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Damage reduction strategies against chemical accidents by using a mitigation barrier in Korean chemical risk management

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ABSTRACT

After the hydrogen–fluoride release accident in 2012, the Korean society realized the importance of chemical safety and many plans have been proposed to improve it. After the big chemical accident, the "Chemical Control Act" was newly established. The law of the "Chemical Control Act" is the most representative measure for chemical safety. According to the law that came into force in 2015, all chemical dealing companies must conduct an off-site consequence analysis of their chemicals and develop a plan for risk management. To reduce off-site consequences from the chemical plant, an innovative risk-management plan was suggested by the Korean industry. A decision was made to build a 30 m high mitigation barrier outside the plant area to protect the public when a chemical release accident occurs. The construction is now under process, and two representative accident scenarios are developed for its simulation to confirm the effect of mitigation barrier. Each scenario follows guidelines of the "Chemical Control Act," and simulation results show that the barrier helps reduce chemical concentration in the public area. This plan is expected to improve the anxiety of residents near the plant and will be a good example of risk management in the industry.

1. Introduction

In the case of an accident involving a chemical substance, it is different from merely physically occurring accidents such as structural collapse and simple collision. Chemical disasters continue to affect local residents, employees in a workplace, and the environment even after the accident. In addition, a large amount of time is required to operate a factory that is shut down because of a chemical accident, resulting in an enormous economic loss. Furthermore, chemical accidents are very threatening as they expose some hazardous substances into the atmosphere and are very difficult to predict (Lee et al., 2016). Nowadays in the chemical industry, prediction of chemical accident becomes more difficult when systems become more complex in a chemical plant system (Vuorio et al., 2017). Thus, prevention of chemical accidents is emphasized, and many countries are striving to prevent and manage chemical accidents by establishing safety regulations and laws (Kwon et al., 2016). Safety regulations differ from other regulations in that they generate much business benefit from industrial activities. In addition, safety regulations prevent the financial and environmental damage by minimizing the crisis in the industrial field (Swuste and Reniers, 2016). Actually, in many countries, industry groups and government agencies have focused on improved safety systems by past lessons on safety management (Fyffe et al., 2016).

In 1982, The European Union instituted the Seveso Directives (EC Directives), which set out legal standards for chemical safety management in EU countries (Kwon et al., 2016). This directive was revised as several major chemical disasters (e.g., Mexico-City (1984), Bhopal (1984), Sandoz-Basel (1986), and Piper Alpha (1988)) occurred in the 1980s (Jain et al., 2016; Swuste and Reniers, 2016). In 1986, the Emergency Planning and Community Right-to-Know Act was enacted in the United States as a result of the accident that occurred in Bhopal, India, in 1984 (Willey et al., 2005). In 1992, Occupational Health and Safety Administration in USA enacted PSM regulations in response to the 1989 explosion of the company Philips (Kwon et al., 2016). Further, in 1999, USA established the US Environmental Protection Agency and Risk Management Program regulation by law (DeWolf, 2003). These valuable law enactments help to develop prevention and protection technologies to avoid chemical exposure risk (Brückner et al., 2016). Similar changes occurred in Korea in 2012 because of chemical accidents.

In 2012, a chemical leakage accident occurred in the 4th National Industrial Complex in Gu-mi City, Gyeongsangbuk Province. Five workers died and 18 were injured; moreover, the chemical accident affected 12,243 residents and caused environmental damages, such as

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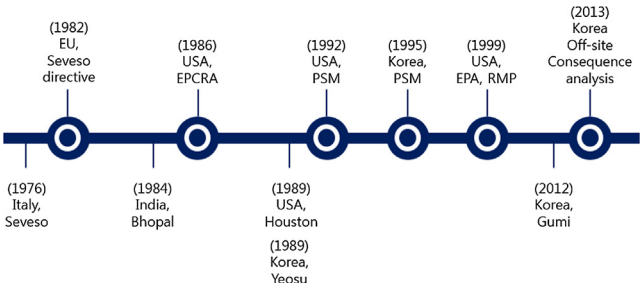

Fig. 1. Risk-management regulation of chemical accident.

Table 1
Safety diagnosis cycle of equipment.

Degree of risk	Safety diagnosis cycle of equipment
Low risk	– 12 years
Mid risk	– 8 years
High risk	– 4 years

crop damage (Jung and Park, 2016). After this chemical disaster, the government revised the related laws and regulations numerous times. The "Chemicals Control Act" and "Off-site Consequence analysis" correspond to these (Lee et al., 2016), as shown in Fig. 1.

The previously mentioned big chemical accident in Korea demonstrates that Korea has several weaknesses that remain unsolved in the aspect of chemical substance management. To build a system in which the relevant agencies may respond to chemical disaster rapidly and efficiently, and raise communication to improve cooperation by removing the partition between departments, the government instituted the Joint Interagency Chemical Emergency Preparedness Center at six main industrial complexes throughout the nation. In each center, the public officer is consigned from the central departments, such as the Ministry of Trade, Industry and Energy; Ministry of Environment; Ministry of Employment and Labor; and National Emergency Management, including the local governments and industrial complex headquarters. They are scheduled to prevent chemical accidents efficiently and make a rapid response to accidents. However, experts and civic groups have been pointing out the inadequacy. The recent chemical accidents that occurred successively exposed the limits of the current "Toxic Chemicals Control Act" regarding the chemical substance management, response to chemical accidents, and relief scheme for damage. As a result, the law was divided into the "Chemicals Control Act" and "Act on the registration and evaluation of chemicals." With this change, discipline was strengthened for chemical management and registration. The amendments include the chemical substance management, response to accidents, cycle of equipment test, and the permission to systems. Especially, Articles 35 and 36 of the "Chemical Control Act" are focused on reinforcement of the management of business places by including the contents in which 5% of total sales at the relevant business place (multiple business places), or 2.5% of total sales at a single business place, is imposed on the violator as a penalty, instead of ordering to suspend the business of the violator (Lee et al., 2016).

2. Off-site consequence analysis

From the design and installation stage, there is a need to establish a facility to safely design and install the handling facilities by considering the external influences, and to secure safety according to the risk. These are described in the "Chemicals Control Act". The "Chemical Control Act" covers the preparation and submission of the chemical accident impact assessment report. According this regulation, the suitability of facility installation is judged and the safety diagnosis cycle of the equipment is determined, as summarized in Table 1. Table 2 summarizes the definitions of the main terms used in this regulation (MOE, 2014b).

2.1. Guidelines for accident scenario selection

To conduct offsite consequence analysis, scenarios are set up according to the accident situation, as shown in Fig. 2. The scenarios are classified into accident scenarios, worst-case scenarios, and alternative scenarios, as summarized in Table 3.

In addition, in this guideline, scenario analysis conditions are presented, and different conditions are applied depending on the scenario types. Analysis conditions include weather conditions, such as wind speed, atmospheric stability, and atmospheric temperature, and accident conditions such as height of the leak source and surface condition. Scenario analysis conditions are specified according to scenario type in offsite consequence analysis, as summarized in Table 4. In the worst-case scenario, the mitigation device is not considered, whereas the alternative scenario is selected by considering the mitigation device. In addition, alternative scenarios reflect the past five years of accident history and process risk analysis results (NICS, 2014).

2.2. Guidelines for influence area estimation

In case of a chemical accident, the scope of the accident is subject to "Technical guideline on estimating the area of accident influence." According to these guidelines, the influence area is determined by the endpoint. The endpoint varies according to the characteristics of the accident material; for toxic substances, the influence range is determined by the endpoint concentration specified in the technical guidelines (NICS, 2015).

2.3. Chemical control act

Owing to subsequent chemical accidents, there is need for strengthening safety management and a preventive management system. As a result, the "Chemical Control Act" was enacted and implemented in January 2015. The key point of this law is to establish accurate understanding and countermeasures for companies to reduce chemical accidents and risks. Otherwise, the company could lead to additional and monetary losses due to the decline in its value. In particular, "offsite consequence analysis" was established under Article 23 of the "Chemical Control Act" and Article 19 of the enforcement regulation of the same act. The "Chemical Control Act" includes an obligation, according to which a workplace that intends to install and operate a hazardous chemical substance-handling facility shall prepare

Table 2
Definition of main terms in "Off-site consequences analysis".

Term	Definition
Chemical accident	Any situation where a chemical spills or leaks into a person or environment
Offsite	Outside the boundary of the site where the hazardous chemical handling facility is installed and operated
Offsite analysis	Determining the level by analyzing the extent of the impacts of chemical accidents on people or the environment outside the workplace
End point	Point to reach values, such as toxic concentration, overpressure, and radiant heat, that can affect people or the environment
Full amount	Maximum capacity to be stored or processed in a storage vessel or piping
Influence range	Areas where toxic chemicals may be burned, exploded, or leaked due to chemical accidents, and may affect people or the environment from the accident site