Chemical hazard perception and post-evacuation behavior following a major earthquake: A case of electrical engineering and chemistry students

Yusuke Koshiba,* [1] Keiji Chiba, [2] Jo Nakayama [3]

1 Department of Materials Science and Chemical Engineering, Faculty of Engineering, Yokohama National University, Yokohama 240-8501, Japan

2 Department of Chemistry, Chemical Engineering and Bioscience, College of Engineering Science, Yokohama National University, Yokohama 240-8501, Japan

3 Division for Environment, Health and Safety, The University of Tokyo, Tokyo 113-8654, Japan

Keywords

Major earthquake; Post-evacuation behavior; Chemical hazard perception; Unsafe action; University members; Emergency management; Decision making

Abstract

It is unsafe to immediately return to an evacuated science or engineering building that stores and handles chemicals after a major earthquake. A questionnaire-based survey was conducted targeting students at a national university in Japan to explore chemical hazard perception and post-evacuation behavior of non-chemistry background students following a major earthquake. The survey incorporated 11 situational questions, and the participants rated the extent to which they were likely to return to their building after a major earthquake in each situation. The results indicated that the students were likely to return if they had evacuated without their personal belongings, and majority of the students did not recognize the risks associated with chemical hazards.

1. Introduction

Hazardous materials (e.g., toxic, asphyxiant, and flammable gases/liquids) are handled and stored in science and engineering buildings at universities. Huston *et al.*[1] concluded that being aware of chemical hazards is crucial for safety. A major earthquake may trigger accidental fires, explosions, and toxic releases in such facilities which may potentially cause casualties. Natural hazard triggering technological disasters (Natechs) are some of the most serious disasters a university could face.[2] Unfortunately, such earthquake-triggered incidents do occur. For instance, Normile[3] reported that following the 2011 Tohoku earthquake, students heard the hiss of gases released from cylinders and were caught in a room fire, while Yamada[4] reported an earthquake-triggered fire in a chemical laboratory of a university during the 1995 Great Hanshin earthquake.

When a major earthquake occurs, university members (students, faculty, and staff) must stop their experiments and evacuate the buildings. Afterward, they tend not to return to the evacuated buildings based on their own judgment, specifically, if visible damages are observed. Immediately after a major earthquake that may lead to a confusion-filled period, authorities (the fire department and campus police) cannot immediately attend each of the buildings on the university campus and guide the people owing to the large number of buildings on the campus and the limited number of authorities.

If the buildings still seem to be intact and the authorities refrain from keeping the people from immediately returning to the buildings, people are expected to return voluntarily[5] (Figure 1). As a matter of fact, many university members were observed to unsafely return to evacuated buildings immediately after the 9.1-magnitude Tohoku earthquake in Japan in 2011. However, even a building without any visual damage may be unsafe, since gas cylinders and chemical storage cabinets within may be damaged, and this might cause fire, explosions, and accidental suffocation.

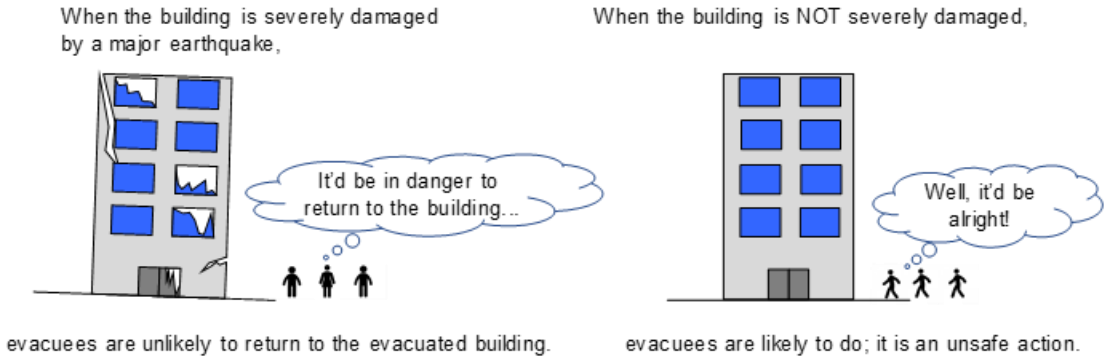

Figure 1 Effects of apparent building's structural integrity on the post-evacuation behavior.

In view of this, investigating the chemical hazard perception (CHP) and post-evacuation behavior (PEB) of university members following a major earthquake would be useful for drafting disaster-management plans and providing effective disaster-management drills in universities. Only few studies have described PEB of university members; Koshiba and Suzuki examined the behavior of members of a department of chemistry.[5] The major objectives of this study were to (i) elucidate the CHP and PEB of university students and (ii) investigate whether their academic majors (electrical engineering and chemistry) influence PEB.

2. Methods

To achieve the abovementioned objectives, in December 2018, we conducted a survey on 52 students in an electrical engineering building in the campus of a national university—the same university where the survey was conducted by Koshiba and Suzuki.[5] This building stores a substantial number of gas cylinders and large amount of chemicals. The risks associated with university buildings strongly depend on the hazardous materials stored in the buildings which probably directly influences the people's risk perception and evacuation behavior. In the present study, students of the electrical engineering building were chosen to directly compare the PEBs between the two groups (i.e., electrical engineering and chemistry members). The participants aged between 21 and 29 years. As shown in Table 1, 58% of the electrical-engineering group were undergraduates in their fourth year of the course, 38% were masters students, and 4% were doctoral candidates. The majority of the participants were male (n = 45, approximately 87%).

The survey instrument (Table 1) was developed using the findings of Koshiba and Suzuki[5] and *Theory of Planned Behavior* (TPB).[6] The following sentence was presented at the beginning of the instructions: "you have just left your electrical engineering building temporarily following a large earthquake." First, the survey asked the following open-response question (Q1): "when you return to your building, what will you watch out for?" Then, based on the 11 conditions in Table 1, the researchers asked (Q2–12): "under what conditions would you want to return to your building?" Participants responded on a 6-point Likert scale (from 1: Not at all likely, to 6: Very likely) to the 11 conditions: in cold weather (Q2), in rainy weather (Q3), if you had left your building without your personal belongings (Q4), if you had left your building without your research data (Q5), when people with disabilities remained in your building (Q6), if you urgently wanted to use the restroom (Q7), if the other evacuees began returning to your building (Q8), at night (Q9), if your building had NOT been severely damaged (Q10), if your building had been severely damaged (Q11), and when gas(es) had leaked in your building (Q12). They were then questioned about their risk perception and level of fear (Q13) that is a key factor in risk perception[7] which has a significant influence on evacuation behavior.[8]

Table 1 Question items, mean/standard deviation values, and academic major differences between electrical engineering and chemistry groups.

Item		Endpoints/category	*M* (*SD*) [a]	*M* (*SD*) [b]	*p*
Q1	When you return to your building, what will you watch out for?	OR, MA			
	Under what conditions would you want to return to your building?				
Q2	Under cold conditions	1: Not at all likely; 6: Very likely	2.29 (1.50)	2.00 (1.13)	0.22 [c]
Q3	Under rainy conditions	1: Not at all likely; 6: Very likely	2.48 (1.63)	2.34 (1.33)	0.56
Q4	If you left the building without your personal belongings	1: Not at all likely; 6: Very likely	3.71 (1.39)	3.39 (1.43)	0.19
Q5	If you left the building without your laboratory research data	1: Not at all likely; 6: Very likely	2.71 (1.55)	2.31 (1.41)	0.10
Q6	If persons with disabilities remain in the building	1: Not at all likely; 6: Very likely	3.87 (1.01)	3.25 (1.14)	0.001**
Q7	If you want to use the restroom facilities	1: Not at all likely; 6: Very likely	2.21 (1.36)	2.23 (1.34)	0.94
Q8	If the other evacuees start returning to the chemistry building	1: Not at all likely; 6: Very likely	3.06 (1.24)	3.27 (1.37)	0.35
Q9	Under night conditions	1: Not at all likely; 6: Very likely	2.27 (1.40)	2.06 (1.11)	0.36[c]
Q10	If your building has NOT been severely damaged	1: Not at all likely; 6: Very likely	3.19 (1.41)	3.12 (1.48)	0.77
Q11	If your building has been severely damaged	1: Not at all likely; 6: Very likely	1.81 (1.05)	1.47 (0.79)	0.041*, [c]
Q12	If a gas leak has occurred in the chemistry building	1: Not at all likely; 6: Very likely	1.56 (0.89)	1.16 (0.53)	0.004**, [c]
	Others				
Q13	Fear	1: Not at all, 6: Very	4.73 (1.01)	5.53 (0.79)	0.000***, [c]
	Demographic questions		*n* and percentage (%)		
Q14	Gender	Male/Female	M (45, 87)[d]; F (7, 13)[d]		
Q15	University membership category	Undergraduate/masters/doctoral	U (30, 58)[d]; M (20, 38)[d]; D (2, 4)[d]		

Note M: mean value/male/master's student; OR: open response; MA: multiple answer; F: female; D: doctoral student; *SD*: standard deviation; *p*: p value; *: $p < 0.05$; **: $p < 0.01$; ***: $p < 0.001$; a: rated score for the electrical engineering students obtained from the present study; b: rated score for the chemistry students adopted from ref. 5; c: determined using the Welch's *t*-test; d: (*n*, %). The larger *M* values indicate that the individual tends to return to the building.

We confirmed that no major earthquakes which might have potentially influenced the students' feedback ratings were recorded between October and December in 2018 in Japan. *t*-tests for homoscedastic data and Welch's *t*-tests for heteroscedastic data were employed. The survey data were analyzed using SPSS Statistics software (Ver. 25) with the significance level set to 5%.

3. Results and discussion

3.1 Chemical hazard perception when returning to a building

In response to Q1, only 10% of the 30 participants who answered the open-response question mentioned hazardous materials (Figure 2), whereas, the majority (approximately 87%) indicated that they would watch out for shattered glass from broken windows, ceiling lights, panels, and walls (seismic vibrations can damage these).

As noted below, there were no significant overall differences in the PEBs of the two groups (Table 1). This finding clearly suggests that the students were unaware of the dangers posed by the chemical hazards in the building.

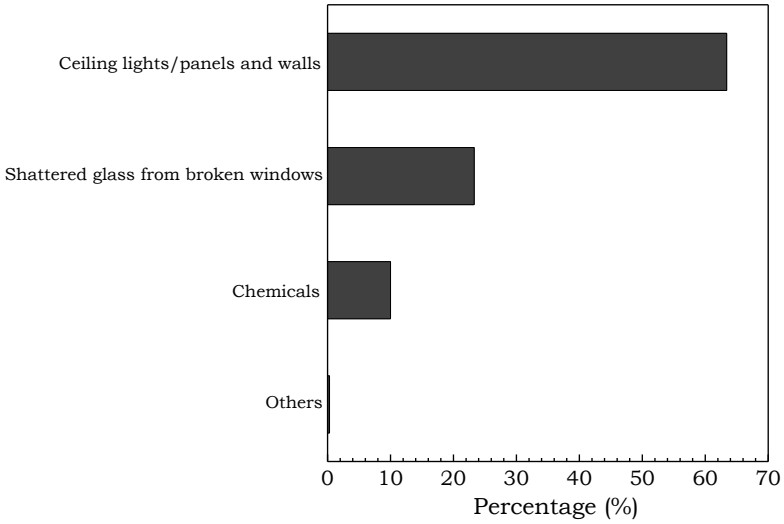

Figure 2 Percentages of open-response Q1: When you return to your building, what will you watch out for?

3.2 Rated scores

The mean values (*M*s) and standard deviations (*SD*s) for the variables are listed in Table 1. The larger values indicated greater intention to return to the building. For the conditions where the building is severely damaged (Q11) and gases are leaking (Q12), the *M* values were 1.81 and 1.56, respectively, suggesting that the majority of the participants would not intend to return. As expected, in the situation when the building is severely damaged (Q11, M_{Q11}

= 1.81), the *M* value of the participants was higher than that where the building is not visibly damaged (Q10, M_{Q10} = 3.19).

The *M* values for Q4 and Q6 were 3.71 and 3.87, respectively, implying that the respondents were likely to return to the building in these situations. As reported by Hara[9], immediately after the occurrence of an earthquake, most Japanese people seek out disaster information and communicate with their family and friends using smartphones. The responses to Q6 further revealed that evacuees are inclined to return to assist others (e.g., nonambulatory people). This observation is consistent with the findings of Kobes *et al*., who established that people re-enter buildings to aid injured individuals.[10]

3.3 Academic majors and post-evacuation behavior

The study investigated whether a student's academic major (i.e., electrical engineering or chemistry) influences PEB. Age generally affects risk perception[11] and ultimately influences evacuation behavior.

First, a *t*-test showed no significant differences in average age between the two groups (chemistry, 22.8 years; electrical engineering, 22.7 years). Furthermore, *t*-tests revealed that—except for the situations described in Q6, Q11, and Q12—there are no significant differences between the behavior of the two groups (Table 1). Note that the questionnaire surveys on the electrical engineering and chemistry department members were conducted in December 2018 and 2016, respectively. In general, risk perception is strongly affected by direct earthquake experience. [12] However, we confirmed that no major earthquakes that potentially affectd the risk perception and evacuation behavior of the participants were observed between December 2016 and 2018 in the Kanto region of Japan where the university is located.

A chi-square test revealed that the percentage of male students who would return if there were people with disabilities in the building (Q6) was significantly higher in the electrical engineering group than the chemistry group (χ^2 = 5.33, df = 1, $p < 0.05$). The gender ratios of the two groups might therefore be important.

4. Limitations and suggestions

Several limitations of the present study are acknowledged herein. First, all the respondents in this study were members from the departments of electrical engineering and chemistry. Hence, further research needs to be undertaken to investigate whether the PEB responses for students with these majors would also hold true for students with other

majors. Second, the sample size was relatively small. Finally, the main limitation was that no combined conditions (e.g., under cold and rainy conditions) were investigated for simplicity.

The survey results unequivocally show that a majority of the students who participated in this study were likely to return to their buildings immediately after a major earthquake without recogination of the chemical hazards in science and engineering buildings on campuses. Hence, it is crucial to inform students of these risks and ensure awareness through disaster-education programs. There should be signs in the buildings that indicate the presence of hazardous materials along with some instructions on what to do in case of an emergency.

The results also indicate that students were likely to return to buildings that were not visibly damaged. Although most university buildings in Japan are earthquake-resistant, they may still be dangerous owing to probable explosions and fires. To prevent loss of life, it is pivotal that universities create and develop emergency manuals and management plans based on students' PEB.

To date, limited papers have been published on PEB of university members. Hence, despite the limitations noted above, the key findings of this work provide a new clue toward establishing an effective disaster-education program and emergency management plan in universities, largely contributing toward reducing earthquake-related casualties.

5. Conclusions

The main findings of this study that indicate the CHP and PEB of electrical engineering and chemistry students are as follows:

1. Participants are more likely to return to a building that is not visibly damaged during an earthquake.
2. Students are likely to return to a building if they evacuated the building without their personal belongings or if people with disabilities were still in the building.
3. There are no significant differences between the PEBs of electrical engineering and chemistry students. Furthermore, while most participants pay attention to shattered windows, ceiling lights, panels, and walls, they do not recognize the other chemical hazards.

The results of this study can be used to develop effective disaster-management plans for universities that store and handle hazardous materials on campuses. These plans could reduce earthquake-related losses.

Author contributions

Y.K. devised the hypothesis and designed the study. Y.K. and K.C. collected and analyzed the data. Y.K. and J.N. interpreted the data. Y.K. wrote the manuscript. Y.K., K.C., and J.N. were responsible for data collection and have approved the final version of the manuscript.

Funding source

This work was supported by a grant (No. JP19K21752) from the Japan Society for the Promotion of Science (JSPS) KAKENHI to Y.K.

Declaration of competing interest

The authors declare no conflicts of interest.

Abbreviations

CHP, chemical hazard perception; *df*, degree of freedom; PEB, post-evacuation behavior; Q, question; TPB, theory of planned behavior; χ^2, chi-squared value.

References

1. Huston E. M., Milligan J. A., Powell J. R., et al.: Development of an undergraduate course in chemical laboratory safety through an academic/industrial collaboration: J. Chem. Educ.: 95, 577–583, 2018. doi: 10.1021/acs.jchemed.7b00599.

2. Nascimento K. R. D. S., Alencar M.H.: Management of risks in natural disasters: A systematic review of the literature on NATECH events: J. Loss Prev. Process Ind.: 44, 347–359, 2016. doi: 10.1016/j.jlp.2016.10.003.

3. Normile D.: Picking up the pieces at ravaged Tohoku University: Science: 333, 153–155, 2011. doi: 10.1126/science.333.6039.153.

4. Yamada Y.: Revival from the Great Hanshin earthquake disaster: J. Synth. Org. Chem. Jpn.: 55, 828–833, 1997. (in Japanese) doi: 10.5059/yukigoseikyokaishi.55.828.

5. Koshiba Y., Suzuki Y.: Factors affecting post-evacuation behaviors following an earthquake: A questionnaire-based survey: Int. J. Disaster Risk Reduct.: 31, 548–554, 2018. doi: 10.1016/j.ijdrr.2018.06.015.

6. Ajzen I.: Perceived behavioral control, self-efficacy, locus of control, and the theory of planned behavior: J. Appl. Soc. Psychol.: 32, 665–683, 2002. doi: 10.1111/j.1559-1816.2002.tb00236.x.

7. Slovic P.: The Perception of Risk: London: Earthscan Publications, 2011.

8. Trumbo C. W., Peek L., Meyer M. A. et al.: A cognitive-affective scale for hurricane risk perception: Risk Anal.: 36, 2233–2246, 2016. doi: 10.1111/risa.12575.

9. Hara Y.: Behaviour analysis using tweet data and geo-tag data in a natural disaster: Transp. Res. Proc.: 11, 399–412, 2015. doi: 10.1016/j.trpro.2015.12.033.

10. Kobes M., Helsloot I., de Vries B. et al.: Building safety and human behaviour in fire: A literature review: Fire Saf. J.: 45, 1–11, 2010. doi: 10.1016/j.firesaf.2009.08.005.

11. Bonem E.M., Ellsworth P.C., Gonzalez R.: Age differences in risk: Perceptions, intentions and domains: J. Behav. Dec. Making: 28, 317–330, 2015. doi: 10.1002/bdm.1848.

12. Ho M.C., Shaw D., Lin S. et al.: How do disaster characteristics influence risk perception?: Risk Anal.: 28, 635–643, 2008. doi: 10.1111/j.1539-6924.2008.01040.x.