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Critical Assessment of the
2012 Gumi Chemical Spill:
An Adaptive Governance Approach



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2017-2-6 Critical Assessment of the 2012 Gumi Chemical Spill: An Adaptive Governance Approach

[Case study]

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Introduction

An industrial accident in a plant operated by the Hube Global Chemical Corporation in Gumi, South Korea, released 8 tons of hydrofluoric acid into the surrounding area on September 27, 2012. The leak killed 5 workers and injured 18, affected 12,243 residents, and damaged 212 hectares of agricultural land and killed or injured 3,944 animals. About 300 residents were evacuated to nearby temporary shelters.

Although rare, such an industrial disaster demonstrates the importance of a crisis management system which can identify, assess, and handle a crisis at high-hazard sites. The challenges facing public agencies reflect the complexity and ambiguity of the administrative authority of those charged to deal with the crisis.

This case study examines how the local, regional, and national governments dealt with an unanticipated crisis by examining the information available and the announcements that were reported by various public agencies during the crisis. Particularly, this case study focuses on the management of complicated issues derived from new or unanticipated situations by using

an adaptive governance approach. Thus, the guiding questions for this case study are:

- How was the 2012 Gumi chemical spill crisis managed in practice?
- What decisions made in crisis management impacted collaborations and the effectiveness of the overall response, and what changes should be made in reference to what we learned from the crisis response?

This case study adopted an adoptive approach which aims to critically evaluate the crisis response to the Gumi chemical spill incident in South Korea. A main focus is on the public sector coping with challenges to emergency management agencies under a crisis situation. The analytical methods used to gain insight into the subject matter was a combination of the mass media, government reports, and press releases from national, provincial, and local government. To reinforce validity of the data derived from diverse sources, the method was to compare the reports and releases in a chronological order. The following subsections present the background on emergency management in South Korea and a brief outline of the 2012 chemical spill incident in Gumi.

Background of the 2012 Chemical Spill in Gumi, South Korea

On September 27, 2012, a toxic chemical leak released hydrofluoric acid at Gumi's National Industrial Complex, located 124 miles southeast of Seoul. The accident occurred when two Hube Global Chemical Corporation workers working on a tanker attempted to unload hydrofluoric acid into a storage tank. About 8 tons of hydrofluoric acid escaped into the atmosphere, spreading across a 4 km radius, killing 5 workers, affecting 12,243 residents, and damaging 212 hectares of agricultural land and 3,944 killed or injured animals.

As of 22 October 2012, it was reported that about 11,083 people had received treatment for nausea, chest pain, rashes, or sore eyes after inhaling fumes from the chemical leak. More than 300 residents including elderly persons were evacuated to public-run facilities in Bongsan-ri, Incheon-ri, and Baekhyeon-ri. Residents living within 1.5 km of the chemical spill site were advised to go for a medical check-up. Figure 1 shows an illustration of the affected area.

| Figure 1 | The Spatial domain of the Gumi chemical spill



Source: Naver Maps(2012, November 22) and YNA(2012, October 16).

Note: One centimeter to respectively one thousand and hundred meters i.e., 1:100,000 and 1:10,000.

As summarized in Table 1, Jung & Park (2016) illustrate that “about 12,243 residents including industrial workers, and public servants had received treatment for nausea, chest pain, rashes, or sore eyes as a result of exposure or inhalation of fumes from the chemical leak.” The City government of Gumi continued advising residents living within 1.5 km of the chemical spill site to go for a medical check-up at the three temporary *ad hoc* healthcare centers as part of the first response. Despite that all risk in polluted areas

was associated with the chemical leak, the national government has delayed in identifying its damages; local government also ignored the seriousness of the toxic gas and was not quick in evacuating its residents (Jung & Park 2016). All emergency response activities are summarized in chronological orders of Table 1.

| Table 1 | Chronological orders of the Gumi chemical spill

Date	Time	Agency	Events
September 27, 2012	15:43	N/A	The Gumi chemical spill occurred
	15:47	LFS/NE MA	Starting agency notification and mobilization
	16:00	LFS	Starting hazard Operations Initial Emergency medical care
	16:10	LPS	Impact zone access control and security
	16:30	LESOH	Operating local EOC
	17:00	MOE	Accepting the chemical spill
	17:50	LFS	Chemical response equipment mobilization
	17:45	MOE	Providing Crisis response information
	19:00	DREA/M OE	Threat detection and emergency classification
	19:10	LESOH	Population warning Starting Population monitoring and assessment
	23:30	LESOH	1st hazard exposure control
September 28, 2012	00:00	NIER	Chemical assessment equipment mobilization Damage assessment
	01:00	DREA	Hazard & environmental monitoring
	01:30	LESOH	2nd hazard exposure control
	03:30	MOE	Terminating the crisis response phase
	08:30	LESOH	Declaring emergency termination
	11:00	LESOH	returning residents home

Date	Time	Agency	Events
October 6, 2012	13:25	LESOH	3rd Hazard exposure control
	14:40	DREA	Hazard & environmental monitoring termination
		Prime Minister's Office	Sending a 26-member team to conduct a three-day assessment of the severity of the crisis
October 24, 2012		Korean Food and Drug Administration	Authorizing to dispose of crops and livestock; Rural Development Administration conducted clean-up operations using lime powder to detoxify agricultural soil

Source: Adopted to Jung & Park (2016).

Note: NEMA (National Emergency Management Agency); MOE (Ministry of Environment); NIER (National Institute of Environment Research); DREA (Daegu Regional Environment Agency); LESOH (Local Emergency Safety Operations Headquarter); LFS (Local Fire Station); LPS (Local Police Station).

As the initial function of emergency response, emergency assessment was caused by late emergency recognition of Ministry of Environment (MOE), indicating that the main elements of this functions also was not accomplished in the first response. According to NEMA (2011, 29), the lead agency for responding to crises related to the toxic chemical substance is the Ministry of Environment, and the ministry is obligated to establish the national safety management basic plan, respond to the chemical spill, and recover its damages. Despite that, the DREA under the ministry of environment unsuccessfully responded to the leak, and even issued a serious emergency warning over 6 hours 47 minutes. Because the Daegu Regional Environment Agency (DREA) broke the crisis response manual for mitigating the secondary damages without any other consideration, the residents were not evacuated over about 4 hours from the accident and gravely affected by HF (YNA 2012, October 16).

Despite the National Institute of Environmental Research (NIER) is a

professional agency obligated to analyze the toxic chemical substances and to suggest effective operations on the crisis, moreover, the agency delayed to dispatch a special chemical analysis vehicle to the scene because the vehicle was not prepared for the potential crisis such as the chemical spill (Chosun 2012, October 23). The crisis response manual on toxic chemical substances (2012: XX) states that the cancellation of the serious emergency warning depends on the decision of the crisis evaluation committee in the ministry of environment. The DREA, however, “canceled the warning after 5 hours after the spill (YNA 2012, October 16).” The city government of Gumi also disputed that since the NIER offered the toxic chemical analysis results that the degree of the HF pollution within .31 mile from the accident was about 1 ppm under 30 ppm as the significant level, we allowed local residents to return to their home even though it was uncertain whether the area was safe from contamination (LESOH 2012, October 4).

On top of that, although rapid hazard operations were performed by local fire fighters as the first responder, they did not effectively mitigate hazard during the initial response. The reason is that MOE and DREA did not provide accurate emergency assessment to local agencies despite rapid hazard operations need the accurate emergency assessment (YNA 2012, October 16). In terms of the hazard operations, NEMA released an announcement about the reason why local fire fighters responded to the chemical leak by using water, noting that the key information guide for the chemical substance provided by the ministry of environment illustrates that the spilled HF gas should be diluted and dispersed by using abundant amounts of water (NEMA 2012, October 10). It implies that the information flow during the crisis caused inappropriate responses resulting in secondary damages to local communities.

As the crisis unfolded, secondary damages cost the local economy and residents' livelihood. Between 77 and 80 companies in the industrial zone

were forced to shut down temporarily, reporting about U.S. \$15.9 million in production lost and U.S. \$1.7 million estimated costs in property damages (Chung 2013). As of 6 October 2012, the media reported that crops on more than 90 hectares of agricultural lands were being grown 200 meters from a chemical plant and animals affected by the chemical leak were exhibiting symptoms of chemical poisoning. The amounts of air pollution and water contamination caused by the chemical leak are unknown, but the government assured the public that only one to five parts per million (ppm) of hydrofluoric acid were found in the air.

According to the National Institute of Environmental Research (NIER) 2012: 4), hydrofluoric fluoride (HF) is “a highly caustic liquid, and should be managed with extreme care.” The symptoms of exposure to hydrofluoric acid may not be immediate. If untreated, however, it can interfere with nerve function as well as result in serious injuries (Korea Medical Association 2012, October 10). The U.S. National Institute for Occupational Safety and Health (NIOSH), the U.S. federal agency responsible for providing recommendations for the prevention of work-related injury and illness said that exposure to HF should be no more than “3 ppm [2.5 mg/m (3)] as limit-time-weighted average for up to a 10-hour workday and a 40-hour workweek, and a short-term exposure limit is 6 ppm [5 mg/m (3)]” (2012, November 16).

In terms of air pollution and water contamination caused by chemical leak, the Ministry of Environment, Daegu Regional Environmental Agency (DREA), and NIER announced that the atmosphere, including groundwater and soil around the accident, are not polluted by hydrofluoric acid (Ministry of Environment 2012, October 18; National Emergency Operations Center [NEOC] 2012, October 23). The Korean Federation for Environmental Movement and the Citizens' Institute for Environmental Studies argued that evacuated residents cannot trust the government announcement (YNA 2012,

October 23).

The Korea Industrial Complex Corp. (KICC) reported that between 77 and 80 companies in the industrial zone were forced to shut down temporarily costing them about U.S. \$ 15.9 million on production lost (Kyeonghyang 2012, October 8). According to Local Emergency Safety Operations Headquarter in Gumi, the estimated physical damages is around U.S. \$ 1.7 million, and crops, vegetable, and fruit on more than 372 hectares (919 acres) of agricultural lands were withering within 200 meters of the explosion site (LESOH 2012, October 8). In addition, about 3,997 cows, goats and other livestock exhibiting symptoms being affected by the chemical leak (LESOH 2012, October 30).

The major events after the chemical spill are outlined in Table 1. The table highlights three important points related to emergency response: (1) It took close to a month for the city to be declared a disaster area. (2) Federal agencies took control of the response. (3) Media outlets were critical of the federal agencies' response efforts.

At the regional level, the North Kyeongsang provincial government committed U.S. \$1 million to the city of Gumi and organized a task force team to support the local government administration (North Kyeongsang Government 2012, October 10). The city government of Gumi announced that it would extend the local tax payment due date for households affected by the disaster up to a maximum of 9 months and reduce their electricity fees by 50% in the villages of Bongsan-ri and Incheon-ri (LESOH 2012, October 12). According to the Korean Times (2012, October 22), "residents of the affected villages will receive a 30 to 50 percent discount for their monthly payments of national health and pension service up to 6 months. The discount will be offered to people who suffered from not only health problems but also damage to their houses, farmland or livestock." Public officials from

the Ministry of Health and Welfare also announced that the national government would pay full medical coverage to the victims who received medical treatment since the industrial disaster occurred (YNA 2012, October 22). The National Emergency Management Agency (NEMA) (22 October 2012), announced that it would “cover medical costs for 264 firefighters who worked at the scene of the gas leak.”

Despite the emergency aid and financial assistance provided by national, provincial, and local governments, the negotiation to compensate the victims and pay the damages from the chemical leak was not successful (YNA 2012, November 13). On October 15, 2012, the citizens exposed to the toxic gas held a press conference and argued that “the city government of Gumi did not respond to the leak and even neglected residents in the polluted area without any other treatments after 18 hours from the accident” (YNA 2012, October 15). The mayor of Gumi announced that “the citizen group is requiring excessive compensations for the damages such as agricultural lands and healthcare compared to other special disaster zones affected by the tropical typhoons” (LESOH 2012, November 12) and “delayed a municipal ordinance to compensate the victims” (YNA 2012, November 13).

In terms of legal action, “the citizen group are filing legal action against national and local governments and KICC demanding about U.S. \$1 billion compensations for agricultural lands and healthcare” (Donga 2012, October 9). However, the National Emergency Operations Center (NEOC) and the Ministry of Environment (2012, October 23) reported that “the effects of the chemical leak on the agricultural lands, domestic animals, and soil exposed to the chemical spill could not considered as a crop production in 2013.” The city of Gumi took legal action against the Hube Global Corporation, “demanding the right to indemnity” (YNA 2012, November 14).

Adaptive Governance Approach to the 2012 Gumi Chemical Spill

Through a critical assessment of the Gumi chemical spill, this case study proposes adaptive governance as a way for national and local governments to respond to challenges. Specifically, this section focuses on crisis management techniques that can be newly adopted by national agencies and local governments to develop the ability to change processes based on public learning and deliberative procedures.

Responsiveness

Adaptive governance is based on critical mechanisms that sustain the response structure under physical and environmental stress as the crisis management system adjusts to cope with shifting conditions (Andrew & Kendra, 2012: 523). It is important for local governments to adopt strategies to reinforce the effectiveness of the crisis management system (Scholz & Stiftel, 2005). The National Assembly's Environment and Labor Committee criticized the poor response of national agencies and the city government of Gumi (Newsis 2012, October 16). The chain of information flow from the 119 local emergency center to other organizations such as national, regional, and local agencies and local government was not accurately designated or coordinated by the crisis management system (Chosun 2012, October 19). The representative of the ruling Saenuri Party, Wan-young Lee, said that "the DREA had been alerted an hour and 20 minutes after the gas leak and questioned whether the delay has to do with the government's past decision to close a bureau dealing with chemicals" (YNA 2012, October 16).

According to NEMA (2011: 29), "the lead agency for responding to crises related to the toxic chemical substance is the Ministry of Environment, and

the ministry is obligated to establish the national safety management basic plan, respond to the chemical spill, and recover its damages.” Despite that, “the DREA under the Ministry of Environment unsuccessfully responded to the leak, and even issued a serious emergency warning more than 6 hours later. Because the DREA did not follow the crisis response manual for mitigating the secondary damages without any other consideration, the residents were not evacuated for more than 4 hours and were gravely affected” (YNA 2012, October 16). In addition, “the NIER is a professional agency obligated to analyze the toxic chemical substances and to suggest effective operations on the crisis, but the agency delayed to dispatch a special chemical analysis vehicle to the scene because the vehicle was not prepared for the potential crisis such as the chemical spill” (Chosun 2012, October 23). The crisis response manual on toxic chemical substances (2012) states that “the cancellation of the serious emergency warning depends on the decision of the crisis evaluation committee in the ministry of environment.” The DREA, however, canceled the warning only 5 hours after the spill (YNA 2012, October 16).

The lack of information and poor judgment of national agencies led to confusion over the appropriate decisions that should be taken by local agencies, which led to secondary damages to local communities. For example, a member of the National Assembly, Sangjung Shim, criticized the national government by highlighting “the wrong information provided by the NIER caused the confusion of the first responders and the wrong evacuation of residents.” She also indicated that even though the chemical crisis response manual presents diverse ways to neutralize the toxic substance, the NIER and the DREA did not transmit the essential information to the local agencies and government (Sisanews 2012, October 17). The local representative, Myengseok Park, argued that “the city government did not provide any information [on] the toxic chemical [to] ... local communities before the

evacuation and even [evacuated] residents at the HF-exposed area without neutralizing the effects of HF on September 28” (Chosun 2012, October 19).

While similar HF accidents had actually occurred 3 years before in the same chemical plant, the city government of Gumi had categorized the firm as a good chemical management firm (Chosun 2012, October 19). The city government of Gumi state that “since the NIER offered the toxic chemical analysis results that the degree of the HF pollution within .31 miles from the accident was about 1 ppm under 30 ppm as the significant level, we allowed local residents to return to their home even though it was uncertain whether the area was safe from contamination” (LESOH 2012, October 4). NEMA also released an announcement about the reason why local firefighters responded to the chemical leak by using water, noting that “the key information guide for the chemical substance provided by the ministry of environment illustrates that the spilled HF gas should be diluted and dispersed by using abundant amounts of water” (NEMA 2012, October 10). These statements imply that the information flow during the crisis caused inappropriate responses, resulting in secondary damages to local communities.

The distrust of the affected community group on the city government delayed the compensation procedure. On 2 p.m. October 2, 2012, the citizen group met the mayor in their village affected by the chemical and demanded the evacuation plan coordinated by the government (LESOH 2012, October 4). However, the Ministry of Environment announced that the chemical investigation result on October 5 reported that the “groundwater within the accident area was safe to drink, and the effects of the HF spill did not influence the groundwater” (Ministry of Environment 2012, October 5). Based on the findings of the taskforce, the city government refused to evacuate. As a result, villagers could evacuate from the affected site on October 6 more than ten days after the event (LESOH 2012, October 7). The affected residents accused

that “the NIER only tried to collect samples in the area .31 to .81 mile away from the accident, and failed to provide a timely evacuation in response to the chemical spill” (YNA 2012, October 7).

To resolve the problem connected to the chemical spill, on October 6, the national government sent a 26-member team consisting of public officials and experts to conduct an assessment on the severity of the crisis. Vice prime minister, Yook Dong-han, said that “the government will make detailed measures and standards to administer support, and plans to carry out another round of in-depth inspections into the region as early as possible” (YNA 2012, October). The national government also dispatched psychiatric experts to a youth center and a food waste disposal facility in Gumi to which some 50 residents evacuated (LESOH 2012, October 30). According to the NEOC’s report (2012, October 26), a total of 12,243 residents received medical examinations. All the evacuated residents received consultations and “21 of them received medication for depression, sleep disorder and headache.” Nevertheless, netizens lambasted “the government’s belated response, city authorities’ incompetence, and the mainstream media’s silence on this critical issue. Twitter users have uploaded photos of affected farmlands” (YNA 2012, October).

Public and Scientific Learning

Adaptive governance plays an important role in establishing mechanisms to enhance learning processes through the crisis management system (Andrew & Kendra, 2012; Scholz & Stiftel, 2005). Since public information and scientific evidence are very limited and complicated due to the incompatibility of the crisis management system, adaptive governance presents guidance for how networks disseminate significant information and diverse experiences

among local agencies beyond bureaucratic boundaries (Brunner & Lynch 2010). In this case, there was limited public information about the chemical leak during the early stages of the accident. Information was mostly reported by online sources rather than by the government.

Lack of information from public agencies exacerbated the confusion regarding the nature of the disaster. For example, “Officials claim there was no explosion. They said, the acid leak was first contained [when firefighters] ... deployed motorized sprinklers to neutralize the poisonous emissions, which caused a chemical reaction and created smoke that made it look like an explosion.” Because of unfamiliarity with the chemical gas and a lack of public and scientific information, firefighters as the first responders responded to the accident without any information about the danger of HF, and thus 506 firefighters were injured during the initial response (27% of injured people) (YNA 2012, October 8; Chosun 2012, October 19). News media also reported that the firefighters did not wear chemical resistant suits and masks to protect themselves against the toxic chemical. Firefighters failed to use calcium hydroxide, the neutralizing agent for hydrofluoric acid, because they did not know they were supposed to until the professional chemical analyst from the NIER arrived about 8 hours after the initial leak.

The mechanism to share learning processes with other local agencies should be adopted to regional and local emergency management agencies, and the ability to learn from public and scientific information may be the fundamental element for adaptive governance. For instance, “During the parliamentary inspection meeting, a representative of the Democratic United Party accused that the government had been wrong in saying that there was no danger in the region even though one to five parts per million (ppm) of hydrofluoric acid were found in the air. The affected communities rejected the short-term compensation plan provided by the government and argued that “the

government did not provide any information and evidence to convince them” (YNA 2012, October 13).

On 24 October 2012, the government finally decided to take action by disposing of crops and culling livestock from the affected region. A special team of on-site inspectors said that overall farming conditions were not a problem since soil and water pollution are below dangerous levels. As part of its precautionary measures, the government ordered the use of lime powder to detoxify the soil for farming. The Chief Director of Rural Development Administration said that “when the acid combines with lime in soil it becomes insoluble. The soil becomes acid-free. It’s possible to farm this land next year.” Despite the assurance, the affected communities were unsatisfied, frustrated, and angry about the lack of information provided by government agencies especially related to their property rights, livelihood, and when they can return to their homes.

Learning from the Crisis: Public and Policy Responses

The lack of hazard information exacerbated the confusion regarding the nature of incident management, indicating that LESOH as the principal EOC did not spontaneously coordinate the predetermined operations. For instance, LESOH claimed there was explosion when the chemical spill occurred, but the acid leak was first contained when firefighters deployed motorized sprinklers to neutralize the poisonous emissions, which caused a chemical reaction and created smoke that made it look like an explosion (YNA 2012, October 8). Because of inadequate communication and documentation, moreover, fire fighters as the first responder were committed to the accident without any information about the danger of the chemical gas, and thus 506 firefighters were injured during the initial response (27% of injured people) (Chosun 2012,

October 19). News media also reported that the firefighters did not wear chemical resistant suits and masks to protect themselves against the toxic chemical. Nevertheless, LESOH carried out cleanup operations to keep residue from running into the Nakdong River, one of the country's four largest waterways, rather than concentrating on the role of the pivotal EOC (LESOH 2012, October 4).

Although local agencies' function and authority to response to natural disaster is clearly specified in the national statutes, disaster caused by large scale industrial accident is not obvious to local government agencies. The hierarchical structure as centralized decision making works well in a highly fragmented administrative system during a large scale disaster, but it has not been as effective in a poorly defined incident management. Local agencies await directives from the provincial and national governments. Yet, it was unclear as to why it took the national government close to two weeks to response to the crisis. From the citizen perspective, the cause of the chemical leak was dysfunctions of incident management system, and inefficient emergency response resulted in miscommunication among national and local agencies.

According to the indication in the inspection of the government office, On October 18, 2012, the Ministry of Public Administration and Safety (MOPAS) announced that 22 crisis management standard manuals will be improved in such a way to meet realistic needs of crisis response and recovery (Segye 2012, October 19). In addition, the Act for the chemical substance legislation and assessment will be also considered as the objective of a follow-up measures because the Act cannot cover small firms dealing the toxic chemical aids under 1 ton (Kookmin 2012, October 11). On October 23, 2012, the government approved a bill to conduct special inspections into companies that deal with dangerous chemicals. However, residents and nongovernmental organizations

are urging the government to ensure there are more systematic ways to deal with the crisis. The recent chemical disaster in the Republic of Korea underscores the critical importance of preparing communities to cope with environmental emergencies for the protection of human health and nature.

Conclusion

Although these segmented functions need adequate communication and information flow, local agencies showed passive response activities and high dependency on national agencies' role such as hazard assessment (Jung & Park 2016). As McConnell (2003) indicated, the principal agency's failure to assess the hazard resulted in failures of other functions of emergency response such as hazard operations, population protection, and incident management. Moreover, a lack of interorganizational communication was connected to other elements of incident management, implying that without adequate information flow among agencies, agency notification, mobilization of emergency facilities, and analysis and planning might not be performed effectively. Lastly, the principal EOC in the jurisdiction needed to have adequate authority to coordinate interorganizational activities. By monitoring and evaluating the coordinated operations crisis management can mitigate damages from the hazard as well as achieve successful emergency response.

On top of that, during the early stage of the emergency response, there was a lack of interagency communication reflecting a highly fragmented and hierarchical governance structure. The crisis was unexpected and small in scale in comparison to other industrial disasters, but it nevertheless threatened lives, livelihoods, and the economic viability of the region. Lack of interagency communication, dissemination of public information and risk communication as well as uncertainty related to the consequences of the

incident affected how public agencies manage the crisis. The inconsistency of information related to the cause also put the national government in an unfavorable spotlight (Hankyoreh 2012, October 23). For example, the national government was blamed for “bringing residents back to the affected area even though the area was still contaminated” (Korea Herald 2012, October 10). There were reports that firefighters were unaware of the composition of the chemical and thus failed to use calcium hydroxide, the neutralizing agent for hydrofluoric acid.

The adaptive governance perspective highlights the problems or aspects that need to be resolved or improved. First, the hierarchical structure can impose inefficiency as decisions by one specialized agency may impose negative externalities on others (Jung & Song 2015). It is to respond to disaster than to mitigate or prepare for the eventuality of a disaster. Second, the Gumi chemical spill crisis can be argued to have been precipitated by organizational failure and human errors. While the situation was grave, during the early stage of the emergency response, it was uncertain as to when public agencies should have taken charge and how they should have activated a systematic approach for managing the crisis. National, provincial, and local agencies were perceived by the public as being too slow and inadequately prepared to cope with emergencies, leading to frustration and anger. The crisis was exacerbated further by the media coverage about human suffering and environmental consequences. Since it may not be effective for the crisis management system to relying on a leading agency when responding to the initial crisis, the principal EOC consisting of diverse agencies in the hazard jurisdiction needs to have adequate authority that can secure appropriate information to make a decision to allocate resources and coordinate the first responding organizations.

This case study provides new insights into how crisis management based

on the adaptive governance perspective can contribute to redesigning the current system, which focuses mainly on natural disasters in developing countries. Since the nationally centralized but segmented crisis management system cannot fully respond to accident-triggered crises such as chemical spills and gas explosions, designing the crisis management system as adaptive governance is important for responding to those hazards by using self-organized networks and deliberative mechanisms to mitigate the costs. Particularly, this case study encourages crisis managers to understand the adaptive governance perspective and identify existing challenges of crisis management. We also hope future researchers will investigate the challenges of emergency recovery and mitigation from the point of view of adaptive governance.

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