

SUMMARY OF PRACTICAL EXPERIENCE IN INTERNAL EMERGENCY PLANNING OF DANGEROUS CHEMICAL ESTABLISHMENTS

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ABSTRACT

The present article draws the reader's attention to the practices and challenges faced by operators in internal emergency planning for major industrial accidents involving dangerous substances, with particular emphasis on the operation of chemical production and storage facilities. The authors examine the current European and Hungarian legal frameworks and present findings based on practical experiences gained during emergency management exercises. Case studies illustrate the complexity of internal emergency planning, training and implementation, with particular regard to human factors, communication, protective infrastructures and their practical applicability. The primary objective of the article is to contribute to the ongoing development of internal emergency planning methodologies and procedures, and also to enhance preparedness for mitigating the consequences of potential emergencies at dangerous establishments.

KEYWORDS:

internal emergency planning, dangerous establishment, dangerous substances, major accident, emergency management

1. Introduction

Since the onset of the COVID-19 pandemic in 2020, the chemical industry has faced a range of political, economic and social challenges. During the initial emergency period the demand for chemical products and consequently, the production declined leading to reduced revenues. This downturn was followed by a strong recovery in chemical production between 2021 and 2022, driven by increased customer demand. At the same time, concerns over the reliability and resilience of chemical production chains prompted companies to build significantly larger stockpiles of chemical substances. By the end of 2022, supply chain concerns

eased, and key end-user markets began to destock, leading to another decline in chemical demand. As a result, global chemical production grew by only 0.3% year-on-year in 2023, while industry revenues fell by 8% compared to the previous year. However, regional trends varied significantly: while China's chemical production grew by 7.5% in 2023 driven by domestic demand and export recovery, production in the European Union decreased by 7.6% and in the United States by 1%. Despite this, the American Chemistry Council forecast a more positive outlook, with global chemical production expected to grow by 3.4% in 2024 and 3.5% in 2025 (Deloitte, 2024).

In addition to market challenges, the chemical industry is under growing environmental pressure from society. Stricter regulations, commitments to carbon neutrality, and the increasing demand for green technologies are forcing chemical industry players to rethink their operations. Meeting sustainability expectations requires not only the renewal of technologies used in production processes, but also the implementation of responsible and transparent solutions across the entire value chain, from raw material procurement to waste management (Vince, 2008). Among environmental considerations, the safe operation of facilities and the prevention of major industrial accidents involving dangerous substances are very important, as such incidents pose significant risks not only to the environment but also to human life and health (Mannan, 2012).

Recent major industrial accidents around the world have shown that the concept of “zero risk” in safety engineering is unrealistic. For instance, according to a report by Coming Clean and the Environmental Justice Health Alliance for Chemical Policy Reform (2023) more than 825 accidents involving chemical substances occurred in the United States of America between January 1, 2021, and October 15, 2023. These incidents resulted in 43 deaths, over 150 injuries, 191 evacuations of nearby communities, and 101 “shelter in place” orders. Similarly, data from eMARS (Major Accident Reporting System) database indicated that 411 major chemical accidents occurred in the European Union between 1980 and 2020, resulting in 620 deaths and 10663 injuries (Cintora et al., 2022).

As recent years have demonstrated, emergency situations involving dangerous substances can arise not only from technological failures, but also from external sources of hazards. For example, on March 21, 2022, an ammonia leak occurred at the Sumykhimprom chemical plant in the city of Sumy following an air strike, contaminating an area within a 2,5 km radius, including the villages of

Novoselitsa and Verkhnia Syrovatka. Due to wind direction, the city of Sumy was largely spared from the contamination (Kharytonov et al, 2024). On May 31, 2022, another airstrike in Severodonetsk caused the explosion of a nitric acid tank prompting a citywide lockdown due to toxic exposure (Levchenko et al., 2024). In addition, extraordinary natural disasters can also trigger major chemical accidents involving dangerous substances. For example, in 2017, Hurricane Harvey damaged over 40 plants and caused more than 100 chemical spills (Khan et al., 2020).

The examples and statistics of major industrial accidents discussed above underscore the critical importance of emergency planning in ensuring the safe and sustainable operation of the chemical production and storage sector. Regulatory requirements for emergency planning at industrial or commercial sites have been part of the international and European Union environmental legislation since the second half of the 20th century. The *Convention on the Transboundary Effects of Industrial Accidents* (UN ECE, 2015), adopted by the United Nations Economic Commission for Europe, requires the development, testing and, where necessary, application of both internal and external emergency facilities falling within its scope.

Within the European Union, including Hungary, these requirements are codified in 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 (2012/18/EU, 2012), commonly referred to as the Seveso III Directive. This Directive has been in force for more than over two decades.

Under the Seveso III Directive, any economic operator involved in the production, use or storage of dangerous substances meeting certain thresholds is classified as a so-called “upper-tier establishment”. For such establishments the Directive explicitly

requires the operator to prepare an internal emergency plan.

The development and implementation of the legal regulations on emergency planning in Hungary has been ongoing since 2001. Accordingly, the authors summarize the practical experience of operators based on both professional insight and expert opinion. While the foundation of the Hungarian regulation is the Seveso III Directive, its scope has been expanded to include so-called “*under-tier establishments*”, which are also subject to emergency planning requirements. In addition, “*lower-tier establishments*” are also required to comply with certain emergency planning obligations. Hungarian regulations also address military facilities, where dangerous substances may be present through specific legislation (Káta-Urbán, 2017).

In this article, the authors analyze and evaluate how operators implement the current Hungarian legal requirements drawing on relevant legislation, emergency planning exercises and past industrial accidents.

Based on their own professional experience and interviews conducted with industrial safety experts, the authors propose a set of professional criteria for internal emergency planning. These criteria are grouped according to the specific sites of protection on the territory of an industrial facility. Furthermore, the article identifies common deficiencies frequently observed among industrial safety professionals during the preparation of internal emergency plans.

2. Analysis of the Emergency Planning Regulations Applied in Hungary

The purpose of the internal emergency plan is to summarize the preparedness, response and recovery measures that can be implemented by the operator to ensure the effective management of protection against major accident events involving dangerous substances. It also aims to support the elimination of environmental damage and the

cleaning and restoration of the environment, while minimizing adverse effects to the greatest possible extent. The Seveso III Directive establishes a two-tier emergency planning system. Within this framework, each upper-tier establishment is required to draw up an internal emergency plan, which defines the measures to be applied within the establishment in the event of a major accident involving dangerous substances. In parallel, the competent authorities are responsible for drawing up an external emergency plan, which contains the measures necessary outside the establishment to protect the population living in the vicinity of the site, the surrounding environment and material assets. The content requirements for both internal and external emergency plans are precisely defined in Annex IV of the Seveso III Directive.

Practical experience shows that major accidents involving dangerous substances, which may endanger the public, can occur not only at upper-tier establishments (Mesics, 2017). Accordingly, in Hungary, the obligation to carry out emergency planning has been extended to establishments operating below the threshold levels, as well as any economic entity whose activities could potentially lead to the occurrence of a major accident involving dangerous substances.

These establishments are identified based on two criteria: firstly, if the quantity of dangerous substances present on site reaches or exceeds 25% of the lower threshold level specified in Annex I of the Seveso III Directive, but does not reach the lower threshold itself; secondly, if the entity conducts special activities or uses high-risk substances in significant quantities, such as ammonia or chlorine. This category also includes the pipeline transport of dangerous substances and hazardous waste treatment facilities, where emergency planning is required due to the inherently hazardous nature of the operations. These establishments are collectively referred to as the “*under-tier establishments*” (Cimer & Varga, 2015).

In accordance with the Seveso III Directive, Hungary also applies a two-stage emergency planning system, being responsible for preparing the internal emergency plan, while the preparation of the external emergency plan is coordinated by the competent authority. However, the authority is not the only organization involved in the preparation of the external emergency plan. All relevant organizations that may be involved in intervention, protection or mitigation efforts during a major accident are involved in the planning process. This includes not only the emergency management agency, but also the police, emergency medical services, environmental and public health authorities, and municipal and infrastructure service providers (such as water and energy suppliers).

The content requirements for internal and external emergency plans are determined by *Government Decree 219/2011. (X. 20.) on the protection against major accidents involving dangerous substances* (GD 219/2011, 2011). The internal emergency plan must include a detailed description of the tasks related to protection from the effects of major industrial accidents involving dangerous substances, as well as an overview of the safety management system and technical equipment in place. The external emergency plan must outline the procedure for alerting the organization responsible for initiating the external emergency plan. It must specify the information to be provided upon alerting, furthermore a detailed information following the development of the emergency situation and the method of communication, as well as the possibilities and conditions for providing assistance in the event of an emergency situation (Cimer et al., 2021).

In line with the findings of Erazo-Chamorro et al. (2022), information about safety risk factors and safety requirements for a safe workplace is of vital importance in the internal emergency planning process.

3. Identification of Professional Criteria for Internal Emergency Planning

An internal emergency plan is considered effective, if it can fully accomplish its primary function, namely, to reduce the consequences of major accidents involving dangerous substances. This requires that the response measures are adequate and proportionate to the potential damage, and that the necessary human, material and organizational resources for their implementation are in place.

In the event of a major accident involving dangerous substances within a dangerous establishment, protective actions are typically carried out in the following key areas: (1) the accident site, (2) the personnel assembly area, and (3) the emergency management center.

3.1. Protection Measures Implemented at the Accident Site

The accident site refers to the area where the emergency has occurred or is likely to occur. The precise boundaries of this area are defined by the so-called “accident site commander” of the fire brigade. It is at this location that direct damage control and intervention efforts are carried out. In the event of a dangerous substance release, immediate and coordinated intervention is critical to minimizing possible consequences. Table no. 1 presents general response measures applicable to all incidents involving the release of dangerous substance into the environment:

Table no. 1*Protection measures implemented at the accident site*

Number	Name of the measure	Content of the measure
1.	Use of personal protective equipment	Intervention personnel must be equipped with appropriate personal protective equipment (PPE) based on the nature of the substance involved, including protective clothing, boots, gloves, and respirators.
2.	Damage site investigation and gas concentration measurement	The hazardous area must be continuously monitored, using instruments to detect explosion risk and toxic exposure levels.
3.	Identification of the released substance	Once the physical and chemical properties of the substance are identified, the selected protective equipment - particularly respiratory protection - must be adjusted accordingly.
4.	Suspension of work	All production activities in the affected area must be immediately halted.
5.	Ordering plant shutdown and evacuation	Based on the severity of the incident, the plant may be partially or fully shut down and the employee evacuation must be ordered, typically initiated by an alarm or siren system.
6.	Carrying out the evacuation	Begin the safe evacuation of employees to the designated assembly point and restrict traffic in and around the hazardous area.
7.	Rescue of injured people and first aid	Injured employees must be rescued and treated, and emergency medical services must be notified if necessary.
8.	De-energizing and eliminating ignition sources	Power to the affected area must be disconnected and potential ignition sources eliminated, especially in cases involving flammable or explosive substances.
9.	Preventing further release of the dangerous substance (implementing exclusions)	To prevent further release of the dangerous substance, the containment actions must be taken, such as closing valves, disconnecting pipes or stopping pumps. These actions can be manual or automatic, and their goal is to stop the leak, and shut down the technological system.
10.	Localizing and removing the spilled substance	Depending on the state of dangerous substance, different methods can be applied to prevent the spread of the dangerous substance: - the spilled out liquid dangerous substance must be confined and then removed by pumping; - the spread of solid substance can be preventing dispersion by covering with foil, or tarpaulin; - the gaseous substances spread can be reduced by installing a water curtains, if the substance non-reactive with water.
11.	Chemical neutralization	In the case of an acidic substance spills, neutralization of the area with calcium hydroxide is used. In the case of an alkaline dangerous substance, the use of a mild acidic neutralizing agent is used, such as acetic acid or citric acid.
12.	Containment, if pumping is not possible	Cover the spilled-out substance with absorbent material, then collect it in a closed barrel for hazardous waste treatment.
13.	Waste management and records	Documented collection of the generated hazardous waste (absorbent material, contaminated equipment) and handover to a licensed waste management specialist.
14.	Use of external assistance	If the accident cannot be stopped, or if there is a significant risk of life or material damage, the fire department units must be alerted immediately.
15.	Documentation and subsequent evaluation	All intervention steps must be documented. An evaluation report must be prepared and the emergency plan must be modified.

(Source: prepared by the authors)

3.2. Protection Measures Implemented at the Personnel Assembly Area

A designated and secure assembly point must be established for employees who are not directly involved in damage

control or recovery. This area plays a critical role during evacuations and for maintaining personnel records. Table no. 2 outlines the key protection measures to be implemented at the assembly point:

Table no. 2

Protection measures introduced at the assembly area of the personnel

<i>Number</i>	<i>Name of the measure</i>	<i>Content of the measure</i>
1.	Conducting a headcount check	Identify all evacuated employees by name, initiate a search for any missing employees.
2.	Identifying injured people and providing first aid	Provide first aid to those with minor injuries, and arrange further medical care if necessary.
3.	Maintenance of order	Prevent panic, control employee movement and ensure no one leaves from assembly area without authorization.
4.	Relocation of the assembly point if necessary	If the designated assembly point becomes unsafe, organize a relocation and promptly inform all affected individuals.
5.	Providing information to employees	Communicate regularly with employees, providing updates on the situation, expected actions, and further steps.
6.	Communication with the emergency management room	Maintain continuous contact with the emergency response teams, prepare situation reports, and provide details on missing and injured persons.
7.	Psychological support arrangements	Engage psychological support or a crisis management specialist if appropriate.
8.	Provision of drinking water and basic supplies during extended waits	Ensure availability of drinking water and essential supplies during prolonged evacuations or extreme weather conditions.
9.	Record keeping	Keep accurate records, including attendance sheets, event logs, and any information that must be forwarded to emergency services or internal stakeholders

(Source: prepared by the authors)

3.3. Protection Measures Implemented at the Emergency Management Room

In the event of a prolonged or complex emergency situation, a designated and secure Emergency Management Room serves as the operational center, from which management – those responsible for

damage control and crisis management – coordinate the intervention and decision-making processes. The Table no. 3 presents the main protection and coordination measures to be implemented in the Emergency Management Room:

Table no. 3

Protection measures implemented at the emergency management center

<i>Number</i>	<i>Name of the measure</i>	<i>Content of the measure</i>
1.	Providing the necessary forces and equipment for damage elimination	Mobilize the company's human, technical and logistical resources to support intervention and recovery operations.
2.	Assessing the possible consequences of the event	Develop propagation models and calculate danger zones to restrict the extent of the hazard area and support the decision to implement population protection measures.
3.	Ordering the shutdown of neighboring facilities	Implement measures to prevent the spread of the accident.

<i>Number</i>	<i>Name of the measure</i>	<i>Content of the measure</i>
4.	Limiting or completely stopping the production	Take action depending on the severity of the event and the degree of danger.
5.	Reorganizing and managing logistical operations	Coordinate material handling, transportation, temporary storage, traffic control as necessary.
6.	Organizing decontamination operations	Direct decontamination activities for affected areas, surfaces, equipment and individuals.
7.	Personnel measures and informing family members	Register injured, evacuated, missing persons, ensure notification of family members where applicable.
8.	Liaising with external authorities, local government	Coordinate with relevant authorities including disaster management authority, police, ambulances services, environmental protection authority.
9.	Communication and preparation of press releases	Activate internal and external communication protocols and public information dissemination to ensure transparency and manage public response.
10.	Reporting to the competent authorities	Submit official accident reports, perform preliminary situation assessment, and maintain event logs.
11.	Launching internal investigations	Investigate the root causes and circumstances of the accident, assign responsibilities, and prepare proposals for preventive safety improvements.
12.	Informing the ownership group	Inform strategic-level decision-makers about the accident and the protective measures implemented.

(Source: prepared by the authors)

3.4. Measures for Ensuring Business Continuity

Business continuity is a key component of modern safety planning and should be addressed either in a standalone plan or as a dedicated annex to the internal emergency plan. During and after an emergency, one of the core responsibilities of the company's Emergency Management Centre is to organize the maintenance and prompt restoration of essential business and production processes. In this context, the following tasks must be carried out:

- Identify activities that are critical to the safe and continuous operation of the establishment.
- Isolate and protect critical infrastructure, such as power supply, water systems and IT network.
- Implement temporary operating procedures needed, which may include adjustments to production priorities, shift rotations, or other workflows.
- Develop a phased restart plan to guide the safe and gradual resumption of operations once the emergency has been resolved.

➤ Recognize that ensuring business continuity of strategic importance is not only a matter of economic stability, but also vital from a social and environmental perspective, especially in critical industrial sectors.

3.5. Determining the Exact Content of the Emergency Response Measures

When preparing the internal emergency plan, it is essential to define in detail the conditions required for the implementation of the specified measures. Each measure must be described precisely, including the technical equipment necessary for its safe execution, and competence of human resources involved in response. The plan should therefore specify:

- The quantity, accessibility and storage location of special tools, PPE, measuring devices, pumps, neutralizing agents, and other critical materials.
- The roles, availability, preparedness and authority levels of the personnel involved in the intervention, including safety and medical staff.

A well-defined set of implementation conditions is crucial for ensuring the practical applicability and effectiveness of the internal emergency plan.

In addition, special attention must be paid to communication and information flow processes. In an emergency situation, fast, reliable and unambiguous communication is a prerequisite for effective intervention, coordinated operations, and the safety of both employees and the public.

The plan must include the following communication-related elements:

- Internal communication chains, including plant management, shifts, and maintenance teams.

- External communication channels, such as links to authorities, ambulance services, disaster management agencies, and municipality organizations.

- Alarm and information protocols, including siren systems, public address systems, and pre-recorded messages.

- Communication tools used during emergencies, such as radios, internal telephone networks, mobile phones, emergency applications, handheld transceivers, and online platforms.

- Clearly defined responsible personnel and the sequence of information transmission.

A communication system functions effectively when it is redundant (supported by multiple means of delivery) and when each participant is fully aware of their role in the alarm chain, including who to contact, how to communicate and what information to convey.

The internal emergency plan must be coordinated with all relevant organizational units and employee groups, ensuring an inclusive process where participants can provide feedback and express concerns. The goal is to evolve the plan from a formal document into practical and operational procedure. It is essential that all affected individuals are familiar with the plan's content, understand their assigned tasks, and receive ongoing training and practice through drill and simulations.

The effectiveness of the internal emergency plan should be evaluated primarily through experience gained during exercises and simulated major accident scenarios.

These practical tests serve to verify whether the measures specified in the plan can be implemented in reality and whether the planned measures are realistic, executable and can be carried out in a timely and coordinated manner. When organizing exercises, it is important to account for different shift patterns (day, night, weekend), and varied operational conditions. Any deficiencies, operational issues or communication breakdowns identified during the exercises must lead to a review of the plan. The internal emergency plan must be modified, clarified or supplemented as necessary to ensure continued relevance and effectiveness in real emergency situations.

4. Assessment of Professional Deficiencies in Internal Emergency Planning

This section highlights some professional shortcomings identified in practice during industrial safety expert activities and internal emergency plan evaluations. The examples below are drawn from real-life emergency exercises and serve to illustrate how certain planning failures can undermine the effectiveness of emergency response systems.

- *Practical Experience 1. Suitability of PPE.*

During the development of the internal emergency plan at a food industry plant operating an ammonia refrigeration system, "Level A" PPE was prescribed for the intervention staff. This was justified by the potential for prolonged exposure to toxic ammonia gas during an emergency.

However subsequent internal emergency exercises revealed significant practical issues. Only a portion of the affected employees (refrigeration operators) were psychologically fit to wear full gas

tight suits. This severely limited the intervention capacity, as the minimum requirement of two responders per shift could not be met consistently. Furthermore, the gas tight suits did not include integrated throat microphone communication system, so they could not communicate effectively during the intervention.

This case illustrates that emergency planning must consider not only the technical requirements derived from hazard sources, but also the human factors, psychological readiness, physical endurance and the availability of proper communication devices.

➤ *Practical Experience 2. Coordination between PPE and Instruments.*

At a drinking water supply plant storing large quantities of chlorine gas responders wear again “Level A” PPE. A touch-screen chlorine gas detector had been procured to support reconnaissance efforts. However, during emergency exercise, it becomes apparent that the protective gloves used rendered the touch screen inoperable. This experience highlights the need for system-based approach integrating new equipment into emergency planning. Devices must be evaluated not only for technical accuracy but also for functional compatibility with protective gear.

➤ *Practical Experience 3. Accessibility of Fire Protection Infrastructure*

At a facility with a mobile fuel station, an emergency drill revealed that fire extinguishers and firefighting equipment were stored inside the container, that likely become the hazard in the event of an accident. This placement rendered the equipment inaccessible at the very moment it was most needed.

➤ *Practical Experience 4. Language Barriers in Emergency Communication*

During the emergency exercise at a multinational business company, language barriers significantly hindered communication and intervention effectiveness. While English was the official language of upper management, many operational level employees lacked adequate proficiency.

The incident commander, who only spoke English, struggled to convey safety instructions clearly to workers who primarily spoke the local language. This case underscores the importance of realistic communication, which requires unambiguous instruction that cannot be guaranteed without proper linguistic support. As a result of this experience, the organization implemented several measures: preliminary language competency assessments for incident commander; targeted language training for key safety-critical actors; the designation of interpreters or multilingual mediators; the preparation of multilingual instructions and pictograms to aid comprehension.

Practical experience clearly highlights that emergency planning is not merely a technical exercise, but a multidisciplinary task that must integrate an organizational, human and communication issue. A well-designed internal emergency plan must simultaneously comply with legal requirements, align with real sources of danger, match employee capabilities and account for applicability of safety infrastructure. The deficiencies identified by the exercises confirm that for an internal emergency plan to be truly adequate, it must be both theoretically sound and practically feasible. Emergency planning is therefore a complex evolving process, whose success depends heavily on interdisciplinary cooperation feedback mechanism and the regular evaluation and refinement of procedure through realistic simulations.

5. Conclusions

Internal emergency planning is not only a legal obligation, but also one of the most important guarantees for protecting employees, the environment and surrounding communities.

As a result of the research conducted in this article, the authors highlight the following main findings:

➤ The examples presented in this article clearly demonstrate that the

effectiveness of an emergency plan can only be ensured if its measures can be implemented in practice.

➤ The alignment of technical, human and organizational factors, along with the functionality of communication systems, and the accessibility and operability of tools are fundamental to the success of real-world intervention.

➤ Regularly conducted exercises and their feedback are essential for the continuous improvement of internal emergency plans.

The authors highlight the following key takeaways and practical policy recommendations for operators, competent authorities and regulators.

➤ The European Union and the Hungarian regulations lack quantitative criteria concerning the conformity of the operator's prevention, preparedness and response measures.

➤ The qualitative criteria written in legal regulations on internal emergency planning should be clarified in an official position statement issued by the competent authorities.

➤ To ensure a uniform and harmonized implementation of the major accidents regulation by the competent authorities, it is recommended to issue legal and technical guidance on the content of the legal provisions and the procedures to be followed by operators.

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