Fire Risk Assessment of Sonadanga Residential Area at Khulna in Bangladesh by Risk Value Indexing of Expert Opinion

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Abstract - Fire is the most frequent man-made hazard in Bangladesh. Khulna is one of the most rapidly growing cities in Bangladesh and Sonadanga residential area is planned residential area in Khulna. There are 305 buildings in this area. This study has been done to find the state of fire safety using and to identify the amount of risk. The data has been collected by a questionnaire survey and based on the data and expert opinion risk value has been set. It has been found 64% of apartments are at high risk. There are rest 36% at moderate risk. No buildings were found at minimum risk. The fire safety equipment using rate has been found very lower to moderate level. Only 36% of premises have fire extinguishers, 50% have emergency escapes and 18% have fire alarms. The state of installation of a fire sign, lighting, and smoke detector was found 0% which increases their fire risk. The fire hydrant did not find in the study area. There are 50% of people know about fire accident and no people has any training on fire safety. Summarizing that result, it may be said the study area is in moderate to high risk conditions.

Keywords: Fire safety in Bangladesh, Fire safety equipment, Vulnerable, Fire assessment

1. Introduction

Globally fire is the leading cause of injury and death. The fatalities for there are more in developing countries (Smith et al. 2007).Bangladesh is a developing country in South Asia and it is the most disaster-prone country in the world. It has a huge experience to face many natural and man-made disasters over the year (Islam & Hossain, 2018). A huge number of population, unplanned development, illegal structures, poor utility management, unaware people, and lack of implementation of activities lead to make vulnerable conditions and help to occur disasters. Fire is one of the most common man-made hazards in the country. A report is shown firing mishap from 2014 to 2016 in Bangladesh was 16213, 17488 and 16858 respectively. The average annual economic loss and damage to property worth more than Tk. 4000 Million (Islam & Hossain, 2018). Another report by the Solidarity Center (2018) has been expressed "from November 2012 to March 2018, there are 161 fire accident has been recorded in ready-made garment (RMG) sector in Bangladesh where 1303 people are deaths and 3875 injured" (p. 1).

The capital Dhaka, which 304 square kilometers (Roy et al, 2018) have experienced many extensive fire events and other big cities are getting riskier. Khulna is the 3rd largest and 2nd port entry of the country (Ahmed, 2011) which is the most premier cities in the country. This city is growing rapidly. Next 10 to 20 years, it might be a megacity due to its rapid urbanization and industrialization. The construction is very common around the city. However, the fire safety system is still absent in existing and new buildings. This state encourages the study on fire safety

assessment in a selected residential area in Khulna city in Bangladesh.

The news portal Dhaka Mirror has reported "Most of the high rise residential and commercial buildings in the Khulna city are extremely vulnerable to fire hazards, due to the absence of fire protection and extinguishing systems, according to officials of the Fire Service and Civil Defense (FSCD), Khulna" ("Khulna high rises", 2013). Salman (2017) stated, "According to the Fire Protection Act, 2003, all buildings, including the commercial establishment, must have adequate fire-fighting equipment and confirm to measures of public security". However, the buildings constructed in Khulna city do not have enough fire safety equipment, emergency exits and space between the adjacent ones. Even, entrances of most of the buildings are too narrow. The fire incident is common in Khulna. The industries, commercial and residential areas have faced some incidents in the last couple of years. In the news headline "14 furniture shop has been gutted in Khulna fire" (2018) was reported, "At least 14 shops were gutted in a fire that broke out at a furniture market in the West Rupsha area of the city early Friday" (para. 1). Another fire accident occurred in F R Jute Mills Ltd. at by-pass road adjacent to BKSP under the city on 27th March of 2018 published in an online news portal (Azad, 2018).

Based on the above background the Khulna city has been chosen to cover the study and the study area has been selected as a residential area, namely Sonadanga residential area which is located in the central position of the city and developed by the Khulna Development Authority (KDA). The total area is divided into three phases. The first, second and third phases is containing 115, 150 and 40 residential buildings consecutively. The number of apartments is 3647, and the total population is approximately 15645, which have been drawn by physically visit and personal communication. How the study area is vulnerable, the state of fire safety using, people at risk, the possible sources of fire, etc. were the research questions which had been trying to find out in this study. This study has been conducted between March to July 2019.

1.1 Objectives

The specific objectives of the study is

- To identify the fire hazards and the status of fire safety using in the study area
- To identify the amount of risk based on states of selected parameters

2. Methodology

First, a residential area was selected as the study area. Then the fire safety assessment procedure has been selected. A questionnaire has been prepared for a survey, data collected based on the questionnaire. After collecting data it has been processed, analyzed and outcomes have been drawn. The risk value index has been used to analyze which has been set by expert opinions. To calculate sample size used Yamane formula and sample number for each stratum (phase) has been calculated by stratified sample calculation method. The questionnaire survey has been conducted based on five steps of fire safety risk assessing.

The numbers of samples have been selected from the population in the very first step. The sample size was determined by online-based software (*www.fluidsurvays.com*) which is adopted by Yamane formula. The number of population (305), confidence level (90%), and margin of error (10%) was input and pressed calculate option, and then the suggested sample size was shown in the result box. The suggested sample size was 56 buildings. Due to time limitation, budget and other circumstances sample reduced by 50%, almost and hence, a total of 28 samples were considered. A stratified sampling method was used to select the number of samples from each stratum or phase. Samples have been identified by date, phase number of residential area, and respondent name.

The sampling frame was considered high and low rise buildings. The building more than six stories or 20m is a high rise building, according to Bangladesh National Building Code (BNBC, 2011) part one of section 2.2. The number of children and elders has been counted and considered them at high risk as they are directly dependent on the other. Elder people are they who are more than 60 years old (Barikdar, 2016) and up to 10 years consider as a child in this study as they cannot move from the premises usually. Though it will argue the age level of the child, whether they are dependent or independent at a fire event.

There are a different number of stories that have been covered in this study and normally it was between 5-10 story buildings. The following table shows the building stories and the number of sample covers.

Table 1: Building stories and number of sample covers

Number of Stores	Percent in Sample
3	3%
5	19%
6	15%
7	22%
8	22%
10	19%

The data has been collected through a questionnaire survey. In this study, a closed format questionnaire survey has been served. There are six sets of questions that have been used in this survey and two to three questions were in each set. The question has been set as per the study objectives. Respondent name, age, gender, profession and number of occupancy were in the first set of questions. The sources of ignition, oxygen, and fuel were in the second set. The safety system like fire signing, lighting, alarming, extinguisher, smoke detector, etc. has been drawn by the set number three of the questions. What type of peoples was at risk and how many people from each premises were at risk has been found from another set of questions. The knowledge and training level of house holders also known through a question set. The questionnaire is given in the Appendix section.

3. Result and Discussion

The result has been generated based on the questionnaire survey. The male to female ratio, number of people at risk, state of fire safety using, fire hydrant and fire safety vehicle accessibility, location of fire service station, the awareness level of the occupancies, etc. has been found out from the study. A total of 15 parameters were set and scoring for all samples. The positive score was set 1, which means good or safe from fire risk and '0' was set as a negative score that means buildings are at risk. The following discussion is representing the extracted result from the study.

3.1 Male-female ratio

The ratio of males to females in a given population usually expressed as the number of males per 100 females. In the case of Khulna division, it is also the same 100:100 found in the population census of 2011 (Asma & Islam, 2019).In this study, male and female number of each premise has been recorded. The study has been found the sex ratio or the male-female ratio was 1:1.14. It was 114 males per 100 females. In percentage, it has been found 47% of females and 53% of males. The male and female in percentage is given in the following figure.

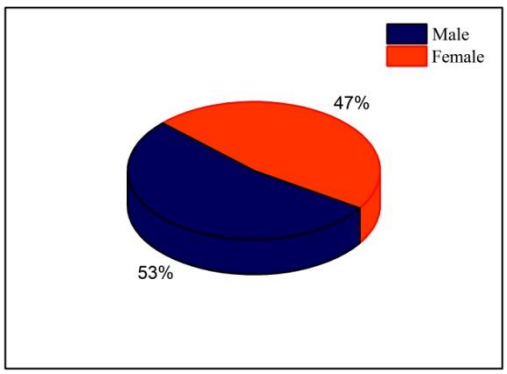

Figure 1: The percentage of male-female in the study area

3.2 Sources of Fire Hazard

Sources of fire hazard are the summation of different sources of ignition, fuel, and oxygen. In the questionnaire, three specific questions were there about these sources. The sources of ignition were found out by not only based on the questionnaire but also by physical observation. Naked flames like match, candle, stoves, electrical socket, and electrical short circuit cooking and catering appliances, smoking materials like a cigarette, lighter, etc. were found as the most common sources of ignition.

Liquid Petroleum Gas (LPG) was found to be the main source of fuel. Most of the residents used LPG for their cooking. Hence, gas is the main source of fuel. The other sources of fuel were mattresses, papers, clothes, furniture, etc. Surrounding was free from commercial or industrial activities, chemical storage, etc. Air was the main source of oxygen. Therefore, the consequences of sources of fuel may be considered as a moderate level. Chemical storage or commercial activities did not find in the study area. There were no sources found which increase the supply of oxygen. Therefore, the hazard can be categories at a moderate level in the study area. No buildings far from the risk of fire occurrence.

3.3 The status of Fire Safety Equipment Using within the Premises

The fire safety equipment (called also firefighting equipment) is an appliance that designed to extinguish fires or protect user from fire hazard. Sometimes it gives pre-information about fire and the situation can be controlled before the fire is in danger. There are many types of firefighting and safety equipment available nowadays, like fire alarms, signals, extinguishers, etc. The status of use of fire safety measures in buildings is discussed below.

(i) Fire Extinguisher (ii) Smoke Detector (iii) Emergency Escape (iv) Fire Alarm (v) Fire Lighting and (vi) Fire Sign

(i) Fire Extinguisher

The fire extinguisher is common firefighting equipment. Thus, many buildings were found that they are using a fire extinguisher. A total of 10 buildings were found among 28 buildings that they have installed fire extinguishers. The result in percentage, 36% building was found that they have a fire extinguisher. Rests of 64% of buildings are at risk for the absence of fire extinguishers. In the following figure is showing the status of fire safety equipment using within the premises.

(ii) Smoke Detector

The early stage of fire is smoke. The smoke detector is one that sensor-based instruments can detect smoke. It is a very good safety for fire. There were no buildings found that they installed a smoke detector. 100% of premises are no smoke detectors. That means 0% of premises were found using smoke detectors.

(iii) Emergency Escape

Emergency escape is a way or path that opens when a fire occurred in a building. It may be a stairway outside of the building or maybe an alternative stair in the building. It has been found 14 premises since 28 that they have an emergency escape way. Therefore, the emergency escape was found in 50% in percentage calculation.

(iv) **Fire Alarm**

Some of the premises were found that they have a fire alarming system. The data from the study calculated and found only five buildings among 28 buildings have an alarm system. This is only 18% of premises has been installed fire alarming system. The majority in the study area was found absent of fire alarms.

(v) Fire Lighting

There were no buildings were found that they used the lighting system. It is important that when any serious moment will come then people can escape quickly by seeing the light signal. This type of safety measures can be used on the slab of balcony, veranda, stairway, etc. Since no firelight was found in any building, therefore the rate of light signaling use was 0% in the study area.

(vi) Fire Sign

It was not found in any premises that they are using for fire signing. Fire safety could be used as a wall painting or sticker. No sign has been found on the premises. Therefore, using the rate of fire signal is 0% found. That why safety has fallen at high risk. The status of fire safety using is given in the following figure.

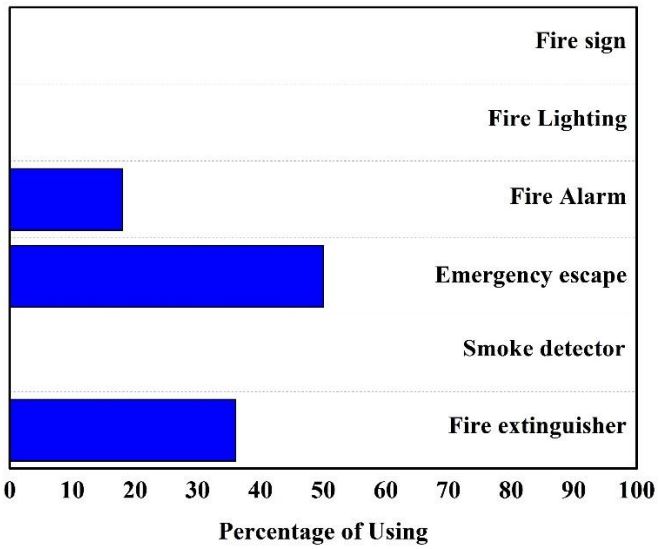

Figure 2: The status of fire safety equipment using within the premises

3.4 Fire hydrant and fire service vehicle accessibility

The fire hydrant is a type of large pipe and system that submerged in the soil of the street and firefighter can get water from it to use fire stopping. In physically visit in the study area there was no fire hydrant found. Thus the risk is higher in case of a fire hydrant. On the other hand, the study area is planned and well-designed hence, every road around the premises was found wide. Any fire service vehicle easily can access into the area. Each apartment faces a well wide road. Hence, its risk is considered low.

3.5 People at Risk

In this study, the child who cannot escape from the premises alone or dependent on family members is considered more vulnerable. Similarly, the elders who are dependent or disable are faced more critical in a fire event. This study considers children who are in below 10 years old and elder person those who are more than 60 years old. This study has been found a total of 77 children from 28 buildings. The number of elderly people has been found 34 in the same 28 buildings. Thus, people are common in each building at risk.

3.6 Awareness (Training, Knowledge, and Fire service number)

The occupancies in the study area did not find as trained. People were asked about their training regarding fire safety and evacuation and the response rate was found fully negative. Hence, the risk can be considered as high. There were 14 samples found they have the knowledge and they are aware of fire safety. In calculation, 50 percent were found the premises have some knowledge about fire hazards. In this case, the risk category considered

moderate. A total of 12 apartments found they have been keeping the fire service number. Thus 42% of premises have a fire service number which considers a moderate risk level. The following table is given the state of awareness as to whether they are trained, knowledgeable or they keep fire service numbers. The status of particulars of awareness (training, knowledge of fire safety, and keeping fire service number) is given in the following table.

Table 2: Percentage of people trained and awarded

Particulars of awareness	Percentage Found (%)
Training	0
Knowledge of fire safety	50
Keeping fire service number	42

3.7 Location of fire service and fire frequency

The fire service and rescue station of Khulna is near to the Sonadanga residential area. It is only 6 KM away from the study area. It will take only 10-15 minutes to reach the study area. Therefore, the risk factor is low in the case of a firefighter of fire service and rescue to reach the study area. The following figure is shown the location of fire service and rescue near the study area.

In the study area, there was found no fire occurrence in the last decade or so. Therefore, the frequency is zero here. So, the risk index is lower in case of fire frequency.

Figure 3: Fire service and rescue center near the study area

3.8 Risk Calculation

A total of 15 parameters were considered for risk indexing. The '0' and '1' have been used for scoring. This scoring consider by discussion with expert opinion. When a parameter meets that protect or prevent fire is positive scored 1 and when the lacking of any equipment or measures that protect fire is scored 0. Hence, the total score has been summed up. A total of 15 parameters have been considered in this study, which made 15 scored. The score is the maximum mean low risk and vice versa. With the expert's opinion, the risk was considered minimum, moderate and high. When the score was found below 5 considered as high risk, from 6 to 10 was considered as moderate and from 11 to 15 is considered as low or minimum risk. The following tables are shown the risk score and how the risk has been set by the expert opinion (table 3), and the next table (table 4) is given set parameters (detail is given in Appendix) and status of building score.

Table 3: Set risk score

Total Risk Score	High Risk	Moderate Risk	Minimum Risk
15	1 to 5	6 to 10	11 to 15

Table 4: Score gained by buildings

SN.	P1	P2	P3	P4	P5	P6	P7	P8	P9	P10	P11	P12	P13	P14	P15	Total
B 1	0	0	0	0	0	0	0	0	1	0	0	1	1	1	1	5
B 2	0	1	0	1	1	0	0	0	1	0	0	1	1	1	1	8
B 3	0	1	0	1	0	0	0	0	1	0	0	1	0	1	1	6
B 4	0	0	0	0	0	0	0	0	1	0	0	1	0	1	1	6
B 5	0	0	0	0	0	0	0	0	1	0	0	0	0	1	1	6
B 6	0	0	0	0	0	0	0	0	1	0	0	1	1	1	1	5
B 7	0	1	0	1	1	0	0	0	1	0	0	1	1	1	1	8
B 8	0	0	0	0	0	0	0	0	1	0	0	0	0	1	1	3
B 9	0	1	0	1	0	0	0	0	1	0	0	1	0	1	1	6
B10	0	0	0	0	0	0	0	0	1	0	0	0	0	1	1	3
B11	0	0	0	0	0	0	0	0	1	0	0	0	0	1	1	3
B12	0	0	0	0	0	0	0	0	1	0	0	1	1	1	1	5
B13	0	1	0	1	1	0	0	0	1	0	0	1	1	1	1	8
B14	0	0	0	1	0	0	0	0	1	0	0	0	0	1	1	4
B15	0	0	0	0	0	0	0	0	1	0	0	0	0	1	1	3
B16	0	0	0	0	0	0	0	0	1	0	0	1	1	1	1	5
B17	0	1	0	1	1	0	0	0	1	0	0	1	1	1	1	8
B18	0	0	0	0	0	0	0	0	1	0	0	0	0	1	1	3
B19	0	1	0	1	0	0	0	0	1	0	0	0	0	1	1	5
B20	0	0	0	0	0	0	0	0	1	0	0	0	0	1	1	3
B21	0	0	0	0	0	0	0	0	1	0	0	1	1	1	1	5
B22	0	1	0	1	1	0	0	0	1	0	0	1	1	1	1	8
B23	0	0	0	0	0	0	0	0	1	0	0	0	0	1	1	3
B24	0	1	0	1	0	0	0	0	1	0	0	0	0	1	1	5
B25	0	0	0	1	0	0	0	0	1	0	0	0	0	1	1	4
B26	0	0	0	1	0	0	0	0	1	0	0	0	0	1	1	4
B27	0	0	0	1	0	0	0	0	1	0	0	0	0	1	1	4
B28	0	1	0	1	0	0	0	0	1	0	0	1	1	1	1	7
Total	00	10	00	14	05	00	00	00	28	00	00	14	12	28	28	

SN. = Serial Number; B1,2,3.....Building Number; P1,2,3.... Parameter Number

In this table, the total 28 buildings (samples) is given in column and set parameters in a row. Which one building meets which one measure and which one did not meet easily find from the above table.

3.9 Discussion

The set score was 15 for a total of 15 parameters. The low score was found 3 and the highest score was found 8. The score was up-down in between 3 to 8. From the following table, the set score and risk status can be seen.

Table 5: The set score and risk status

Total Score	High Risk	Moderate Risk	Minimum Risk
15	1 to 5	6 to 10	11 to 15
Number of Building	18	10	0
In Percentage	64%	36%	0%

There were a total of 15 parameters considered for risk assessment of the 28 buildings in the study area. The score was analyzed and found no buildings gain above score 10. Therefore, no buildings are at minimum risk. The highest score was found eight, and thus all premises are at either medium risk or maximum risk.

From the table, 5 it is seen 18 buildings have been gained score 1 to 5. Therefore, nineteen buildings are under high risk. In percentage, almost 64% of buildings in the study area are found at high risk. On the other hand, nine buildings score at 6 to 10 which means nine buildings are at moderate risk. In percentage, 36% of buildings of the study area are found at moderate risk. There are no buildings are found at minimum risk.

4. Conclusion

The Sonadanga residential area has been selected as a study area and a structural or closed format questionnaire survey has been done for data collection. The questionnaire has been set up based on the research question. The collected data have been decorated and analyzed and finally, findings or result has been drawn. The main sources of fire ignition, fuel and oxygen was found naked flames, electrical circuit; gas cylinder and ambient air, respectively. Fire sign, lighting, alarming, emergency escaping, smoke detector and fire extinguisher system in the premises are respectively 0%, 0%, 18%, 50%, 0%, and 36%. There is 7% of children (below 10 years) and elder (over 60 years) at fire risk. It is also found there is no people in the premises are trained, 50% of people know about fire safety and risk. Only 42% of people were found who have kept the fire service number. There were 68% of buildings got only score five or below which means 64% of buildings in the study area were found at high risk. The rest of 36 percent was fallen under moderate risk. Because these 36 percent of buildings were got score 6 to 10, which set a moderate score by expert opinion. This result shows how the study area is under fire risk. It was the first study of fire risk assessment in any residential area of Khulna city so far.

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Appendix A

S.L.	Name of set Parameters	Building 1		Building 2		Building 3		Building 4		Building 5		Building 6		Building 7	
		Score		Score		Score		Score		Score		Score		Score	
		1	0	1	0	1	0	1	0	1	0	1	0	1	0
1	Fire Hazard		0		0		0		0		0		0		0
2	Fire Extinguisher		0	1		1			0		0		0	1	
3	Smoke Detector		0		0		0		0		0		0		0
4	Emergency escape		0	1		1			0		0		0	1	
5	Fire Alarming		0	1			0		0		0		0	1	
6	Fire Lighting		0		0		0		0		0		0		0
7	Fire Signing		0		0		0		0		0		0		0
8	Fire Hydrant		0		0		0		0		0		0		0
9	Accessibility of Fire service vehicle	1		1		1		1		1		1		1	
10	Child and Elder people		0		0		0		0		0		0		0
11	Training		0		0		0		0		0		0		0
12	Knowledge	1		1		1			0	1		1		1	
13	Fire service number	1		1			0		0	1		1		1	
14	Location of Fire Service Station	1		1		1		1		1		1		1	
15	Frequency of Fire Occurring	1		1		1		1		1		1		1	
	Score (15)	5		8		6		3		5		5		8	

S.L.	Name of set Parameters	Building 8		Building 9		Building 10		Building 11		Building 12		Building 13		Building 14	
		Score		Score		Score		Score		Score		Score		Score	
		1	0	1	0	1	0	1	0	1	0	1	0	1	0
1	Fire Hazard		0		0		0		0		0		0		0
2	Fire Extinguisher		0	1			0		0		0	1			0
3	Smoke Detector		0		0		0		0		0		0		0
4	Emergency escape		0	1			0		0		0	1		1	
5	Fire Alarming		0		0		0		0		0	1			0
6	Fire Lighting		0		0		0		0		0		0		0
7	Fire Signing		0		0		0		0		0		0		0
8	Fire Hydrant		0		0		0		0		0		0		0
9	Accessibility of Fire service vehicle	1		1		1		1		1		1		1	
10	Child and Elder people		0		0		0		0		0		0		0
11	Training		0		0		0		0		0		0		0
12	Knowledge		0	1			0		0	1		1			0
13	Fire service number		0		0		0		0	1		1			0
14	Location of Fire Service Station	1		1		1		1		1		1		1	
15	Frequency of Fire Occurring	1		1		1		1		1		1		1	
	Score (15)	3		5		3		3		5		8		4	

S.L.	Name of set Parameters	Building 15		Building 16		Building 17		Building 18		Building 19		Building 20		Building 21	
		Score		Score		Score		Score		Score		Score		Score	
		1	0	1	0	1	0	1	0	1	0	1	0	1	0
1	Fire Hazard		0		0		0		0		0		0		0
2	Fire Extinguisher		0		0	1			0	1			0		0
3	Smoke Detector		0		0		0		0		0		0		0
4	Emergency escape		0		0	1			0	1			0		0
5	Fire Alarming		0		0	1			0		0		0		0
6	Fire Lighting		0		0		0		0		0		0		0
7	Fire Signing		0		0		0		0		0		0		0
8	Fire Hydrant		0		0		0		0		0		0		0
9	Accessibility of Fire service vehicle	1		1		1		1		1		1		1	
10	Child and Elder people		0		0		0		0		0		0		0
11	Training		0		0		0		0		0		0		0
12	Knowledge		0	1		1			0		0		0	1	
13	Fire service number		0	1		1			0		0		0	1	
14	Location of Fire Service Station	1		1		1		1		1		1		1	
15	Frequency of Fire Occurring	1		1		1		1		1		1		1	
	Score (15)	3		5		8		3		5		3		5	

S.L.	Name of set Parameters	Building 22		Building 23		Building 24		Building 25		Building 26		Building 27		Building 28	
		Score		Score		Score		Score		Score		Score		Score	
		1	0	1	0	1	0	1	0	1	0	1	0	1	0
1	Fire Hazard		0		0		0		0		0		0		0
2	Fire Extinguisher	1			0	1			0		0		0	1	
3	Smoke Detector		0		0		0		0		0		0		0
4	Emergency escape	1			0	1		1		1		1		1	
5	Fire Alarming	1			0		0		0		0		0		0
6	Fire Lighting		0		0		0		0		0		0		0
7	Fire Signing		0		0		0		0		0		0		0
8	Fire Hydrant		0		0		0		0		0		0		0
9	Accessibility of Fire service vehicle	1		1		1		1		1		1		1	
10	Child and Elder people		0		0		0		0		0		0		0
11	Training		0		0		0		0		0		0		0
12	Knowledge	1			0		0		0		0		0	1	
13	Fire service number	1			0		0		0		0		0	1	
14	Location of Fire Service Station	1		1		1		1		1		1		1	
15	Frequency of Fire Occurring	1		1		1		1		1		1		1	
	Score (15)	8		3		5		4		4		4		7	

Appendix B

Khulna University of Engineering and Technology
Institute of Disaster Management
Project work for Post Graduate Diploma in Disaster Management

Fire safety Risk Assessment in Sonadanga Residential Area, Khulna, BD

Date..... Time..... Day.....

Premises No.....

Address.....

Respondent Name.....

Age..... Gender M F Profession.....

People occupancy.....

Identify Fire Hazard

Sources of ignition.....

Sources of fuel.....

Sources of Oxygen.....

Fire safety Systems within premises

Fire sign Y N Fire extinguisher Y N Fire Alarm Y N

Emergency escape Y N Lighting Y N Smoke detector Y N

Identify People at Risk

Child (Age below 10) Women Elder (Age above 60)

Training and Emergency Action Plan

Have any training Y N Knowledge Y N Fire service number Y N

Comment :

What do you think about develop the fire safety issues:

Do you have interest about using fire safety? Y N May be