Int J Disaster Risk Sci (2022) 13:359–371
https://doi.org/10.1007/s13753-022-00409-2

www.ijdrs.com
www.springer.com/13753

ARTICLE

Insights on Chemical and Natech Risk Management in Japan and South Korea: A Review of Current Practices

Hyejeong Park[1] **· Ana Maria Cruz**[1]

Accepted: 16 March 2022 / Published online: 4 April 2022

Abstract A growing number of natural hazard-triggered technological accidents (Natech) has been reported by several researchers, and this trend is expected to continue due to climate change. As a result, some governments have initiated direct efforts to manage Natech risks, particularly in the United States and Europe. However, two surveys conducted by the Organisation for Economic Co-operation and Development (OECD) in 2009 and 2017 found that there was a lack of proper risk management and risk governance for Natech among OECD member states, including Japan and South Korea. This study aimed to identify relevant regulations and practical considerations for chemical and Natech risk management from government perspectives in Japan and South Korea. The article provides a review of the current state of risk management, emergency response, and risk communication on chemical and Natech risk management in the two countries, and concludes with a discussion of some of the issues that require improvement of the current chemical risk management. Current practices for chemical risk management in Japan and South Korea point to the possibility of improvements in dealing with the Natech risks. These practical lessons will be valuable for improving the capacity for dealing with challenges in chemical and Natech risk management.

Keywords Chemical accidents · Government perspectives · Japan · Natech · Risk governance · Risk management · South Korea

✉ Ana Maria Cruz
cruznaranjo.anamaria.2u@kyoto-u.ac.jp

[1] Disaster Prevention Research Institute, Kyoto University, Kyoto 611-0011, Japan

1 Introduction

A natural hazard-triggered technological accident is known as a Natech (Cruz et al. 2004). Even though Natech accidents are relatively rare events—representing only 2–5% of chemical accidents in industrial accident databases (Sengul et al. 2012)—the accidents can cover a wide area, have large-scale consequences (Masys et al. 2014), and lead to a cascade of events (Cruz et al. 2004). Some examples of Natech accidents include gas and oil releases caused by Hurricane Katrina and Rita in 2005 (Cruz and Krausmann 2008, 2009), and several chemical accidents involving fires, explosions, and oil spills during the Great East Japan Earthquake (GEJE) and tsunami in 2011 (Krausmann and Cruz 2013).

During these and other Natech events, local governments, first responders, industry, and local residents were often unprepared to prevent, mitigate, or respond to the Natech accidents. Notably, there has been little to no information regarding chemical accident risk and emergency response actions that should be taken by local stakeholders. The Natech cases demonstrated that the residents living near industrial facilities had to evacuate relying on their limited knowledge and experiences. Past Natechs have illustrated three common problems: (1) a lack of Natech accident preparedness at the government level; (2) limited or no Natech-specific risk management practices by industry; and (3) inappropriate Natech emergency response plans and information to ensure the safety of the public (Park 2020). Since Natech accidents have received little consideration in disaster risk management planning, Natech risk management now faces significant challenges.

With global climate change, the increasing trend in Natech accidents may be expected to continue (Luo et al. 2020, 2021). In recent years, efforts have been made to analyze past accidents, understand Natech risks, and improve risk assessment methodologies. The need for a comprehensive approach to risk management and governance of Natech hazards has also been raised by the international research community (Cruz et al. 2014; Suarez-Paba et al. 2019; OECD 2020). Cruz et al. (2014) in particular noted the importance of Natech risk governance based on risk communication, local stakeholder participation, and adequate risk reduction methods in an integrated approach.

While past studies have highlighted the need for Natech-specific risk management (Cruz 2012; Krausmann and Baranzini 2012; Suarez-Paba et al. 2019), it remains unclear how much countries have advanced towards this goal. Some countries and regions have adopted Natech-specific regulations. For example, the European Union (EU) issued the Seveso III (Directive 2012/18/EU) that explicitly aims to prevent major chemical accidents from industrial activities, and requires the analysis of potential domino effects and the impacts of natural hazards (that is, earthquakes, floods) (EU 2012). The California Accidental Release Prevention (CalARP) program in the United States requires a seismic hazard assessment (Cal OES 2020) of regulated processes to ensure that they remain in operation following a major earthquake. The Organisation for Economic Co-operation and Development (OECD) conducted two surveys regarding Natech risk management and awareness in OECD member countries in 2009 and 2017 in order to identify the current practices of chemical accident and natural hazard-related disaster management. Although the 2009 results showed that there had been a lack of appropriate legislation and guidelines to prevent Natech accidents (Krausmann and Baranzini 2012), the 2017 results showed that the countries that participated in the surveys had gradually recognized natural hazards as a potential external risk for industrial facilities and made efforts to develop a system for Natech risk management (OECD 2020).

With an appreciation of the global effort, the aim of this study was to investigate Natech risk management regulations and practices from a government perspective in Japan and South Korea—countries that share geographical proximity but different regulatory backgrounds on chemical accident risk management. We conducted field surveys, including interviews with government officials and field visits, in both countries to examine practices in Natech/chemical accident management and collect data. The interviewees were government officials from Osaka and Okayama Prefectures in Japan, and the Joint Inter-agency Chemical Emergency Preparedness Centers (JICEPCs), a collaborative governmental organization, in South Korea.

Section 2 reviews advances in Natech and chemical accident risk management in the United States, the EU, and several international organizations, setting the background for the study. Section 3 introduces the study areas and data collection methods. Section 4 provides the results of the study with respect to regulations and laws, institutional arrangements for chemical accidents and Natech risk management, response resources, and risk communication in the context of Japan and South Korea. Section 5 discusses the overall findings and suggests ways for improving Natech risk management.

2 Advances in Chemical Accident and Natech Risk Management

There is a growing body of research concerning Natechs (Suarez-Paba et al. 2019). Natech research has focused on reducing and managing Natech risks, such as using and developing tools for Natech risk assessment (Cozzani et al. 2014; Antonioni et al. 2015), investigating past Natech events in order to extract lessons learned (Cruz and Krausmann 2009; Krausmann and Cruz 2013), and promoting and improving risk communication and awareness of Natech risks (Yu et al. 2017; Tzioutzios and Cruz 2021).

Several studies have pointed to the need for comprehensive Natech risk management and risk governance to reduce Natech risks (Cruz 2012; Cruz et al. 2014; Suarez-Paba and Cruz 2022) due to unpredictable consequences that affect wide areas, often across different jurisdictions near industrial parks. In addition, previous studies have shown that adequate Natech accident preparedness by all local stakeholders could reduce potential losses under the uncertain impacts. Recent chemical accidents in Japan (Araki et al. 2021) and South Korea (Lee et al. 2016), as well as regulatory changes in both countries (Krausmann et al. 2017), have indicated the necessity of better understanding current practices and advancing Natech risk management.

Krausmann and Baranzini (2012) reported on a survey of government authorities in charge of chemical accident prevention in OECD member states and found that there was a need for better risk communication among all government stakeholders, increased Natech risk awareness, and appropriate regulations and guidelines for Natech accident management. Although the findings showed that Natech risk management practices varied significantly across the countries surveyed, most countries that participated in the survey have acknowledged the importance of good Natech risk management practices. Therefore, a call for an integrated system of Natech risk management and governance through a multidisciplinary approach is consistently recognized in order to deal with joint natural and technological hazard risks successfully and their cascading effects entailing complexity and uncertainty in a territory.

The following section summarizes chemical accident risk management regulations in the United States and the EU, which have pioneered Natech research and Natech risk management.

2.1 Chemical and Natech Accident Risk Reduction in the United States and the European Union

In the United States and the EU, there are multifarious laws and regulations for chemical accident prevention. The United States enacted the Emergency Planning and Community Right to Know Act based on Title III of the Superfund Amendments and Reauthorization Act of 1986 (SARA Title III) in an effort to minimize the consequences of catastrophic technological accidents. SARA Title III requires setting up local emergency planning committees (LEPCs) that involve information dissemination on hazardous materials (HAZMAT), appropriate risk communication with citizens, preparation of emergency plans, and community vulnerability assessment to deal with chemical accidents.

Local emergency planning committees encourage local communities living near industrial facilities to identify their vulnerabilities and build strategies to respond to chemical accidents. Relevant studies have underlined that local stakeholders, including government officials, associated experts, safety managers and operators from industries, and community representatives, must be involved in the emergency planning process that supports and enhances communal bonds and the coping capacity among the local stakeholders (Lindell and Perry 1996; Whitney and Lindell 2000).

The US Environmental Protection Agency (EPA), in 1996, introduced the Risk Management Plan (RMP) rule with the focus of protecting the public from accidental releases of HAZMAT (US EPA n.d.). The RMP rule requires the dissemination of adequate risk information to local stakeholders to prepare for and respond to potential chemical accidents. However, the rule does not explicitly contemplate chemical accidents that could be triggered by natural hazards.

The state of California has promulgated the California Accidental Release Prevention (CalARP) program to carry out specific risk management related to earthquake hazards. This program is designed to prevent and minimize accidental HAZMAT releases that could have substantial effects on the public and the environment during earthquakes. The CalARP program stipulates that individual firms must provide the results of risk assessments and risk information that is available to the public who is interested in the chemical risks. The program also offers opportunities for public participation in decision-making processes as risk reduction activities.

The EU authorized the Seveso Directive in 1982 to control significant chemical accident hazards that pose a threat to the public (EU 1982) following a dioxin release from a chemical company in Seveso, Italy, in 1976. The Directive highlighted that risk communication between the public, industry, government officials, and associated organizations is indispensable in risk management. The Directive pointed out that risk communication may facilitate affordable risk management through the active participation of citizens in applying the Seveso Directive successfully. The Seveso II Directive was then issued in 1996 based on lessons learned from past chemical accidents (EU 1996). It stipulated that Seveso installations are required to disseminate information about HAZMAT, such as storage conditions, emergency plans, possible accident scenarios, and potential impacts on neighboring communities, in order to reduce chemical accident consequences.

In 2012, the Seveso III Directive came into force taking into account the evolution of legislation with HAZMAT classification and increased public risk awareness. In particular, Seveso III has more specific requirements regarding external hazards such as earthquakes or floods in risk assessment. The primary aim of Directive III is to prevent and manage potential major chemical accidents and consequences in industrial facilities that could affect human health and the environment (EU 2012). The Seveso III Directive highlights the importance of risk communication by requiring transparent and correct information disclosure to the public, community participation in decision-making processes concerning HAZMAT risk, and public risk awareness improvement. However, the Directive does not cover all chemical accident risks, such as military facilities, nuclear hazards, transport of hazardous materials, mineral exploitation, waste landfills, and gas storage (Krausmann et al. 2017).

2.2 International Efforts to Reduce Chemical and Natech Accident Risk

Some of the most significant efforts to address Natech risk management have been made by the OECD. In 2009 and 2017, two surveys on Natech risk management were conducted among competent authorities in OECD member states, including Japan and South Korea. The purpose of the surveys was to determine government efforts for Natech risk management, including the adoption of regulations, good practices, risk management systems for Natech and natural hazards-related disasters, and risk awareness. The 2009 survey showed that natural hazards are increasingly recognized as a critical external factor in risk management for the chemical industry (Krausmann and Baranzini 2012). The results also identified a lack of Natech risk management, particularly Natech-specific risk assessment, due to insufficient tools for managing Natech risks and comprehensive knowledge of the dynamics of Natech events (OECD 2020). The 2017 survey revealed increasing concerns about Natech risks and the need for improving regulations or codes that would support comprehensive Natech risk management by promoting more efforts to reduce the risks. The results showed that integrated Natech risk management should be implemented along with the development of Natech hazard and risk maps. The survey also pointed to the need for effective Natech risk communication and transboundary cooperation with neighboring countries.

Due to the increasing concerns raised by past Natech accidents, the United Nations (UN) incorporated the consideration of Natech risks into the Sendai Framework for Disaster Risk Reduction 2015−2030 (UNDRR 2015). The Sendai Framework highlights the proactive engagement of multi-stakeholders to manage complex risks, including technological hazards and Natechs. In addition, the Awareness and Preparedness for Emergencies at Local Level (APELL) program of the United Nations Environment Programme (UNEP) was improved in 2015 to examine Natech disasters at the local community level (UNEP DTIE 2015). The significant goals of this advanced program are to advocate for communities to be resilient to multi-hazards, particularly technological hazards, increase technological risk awareness, and promote coordinative, integrated, and flexible emergency strategies based on the current local emergency plans. The program was amended in reflection of the Sendai Framework, and it is expected to enhance local stakeholders' coping capacity with all hazards (UNDRR 2018).

2.3 Importance of Risk Governance in Dealing with Natech Risks

Previous studies have noted the significance of risk governance to enable risk reduction of chemical and Natech accidents (Cruz and Suarez-Paba 2019; Suarez-Paba and Cruz 2022). In general, the aim of risk governance is to ensure that all actors, together with government authorities, industry operators/owners, scientists, and citizens, participate proactively in risk management and decision making related to multiple risks that they may be exposed to (IRGC 2017). Current practices for managing chemical accident hazards have been advanced by professional engineers and well-trained safety managers in many countries. However, several major and minor Natech accidents have shown that more needs to be done concerning risk assessment and management systems to deal with these conjoined hazards and their potential consequences (Cruz et al. 2014). Furthermore, past Natech accidents have illustrated that all stakeholders must cooperate and collaborate to better manage Natech risks with uncertainty and complexity (Cruz et al. 2014; OECD 2020).

3 Methodology

Japan and South Korea were selected as study areas for several reasons. Both countries have large industrial parks and facilities that handle large amounts of hazardous chemical substances along their coastlines or rivers in the vicinity of local communities. Both countries also face hydrometeorological hazards, such as typhoons, storms, floods, and heavy rain in the same seasons due to their geographic location. In recent years, the two countries have experienced minor Natech accidents. A massive aluminum recycling plant explosion, for example, was caused by heavy rains and floods in Okayama Prefecture, Japan, in July 2018. In South Korea, a large fire and explosion occurred at a magnesium-aluminum recycling plant in a humid atmosphere after prolonged heavy rains in August 2018. Since those metal recycling industries fall outside regulations related to hazardous materials in both countries, the plants could easily be exposed to Natech risks. Japan and South Korea have established somewhat similar regulations and laws to prevent and manage chemical accident risks. However, there is little consideration of natural and chemical hazards together in the current risk management practices in both countries. Thus, it will be valuable to gain insights into the risk management practices and investigate challenges from the point of view of government authorities in the two countries.

This study reviewed relevant documents, including laws and regulations released by the Japanese and South Korean governments. Field surveys with two interviews in Japan and three interviews and field visits in South Korea were arranged. Each field survey, including interviews and field visits, lasted two or three hours. In Japan, the first-round interview was conducted on 21 June 2018 with government officials in Takaishi City, Osaka Prefecture, who are responsible for managing chemical accident risks in the Sakai-Senboku Industrial Park, Osaka Prefecture's largest industrial park. The second-round interview was conducted on 11 December 2018 with government officials from the Osaka prefectural government, who are in charge of chemical accident prevention programs. In South Korea, three interviews and field visits were carried out with government officials at the JICEPCs in Ulsan, Yeosu, and Siheung, where the largest national industrial parks are located, on 25, 27, and 28 February 2019, respectively.

Interview questions were structured into four sections to investigate government views concerning risk management practices. First, we explored the roles and functions of the governments and their organizations and responsibilities for managing chemical and Natech accidents. The second part aimed to examine the current regulations and guidelines for chemical and Natech emergencies at the national and local levels. Third, we asked about chemical and Natech risk management systems, including risk assessment, emergency planning, educational programs, and response resources. Finally, we looked at risk communication for chemical and Natech events among all stakeholders, including residents living near industrial facilities.

4 Chemical and Natech Risk Management Practices in Japan and South Korea

This section presents the main results of the study. Data collection consisted of field surveys, including interviews and field visits, and a review of the literature and documents. The analysis of chemical and Natech risk management practices in Japan and South Korea was divided into four categories: (1) laws and regulations; (2) institutional arrangements and/or strategies; (3) response resources for chemical emergencies; and (4) risk communication among all stakeholders. Table 1 presents the categories analyzed and the data collection methods used.

4.1 Laws and Regulations for Managing Chemical and Natech Risk

The results of the review of recent documents and regulations regarding chemical and Natech risks and emergencies are described below. Japan and South Korea have a myriad of laws and regulations in place for the safe handling and management of HAZMAT. Table 2 presents a summary of associated laws and regulations. These will be discussed below for each country.

4.1.1 Japan

Japan has ranked as one of the largest chemical-producing and consuming countries in the world (JCIA 2018). According to relevant laws and regulations, Japan established the Act on the Evaluation of Chemical Substances and Regulation of their Manufacture, etc. (the Chemical Substances Control Law, CSCL) in 1973 following the release of polychlorinated biphenyls (PCBs) in 1968. The accident resulted in severe and chronic health and environmental problems in western Japan (Yoshimura 2012). Following the event, several laws and regulations for chemical material management and accident prevention systems, including safety management in industry, were introduced (Table 2). Before the GEJE in 2011, the legislation had not addressed natural hazards in chemical risk management.

Following the experience of some chemical accidents caused by earthquakes that included a large fire at an oil refinery caused by the 2003 Tokachi-Oki earthquake, and the 2011 GEJE, the Petroleum Complex Disaster Prevention Law was amended in 2013 to address chemical accident risk reduction due to earthquakes. Furthermore, the High-Pressure Gas Safety Law (revised in 2020) stresses that industrial facilities are required to prepare adequate measures for reducing the likelihood of chemical accidents caused by earthquakes and tsunamis. After the 2011 GEJE and tsunami, Japan also improved the seismic code to minimize the damage to high-pressure gas storage facilities that could be struck by long-period seismic events. Moreover, the Land Resilience Basic Law, which was introduced in 2013 to promote national resilience, requires the adoption of comprehensive countermeasures against earthquakes and tsunamis that induce chemical accidents to ensure the continuity of businesses in petroleum parks located along the coastlines.

4.1.2 South Korea

South Korea has been ranked as the fifth largest country in terms of the chemical industry in the world (KOTRA 2019). The review of relevant documents and regulations showed that the Korean government has a somewhat similar system to that of Japan. However, specific chemical accident prevention regulations were not introduced until the 1990s (Table 2). The government enacted several legislations, for instance the High-Pressure Gas Safety Control Act, the Occupational Safety and Health Act, the Framework Act on Fire Services, the Nuclear Safety Act, the Marine Environment Management Act, the Act on the

Table 1 Analyzed categories and data collection methods

Categories	Data Collection Methods
Laws and regulations	Regulatory instruments and document review
Institutional arrangements	Document review and field surveys (interviews)
Response resources	Document review and field surveys (interviews, field visits)
Risk communication	Regulatory instrument review and field surveys (interviews)

Table 2 Relevant laws and regulations for effective hazardous materials (HAZMAT) management in Japan and South Korea

Country	Japan	South Korea
Initiation	1973	1990
Major law	Act on the Evaluation of Chemical Substances and Regulation of their Manufacture, etc. (1973)	Toxic Chemicals Control Act (TCCA) (1990−1996), reenacted in 2014 as the → Chemicals Control Act (CCA)*
Other relevant acts and regulations	Act on Confirmation, etc. of Release Amounts of Specific Chemical Substances in the Environment and Promotion of Improvements to the Management thereof	High-Pressure Gas Safety Control Act
	Pollutant Release and Transfer Register (PRTR) system	Occupational Safety and Health Act
	Industrial Safety and Health Act	Framework Act on Fire Services
	High-Pressure Gas Safety Law	Nuclear Safety Act
	Air Pollution Control Act	Marine Environment Management Act
	Water Pollution Control Law	Act on the Safety Control of Hazardous Substances
	Soil Contamination Countermeasures Act	Act on Registration, Evaluation, etc. of Chemicals
	Basic Environment Law	Act on Safety Management of Consumer Chemical Products and
	The Petroleum Complex Disaster Prevention Law	Biocides

* The Chemicals Control Act includes requirements with respect to the disclosure of specific risk information and emergency plans prepared by chemical firms

Safety Control of Hazardous Substances. These laws and acts are aimed at managing various types of chemical hazards and preventing potential chemical accidents.

In September 2012, a severe chemical accident occurred when eight tons of hydrogen fluoride gas, a highly toxic and corrosive substance, leaked from a tank due to human error at a national industrial park. The accident killed five workers, affected 12,243 citizens near the national industrial park, and killed 3,944 heads of livestock. Following this chemical accident, South Korea enacted the Chemicals Control Act (CCA) in 2014 (formerly known as the Toxic Chemicals Control Act, TCCA; 1990–1996). The CCA aims to refine and improve the chemical accident risk management system in South Korea. Moreover, Article 42 in the CCA calls for an integrated chemical information system, including the requirement for chemical industries to disclose risk information and emergency response guidance to local communities living near industrial facilities. The Act on Registration, Evaluation, etc. of Chemicals requires that pertinent risk information concerning chemical materials should be appraised to implement effective risk communication among all stakeholders and expert groups, including government agencies.

4.2 Institutional Arrangements for Chemical and Natech Risk Management

In this section, the findings concerning institutional arrangements for chemical emergencies are provided.

4.2.1 Japan

According to the Japanese regulatory system, the government adopts a multidisciplinary approach for chemical safety management enforced by various governmental organizations, such as the Fire and Disaster Management Agency, the Ministry of Environment, and the Ministry of Economy, Trade, and Industry. The government has arranged the relevant divisions within the Ministry of Environment to collaborate with local stakeholders, including representatives of chemical firms, and to respond effectively to chemical accidents.

Guidance regarding the planning of responses to chemical accidents was published by the Ministry of Environment in 2009 (Ministry of Environment, Government of Japan 2009). The document says witnesses—that is, workers of a firm and/or neighboring residents—have a duty to report to the local fire and/or police departments when they discover any chemical accidents that have occurred in an industrial facility. A fire department within the jurisdiction is the most important first responder during an emergency involving fires, explosions, and physical effects. The local environmental organization, which is affiliated with the Ministry of Environment, also participates in response to an event by cooperating with local fire departments, local government offices, and police departments through previously established mutual aid agreements. Moreover, the environmental organization is

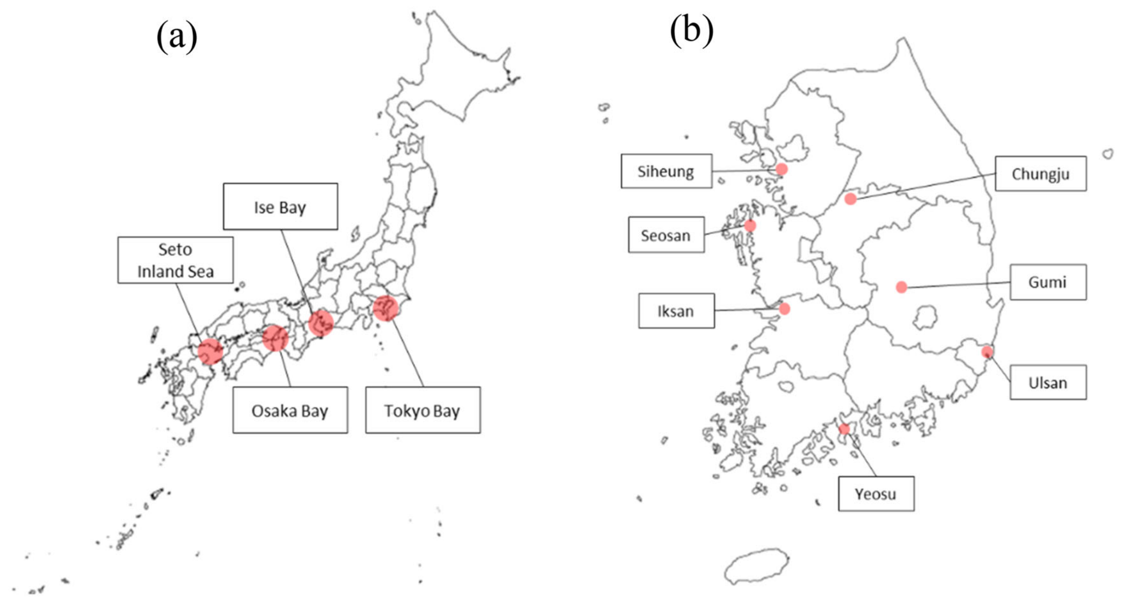

Fig. 1 Major locations of institutions for managing chemical accidents in Japan and South Korea: **a** four major locations of the Maritime Disaster Prevention Center (MDPC) in Japan; and **b** the seven locations of the Joint Inter-agency Chemical Emergency Preparedness Centers (JICEPCs) in South Korea

responsible for collecting details about the chemical accident and disseminating adequate information to citizens.

In order to respond to offshore and maritime chemical accidents, the nonprofit Maritime Disaster Prevention Center (MDPC) has been in charge since 1976 under the Prevention of Marine Pollution and Maritime Disasters Law (amended in 2017). The MDPC deploys a nationwide maritime disaster management system that provides services for maritime and inland disaster safety; hazardous material safety; and hazardous materials emergency response. The branch offices of the MDPC are strategically located in several high-risk zones throughout Japan—particularly Tokyo Bay, Osaka Bay, Ise Bay, and the Seto Inland Sea (Fig. 1a)—to support rapid chemical accident response. The centers provide further services, including training and education regarding response to chemical accidents in coastal areas. However, the role of the MDPC, as a private organization, is focused on emergency response to accidents, prevention, and cleanup of oil spills. They are not responsible for the protection of neighboring inhabitants from chemical accidents.

Although Natech accidents have not been explicitly considered in the disaster risk management system, concern regarding Natech hazards triggering chemical accidents has gradually increased since the 2011 GEJE and tsunami. Changes have been introduced by the Petroleum Complex Disaster Prevention Law and the National Resilience Law involving requirements for accident prevention, mitigation, and emergency response following an earthquake and tsunami.

4.2.2 *South Korea*

The 2012 hydrogen fluoride leakage resulted in the establishment of a new nationwide chemical risk management system in South Korea. In particular, the new system founded an integrated organization that comprises seven Joint Inter-agency Chemical Emergency Preparedness Centers located at major industrial parks in the country (Fig. 1b). The integrated organization consists of five divisions dispatched from different ministries and other agencies: (1) Environment: Ministry of Environment, National Institute of Chemical Safety, Korea Environment Corporation; (2) Chemical emergency response: National Fire Agency; (3) Industrial safety: Ministry of Employment and Labor, Korea Occupational Safety and Health Agency; (4) Gas safety: Korea Gas Safety Corporation, Korea Industrial Complex Corporation; and (5) Local government. This agency performs tasks and roles regarding chemical accident risk management, as well as accident preparedness and response. In addition, each division implements their own specific responsibilities under different work scopes issued by the parent ministries and agencies.

According to the interviews, the JICEPCs publish lists of regulated HAZMAT frequently used by industrial facilities, to manage chemical materials based on the requirements and specific guidelines of the different ministries. The Ministry of Environment, for example, has classified 772 materials as hazardous chemicals and substances that require preparedness against unexpected accidents. In addition, 97 poisonous agents designated by the Ministry of Employment and Labor, 69 chemical agents designated by the Ministry of Trade, Industry, and Energy, and 6,828 chemical substances designated by the National Fire Agency are available in an official national hazardous material information system.

The JICEPCs implement risk management considering industrial facilities and environmental conditions. They develop guidelines that involve several accident scenarios, hazard maps, and potential consequences. In particular, the created scenarios include information regarding hazardous chemical materials, task allocation of first responders, necessary response equipment, the extent of damage, access routes, and other possibilities of cascading effects, required time for response, and potential obstacles. The interviewees emphasized that they often estimate the worst cases that are potential cascading consequences of a chemical accident under severe weather conditions, such as typhoons and heavy rain. Hazard maps consider the location of hazardous materials and the facilities' risk management performance, including preparedness and response measures. However, since severe Natech or chemical accidents have not occurred thus far, the interviews showed that the government officials tended to overlook Natech hazard risks. The results also show that the JICEPCs still do not sufficiently consider specific Natech risks and emergency plans in their risk management system. Even though they consider the interaction between natural hazards and chemical or technological accidents to a lesser degree, the officials interviewed said that they are aware that dealing with Natech risks should be one of their priorities. However, they still believe that the systems currently in place may be sufficient to prepare for and respond to Natech accidents that could occur sometime.

4.3 The Preparation of an Appropriate Response to Chemical Emergencies

This section demonstrates the status of chemical emergency preparedness and response resources with an example of response challenges based on document reviews and interviews. Response resources here are related only to chemical emergencies and do not consider Natech accidents since the development of the national preparedness system for Natech accidents is still ongoing in both countries.

4.3.1 Japan

In order to understand chemical accident response in Japan, we examined the activities reported and introduction materials provided by the MDPC. As a well-organized chemical accident response agency, it has 46 bases throughout the country to respond in a timely manner to chemical emergencies that occur inland and offshore. Among them, 32 branches of the MDPC retain appropriate response capacity and resources to respond to HAZMAT releases. Although we could not directly obtain specific information regarding response resources in the MDPCs, they report available HAZMAT transporters, HAZMAT investigation devices, firefighting equipment, and so on, on their web pages. The centers also include a HAZMAT analysis division to determine the environmental impacts and appraise the hazardous factors of different HAZMAT.

The Petroleum Complex Disaster Prevention Law requires specified businesses to initiate individual disaster prevention organizations to prepare for chemical accidents. Based on the law, the Japanese petroleum industry has developed a safety management system and equipped response resources (PAJ 2011). Chemical firms, for example, must take into account all available safety measures and potential impacts of chemical accidents on surrounding environments from the beginning of construction. Specifically, all plants and storage tanks must be designed to resist large earthquakes. Petroleum businesses must set up their own disaster prevention associations that work together with the local responders and provide safety education to their employees for a quick response during a chemical incident. These efforts are expected to enhance the response capacity to chemical and Natech accidents in the petroleum industry. In addition, petroleum industrial parks can be supported by the MDPCs in the case of potential Natech disasters in the future.

Small firms, particularly those outside the industrial parks, are required to have fire safety facilities depending on the scale of their businesses. However, they should have fire extinguishers and detectors and appoint a fire safety and/or a general safety manager. Furnishing safety instruments and personnel depends on the size of the workplace and the number of employees according to the Fire Prevention Law. Thus, when fires or chemical releases occur, small firms using hazardous materials must rely on emergency response from a fire department. The absence of appropriate preparedness in the firms means that the initial or quick response could be delayed.

4.3.2 South Korea

According to the interviews and field visits, each JICEPC owns seven or eight special vehicles, all of which can be used during chemical accidents. These are technically specialized for physical response (unmanned water spray vehicles, high-performance chemical vehicles, and multipurpose excavators), elimination of chemicals and toxic materials (multipurpose decontamination vehicles), response assistance (equipment carrying vehicles), and inspection for detecting HAZMAT. In terms of human resources, there are six to seven team members per shift for emergency response, which may be considered suitable for an ordinary day. However, since the response team is operated in three shifts a day, all members must be able to handle each specialized vehicle in the case of chemical accidents. At the time of an emergency, on-call members are dispatched directly to the on-site response, and a JICEPC may have to request additional support units from the local fire departments if needed.

Although the JICEPCs can respond cooperatively to chemical accidents within the jurisdictions of national industrial parks, the simultaneous response seems to be unavailable in the case of multiple events. Some cases were discussed during the interviews. For example, take the case where you have two areas, A and B, each at a distance of 100 and 150 km in opposite directions from a JICEPC, within the same jurisdiction. When a chemical accident occurs in area A, the agency will dispatch all vehicles and response equipment with first responders to the accident area A. If at the same time another chemical accident occurs in area B, the response team working in A may not be able to move to accident area B, which will now be at a distance of 250 km. In this situation, quick and appropriate response to the second accident would not be possible. While it is unlikely that two accidents will occur at the same time during normal day-to-day operations, the chances of having multiple chemical accidents during a disaster increase, particularly for major natural hazard events (Santella et al. 2011).

4.4 Different Approaches to Risk Communication among Multi-Stakeholders

The results of this study show that there is ample room for improvement regarding risk communication about chemical and Natech risks among all stakeholders in Japan and South Korea.

4.4.1 Japan

According to the field surveys of our research team, the government, particularly the Osaka Prefectural government, supervises several industrial parks near the ports. Since industrial parks contain depots of large amounts of imported fuels and HAZMAT, these facilities are designated as "particular disaster prevention areas." The government officials interviewed, who are working on chemical accident risk management, stated that the local government is responsible for preparing chemical accident emergency response plans in collaboration with all stakeholders. As reported by the government officials during the interviews, the Osaka prefectural government developed a chemical accident disaster prevention plan that is annually reviewed with other relevant actors. They make the plan available online at an official website. However, even though the plan includes detailed information about risk assessment and safety measures taken by the chemical facilities, the document is difficult for the public to understand due to the technical vocabulary used. In addition, the plan does not incorporate practical guidance for emergency procedures in the case that a chemical accident does occur.

The Osaka prefectural government makes steady efforts to reduce chemical accident hazards triggered by all kinds of natural hazards. However, risk management for chemical and Natech accident risks still barely considers the local residents living near the industrial facilities. The results of the interviews with the government officials highlighted that there is a lack of sufficient notification of the citizens about risk information by chemical firms and professional stakeholders. Moreover, insufficient regulations regarding the disclosure of chemical risk information to the public in Japan have prevented residents from accessing risk information held by local governments and industry owners/operators. Thus, developing a comprehensive risk management strategy that includes the disclosure of chemical and Natech hazard risk information remains a priority for the government and policymakers.

4.4.2 South Korea

Risk communication implemented by the JICEPCs is more focused on information sharing between governmental organizations and firms that handle chemical materials than communicating with the public. When a chemical accident occurs, the JICEPCs share real-time information with other agencies' stakeholders in other regions through the local governments' hotlines, wireless communication, social network systems, and physical documents. According to the interviews, officials in the JICEPCs primarily distribute risk information about natural hazard-related and chemical disasters, general fires, and severe accidents to others in different authorities and exchange their points of view to deal with the cases effectively. Regarding chemical accident inspection and report procedures, each division in the JICEPCs investigates events separately and reports the results to their parent organization individually. The major accident causes derived from the inspection are shared with other divisions, but the details are usually not included due to their work scopes. It implies that each part of the JICEPCs has functioned effectively, but there is a lack of effective information sharing and cooperation in the risk management process.

The JICEPCs offer monthly educational programs to firms in the national industrial parks, particularly to representative councils of roughly 2,000 businesses, to increase their risk awareness and identify problems in chemical accident preparedness. The programs contain general fire safety, chemical accident response, identification of access routes to an accident scene, guidance on the use of response equipment, and a consultant on common security. Tabletop exercises applied to the programs allow the participants to explore potential challenges or limitations for better risk management. The results are also used to update emergency strategies and risk information.

Regarding risk communication for the citizens, the JICEPCs are not directly engaged in risk communication activities for citizens since their main targets are the firms that handle HAZMAT in the national industrial parks. Another reason is that there are still no adequate risk communication channels and no clear obligations of the JICEPCs to provide educational programs to the local communities. However, according to our interviews, the Ministry of Environment offers various information formats, including firms, chemical materials and health impacts, and accident response measures on a specially organized website in accordance with the CCA.

5 Discussion

Our study found that Japan and South Korea are committed to coping with natural hazard-related and technological disaster risks independently by establishing a well-defined legal system. Following major chemical accidents in both countries, they have improved chemical accident risk management practices. The Japanese government has considered technological accident risks in emergency and disaster management regulations, primarily focusing on earthquake and tsunami hazards. The South Korean government has shown the value of an interorganizational body in incorporating holistic risk management for chemical accidents through a multidisciplinary approach. Although the two countries' governments have made some efforts to address Natech risks, this study identified some issues requiring improvements.

5.1 The Path to Better Natech Risk Management

Our study showed that the state of Natech risk reduction in Japan has been influenced by past Natech accidents. Since the GEJE and tsunami, the Japanese government has amended several laws based on lessons learned during the disaster. In particular, it has enacted the Land Resilience Basic Law that requires business continuity planning in the petroleum industries that could be affected by earthquakes and requires that they take the necessary countermeasures to remain operational following a large-scale earthquake and tsunami. While South Korea has not suffered major Natech accidents, the chemical accident in 2012 resulted in changes to the regulatory systems and the establishment of integrated chemical accident preparedness agencies at the national industrial parks. Despite both governments' efforts to improve laws and regulatory instruments for chemical and Natech hazards, this study illustrated that the governments still need to make more efforts to improve existing chemical risk management considering Natech risks by developing specific guidelines and improving technical skills for strategic risk management.

Given the complexity and uncertainty of natural and technological hazards, a multidisciplinary approach to Natech risk management is required. Notably, the government must support the improvement of risk management systems for chemical and Natech accidents and enhance the coping capacity with potential accidents in different aspects of industrial infrastructure, safety management, external environment, and risk governance and communication (Suarez-Paba and Cruz 2022). At the same time, the multidisciplinary approach can gather all stakeholders together, including first responders, various experts in natural, environmental, and technological hazards, industry operators, safety managers, decision and policymakers, and local community members (Cruz et al. 2014; Park 2020; Suarez-Paba and Cruz 2022) under the same objectives. The risk management in this approach is expected to enable the allocation of the right man and resources in the right place during a Natech emergency and disseminate necessary risk information and knowledge since each participant group has their own expertise and skills regarding complex Natech risk management.

Moreover, under a general pooling system in both Japan and South Korea, the two governments force local officials to rotate their positions in a 2–3 year period in order to prevent possible corruption and career stagnation. This system may interrupt the continuity of the professional works of the officials that require abundant expertise and experiences for Natech risk management, appropriate knowledge and experiences, and trust and partnership with other stakeholders. Thus, the governments need to create qualified expert pooling systems that support the officials' long-term professionality in order to overcome the regulatory limitations and implement successful Natech risk management.

5.2 The Need to Increase Natech Risk Awareness and Encourage Effective Natech Risk Communication among Multi-Stakeholders

This study showed that chemical and Natech risk awareness is still limited in the two countries. In South Korea, the government has clearly considered the necessity of increasing the risk awareness of citizens by adding specific requirements for chemical industries located near local communities to disclose risk information and emergency plans. However, the Japanese and South Korean government officials we interviewed admitted that they have not yet deeply considered the way to communicate with local residents about chemical and Natech risks.

The governments in both countries have made available information that the public can easily obtain from their official websites. While the Japanese government offers detailed emergency plans with safety measures, the South Korean government provides essential chemical information and emergency plans prepared by firms that handle hazardous materials. However, the governments and firms in the two countries do not yet disseminate explicit risk information to citizens, such as possible impacts and consequences of accidents. Although there have been various advances in risk communication, government officials are still concerned about the negative effects of risk information that may promote public fear, social conflict, and a decrease in land prices.

Currently, the governments in Japan and South Korea have little legal responsibility to provide adequate risk communication to citizens living near industrial facilities. However, in order to prepare for potential chemical and Natech accidents, effective risk communication among all stakeholders including local residents requires better interpretation of chemical and natural hazard risk information (Miller 2016; Cruz and Suarez-Paba 2019; Krausmann et al. 2019). Local government officials, who are more familiar with their local environments and relevant regulations, could play an important role between the citizens and chemical firms. Local governments should also establish open channels of communication with all stakeholders, but most importantly with local residents. These efforts could build citizen trust in government and industry and could help reduce concerns regarding chemical and Natech risks.

6 Conclusion

Due to urbanization, environmental degradation, and climate change in areas subject to natural hazard impacts, the potential for Natech accidents may increase in the coming years. Natech accidents may cause area-wide consequences that represent important risk management challenges. This study aimed to review relevant documents regarding chemical and Natech risk management and practices from a government perspective and conducted interviews with government officials in Japan and South Korea.

In Japan, chemical accident risk management and risk information disclosure regulations have not been introduced yet. But, given the high risks of natural hazards, the Japanese government has strict safety and maintenance regulations to minimize accidents, mainly at oil and petroleum industrial parks. In South Korea, regulations for chemical risk management, including requirements for providing chemical risk information to residents living near large industrial parks, were explicitly introduced. In South Korea, the government established an integrated, multi-agency organization to manage and respond to chemical accidents and to some extent Natech accidents, as the Korean government has not yet considered Natech-specific regulations in their disaster risk management system.

This study shows that there is still limited consideration of integrated risk management and risk governance for natural, chemical, and Natech risks. Both countries' governments may need to pay more attention to Natech risks in their disaster risk management and better prepare for potential Natech disasters by improving their regulatory systems. This can be supported by providing appropriate human and physical resources, considering the level of expertise needed, ensuring better transfer of knowledge that is often lost due to the frequent rotation of government staff, and improving overall risk management skills for chemical and Natech hazards. Effective risk governance requires risk communication and participatory approaches for decision making. This necessarily involves chemical and Natech hazard and risk information disclosure. Government authorities in Japan and South Korea now face an important phase to advance integrated chemical and Natech risk management systems and promote effective interaction and cooperation among all stakeholders prior to more severe Natech disasters. Their effort would be valuable for the success of chemical and Natech risk reduction and promoting a more resilient society in the face of these complex disaster risks.

Acknowledgment This study was supported by a Disaster Prevention Research Institute (DPRI) grant of Kyoto University for collaborative research in 2018, and the Ministry of Education, Culture, Sports, Science, and Technology of Japan (MEXT scholarship, 2017–2020).

References

Antonioni, G., G. Landucci, A. Necci, D. Gheorghiu, and V. Cozzani. 2015. Quantitative assessment of risk due to NaTech scenarios caused by floods. *Reliability Engineering and System Safety* 142(C): 334–345.

Araki, Y., A. Hokugo, A.T.K. Pinheiro, N. Ohtsu, and A.M. Cruz. 2021. Explosion at an aluminum factory caused by the July 2018 Japan floods: Investigation of damages and evacuation activities. *Journal of Loss Prevention in the Process Industries* 69: Article 104352.

Cal OES (Governor's Office of Emergency Services of California). 2020. California accidental release prevention (CalARP) program guidance. https://www.elsegundofd.org/home/showpublisheddocument/3516/637545929891270000/. Accessed 24 Aug 2020.

Cozzani, V., G. Antonioni, G. Landucci, A. Tugnoli, S. Bonvicini, and G. Spadoni. 2014. Quantitative assessment of domino and NaTech scenarios in complex industrial areas. *Journal of Loss Prevention in the Process Industries* 28: 10–22.

Cruz, A.M. 2012. Challenges in Natech risk reduction. *Revista de Ingeniería* 37: 79–86.

Cruz, A.M., and E. Krausmann. 2008. Damage to offshore oil and gas facilities following hurricanes Katrina and Rita: An overview. *Journal of Loss Prevention in the Process Industries* 21(6): 620–626.

Cruz, A.M., and E. Krausmann. 2009. Hazardous-materials releases from offshore oil and gas facilities and emergency response following Hurricanes Katrina and Rita. *Journal of Loss Prevention in the Process Industries* 22(1): 59–65.

Cruz, A.M., and M.C. Suarez-Paba. 2019. Advances in Natech research: An overview. *Progress in Disaster Science* 1: Article 100013.

Cruz, A.M., Y. Kajitani, and H. Tatano. 2014. Natech disaster risk reduction: Can integrated risk governance help?. In *Risk governance*, ed. U.F. Paleo, 441–462. Dordrecht: Springer.

Cruz, A.M., L.J. Steinberg, A.L.V. Arellano, J.-P. Nordvik, and F. Pisano. 2004. State of the art in Natech risk management. Brussels: European Comission. https://www.unisdr.org/files/2631_FinalNatechStateofthe20Artcorrected.pdf. Accessed 10 Feb 2020.

EU (European Union). 1982. Council Directive 82/501/EEC of 24 June 1982 on the major-accident hazards of certain industrial activities. http://data.europa.eu/eli/dir/1982/501/oj. Accessed 20 Feb 2020.

EU (European Union). 1996. Council Directive 96/82/EC of 9 December 1996 on the control of major-accident hazards involving dangerous substances. https://eur-lex.europa.eu/eli/dir/1996/82/oj. Accessed 20 Feb 2020.

EU (European Union). 2012. Directive 2012/18/EU of the European Parliament and of the Council of 4 July 2012 on the control of major-accident hazards involving dangerous substances, amending and subsequently repealing Council Directive 96/82/EC. https://eur-lex.europa.eu/eli/dir/2012/18/oj. Accessed 20 Feb 2020.

IRGC (International Risk Governance Council). 2017. Introduction to the IRGC risk governance framework, revised version. https://irgc.org/risk-governance/irgc-risk-governance-framework/. Accessed 20 Feb 2020.

JCIA (Japan Chemical Industry Association). 2018. Chemical industry of Japan 2018. https://www.nikkakyo.org/sites/default/files/2018%20CHEMICAL%20INDUSTRY%20OF%20JAPAN%20IN%20GRAPHS_0.pdf. Accessed 20 May 2020.

KOTRA (Korea Trade-Investment Promotion Agency). 2019. Specialty chemicals. https://www.kotraspain.org/wp-content/uploads/2019/07/Specialty_Chemicals_leaflet_eng.pdf. Accessed 20 Jun 2020.

Krausmann, E., and D. Baranzini. 2012. Natech risk reduction in the European Union. *Journal of Risk Research* 15(8): 1027–1047.

Krausmann, E., and A.M. Cruz. 2013. Impact of the 11 March 2011, Great East Japan Earthquake and tsunami on the chemical industry. *Natural Hazards* 67(2): 811–828.

Krausmann, E., A.M. Cruz, and E. Salzano. 2017. *Natech risk assessment and management: Reducing the risk of natural-hazard impact on hazardous installations*. Amsterdam: Elsevier.

Krausmann, E., S. Girgin, and A. Necci. 2019. Natural hazard impacts on industry and critical infrastructure: Natech risk drivers and risk management performance indicators. *International Journal of Disaster Risk Reduction* 40: Article 101163.

Lee, K., H. Kwon, S. Cho, J. Kim, and I. Moon. 2016. Improvements of safety management system in Korean chemical industry after a large chemical accident. *Journal of Loss Prevention in the Process Industries* 42: 6–13.

Lindell, M.K., and R.W. Perry. 1996. Addressing gaps in environmental emergency planning: Hazardous materials releases during earthquakes. *Journal of Environmental Planning and Management* 39(4): 529–544.

Luo, X., A.M. Cruz, and D. Tzioutzios. 2020. Extracting Natech reports from large databases: Development of a semi-intelligent Natech identification framework. *International Journal of Disaster Risk Science* 11(6): 735–750.

Luo, X., A.M. Cruz, and D. Tzioutzios. 2021. Climate change and temporal-spatial variation of tropical storm-related Natechs in the United States from 1990 to 2017: Is there a link? *International Journal of Disaster Risk Reduction* 62: Article 102366.

Masys, A.J., N. Ray-Bennett, H. Shiroshita, and P. Jackson. 2014. High impact/low frequency extreme events: Enabling reflection and resilience in a hyper-connected world. *Procedia Economics and Finance* 18: 772–779.

Miller, D.S. 2016. Public trust in the aftermath of natural and na-technological disasters: Hurricane Katrina and the Fukushima Daiichi nuclear incident. *International Journal of Sociology and Social Policy* 36(5–6): 410–431.

Ministry of Environment, Government of Japan. 2009. A guidance for developing a chemical accident response manual in the local environment department. Tokyo: Ministry of Environment, Government of Japan (in Japanese).

OECD (Organisation for Economic Co-operation and Development). 2020. Natech risk management: 2017–2020 project results. https://www.oecd.org/officialdocuments/publicdisplaydocumentpdf/?cote=env/jm/mono%282020%294&doclanguage=en. Accessed 15 Feb 2020.

PAJ (Petroleum Association of Japan). 2011. Petroleum industry in Japan: 2011. https://www.paj.gr.jp/english/data/paj2011.pdf. Accessed 20 May 2020.

Park, H. 2020. Development of a community-based Natech risk management through the lenses of local community, first responders and government. PhD dissertation. Kyoto University, Japan.

Santella, N., L.J. Steinberg, and G.A. Aguirra. 2011. Empirical estimation of the conditional probability of Natech events within the United States. *Risk Analysis* 31(6): 951–968.

Sengul, H., N. Santella, L.J. Steinberg, and A.M. Cruz. 2012. Analysis of hazardous material releases due to natural hazards in the United States. *Disasters* 36(4): 723–743.

Suarez-Paba, M.C., and A.M. Cruz. 2022. A paradigm shift in Natech risk management: Development of a rating system framework for evaluating the performance of industry. *Journal of Loss Prevention in the Process Industries* 74: Article 104615.

Suarez-Paba, M.C., M. Perreur, F. Munoz, and A.M. Cruz. 2019. Systematic literature review and qualitative meta-analysis of Natech research in the past four decades. *Safety Science* 116: 58–77.

Tzioutzios, D., and A.M. Cruz. 2021. Sociodemographic influences on public interest in Natech risk information: Insights from Japan and S. Korea. *Journal of Integrated Disaster Risk Management* 11(1): 83–107.

UNDRR (United Nations Office for Disaster Risk Reduction). 2015. Sendai framework for disaster risk reduction: 2015–2030. https://www.undrr.org/publication/sendai-framework-disaster-risk-reduction-2015-2030. Accessed 25 Mar 2020.

UNDRR (United Nations Office for Disaster Risk Reduction). 2018. Words into action guidelines: Man-made and technological hazards. https://www.undrr.org/publication/words-action-guideline-man-made/technological-hazards. Accessed 20 May 2020.

UNEP DTIE (United Nations Environment Program – Division of Technology, Industry and Economics). 2015. A process for improving community awareness and preparedness for technological hazards and environmental emergencies. https://reliefweb.int/report/world/process-improving-community-awareness-and-preparedness-technological-hazards-and. Accessed 20 May 2020.

US EPA (United States Environmental Protection Agency). n.d. Risk Management Plan (RMP) Rule. https://www.epa.gov/rmp/. Accessed 8 Feb 2020.

Whitney, D.J., and M.K. Lindell. 2000. Member commitment and participation in local emergency planning committees. *Policy Studies Journal* 28(3): 467–484.

Yoshimura, T. 2012. Yusho: 43 years later. *The Kaohsiung Journal of Medical Sciences* 28(7S): S49–S52.

Yu, J., A.M. Cruz, and A. Hokugo. 2017. Households' risk perception and behavioral responses to Natech accidents. *International Journal of Disaster Risk Science* 8(1): 1–15.