water source availability in refugee camps. As shown in Figure 3, in Cox's Bazar, the water deficit is lowest from May to November and highest between January and March. Potential evapotranspiration (PET) and evapotranspiration (ET) are highest around May, and total water (W) due to precipitation is highest around July. Soil moisture content (SOIL) is lowest from January to April but it is slightly higher and constant from May to December and is dependent on W. Hence when W is higher than PET and ET, there is a surplus of water, and thus an increased SOIL. The water surplus is highest in July and the lowest from November to April. A high PET/ET and a low W, which usually is the trend during the summer seasons, accounts for the water deficit, which is highest in March. This climate trend explains why 26% of the households felt that water sources were unavailable during the summer. Overall, however, most households (74%) reported source availability round the year.

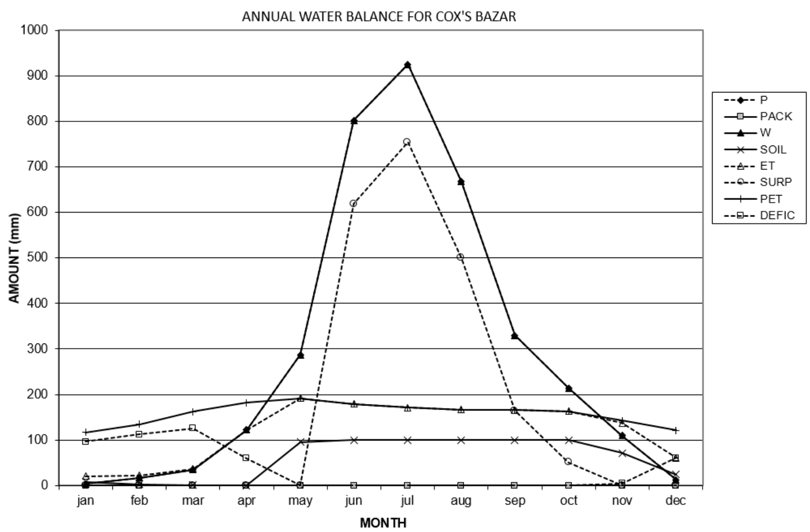

Figure 3. Monthly Water Balance Graph of Cox's Bazar using average monthly temperature and precipitation from 1981–2010, constructed using the Thornthwaite Water Balance Model.

In Camp 2, 14.3% of households reported facing water shortages daily, 40% weekly, and 25.7% monthly, while 20% reported never facing water shortages. In Camp 4Ext, 10% reported facing water shortages daily, 10% weekly, 40% monthly, and 40% reported never. The UNHCR has built five new solar-powered water networks that are clean and affordable alternatives to water trucking. The pump motor, powered by solar panels, draws water from chlorinated water tanks and pumps it to tap stands. Unlike unprotected groundwater aquifers, tank walls eliminate the possibility of contamination through the percolation of wastewater. The solar-powered water system is observed all over Camp 4Ext, providing residents with safe water to drink. Those who collect drinking water from tap stands (14%) reported water availability only when it is sunny.

A common hindrance to source availability in Camp 2 is the mechanical breakdown of tube wells, caused by increased stress. Each tube well is meeting the water requirements of hundreds of refugees. Prolonged pumping throughout the day can place significant stress on the tube well mechanism, which leads to failure, especially if the water levels drop and pump lifts increase. The result is a higher demand for an adjacent source, which then increases both the pressure on that source and the chance of breakdown. Residents said that they inform the NGO workers when this happens, and the pump is usually fixed within 1–2 h, but it can take 1–2 days if there are delays. Camp 4Ext households have the option to alternate between sources. They use the taps when it is sunny. During monsoon season, there is groundwater recharge so they can rely on tube wells. However, Camp 2 has fewer solar power water systems, limiting options for residents during summer.

Rainwater harvesting (RWH) could be useful to help overcome water shortages that occur during the summer or due to the decreased groundwater table, but there is little evidence that it has been considered for the Rohingya refugee camps. A study conducted in the Jerash refugee camps in Jordan concluded that RWH systems are technically and economically feasible, help alleviate water scarcity, and also improve sanitation [67]. RWH systems can serve as sustainable and cheap water supply options for refugee camps by making minimal modifications to emergency tents, such as "hemming up the edges of tarpaulin roofs to form pseudo-guttering and issuing funnels to assist the direction of runoff into containers" [68] (p. 124).

3.1.4. Water Collection Time

In addition to the 20 min that it takes, on average, to travel to and from water sources, a large amount of time is also spent waiting in queues to collect water. For Camp 2, 14.3% of households reported spending a total of less than 1 h collecting drinking water every day, with 64.3% spending between 1–3 h, 11.4% spending 3–5 h, and 10% spending more than 5 h. The long water collection time is attributed to overcrowding, due to the high people-to-tube well ratio. Although tube wells lie nearby—15 min away from most households—there are not enough of them for the number of people who are using them. Waiting a long time in line to collect water was a very common complaint among most women respondents, who are primarily responsible for fetching water for the household. It was also frequently suggested that more tube wells should be installed in the camps.

Camp 4Ext shows a distinct improvement in accessibility in terms of sources used for drinking water. 30% of households reported a collection time of less than 1 h, 60% reported between 1–3 h, 10% reported between 3–5 h and no-one reported spending more than 5 h. Solar-powered water systems, distributed throughout the camp, are considered by residents to be the most accessible and are more widely used than tube wells. Participants gave mixed responses about using both tube wells and taps, but taps were the most used water source. Some use tube wells when the taps do not work. Taps were found to be almost always located outside the household and used by multiple families as shared utilities. In comparison with Camp 2, Camp 4Ext residents spend less time fetching water because of the shorter distance to the source, and the lower people-to-source ratio.

3.1.5. Water Collection Responsibility

Responsibility for fetching drinking water falls disproportionately on women and girls. In 57% of the sample households, women were the sole collectors of water, while in 15% of households it fell to women and girls. Figure 4 shows two young girls who were collecting water for their families. In the remaining 28% of households, water was collected by a combination of men, women, boys, and girls.

Figure 4. Water collected by girls in Camp 2, October 2019, Credit: SMN Uddin.

The findings of this particular section are consistent with statistics showing women to be the ones who bear the burden of fetching water worldwide. The WHO recommends 20–50 L of water per person per day for drinking, cooking, and washing. There are separate tube wells for drinking water and for household purposes. Women often need to travel long distances several times a day and carry heavy loads, which may result in physical injury. For residents living in settlements built on the top or sides of the hills, the tasks become even more demanding, with increased risk of tripping or falling on the steep, uneven paths, especially when returning with containers full of water while walking uphill. The danger amplifies for pregnant women, women carrying toddlers, or children who accompany their mothers because nobody is at home to look after them. The cost in terms of the loss of opportunity for these women is huge. The hours lost collecting water could be spent on childcare, informal education, voluntary work, or other productive activities. Children of six years old were found to do water collections, severely impacting their education. Girls at times drop out of school to share household chores, and water collection is a central part of these chores.

Men and boys help with water collection when the woman in their house is pregnant or sick. Of the 4% who said boys collect water, it was because there were no girls in the house. While female respondents had no answer as to why they felt water collection was their responsibility, some of them said that their husbands were working during the day while they stayed home. They have to collect water in the daytime since nighttime brings dangers of sexual assault. The consequences apply to a lesser extent to Camp 4Ext residents, for whom the water sources are nearer, and they do not have to wait in line for so long. However, the unequal distribution of responsibility is found in both camps.

3.1.6. Maintenance of Water Containers

The cleanliness of containers used for the transport and storage of water impacts the quality. Not cleaning the container for a long time may cause the accumulation of dirt and pathogens or the formation of biofilm on the inner walls. The practice of covering containers during transportation was found to be high among participants, unlike in the study by Hsan et al. (2019) conducted in 2018 that found that nearly half of the households surveyed did not cover the containers during transportation [22]. 97% of the participants cleaned their containers every day. However, not everyone cleaned their containers with soap. Most simply rinsed it with water from the tube well during water collection. Washing with water alone removes pathogens, but is not as effective as using soaps [69], which have a stronger effect due to the high pH that disperses and kills pathogens. Other materials employed for rinsing were grass, leaves, and sand, which are not nearly as effective as soap. Some homemakers from Camp 4Ext reported rinsing the containers with sand when soaps run out. They are provided with soap each month, sufficient for washing and bathing purposes, but it runs out faster when they use it for cleaning containers. Most participants reported awareness of the need for cleaning their containers with soap and demanded more soaps be provided to them by NGOs.

The methods used for drawing water also have an effect on water parameters, along with the storage vessel/container [61]. From observations by the researchers, it was found that most respondents used a safe pouring method—tilting the vessel—to draw water as opposed to dipping a cup or mug inside the containers, which can cause contamination to the stored water by unclean cups or unwashed hands.

3.1.7. Water Container Material

83% of the respondents used metal containers to store water, 6% used plastic buckets, 6% used both metal containers and plastic buckets, and 5% used other vessels (i.e., clay pots). The refugees commonly used metal containers because they are provided by the NGOs. Although metal vessels can deteriorate storage water quality, this does not have a measurable outcome in this case since participants do not store water for long periods of time (all participants reported collecting water every one or two days), except when there is a period of unavailability, as explained in Section 3.1.3.

3.1.8. Water Treatment

Most households in both camps do not use any form of treatment prior to drinking. When asked whether water is boiled before drinking, 51 participants (72.9%) out of 70 said no in Camp 2, and 23 participants (76.7%) out of 30 said no in Camp 4Ext. A common reason explaining this is the perception that "the water is already clean", so an additional step for purification is deemed unnecessary. Many of the respondents said that they do not have access to gas. A few blocks in Camp 2W have community kitchens, but they receive a limited amount of gas per month which they need for cooking. On top of that, there are too many people using those kitchens, so boiling water seems to them like a needless chore that wastes resources. Households reported occasionally boiling water for children. Of the households that reported treating water, some use Aquatab (tablets that chlorinate water) to reduce contamination. They said that the tablets are distributed by NGO workers and they showed a proper understanding of their use, indicating the success of awareness campaigns held in the camps. The use of Aquatab was noted to be higher in Camp 2 than Camp 4Ext, although people in the latter are less likely to use them because they do not receive them.

3.2. Sanitation

Understanding sanitation conditions and practices in the camps are crucial for assessing water security because unhygienic practices such as open defecation, dirty latrines, and unplanned waste disposal increase the risk of waterborne disease transmission. NGOs have built pit latrines in the settlements to improve their sanitation system.

3.2.1. Latrine Use, Desludging and Waste Disposal

The refugees have been using temporary communal latrines. Although NGOs working in the camps responded to the sanitation needs of the refugees during the initial emergency phase, 32% of the residents continue to face problems regarding access [16]. With too many people using one latrine, they quickly overflow and become unusable, further worsening the problem of latrine shortage. Camps 2E and 2W have 889 and 942 latrines respectively, with each latrine being shared by 34 and 28 people respectively, which is higher than the standard level of 20 people per latrine [64]. With a total of 423 latrines, 17 people share each latrine in Camp 4Ext [64]. Participants have shared concerns about overcrowding and the cleanliness of the latrines. The residents using the latrines are responsible for maintaining them, but many do not follow the guidelines and leave them dirty. This conclusion has been validated with the results from both the FGDs and KIIs.

The rugged geography of the camps is an additional challenge to the distribution of latrines. In Camp 2, for instance, some latrines were precariously balanced on steep landings with stairs near drop-offs. Dirty water was observed to be leaking down from them, which raises public health concerns. The liquid waste also percolates into the sub-soil via the permeable walls of the pit, potentially contaminating groundwater. Since most latrines were built on elevated land, water flowing from upstream can increase the risk of fecal contamination. In contrast, Camp 4Ext has both water sources and latrines on level ground. The majority of the respondents (77%) use tube wells as their drinking water source. Water is mostly collected from deep tube wells because shallow tube wells are more likely to draw fecally contaminated water.

The refugees complained about the lack of electricity, which means they cannot use the latrines because, without lights, the uneven paths and open drains make it dangerous for residents to use them at night. Drains were often very close to households, particularly those bordering the block, and residents have to be careful on their way in and out of the house, with the lack of light exacerbating the risk of physical injury. The problem worsens during rainy seasons, making the gravel road more slippery. Women are at risk of assault when using latrines in the dark, too, and do not feel safe stepping out of the house at night.

KIIs revealed that there are challenges found in both Solid Waste Management (SWM) and Fecal Sludge Management (FSM) in terms of technological feasibility and awareness. The technological challenges are mainly found within the FSM and SWM operation and maintenance systems, including insufficient desludging capacity relative to the population, a lack of experts on FSM and SW disposal, the incomplete cycle of desludging, improper waste segregation, and no standard designs for FSM and SWM. These challenges may accelerate the cross-contamination of water and increase the risk of health hazards. Additionally, the lack of knowledge on waste segregation and dumping could increase the water security challenges in the camps.

3.2.2. Distance between Water Source and Latrine

The distance between the water sources and latrines was investigated to explain any coliform contamination found in the water samples. 60% of the households reported that the distance is more than 30 ft, which is the safe minimum distance to prevent groundwater contamination by coliform bacteria. 40% reported a distance between latrine and their water source to be less than 30 ft. During the emergency response phase, many water points were installed too close to latrines, and they had to be moved later. However, some tube wells remain within unsafe distances of latrines due to the shortage of space in the camps. In Camp 2, the flow of groundwater from upstream increases the possibility of microbial transport from fecal sludge to groundwater aquifer.

3.3. Health Hazards and Disease Prevalence

There is a clear difference between the two camps in terms of disease prevalence. 35% of the respondents said they were not facing any health issues (23% Camp 2, 12% Camp 4Ext). Although the tested water samples were free of fecal and total coliform, 18% of the respondents reported suffering frequently from diarrhea (14% Camp 2, 4% Camp 4Ext), 16% from diarrhea and skin diseases (14% Camp 2, 2% Camp 4Ext), 27% from skin diseases and others (17% Camp 2, 10% Camp 4Ext), and 4% from diarrhea and cholera (4% Camp 2, 0% Camp 4Ext). Skin diseases were prevalent among the respondents. The overcrowded shelters and their unhygienic living conditions may be responsible for various skin diseases. To confirm its correlation to drinking water, it would be necessary to test for other parameters.

A number of deaths due to diarrhea were also reported during the time of the survey in October 2019. When asked about diseases they usually experience, some refugees shared stories about children passing away in neighboring houses.

FGDs and KIIs revealed that children below the age of 5 are unable or reluctant to use latrines and consider open defecation more convenient. Some latrines in Camp 2 were found to be built on elevated platforms that are not safe for children. Children are not stable enough to position themselves on the latrine, and more often than not, instead of seeking help from an adult, they defecate elsewhere, such as near open drains or, for very small children, outside their house beside the doorstep. They tend to put their hands in their mouth frequently, sometimes without washing after defecation. Mothers dispose of the feces in the drains or waste bins, where they are not separated from human contact as in sewers. The area of defecation is cleaned by scrubbing with soapy water rather than using disinfectants. In addition, a few latrines had wastewater running down the slopes. These make for very unhygienic environments with a high risk of pathogen transmission.

By contrast, latrines in Camp 4Ext were built with more planning. Due to the advantage of the camp's location, the latrines were built on level ground within accessible distances. Adults and children in Camp 4Ext found it easier to use the latrines, and handwashing following defecation was more commonly practiced due to the existence of a tube well right next to the latrine. No leakage from the latrines was observed in Camp 4Ext. The comparatively better hygiene regime was reflected in the lower prevalence of diarrhea, cholera, skin disease, and other diseases.

However, there are factors common in both camps which contribute to health hazards. While bathing, children sometimes drink water from shallow tube wells, which is unsafe for consumption due to the high chance of being arsenic-contaminated [70]. They might also contain coliform bacteria from nearby latrines and other physiochemical parameters beyond the permissible range for drinking water. At the water collection point, women tend to rinse the container and clean it by rubbing their hands around the inside. This attempt at hygiene is deemed highly responsible for the contamination of water seconds after collection, which is otherwise coliform free at source. Hands that are not washed with soap have more pathogens than the dry surface of the container. Therefore, this practice of cleaning water containers without soap does not serve its purpose and may do more harm than good, by transferring pathogens to the water collected. It has been reported through KIIs that the prevalence of Acute Watery Diarrhea (AWD) is higher in the camps during the period of February–March and September–October. These could be during heavy rainfalls when sewage can contaminate deep tube wells, as well as during water-scarce periods when refugees are forced to depend on poor quality water sources. Cases of AWD have also been reported by WHO (2019) in other camps, which may be a result of water contamination due to the aforementioned reasons [71].

3.4. Key Threats in the Future

3.4.1. Perceptions of Key Threats in the Future

Participants were asked about the kind of challenges they think they might face regarding water security in the future. The goal was to get a sense of their knowledge and awareness about resource availability, and how they might respond to future threats. Almost half of the participants (47%) believed they will face no problem with water sources in the future and will continue to collect drinking water as they currently do. 13% agreed that population growth in the camps will create problems in getting water, in particular highlighting shortages and longer wait periods at the water points. 10% thought that natural disasters may pose a threat to the water source but did not possess a clear understanding of how this might happen. 13% reported other reasons which included the longer summers that are occurring due to changes in weather patterns, and rain, which participants said affects the solar panels that power the water pumps. It was noted during the FGDs, and indeed from interactions with participants and other camp residents, that refugees do not have many negative perceptions about future risks.

3.4.2. Key Threats that could emerge as a Result of Gaps in Water Programming

Against the backdrop of current sub-standard living conditions, long waits at water sources, groundwater insufficiency, and contamination, there are future threats that could potentially increase water insecurity in the camps. Summer in Bangladesh used to last from March to June. In recent years, weather patterns have changed, including the extension of summer into as far as August, which is usually monsoon season. The longer summer heat combined with limited rainfall exhausts groundwater resources. With only sporadic rainfall since November 2018, the water table for the refugee population in Teknaf was critically lowered during 2019 [72]. Their daily ration reduced from a standard 20 L per person to 15 L, and the lack of groundwater availability cost UNHCR up to $60,000 per month in transporting trucked water [73]. The water insecurity in Teknaf has increased concern regarding the health and hygiene standards of the population there, and the likely spread of waterborne diseases. Outside the refugee camps, areas of Teknaf have been affected by the extra use of groundwater by the refugee community. Agricultural prospects in the area, which have always suffered due to a lack of fresh water, are now more threatened than before [73]. The study area Kutupalong is not yet facing water scarcity as severe as Teknaf, but that is not to say it will not in the future. Continued extraction of groundwater at the current rate might not be sustainable for very long and could mean nearby areas will have to deal with challenges similar to Teknaf [73].

These refugee camps are highly prone to rainfall-induced landslides, flash floods, and cyclones. The threat to refugees is significant because the camps are mainly situated on low ground, and thus, susceptible to flash-flooding [74]. Forests on the adjacent hills have been randomly cut in order to build temporary shelters, with little consideration given to the risks of landslides. The resilience of the current water and sanitation infrastructure is poor and would be at risk of severe destruction if the area was hit by natural disasters such as earthquakes or cyclones. The congested shelters and absence of evacuation centers would very possibly result in an increase in disease [74]. Heavy rain in Cox's Bazar in 2018 took a heavy toll on the drainage systems, and it cost up to USD 1 million to clear blocked channels and protect them from future hazardous flooding [75]. Functional canals and drains are necessary to avoid flooding and the deposition of stagnant water, both of which can result in contamination of water sources, and create conditions for deadly diseases to flourish. Large open drains exist in Camp 2 and the rapid accumulation of sediment in drain structures during monsoons is a serious concern for the future.

A recent study conducted by AUW, Oxfam, and UNHCR (2020) reported the lack of training among staff who are working on the management of the water supply in the camps [45]. While there has been training on bore-hole drilling, surface water treatment, and laboratory testing, these limited training initiatives have not improved the skills of the technical team sufficiently to result in the design of good quality piped water networks in the camps. This leads to poor infrastructural planning and design as most of the organizations fail to perform appropriate, in-depth research, such as geographical surveys, before the installation of water systems, resulting in poor sustainability. Also, follow-up mechanisms are not well established in most organizations, leading to infrastructure breaking over time. Figure 5 shows the key gaps in water programming in the camps. Both technological and non-technological gaps were identified which can lead to future threats if not addressed immediately.

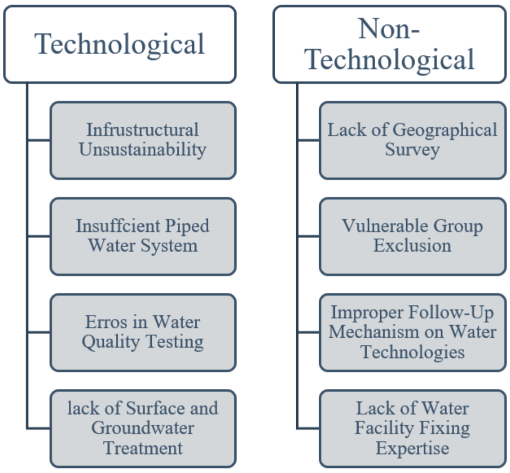

Figure 5. Gaps in water programming in the Rohingya refugee camps [45].

3.4.3. COVID-19 and Water Security: A New Threat?

During the period of the data collection for this study, the global COVID-19 pandemic [76] was yet to become a public health crisis in Bangladesh, although refugees and migrants in other countries had already been affected [77–79]. There were 306,794 cases reported in the country with 4174 deaths attributed to the disease [80]. With 62 confirmed cases in the Rohingya refugee camps [81], the government and humanitarian agencies took prompt action to try to prevent an outbreak in the camps. These interventions included awareness spreading through door-to-door household visits, the involvement of community leaders, mass media, art creation, community engagement activities, and COVID-19 awareness sessions with the elderly and persons living with disabilities [51]. During our research, the KIIs stated that a Communication with Communities (CwC) Working Group had been developed to inform people about COVID-19 and other health issues and to monitor every intervention through a strong operation and maintenance system with the help of all actors in the camps. KIIs also revealed that new handwashing stations were being set up at public places, in households, and near latrines and that old handwashing points were being repaired. In addition, soap distribution was being managed with the support of NGO workers and volunteers. 1700 isolation beds were set up for Rohingyas in preparation for an outbreak [82]. Although these steps may not prove to be sufficient in terms of the population size in the camps, KIIs expressed faith that these measures would help tackle the crisis to some extent. When addressing the question of migration from Myanmar during the pandemic [83], one respondent said that new arrivals and aid workers were prevented from entering the camps unless absolutely necessary.

However, challenges in prevention arise from extremely congested living conditions, which makes social distancing difficult. A lack of funding will pose a hindrance to the provision and/or sustainability of interventions to tackle COVID-19 across the camps. In addition, the low immunity of some refugees and a weak healthcare system with a low test rate [84] could create an enabling situation for COVID-19 in the camps. Most importantly, challenges pertaining to water availability, accessibility, and quality, due to socioeconomic, technical, and environmental could hinder the prevention of COVID-19 in refugee settlements [85]. In the context of Rohingya refugee camps, contaminated water sources and water shortages attributed to the absence of running water points in households, a lack of underground water access (particularly in the Teknaf area), downward movement of the groundwater table, and climate-induced low rainfall could make prevention extremely challenging, as regular handwashing with soap and water, and social distancing, are the key COVID-19 prevention strategies.

4. Conclusions and Recommendations

4.1. Conclusions

The collective efforts of numerous humanitarian agencies and the government of Bangladesh have tried to improve conditions for Rohingya refugees since their arrival. At present, the Department of Public Health Engineering (DPHE) in collaboration with UNICEF and Action against Hunger work to manage, oversee, and prepare strategic response plans for all WASH elements in the humanitarian sector. However, the Rohingya population is still dealing with challenges arising from congested and unhygienic camp conditions, the lack of sufficient water and sanitation infrastructure, fecal contamination, and geographical limitations such as a shortage of land area and groundwater, and a susceptibility to natural disasters including floods and landslides. This study inquired into the water security of Rohingyas in the refugee camps by assessing the availability, accessibility, and quality of water they use.

Considerable progress was noted in terms of water handling practices among refugees in both camps, which reflects positively on the awareness sessions conducted in the camps. Further awareness-raising is required with regards to washing transport containers (the current practice of rubbing with hands without soap is not safe) and the disposal of waste. Since the occurrence of diarrhea is higher among children below five years of age, special attention should be paid to try to rectify their habits of open defecation, and drinking shallow tube well water during bathing. Findings show that the prevalence of diseases and the water collection time is lower, and access to water source and sanitation is higher, in Camp 4Ext, confirming that this camp is better in several aspects than the other camps, which can be attributed to the proper planning that went into its construction. Almost all of the Camp 4Ext residents reported satisfaction with their living conditions, with minor exceptions of occasional water unavailability and technical failures of infrastructure. It is also important to realize that the population density in Camp 2 is 21 m^2/person, which is more cramped than the international guideline of 30–45 m^2/person for refugee camps [19], while Camp 4Ext is in line with this guideline. The benefit of this lower population density could account for the improved facilities and services provided in Camp 4Ext compared with Camp 2. The Camp4Ext was newly built with better planning to provide the services with fewer challenges. Therefore, this comparison can attract the attention of the researchers, government agencies, and development organizations in the Rohingya refugee camps and other camps at the global level to the design of Camp 4Ext, and it is expected that those working in the field can borrow aspects of the design of Camp 4Ext that has enhanced water security in that camp relative to others, while address the limitations that Camp 2 and at times, Camp 4Ext, has in their builds that affects safe and adequate water availability and accessibility to refugees in such settlements.

The outcome of this study can help not only the camp authorities and various agencies working to improve the wellbeing of the Rohingya refugees in Cox's Bazar, but also provides useful information and strategic direction to the global research and development communities who are working to tackle water security challenges in refugee camps across the world.

4.2. Recommendations

1. The current approach is providing basic humanitarian support to refugees, but it is not sufficient in the long-term. Given the uncertainties in Rohingya refugees returning to Myanmar, the government of Bangladesh should consider implementing projects to design and build water infrastructure that ensure the long-term water supply to the camps.
2. Rainwater harvesting could be adopted as a sustainable solution to water scarcity in the dry seasons. The strategic construction of these systems could also reduce the risk of flooding in the camps.
3. Since pit latrines are quick to overflow and pose risks of fecal contamination to nearby water sources, alternative methods for sanitation should be considered. Urine Diversion Dehydration Toilets (UDDTs) are a cost-effective and sustainable sanitation technology introduced in many

low-income countries [86], including Bangladesh [87,88], and should be considered in the Rohingya context.

4. The absence of residual free chlorine in drinking water samples is a possible health concern for refugees. Responsible agencies should take necessary steps to preserve residual chlorine at distribution points.
5. Indiscriminate disposal of waste around the camps leads to reduced hygiene and increases the likelihood of contamination during water collection, transportation, and storage. An additional effort from authorities is required to ensure proper disposal and management of waste.
6. Impairments to water quality require a response that integrates hygiene education and improvements to the sources, treatment, and storage of water.
7. Basic training on water infrastructure repair and maintenance can be provided to the camp-based community resource volunteers among the Rohingya refugees who can take care of the water infrastructure in the camps and can support their community when needed.

Supplementary Materials: The following are available online at http://www.mdpi.com/2071-1050/12/18/7325/s1.

Author Contributions: Conceptualization, S.M.N.U.; methodology, M.A. and S.M.N.U.; validation, M.A. and S.M.N.U.; formal analysis, M.A. and N.R.; investigation, M.A., S.M.N.U., and S.M.H.; resources, S.M.N.U.; data curation, M.A. and N.R.; writing—original draft preparation, M.A.; writing—review and editing, M.A., S.M.N.U., N.R., C.S., and W.P.; visualization, M.A. and S.M.N.U.; supervision, S.M.N.U.; project administration, S.M.N.U. and S.M.H.; funding acquisition, S.M.N.U. All authors have read and agreed to the published version of the manuscript.

Funding: This research received some logistic supports from a research project funded by the Center for Asia Pacific Initiatives (CAPI) at the University of Victoria, Canada through Prof. Jutta Gutberlet. Director of Community-based Research Lab (CBRL).

Acknowledgments: We acknowledge field support from Anika Tasnim Chowdhury, Tahlil Ahmed Parisa, Elham E. Sabah, and Sidratun Nur Chowdhury during our data collection. We want to thank the Office of the Refugee Relief and Repatriation Commissioner (RRRC) for providing us the permission to conduct our research. Special thanks go to Mohammad Mizanur Rahman, Additional RRRC, Cox's Bazar, Bangladesh, for his continuous support and guidance in completing our investigation. Thanks also go to Action Contre la Faim (ACF) Bangladesh, WASH Sector Coordinator (Md. Asif Arafat), RRRC officers in Camp 2 (E&W), and Camp 4 Ext., and Rohingya volunteers who supported us in every aspect of our data collections. Moreover, we thank former Chief Engineer Mr. Zohurul Hoque, Executive Engineer Md. Sadekuddin Chowdhury and Mr. Abu Mansur of CWASA for their help in doing laboratory analysis of water samples.

Conflicts of Interest: The authors declare no conflict of interest.

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