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Earthquake and Tsunami Knowledge, Risk Perception and Preparedness in the SE Bangladesh

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Abstract

Frequent tropical cyclones and floods, and less frequent earthquakes and tsunamis affect Bangladesh. In absence of recent large earthquake and tsunami experience, the country's disaster risk reduction strategies have been developed from the learning dealing with frequent tropical cyclones and floods. However, an analysis of historical earthquake and tsunami suggests that the country is also vulnerable to earthquakes and tsunamis. For example, the 1762 earthquake originating within the Arakan Subduction Zone generated a tsunami in the northern Bay of Bengal that struck SE Bangladesh. This research aims to understand how local residents perceive and prepare for earthquake and tsunami in SE Bangladesh. In order to achieve this objective, this research used both quantitative (i.e. questionnaire survey) and qualitative (i.e. focus group discussions and informal interviews) data collection techniques in SE Bangladesh. The results of data analysis suggest that the local residents have lesser level of risk perception and preparedness in absence of their direct experience of earthquakes and tsunamis. As such, this research recommends further assessment of community vulnerability to earthquakes and tsunamis and implementing risk reduction strategies.

Keywords: Earthquake; Knowledge; Perception; Preparedness; Risk; Tsunami

Introduction

Bangladesh (Figure 1) is currently ranked as one of the world's most disaster prone countries. Approximately ninety seven percent of the total land area and all inhabitants are at risk of multiple hazards including tropical cyclones, floods, droughts, riverbank and coastal erosion. Bangladeshi communities have significant experience of frequent tropical cyclones and floods [1-3]. However, the recurrence interval of great earthquakes and tsunamis is very long in the northern Bay of Bengal region [4-8]. As such, people may not perceive earthquakes and tsunamis as major hazards, but the main hazard lies in potentials for rare but catastrophic high-magnitude earthquake and tsunami events. In this regard, this research is an attempt to understand that local residents' risk perception and preparedness about earthquake and tsunami in SE Bangladesh that has recently been identified prone to these types of hazards [4].

The Himalayan Mountains are located 200 km from the northern border of Bangladesh. Between the Himalayan Mountains and Bangladesh, the Dauki Fault and the Assam Seismic Fault are located (Figure 1). In addition, the Bogra Fault System (BGF), the Jamuna Fault (JF), the Madhupur Fault (MF) and the Sylhet Fault (SF) are located within Bangladesh (Figure 1). To the south, the country is bordered by the Bay of Bengal. The Arakan Subduction Zone (ASZ) along the northern end of the Bay of Bengal extends up to the SE Bangladesh. It is a tropical low-lying country having a long, funnel-shaped coast (Figure 1). Bangladesh has a coastline over 710 km long, joining the vast 47,201 km² areas of coastal plain with the Bay of Bengal [9]. The country has 64 administrative districts and 19 districts are considered as coastal [10]. The coastal zone accounts for 32% of the total area of the country and 28% of the people lives in this zone. The triangular shape of the Bangladesh coast at the northern Bay of Bengal and high astronomical tidal ranges increase exposure to tropical cyclone [1,11].

The first record of an earthquake dates back to an event occurring in 1548 that affected both Bangladesh and India [12]. The 1548 earthquake may have ruptured large areas within Bangladesh and NE India. Few destructive earthquakes (Table 1) can be identified from the published and unpublished literature. However, in historical and recent times, the major cities, Dhaka and Chittagong, (Figure 1) have experienced ground shaking with intensities between III and VIII on the Modified Mercalli Intensity (MMI) scale from both distant and local severe earthquakes [12]. Earthquakes that occurred in 1897, 1934 and 1950 ruptured large areas adjacent to Bangladesh. The 1762 and 1897 earthquakes severely shook the floodplain of the Bengal Basin and caused landslides and liquefaction in Bangladesh [13,14]. Thus, earthquakes in Bangladesh are low-frequent catastrophic events and the vast majority of people have lack of experiencing significant earthquakes in their lifetimes.

The 2004 Indian Ocean Tsunami has already challenged the level of regional risk, rupturing around 1300 km of seafloor from Sumatra to the Andaman Island [15,16]. During the 2004 Indian Ocean Tsunami, the tsunami reached the coast of Bangladesh within 2.2 hours. The largest wave amplitude was 31 cm inland of the most southern coast of Bangladesh [17]. Officially, two human deaths occurred in Bangladesh [18]. The 2004 Sunda Subduction Zone earthquake was strongly felt [12]. Old buildings in Dhaka and Chittagong (two major cities in Bangladesh) developed cracking and some people were frightened following the 2004 Indian Ocean Tsunami [19]. People who were residing in these old buildings suddenly became panic and came out at street. The effects of the 2004 SSZ earthquake ranged between V-VI on the MMI scale from the coast to inland of Bangladesh [12].

Recently debate has arisen regarding the 1762 earthquake that originated in the Arakan Subduction Zone (ASZ) in the northern Bay of Bengal and whether or not it generated a 'mega-tsunami' similar to the one that devastated several Indian Ocean countries in December

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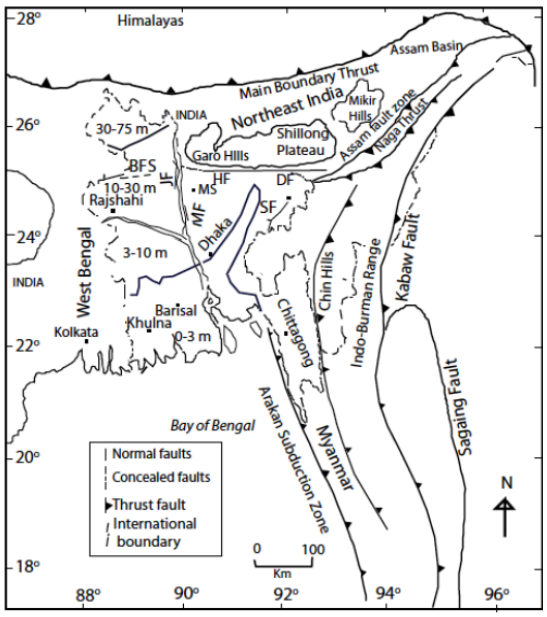

Figure 1: Location of Bangladesh in relation to regional active fault sources. ASZ: Arakan Subduction Zone, BFS: Bogra Fault System, DF: Dauki Fault, HF: Haluaghat Fault, JF: Jamuna Fault, MF: Madhupur Fault, SF: Sylhet Fault and MS: Mymensingh. The dark solid contour lines show the demarcation of different zones from the mean sea level (Source: map prepared adapting tectonic elements from Alam et al. [51], Ali et al. [21], Khan [7], Mukherjee [52].

2004 [5]. Cummins [5] refers to old 'historic' accounts of the effects of the earthquake in the region of Chittagong, Bangladesh. Later, Alam et al. [20] and Alam and Dominey-Howes [4] provide a detailed analysis of earthquakes and tsunamis in the northern Bay of Bengal. They reveal evidence of major historical earthquake and tsunami occurrence in SE Bangladesh. For example, they suggest that the 1762 earthquake generated several local tsunamis which flooded the Chittagong coast [4].

In the following sections, at first, I discuss earthquake and tsunami preparedness activities in Bangladesh. I then provide an overview of theoretical framework of earthquake and tsunami risk perception and preparedness, and a review of earthquake and tsunami literature in Bangladesh. Followed by this, I outline methods used for this research. In the subsequent sections, I present results and discussion of this paper. Finally, I make a series of recommendations for future research and implementing risk reduction strategies.

Earthquake and Tsunami Preparedness Activities in Bangladesh

The government of Bangladesh has a well-planned disaster response and mitigation mechanism for frequently occurring floods and tropical cyclones. However, it's programs and policies to mitigate the effects of less frequently occurring earthquakes and tsunamis are still in progress. In the late 1970s and early 1980s, many bridges, buildings and industrial structures were constructed. Following this, the assessment of seismic risk in different regions in the country was of great concern of engineers and scientists [21]. Research was undertaken to identify areas liable to severe seismic effects in Bangladesh [22,23]. The seismic zoning maps of Bangladesh have been revised ever since. The revised standing orders on disasters published in 2010, emphasised the need for mapping areas liable to earthquake damage.

The 12 May 1977 earthquake reaffirmed the need for improving seismic zoning in Bangladesh. Consequently, in June 1977, the Government formed a committee of experts to undertake the seismic zoning of Bangladesh and formulate policy options. The committee reviewed all the available information, revised seismic risk maps and outlined the building codes for earthquake resistant designs. In 1992, this exercise was repeated. Both seismic risk maps and building codes were revised to provide better guidelines of earthquake resistant design. For this mapping exercise, Bangladesh was divided into three zones (Figure 2): zone 3 (liable to severe damage); zone 2 (liable to moderate damage); and zone 1 (liable to slight damage).

The Disaster Management Bureau, a technical division of the government of Bangladesh, has attempted to increase public awareness in order to enhance preparedness for the pre- and post- earthquake periods in Bangladesh. Awareness activities included the publication of preparedness manuals and launching of programs in national broadcasting media, such as TV and radio [24]. In 2009, the Disaster Management Bureau published a manual that outlined pre-disaster measures and recommended activities that should be carried out during earthquake events [24] (Table 2).

Although some measures have been adopted (Table 2), there is no effective earthquake preparedness strategic plan. The policies and practices, which are based on those applying to tropical cyclones and floods, and they may not be adequate to mitigate the consequences of earthquakes. The review of the work of the Ministry of Food and Disaster Management and Disaster Management Bureau suggests that the government of Bangladesh is still working towards indentifying earthquake prone areas and improving disaster risk reduction for earthquake-related hazards.

Being a member of the Indian Ocean Tsunami Warning System (IOTWS), Bangladesh receives tsunami-related information for the Indian Ocean. Although the effects of the 2004 Indian Ocean Tsunami along the Bangladesh coast were minimal, this event raised considerable concern about the risk of tsunami hazard in Bangladesh [20]. Following the 2004 Indian Ocean Tsunami, the government of Bangladesh has incorporated tsunami hazard into its disaster risk reduction program, specifically in the second phase of the comprehensive disaster management program. The Disaster Management Bureau developed guidelines for tsunami preparedness (Table 3) that complement the cyclone preparedness strategies [4]. Because the tsunami is a rapid onset hazard and damage associated with its occurrence is different to that associated with tropical cyclones, these activities (Table 3) cannot adequately deal with the consequences of tsunamis. This research may help reducing community vulnerability to earthquakes and tsunamis in Bangladesh.

Theoretical Framework of Disaster Risk Perception and Preparedness

In order to mitigate the impacts of earthquake and tsunami hazards, it is essential to understand the many factors that influence people's ability to effectively respond to future events. A review of literature indicates that the following three issues are particularly important in relation to this study.

- Hazard knowledge
- Risk perception
- Disaster preparedness

Date	Name of earthquakes	Latitude /Longitude	Affected areas	Magnitude	Death/ Injuries
1548	-	26/ 92	India and Bangladesh	-	-
02-04-1762	Chittagong Earthquake	22/ 92	India, Bangladesh and Myanmar	7.8?	200
10-01-1869	Cachar Earthquake	24.75/ 93.25	India and Bangladesh	7.5	-
14-07-1885	Bengal Earthquake	24.8/ 89.5	Bangladesh and India	7.0	75
12-06-1897	Great Indian Earthquake	26/ 91	India and Bangladesh	8.7	1626
18-07-1918	Srimangal Earthquake	24.3/ 91.7	Bangladesh and India	7.6	9
02-07-1930	Dhubri Earthquake	25.8/ 90.2	India and Bangladesh	7.1	1
15-01-1934	Bihar-Nepal Earthquake	26.5/ 86.5	Nepal, India and Bangladesh	8.3	13772

Table 1: The occurrence of large earthquakes in and around Bangladesh [12,53].

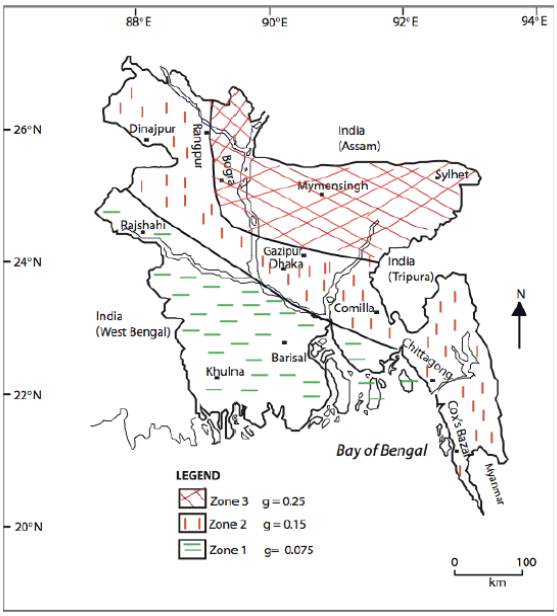

Figure 2: The current seismic zoning map of Bangladesh with probable earthquake zone coefficients. The g value equals maximum ground acceleration that can be expected based upon the associated from historic earthquakes of last 200 years. Zone 1 includes NE of Bangladesh and Sylhet City lies within this zone. Zone 2 includes Dhaka and Chittagong cities. Zone 3 includes SW Bangladesh [21].

Pre earthquake preparedness measures
Having information about morphological characteristics and active fault before building house
Identification of strong structures inside the house to take shelter during the earthquake
Discussing preparedness plan (evacuation route) with family members
Having always first aid kit at home
Keep a battery-operated working torch at home
Having a battery-operated working radio at home
Having a bed and table made of hard materials at home
Manage to have a helmet for each family member
Taking part in the preparedness activities launched by the Government of Bangladesh or NGOs
Activities to perform immediately after an earthquake
Leave the house/apartment as quickly as possible after first tremor and stay in open space
Put helmet on and ask everyone else to do so
While exiting ask the neighbours to leave house/apartment
Switch off electric and gas lines and do not make any fire
Do not try to carry any belongings
Keep safe distance to buildings and electric poles
In case unable to leave house, take refuge in one corner of the house; if the house is built with concrete columns, take refuge at the bottom of a column
If the resided house is made of tin, take refuge under bed
Provide first aid for the injured and manage to go to hospital as soon as possible

Table 2: Recommended earthquake preparedness measures and activities to perform immediately after an earthquake, for individuals and households [24].

In order to mitigate the effects of natural hazards, it is essential to understand how people living in places at risk perceive hazards, risk and their knowledge and preparedness in relation to particular hazards [25,26]. Enhancement of earthquake hazard knowledge may result in an increase in risk perception and preparedness actions [27] to reduce future vulnerability. In contrast, Mullis et al. [28] revealed that even when individuals have a better understanding of hazards and perceived risk, they may not undertake preparedness activities. In relation to volcanic hazards. Johnston et al. [29] suggest that only direct experiences may increase hazard knowledge and risk perception. When people perceive hazards [30], they are supposed to take more protective measures [31]. Again, this may not essentially lead to better preparedness [29]. Despite this, hazard knowledge and risk perception are important components of risk mitigation approaches [32]. The reason is that it is unlikely that an individual will be prompted to take part in mitigation measures for natural hazards without any appreciation of the hazard and risk [33].

The adoption of personal preparedness measures to reduce the risk of earthquake and tsunami hazard consequences may include but not limited to: education, age of residents, income level, ownership of residential unit in which currently residing, previous property loss due to an earthquake, knowledge of local alert systems and emergency response plans [34,35]. However, many factors influence and complicate people's decisions to adopt preparedness measures [36].

The review of the literature on the earthquake hazards in Bangladesh shows that much research was conducted to understand the morphology and seismic risk in Dhaka [12,37,38] and Chittagong [22] and Mymensingh cities (Figure 1) [39]. Paul et al. [34] conducted a quantitative survey of 444 residents of Dhaka to understand risk perceptions and preparedness about earthquakes. The findings of their research suggest that 83% of the residents were not prepared for a future major earthquake. Alam [4] suggested that the 1762 earthquake caused liquefaction, compaction, landslides and co-seismic subsidence, deaths and injuries in SE Bangladesh. However, in the past, limited research was conducted in order to understand risk perception of and preparedness to less frequent earthquakes and tsunamis in SE Bangladesh. As such, this research aims to fill this gap in knowledge by exploring communities' risk perceptions and their preparedness to mitigate risks of earthquake and tsunami hazards.

Methods and Materials

In order to gain a better understanding of community perception

Pre tsunami preparedness measures
Organise meetings, seminars, symposium and workshops to create awareness about tsunami
Arrange improved training for rescue team
Organise grassroot level voluntary team
Providing of primary treatment training in household levels
Strengthening *Upazila* and *Union* level disaster management committee
Recommended activities during tsunami
Take shelter in nearest distant cyclone shelter after receiving tsunami warning
Measures should be taken to evacuate people at risk before tsunami arrived in the coast
Prioritise evacuating women and children in tsunami period
Activities to perform following tsunami
Launch rescue operation following the tsunami involving all public and private organisations
In emergency rescue operations, providing food, clothing, medicine, and safe water. Additionally strengthening rehabilitation program following the tsunami
Disseminating information to the grassroot levels by mobile phone

Table 3: Suggested tsunami preparedness activities to perform in pre, during and post tsunami period [24].

of hazard and risk, and their preparedness [36,40] in SE Bangladesh, both quantitative and qualitative methods were utilized in this study. Both approaches have limitations [41]. However, mixed methods may bring in more robust evidence than either qualitative or quantitative approaches provide when they are used separately [42]. As such, household survey questionnaires, focus group discussions (FGDs) and informal interviews were used to gain a deeper understanding of hazard perception and preparedness.

Rationale of research area selection

The SE Bangladesh was selected as the research area for mainly three reasons. First, as outlined in section two, limited research was conducted in order to understand earthquake and tsunami risk perception and preparedness in SE Bangladesh. Although, Alam [4] provided significant evidence of earthquake and tsunami occurrence in SE Bangladesh, the government of Bangladesh considers this region as a moderate seismic risk zone (Figure 2) due to lack of knowledge about major earthquake occurrences [21].

Secondly, with over six million people, the second largest Chittagong City in Bangladesh is situated in this region. Due to agglomeration of industries and business and the fact that the main seaport is located in this region, Chittagong City is called the commercial capital of Bangladesh. Over 80% of the export-import of the country has been operated by this city. Like unplanned development in Dhaka City, in the last three decades, residential, commercial and industrial buildings in Chittagong City have also been developed without following proper planning and building codes. Such unplanned development may increase susceptibility to earthquakes and tsunamis.

Thirdly, the effects of the Indian Ocean Tsunami 2004 in the SE Bangladesh were moderate. After this tsunami occurrence, the significant concern arose from scientists, policy planners, the government of Bangladesh and international development organizations about future risk along the Bangladesh coast.

Survey design and implementation strategies

The fieldwork of this research can be divided into two phases. In the first phase, the primary knowledge of earthquake and tsunami risk perception and preparedness were acquired whilst conducting field visits and investigations during November 2010 and January 2011 for the research work of Alam [4]. The lead author of that research went for field visits to identify the locations of effects of the 1762 earthquake and tsunami in SE Bangladesh. While ground-truthing the locations of the effects of the 1762 earthquake described in historical documents, "impromptu" opportunities arose to consult 30 local residents at Bajalia, Dohazari, Baharchhara (BH1 in Figure 3), Burumchhara and Akilpoor in Chittagong (Figure 3). They were asked about history of earthquakes and tsunamis and knowledge, awareness and risk perceptions they had of future earthquake and tsunami occurrence. This type of knowledge development about the research area and local residents can be coined as 'scoping exercises' (conducted to identify existing knowledge and develop guideline for further research [43]. Synthesis and analysis of the primary informal discussion and interviews guided to the development of detailed household survey questionnaires, FGDs and informal interviews [44].

In the second phase of the research (December 2012 to February 2013), detailed questionnaire surveys, FGDs and informal interviews were conducted. Before this, a list of households from the selected study areas was prepared. Selection of these households was based on the provision that household heads would be available for interview. The information from in-depth questionnaires were collected from the 25 heads of households (i.e. 15 male and 10 female headed households) as they play the main role in economic activities as well as disaster response processes [36]. Five in-depth household questionnaire surveys were conducted in each location. Five FGDs were conducted, which include two in each location (Figure 3), consisting of 10 people in each group (equal number of male and female in each group) at a convenient time and place for the participants. The respondents in the household questionnaire survey and FGDs were randomly selected for interview. The duration of the each FGD was approximately 1 hour. The ages of the participants in the FGDs were over twenty-five. The occupations of the FGDs participants included labourer, local vehicle drivers, farmers, fishermen, housewives and small shopkeepers.

Informal interviews were conducted with 20 local educated and influential people, comprising of four individuals each from Bajalia, Dohazari, Baharchhara, Burumchhara and Akilpoor (Figure 3). The respondents were selected on the basis of general recommendation by the local community. It was believed that these respondents possessed better knowledge of earthquakes and tsunamis. The participants were over forty years of age, male, and had completed at least 12 years of schooling. Professionally, they were local councillors, journalists, community leaders and school teachers.

Discussion in the questionnaire survey, FGDs and informal interviews was concentrated on the following questions:

- What people knew about the term earthquake and tsunami?
- Perceptions of earthquake and tsunami risk,
- Personal experience of earthquake and tsunami particularly about the 2004 IOT;
- Whether people and their communities have any oral stories available about the 1762 earthquake;
- Whether people thought that their area could be affected either by an earthquake or a tsunami in the future;
- What is the most perceived natural hazard in the area?
- Preparedness for the most perceived hazard;
- Awareness and preparedness activities for earthquake and tsunami; and

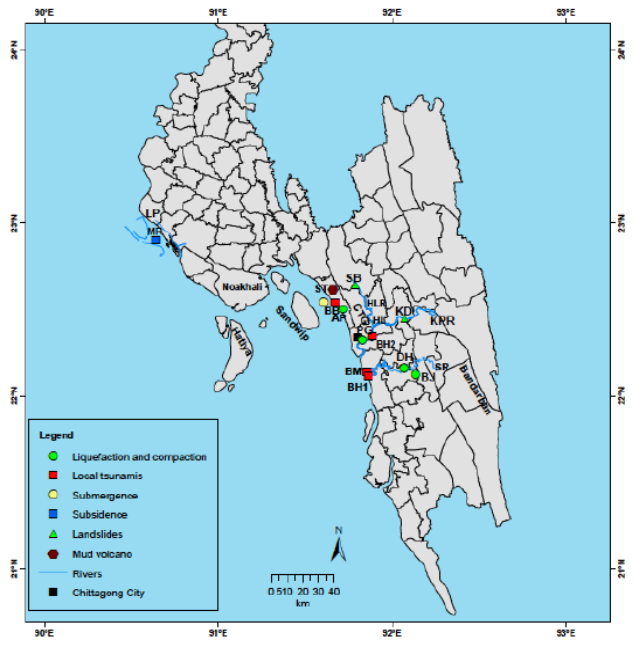

Figure 3: Location of field visits and the effects of the 1762 earthquake along the SE Bangladesh coast [4]. AP: Akilpoor, BB: Bansbaria, BM: Burumchhara, BH1: Baharchhara 1, BH2: Baharchhara 2, BJ: Bajalia, CTG: Chittagong City, DH: Dohazari, HL: Howla, KD: Kodala, LP: Lakshmipur, PG: Pathorgatha, ST: Sitakund, SB: Suabil, KPR: Karnafuli River, MR: Meghna River, SR: Sangu River.

- Knowledge about disaster preparedness program by Governmental Organizations and Non-Governmental Organizations (NGOs) and their involvement with any past or current disaster risk reduction programs.

Results

In the following sections, key findings are provided that ought to be of interest to organizations responsible for developing earthquake and tsunami risk mitigation strategies and for assisting the government of Bangladesh to determine the appropriateness of its preparedness strategy. Table 4 provides a 'quick-look reference' to the key findings of this research. Sequentially, this research explores the following:

- Knowledge about earthquake and tsunami;
- Knowledge about historical and contemporary earthquakes and tsunamis;
- Risk perception and preparedness about earthquakes and tsunamis; and
- Knowledge about disaster responding organizations

Knowledge about earthquake and tsunami

In order to gain a better understanding of the local residents' hazard knowledge and risk perception, the research participants were asked if they knew about earthquakes or tsunamis. All the people I spoke to, they knew the term Bhumikompo. Bhumikompo is the Bengali term for earthquake, which consists of two words Bhumi (land) and kompo (shaking). Along with its scientific name, the local residents refer to tsunami as Jalhosti, which consists of two Bengali words Jal (water) and Hosti (Elephant). The reason for the use of this term is that, the participants suggested that the ground shaking of an earthquake caused

Earthquake and tsunami knowledge, risk perception and preparedness	Sources of information
Earthquake and tsunami knowledge	
Have general understanding of the natural processes of earthquake and tsunami generation	Interviews and FGDs
Have heard the IOT 2004 and aware about its devastative effects	Interviews
Lack of knowledge about the occurrence of historical earthquakes and tsunamis	Interviews
Lack of knowledge about damage associated with historical earthquakes and tsunamis	Interviews
Low risk perception and subsequent lack of preparation	
Lack of direct experiences of earthquakes and tsunamis	Informal interviews and FGDs
Apathetic belief about possible occurrence of earthquakes and tsunamis in the region. Dependency on *Allah's* wish about future occurrence of earthquakes and tsunamis	FGDs
Lack of preparation for the occurrence of future earthquakes and tsunamis	Interviews
Lack of government and NGOs disaster risk reduction preparation for earthquakes and tsunamis	Interviews
Local residents have preparation for the occurrence of frequent hazards (i.e. tropical cyclones). However, they were apathy towards less frequent hazards (i.e. earthquakes and tsunamis)	Interviews and FGDs

Table 4: The SE Bangladeshi communities' earthquake and tsunami knowledge, risk perception and preparedness.

the turbulence of fresh pond water resulting in viscosity. The informal interviews and group discussions revealed that the participants also knew about certain observable aspects of earthquakes and tsunamis. They were aware of the sudden onset nature of these hazards that leave people with limited time to prepare and evacuate.

Knowledge about historical and contemporary earthquakes and tsunamis

All participants in interviews and discussions suggest that they did not have any knowledge about historical earthquake (Table 1) and tsunami occurrence in their region. None of them had ever heard about the 1762 event. Even none of the participants were aware of the tsunami events that had occurred before the 2004 Indian Ocean Tsunami. During the 2004 Sumatra-Andaman earthquake the participants experienced severe shaking, observed agitation of water in ponds and witnessed the rise of sea water adjacent to the Bay of Bengal coast. Experiencing the 2004 Indian Ocean Tsunami, the local residents are now familiar with the possible destructive effects (i.e. deaths, injuries and damage to houses and other infrastructures) of tsunami and the generation earthquake-induced tsunami.

Risk perception and preparedness about earthquakes and tsunamis

Having directly experienced severe ground shaking during the 2004 Sumatra-Andaman earthquake, 75% of the respondents thought that Bangladesh was at risk of earthquake and tsunami. However, in response to possible attack either by an earthquake or a tsunami in the selected study area, 100% respondents replied that they had no idea what will happen in the future. For the same question, all the participants in the group discussions replied that this depends on Allah's (God) wish. Apparently, none of the participants in the interviews and group discussions had any direct experience of facing damage, injury and deaths as a result of any known earthquake and tsunami. When

they were asked about their preparedness to earthquakes and tsunamis, 100% replied that they had not taken any preparedness actions to reduce the future risks that may occur due to these events. This means that Bangladesh resident's perceptions of and preparedness for earthquake and tsunami hazards are significantly influenced by their lack of experience of these hazards (perhaps during their life time) or by the low frequencies of these hazards.

Talking about natural hazards, the participants ranked the tropical cyclones as the damaging events in their areas. In relation to this, they recalled their own experiences and oral stories passed down from past generations' experiences of tropical cyclones (i.e. 1970, 1991 and 2007 that affected the Bangladesh coast). They also predicted that they would face tropical cyclones in the future and, as such, had their personal preparedness plans for that. As such, the findings of this research coincide with seminal hypothesis of the White [26] that hazard perception and preparation depend on frequency and magnitude of past hazard experiences.

Knowledge about disaster responding organizations

In Bangladesh, the Ministry of Food and Disaster Management (MoFDM) (http://www.dmrd.gov.bd/) is the main organisation responsible for dealing with disaster risk reduction. This ministry develops the legislative framework (i.e. the Disaster Management Act), and the policies and plans for disaster risk reduction in Bangladesh. In the field level, the local governmental organisations (i.e. Deputy Commissioner Offices, City Councils, Upazila Nirbahi Offices and Union Parishad Councils) and NGOs (i.e. CARE, ActionAid, Plan International and Oxfam etc.) worked both collaboratively and independently for implementing disaster risk reduction programs. All the respondents were aware about disaster responding governmental organisations and NGOs' preparedness activities for tropical cyclones and they were also involved at least one time in their lifetime in such programs. However, the findings revealed that not any risk reduction programs were in operation for earthquake and tsunami. None of the participants were involved in disaster risk reduction programs on earthquake and tsunami.

Conclusions and Recommendations

Interviews and discussions with people living in SE Bangladesh reveal that they have knowledge about less frequently occurring earthquake and tsunami. However, they perceived the hazards as a low risk because they believe that hazard occurrence depends on Allah's wish. In addition, the majority have not considered the hazards as a personal risk because they did not experience severe earthquakes and tsunamis in the past. People intended to take preparedness for tropical cyclones because they have past experiences, but they showed apathy towards less frequently occurring earthquake and tsunami due to lack of personal experiences. Thus, vulnerability to earthquakes and tsunamis along the Bangladesh coast will heighten because they have very low risk perception, leading to non-preparedness to hazards. Here it should be noted that prior to the 1991 tropical cyclone, the most local residents on the Bangladesh coast had strong beliefs that the occurrence of tropical cyclones was a matter of Allah's (God) wish. Such a belief led them to perceive low hazard risk that resulting in obstruction to long-term preparedness to hazard [35,45,46]. Consequently, tropical cyclones have taken numerous lives in Bangladesh.

This research has shown that the resident populations of SE Bangladesh are at high risk from future earthquakes and tsunamis because they do not have any preparation for such less frequently occurring hazards. As such, this research recommend taking proactive measures in relation to earthquakes and tsunamis in Bangladesh by launching of appropriate awareness programmes and implementing risk management strategies. For example, the following preparations should be made for earthquake and tsunami hazard mitigation in SE Bangladesh:

- Enhancing community knowledge by informing local communities about local and distant tsunami risk by citing examples of the 1762 tsunami and the 2004 IOT;
- Launching a continuous education program in order to reduce the vulnerability of local communities to earthquakes and tsunamis by informing them of losses associated with past events, for example;
  - Land level changes (i.e. liquefaction, compaction, landslide, subsidence, submergence);
  - Human casualties and injuries;
  - Damage to houses;
  - Damage to lifelines (i.e. electricity and water); and
  - River seiches;
- Enhancing community knowledge about the occurrence of historical earthquakes in Bangladesh (i.e. 1762 and 1885) [47];
- enhancing community knowledge about potential damage in Bangladesh associated with earthquakes from India and Myanmar [48];
- Launching an awareness program and risk management strategies;
- Whilst this research was conducted for assessing community vulnerability to earthquakes and tsunamis in SE Bangladesh, such findings should be further validated by conducting in depth community surveys on the other areas particularly in major urban population centers across Bangladesh; and
- This research recognizes that the quantification of hazard and risk can be more extensively conducted with rigorous analysis of the physical and social (i.e. local community) context [40,49]. A comprehensive analysis of the local context and the community's living knowledge would need to be undertaken to achieve this [50-52].

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